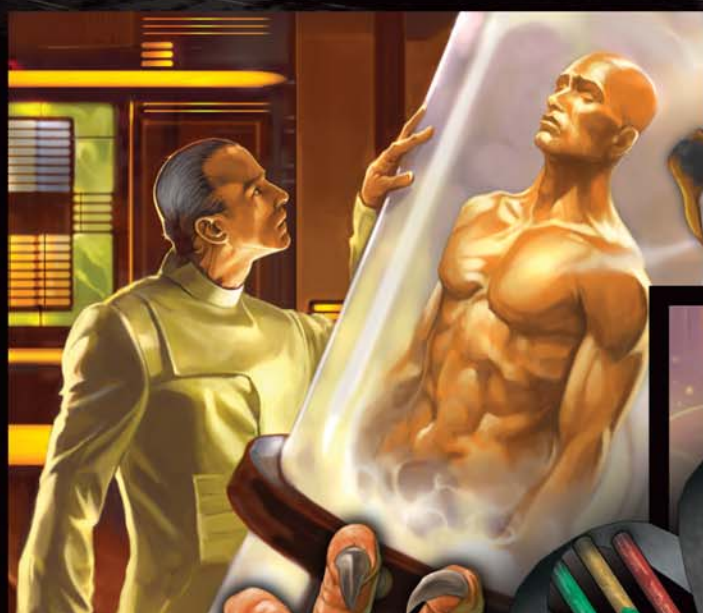


GURPS

Fourth Edition

BIO-TECH™



BY DAVID MORGAN-MAR AND DAVID PULVER

STEVE JACKSON GAMES

GURPS®

Fourth Edition

BIO-TECH™



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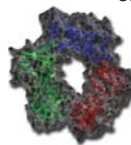
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INTRODUCTION

Genetic engineering and other biomedical technology are starting to change the world in ways we can only begin to guess at.

Can we resist the temptation to tinker with our genes when the potential rewards include immortality? Will exotic wonder drugs soon be produced in cows and goats? Could natural or artificial plagues wipe us out, or will biotech conquer disease or transform us into posthuman superbeings? And just how do genetic engineering and cloning work, anyhow?

GURPS Bio-Tech explores these and other questions, examining the promise and perils of medical and biotechnologies real and imagined, and their effects on characters and societies. The answers may surprise you . . .

Using This Book

Biotechnology breeds its own jargon. While most technical terms are explained as they are introduced, if you run into an obscure term, check the Glossary (p. 231).

Fictional quotes introduce many sections of this book. Capsule biographies of our “commentators” appear in Chapter 8 (p. 216).

PUBLICATION HISTORY

This is the second edition of **GURPS Bio-Tech**; it has been revised to the **GURPS Fourth Edition** rules and expanded to cover medicine, drugs, magic, and new technologies. Some variant races and wonder drugs were introduced in **GURPS Space** (by William Barton and Steve Jackson). The biological android (bioroid) and proteus virus rules originated in **GURPS Robots** (David Pulver). The first edition of **GURPS Bio-Tech** (by David Pulver) was 144 pages long and focused on modern and future technology. Some of its fictional vignettes established ideas that would later be expanded in the **Transhuman Space** series. In turn, a few biotech and variant races in this edition are derived from material introduced in **Transhuman Space** (David Pulver) and its supplements **Deep Beyond** (David Pulver), **Fifth Wave** (Jon F. Zeigler), and **Under Pressure** (David Morgan-Mar, Kenneth Peters, and Constantine Thomas). The biotech spells are based on those in David Pulver’s **Bio-Tech** Designer Notes in *Pyramid*. The medical care flowchart and some advanced medicine rules are adapted from a *Pyramid* article by Eric Funk.

ABOUT THE AUTHORS

David L. Pulver is a freelance writer and game designer who lives in Victoria, Canada. He has written or co-authored numerous **GURPS** books, including **GURPS Basic Set Fourth Edition**, **Transhuman Space**, and the original **Bio-Tech**.

David Morgan-Mar is a research engineer who lives in Sydney, Australia. He is the author of **GURPS Update** and co-author of **Transhuman Space: Under Pressure**, and has contributed to several **GURPS** books including **Monsters** and **Steam-Tech**.

About GURPS

Steve Jackson Games is committed to full support of **GURPS** players. Our address is SJ Games, P.O. Box 18957, Austin, TX 78760. Please include a self-addressed, stamped envelope (SASE) any time you write us! We can also be reached by e-mail: info@sjgames.com. Resources include:

Pyramid (www.sjgames.com/pyramid/). Our online magazine includes new **GURPS** rules and articles. It also covers the **d20** system, **Ars Magica**, **BESM**, **Call of Cthulhu**, and many more top games – and other Steve Jackson Games releases like **Illuminati**, **Car Wars**, **Transhuman Space**, and more. *Pyramid* subscribers also get opportunities to playtest new **GURPS** books!

New supplements and adventures. **GURPS** continues to grow, and we’ll be happy to let you know what’s new. For a current catalog, send us a legal-sized SASE, or just visit www.warehouse23.com.

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Errata. Everyone makes mistakes, including us – but we do our best to fix our errors. Up-to-date errata sheets for all **GURPS** releases, including this book, are available on our website – see below.

Internet. Visit us on the World Wide Web at www.sjgames.com for errata, updates, Q&A, and much more. To discuss **GURPS** with SJ Games staff and fellow gamers, come to our forums at forums.sjgames.com. The **GURPS Bio-Tech** web page is www.sjgames.com/gurps/books/bio-tech/.

Bibliographies. Many of our books have extensive bibliographies, and we’re putting them online – with links to let you buy the books that interest you! Go to the book’s web page and look for the “Bibliography” link.

Rules and statistics in this book are specifically for the **GURPS Basic Set, Fourth Edition**. Page references that begin with B refer to that book, not this one.

CHAPTER ONE

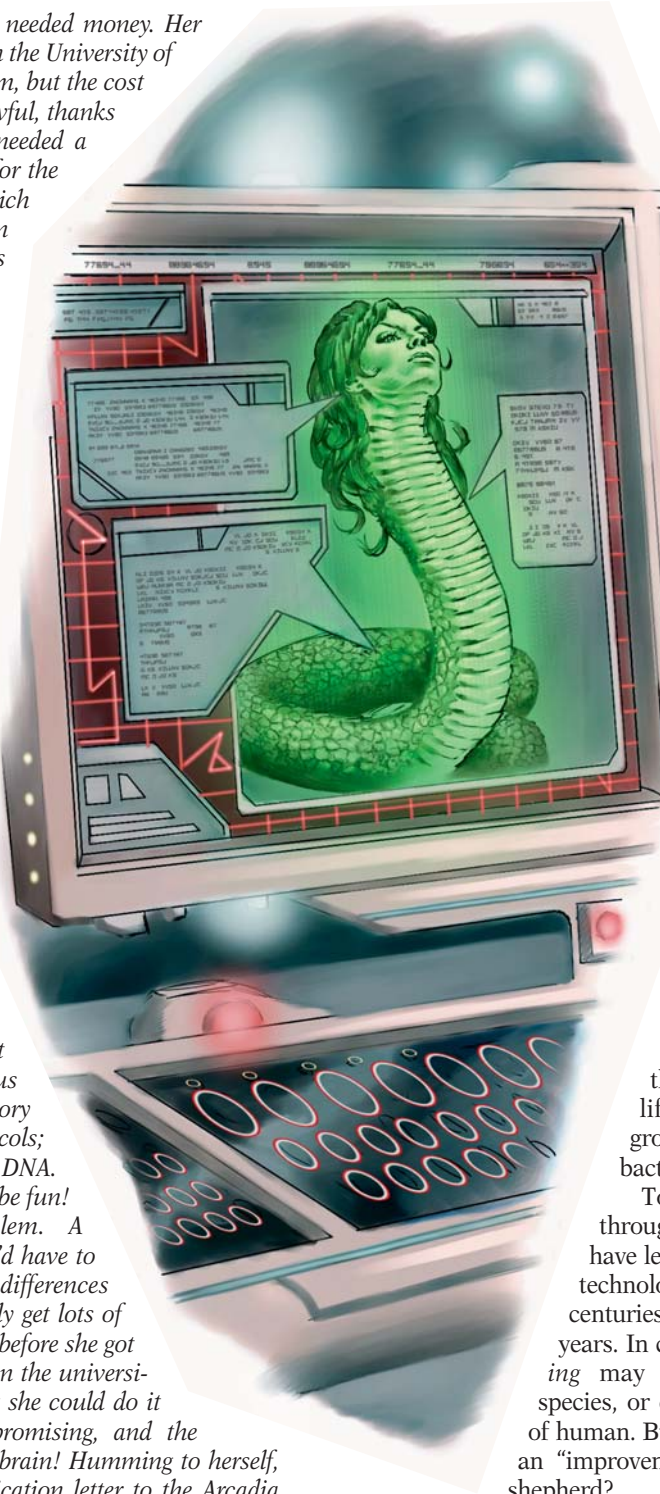
BIOTECHNOLOGY

Tika Dawnstar frowned. She needed money. Her scholarship covered her tuition in the University of Mars' genetic engineering program, but the cost of living at Nix Olympica was awful, thanks to the terraforming taxes. She needed a winter job, one that would pay for the cutting-edge neurovirus with which she hoped to upgrade her brain in time to ace the upcoming term's exam.

Plugging into her biocomputer, she scanned the "Help Wanted" column on GeneWeb. Assistant on a project to develop a pollution-eating, cryogenic bacteria to clean up a vatspill on Titan? Bleah. Design new porkapple plants? Yuck. She was a vegetarian, anyway. She scrolled down the page, then stopped. High Arcadia was an orbital habitat – an adventure theme park based on Greek mythology. They wanted a freelancer with grad-level expertise to design one of the creatures that would populate the park: a lamia, with a snake's body and a human head. Tika's eyes widened . . . The lamia was to be fully sapient!

Wasn't that illegal? Tika called up a law database and cross-checked: Nope. It was bioethically questionable, but High Arcadia was an autonomous extra-national entity, not a signatory to the Genetic Regulatory Protocols; she could work with human DNA. Tika hugged herself – this would be fun!

She considered the problem. A snake/human cell fusion, so she'd have to smooth out the biochemical differences between species . . . and probably get lots of false starts and aborted embryos before she got it right, even if she rented time on the university's vatbrain megacomputer. But she could do it with the facilities they were promising, and the advance would pay for her new brain! Humming to herself, Tika began composing her application letter to the Arcadia Entertainment Group.



Biological manipulation is nothing new. Humans have been influencing the genetics of plants and animals for thousands of years through selective breeding. For example, most sheep once had long legs. That's better for the sheep, since they can run away from predators, but not so good for a farmer, who finds it harder to control and shear a nimble animal. So shepherds bred the sheep with shorter legs. The result? After many generations, the "improved" sheep are all short-legged, and farmers now need specially bred sheep dogs to keep the predators away.

The trouble with selective breeding is that it takes generations to produce results. Consequently, much of what we know about genetics comes from studying organisms that have relatively short lifespans, such as fast-growing plants, fruit flies, or bacteria.

Today, dramatic breakthroughs in molecular biology have led to genetic engineering, a technology that allows the work of centuries to be done in months or years. In coming decades, *gengineer-ing* may create modified animal species, or even an "improved" breed of human. But who determines what is an "improvement" – the sheep or the shepherd?

BASIC PRINCIPLES

All terrestrial life is made up of cells: one cell in the case of simple organisms like bacteria or protozoa, and about 800 billion in a human. A cell consists of a membrane which encapsulates a watery soup of subcellular bodies. Among the most important of these are skinny strands called *chromosomes*. Bacteria, the simplest life forms, have a single chromosome (and several smaller ring-shaped bodies called plasmids). In more complex forms of life, the nucleus in the center of the cell houses multiple chromosomes; e.g., each human cell contains 23 pairs of chromosomes. Every cell in a particular organism, except the reproductive cells, has the same number and type of chromosomes. Collectively, the chromosomes form an instruction manual that contains all the information an organism needs to grow and reproduce.

Chromosomes are made of *deoxyribonucleic acid*, or *DNA*. This is a long, complex molecule with a tightly coiled double helix shape, resembling a twisted ladder. The “rails” are formed from deoxyribose sugar and phosphate molecules, while each “rung” on the ladder is composed of two compounds, called bases, locked together to form a pair – either the molecules adenine and guanine (an AG pair), or cytosine and thymine (a CT pair).

If chromosomes are an instruction manual, then these base pairs (approximately three billion in a human cell!) can be thought of as the “letters” in the genetic code

that it is written in. To continue the analogy, particular arrangements of AG or CT base pairs form words, and a single coherent sentence is a *gene*. Each gene contains a specific instruction that tells the cell how to manufacture the chemicals needed for life.

A gene sends out instructions to the cell by making a copy of the genetic code using *messenger RNA* (ribonucleic acid). Messenger RNA carries a gene’s instructions to big, lumpy molecules that float around the chromosome, known as *ribosomes*, which are the cell’s biological factories. They read the genetic message written in the RNA as an instruction to start manufacturing a particular protein (see below) from available chemicals.

Proteins are complex molecules (made of amino acids) used in cellular chemical reactions. By analogy to the genome – the list of genes in an organism – biologists also speak of the proteome. This is the list of proteins expressed by the organism’s DNA, and can be longer than the genome. Some proteins make up the structure of cells. Others, called *enzymes*, act as catalysts to induce molecules to form new combinations, or break complex molecules (such as food) down into smaller components.

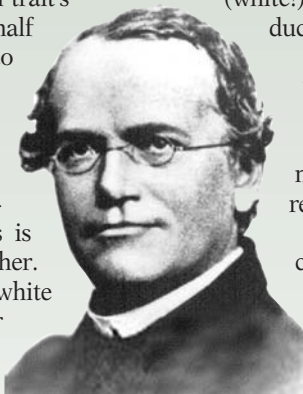
What differentiates one species or individual from another are the different proteins that their cells produce, and the order in which they produce them. These metabolic processes – digesting chemicals from food and making

Mendelian Heredity

In the nineteenth century, a monk named Gregor Mendel studied pea plants. He postulated that each inherited trait (like whether a plant is short or tall) is determined by a specific factor, which we now call a gene. An organism has two copies of each trait’s gene. In reproduction, each parent passes half of its genes (determined semi-randomly) to its offspring. The other half come from the other parent.

For example, flower color in plants is a genetic trait. If one plant has red flowers and the other has white, will the flowers of their offspring be pink? No! This is because those genes don’t blend together. Instead, the offspring of a cross between white and red parents would also be either red or white. Which gene is obeyed depends on whether that gene’s trait is a “recessive” or “dominant” one. If red flowers were dominant over white for a particular plant, then the hybrid offspring would be red.

However, that isn’t the end of the story. While the hybrid plant looks red (this is called its *phenotype*) its actual genes governing color (or *genotype*) are a mix of one for redness and one for whiteness. Suppose it is



cross-pollinated with another red hybrid that has one red and one white gene. The luck of the draw may lead to their offspring having two red genes (thus being red), a red and a white gene (also red), or two white genes (white!). Thus, two plants with red flowers can produce one with white flowers.

Recessive traits can skip generations, which is why you sometimes see children who don’t resemble their parents.

In humans, many rare traits, including most inherited genetic defects, tend to be recessive.

In practice, heredity is actually a lot more complex than the “ideal” Mendelian model – there are mixed-dominant, cross-dominant and non-Mendelian traits that break the rules described above. Some traits are also “sex-linked” – that is, they are located on sex chromosomes, and are transmitted differently between males and females.

In many science fiction stories that deal with psi abilities, mutant powers, or other exotic hereditary gifts, recessive and sex-linked traits are used to explain why these powers are rare, or why women or men are more likely to manifest them.

more DNA, RNA, and enzymes so that cells can replicate – are what characterizes life on the cellular level.

Cells replicate by splitting in two. When this happens, each of the chromosomes within them also divides down the middle, so that both new cells have a copy of each chromosome. These half-chromosomes then reconstitute themselves from the loose chemicals in the cell. In this way, each cell remains a duplicate of the original. In the case of asexual, single-celled organisms like bacteria, this ensures that each one is identical.

Multicellular creatures that reproduce sexually are an exception to this. Each parent's reproductive cells carry only half the normal number of chromosomes. When they unite (in a human, when an egg is fertilized by sperm), they form a single, complete cell with the full number of chromosomes. Half of the chromosomes (and their genes) come from one parent, half from the other. After this, the joined cell replicates normally.

As a multicellular organism grows, genes are activated to cause individual cells to specialize. Some become nerve cells, others become skin cells, and yet others form different organs – all in accordance with the instructions in their genes. In humans, a fertilized egg (zygote) develops first into a blastocyst, then an embryo, and finally a fetus that will become able to survive outside the womb as a baby.

Introns

Genes that make proteins used by the body only account for about 2% of the genetic material on the chromosomes of most species. Much of the rest are regulators for control sequences which tell the genes when to turn on or off.

The two main categories of terrestrial life are *prokaryotes* (bacteria) and *eukaryotes* (plants, fungi, and animals) – see

The Domains of Life (p. 103). One of the distinguishing features of eukaryotic cells is the existence of *introns* (first discovered in 1977) – long, seemingly meaningless sequences with no apparent function. Eukaryotic cells possess mechanisms to ignore the intron sequences when making proteins.

How did these “worthless” introns get into the genetic code? Current research suggests introns appeared after eukaryotic cells diverged from bacteria some two billion years ago, but their exact purpose remains controversial.

One theory is that they represent changes introduced by ancient viral hitchhikers, or are simply the genetic debris of evolutionary dead ends. It's also possible that they act as genetic speed bumps to slow down and regulate the rate at which certain proteins are manufactured. Maybe they act as genetic spare parts, usable in future mutations. In a cinematic campaign, introns may have a more sinister purpose – they could contain latent genetic sequences that await the proper control signal to activate. Perhaps they would express themselves as super-powers!

If genetically engineered creatures are manufactured from scratch (TL10+), the designer may decide not to include introns, to make his task simpler and the results easier to predict. This means that engineered organisms may have highly compact genomes. This would be a good way to tell if a blood sample is from an evolved organism or a manufactured one.

One far-out use for introns would be to code non-genetic information into an organism's cells. For example, trademarks, serial numbers, secret messages, or other data could be written into an organism using coded arrangements of introns! And what if ancient astronauts coded an interstellar treasure map into our introns?

DNA SEQUENCING

Although you inherit your genes from your parents, you can't tell what genetic characteristics you will develop during life just by looking at their physical and psychological traits. You may inherit a combination of recessive genes that neither of your parents shows any sign of carrying, and end up being a blue-eyed child of two brown-eyed parents, or with some debilitating genetic disease. If you're male, you may acquire a sex-linked gene from your mother and be color-blind, or hemophiliac. Your parents could be healthy, but pass on genes that predispose you to developing severe degenerative diseases. Or one of the mutations that routinely accumulate during reproduction could hit a gene that controls one of your body's vital functions.

In order to make any sense of all this potential genetic information, someone needs to take a sample of DNA and then *sequence* it – analyze it with a machine to read the sequence of base pairs that make up the genetic code. The code can then be compared to a map of the human genome to determine which parts correspond to which genes, and what *alleles*, or variations of them, are present. Only then can a skilled geneticist make any practical determinations about the person who supplied the sample.

PCR Machine (TL8)

One of the basic tools in any genetics lab since the late 1980s is the polymerase chain reaction (PCR) machine. This can rapidly replicate DNA from very small amounts of source material in a matter of hours, creating thousands of copies of DNA fragments from single cells.

Besides its use in genetic engineering, PCR allows genetic testing from as little material as a hair follicle or a tiny drop of blood (see *DNA Testing Procedures*, p. 8), permits the automation of gene sequencing (permitting genome analysis projects), and allows genetic reconstruction (p. 14), enabling researchers to isolate and replicate DNA samples.

One weakness of PCR is that it is so sensitive; technicians must use great care to ensure that whatever DNA they are amplifying actually comes from a particular sample, rather than contaminants – say, a skin flake from the researcher. All TL8+ genetics labs include PCR machines or their ultra-tech equivalents. On their own, PCR machines may cost from \$3,000 to \$125,000, depending on their speed and capabilities. LC4.

The Human Genome Project

The complete set of instructions for making a particular organism is called its *genome*. It exists in the nucleus of every cell, and acts as the blueprint for all cellular structures and operations.

The Human Genome Project was a 13-year international endeavor to discover the thousands of protein-coding genes in human DNA (the human genome) and determine the complete sequence of the three billion DNA subunits (base pairs) that make them up. The full project was under way by 1990. The project was intended to be finished around 2010, but advances in automated gene sequencing and parallel computing resulted in early completion in 2003.

A major part of the project was the development of technologies for rapid DNA mapping and sequencing. Projects to map the genomes of other species have also begun, and many have been completed, although it may be decades before even a small fraction of all Earth species are mapped.

One of the more surprising discoveries from the human genome project was the relatively small number of human protein-coding genes. Thought to be as many as 100,000 at the start of the project, the actual number turned out to be less than 25,000.

The completion of the Human Genome Project was the first step to understanding the structure, organization, and function of DNA in chromosomes, and a necessary precondition toward advancements in technologies

such as gene therapy (p. 181) and very precise genetic testing (see *Privacy and Discrimination*, p. 198).

Genetic Differences

How similar are the genes of humans and other animals? All mammals have (very approximately) the same number of genes. Within the DNA sequence – the arrangements of nucleotides – ape and human genes differ by less than 10%. For non-primate mammals, like cats or mice, the difference is about 20-30% overall.

Physical differences between species are sometimes the result of very subtle changes in the nucleotide sequences that make up the genes. These in turn produce somewhat different proteins which result in cellular distinctions.

However, many distinctions are not even the result of *different* proteins, but rather from the order, locations, or quantities in which they are produced. Changes in the quite small number of genes that regulate this (called Hox genes in animals, or MADS box in plants) determine much of an organism's physiology; together with the small number of completely different genes they add up to make the difference between species, spelling "human," "mouse," or "cat." Mutations in these genes are also the source of most of the single-mutation "monsters" encountered in both reality (flies with legs in place of antennae, or starfish with extra arms, for example) and in the Atomic Horror genre.

DNA TESTING PROCEDURES

Everyone's DNA is unique (with the exception of clones and identical twins), and this genetic record is contained within every cell. A person's DNA will be similar to his blood relatives', and so can be used to help determine his ancestry.

Starting at TL8, genetic tests can be performed on blood or tissue samples. Various types and applications of genetic testing are discussed below.

These procedures require a genetic lab (p. 16) and generally take a day or more at TL8 (but commercial labs might take weeks to report). At TL9+, a portable genetic scanner can take samples in a few seconds (prick a finger, for instance), analyze them, and upload the data to a computer for an instant cross-check against a database of known genetic markers. A pocket scanner is \$500 and one pound at TL9; roll vs. Electronics Operation (Medical)+2 or Forensics+2 to use it. People like police officers will usually be able to connect their personal computers to large genome databases for rapid analysis.

Genetic Identification (TL8)

This is a simple test to determine if a person (or corpse) is who he is supposed to be, by matching a sample against

existing genetic records. Roll against Electronics Operation (Medical)+4. At TL9+, testing procedures may be fast enough to be useful for on-the-spot "biometric" identity checks, comparing a blood sample (requires only a pinprick) or saliva sample with personal data contained on an ID card or in a database. This may be common in high-security areas; treat this as an automatic procedure (don't bother to roll).

Genealogy Determination (TL8)

Key sequences in a person's DNA can serve as markers that have been inherited from successive generations of ancestors. This is often known as *paternity testing*, because the most common application is to establish the identity of a child's father. It's possible to go back multiple generations; the limiting factor is the availability of an unbroken chain of ancestral DNA samples (or complete genome records). A one-generation gap can usually be bridged with minor uncertainty ("he's either your grandfather or your grand-uncle"), but otherwise testing will show approximate kinship, rather than a specific relationship.

Testing requires the same time and skill rolls as DNA forensics; roll at +4 for a simple test (e.g., "is that person my real father/mother?"), or at TL9+, use a genetic scanner for an instant comparison test as described above. The better the success roll, the more detailed the ancestral information. Tracing a long line of descent may require History or

Research skill rolls to locate ancestral DNA samples (e.g., finding where bodies are buried) or to dredge up old records that may contain genetic data.

DNA Fingerprinting (TL8)

Trace DNA samples – such as remains, or bodily fluids left on a crime scene or victim – can be compared with genetic records in a database.

This technique exploits the variability of human DNA to positively identify an individual from a small cell sample. It can thus link a suspect to tiny traces of physical evidence at a crime scene such as skin cells, hair, and saliva.

Genetic fingerprinting can also identify human remains if a sample of DNA is available from another source. Useful DNA can be extracted from bones, teeth, and hair for decades after death . . . even after a body has been burned to ash in the case of teeth.

Obtaining a DNA sample without contaminating it requires a portable forensics lab and a Forensics roll. At TL8-9, Forensics skill and at least an hour (and sometimes many days) of work are required to properly gather and prepare samples; a failed roll may result in missed or contaminated evidence. At TL10+, forensic microbots – or nanomachines, at higher TLs – can be introduced into a crime scene to locate nearly all traces of blood, tissue, and other evidence in a few hours. These can uncover traces dating back weeks or months. A package of forensic microbots or nanobots is \$4,000 and gives +3 to Forensics skill rolls to find such evidence. See ***GURPS Ultra-Tech*** for more details on microbots and nanomachines.

Recovered samples are tested and compared to another specific sample to determine if a match exists. This requires an Electronics Operation (Medical) roll if using a lab. Success will find a match (if it exists); failure means the results are uncertain with that sample. Critical failure can result in a mistaken result (false positive or negative).

If genome information is on file, it may be possible to compare DNA forensic results against a computerized database. At TL9+ this allows use of a TL9+ genetic scanner for an instant check. Some organizations may routinely keep DNA records (e.g., military forces may do so to make it easier to identify bodies, or records may be kept of hospital patients or criminals). In some ultra-tech societies, *everyone's* genome may be on file; others tightly restrict this information due to privacy concerns, and legal access may require permission, court orders, or high-level security clearances. Searching databases may require a Research or Computer Operation roll to search genetic records.

Since its introduction in 1985, genetic fingerprinting has been subject to legal restrictions in many jurisdictions, as civil rights groups and some legislatures see the analysis of genetic material without permission as a violation of privacy. As the technique becomes more common, it may become less regulated (as fingerprinting is today) or be subject to even more stringent oversight. Police departments around the world are now compiling genetic databases of criminals for use in identifying repeat offenders.

At present, and in future societies where only a relatively small percentage of people have their genomes on file, the utility of DNA forensics depends on having an idea

who to test. While it is sometimes possible to (for example) get samples from hundreds of suspects in an area, this is often impractical. On the other hand, DNA forensics can be very useful to *clear* an innocent person; many prisoners have been released due to DNA evidence.

Despite its high accuracy, genetic fingerprinting can be defeated by the age-old trick of planting false evidence. In an ultra-tech society this could include implants of foreign tissue or genetic surgery to provide false samples. In addition, cautious criminals will take increasingly meticulous care not to leave so much as a cell behind at a crime scene – arson, acid, or nanocleaners (***GURPS Ultra-Tech***) can help scour a site clean.

*La vie est une fonction
chimique.
(Life is a chemical process.)
– Antoine Laurent Lavoisier*

Genetic Profiling (TL8)

This involves analyzing a DNA sample and comparing it against what is known of the species' genome to determine what hereditary traits the subject possesses. Privacy considerations may lead to laws that limit the widespread use of genetic profiling – see ***DNA Profiling and Identification*** (p. 198) for a discussion of this.

Genetic profiling requires a genetics lab (p. 16) at TL8 or a genetic scanner (p. 8) at TL9+. Roll against the lower of Biology skill (the Genetics specialty is appropriate) and Electronics Operation (Medical) skill.

At TL8, the information that can be extracted is limited, but may include race, hair, and eye color, as well as the presence of specific hereditary diseases. This requires a lab test and at least a day's work. At TL8, genetic profiling can identify chimeras (p. 38), bioroids (p. 26), or detect species modification (p. 37), but it will not be able to determine if someone is the result of germline genetic engineering (p. 13).

At TL9+, the above information can all be detected with a handheld genetic scanner: all that's needed is a few seconds' scan and comparison with a genetic database. However, actual lab tests can reveal even more details, as future science uncovers exactly how each gene functions, what proteins they code for, and how they influence specific mental and physical traits (or even psi or super-powers, in settings where exotic abilities have genetic causes). If an advantage or disadvantage is inborn rather than otherwise acquired, it may be detected by genetic profiling. This will also detect any genetic tinkering. Chapter 2 suggests TLs for engineering particular traits; the GM may rule that this is also the TL of lab tests that are required to identify genes associated with these traits.

RNA Sample Dating (TL8)

The molecular structures of messenger RNA and ribosomal RNA decay at different rates, so measuring their relative abundances in a biological sample can reveal how long ago it was removed from a living body. This can be applied to blood or tissue samples the size of a pinhead and is accurate for up to a year after the sample was deposited. The method does not work for hair or nail samples, since the cells in these die before they become detached from the body. This requires the same skills as genetic fingerprinting, but more sophisticated equipment – at minimum, a full genetics lab (p. 16).

Genetic Simulation (TL9)

This is a higher order of genetic profiling. Since our genes control how we develop, a DNA sample alone can tell us a lot about a person. A computer program could read the genetic code and be used to create a computer simulation of what the subject might look like, assuming various ages and environmental influences such as diet, in the absence of cosmetic surgery or facial trauma.

For this to work, more is required than just the genetic sequence (which is why the Human Genome Project was only a first step). Genetic simulation requires expertise in the area of human physiology, nutrition, biometrics, and their intersection with human genetics.

While DNA is indeed a blueprint for an organism, it is useless without the context in which it can be read (the architectural or engineering symbols used in the blueprint, to extend the analogy). For DNA, this means the right biochemical and physical environment. As an example, mouse DNA produces a baby mouse – when inside a

mouse ovum. When placed inside a rat ovum, the different interactions cause mouse DNA to express a different series of proteins, which ultimately end up killing the cell before it can develop into a mouse.

A human ovum is a relatively known environment and some sort of average can be assumed for the computer simulation. This will give an indication of the DNA donor's gross physical features. But many features are controlled by subtle differences in the mother's womb and during early childhood development. So while simulation can give hair color and approximate facial bone structure, it can't predict exact height, body weight, or fingerprint patterns. Personality traits are even more dependent on upbringing – some general tendencies can be predicted, but a tendency to shyness is not a guarantee the person will turn out that way.

Genetic simulation requires successful genetic profiling as a prerequisite, as well as additional data described above. Gathering it may require Research and Biology (often the Genetics optional specialty) rolls. Once the data is available, the actual genetic simulation takes a day to set up. To determine success, roll against the lower of Forensics or Physiology skill; the better the success, the closer the match, within the limits of the technology. At TL9, genetic simulation is inexact and produces only obvious physical characteristics (as per trait analysis), along with vague probabilities for features such as height and weight. At TL10+, if the birth mother's DNA is also available (*not* the biological mother's if she was different) and/or there is information on her nutrition during gestation, then the simulation can be more accurate, predicting features such as height and refining probabilities of various body weights and personality traits.

SELECTIVE BREEDING

It's possible to produce desired changes in heredity through a conventional breeding program. This can be done at any TL, although it's most effective when the laws of heredity are understood. It requires locating breeding stock with suitable traits, mating them, and observing the offspring. The process is repeated with each generation, with new mates chosen to strengthen desirable traits or remove undesirable ones.

This has been used for thousands of years to breed plants and animals. As far as we know, no one's ever done it successfully with humans – although to a limited extent, the entire Earth is an exercise in eugenics ("evolution in action"), since most people choose their mates with at least some eye toward suitability for children.

This brings up the main problem with human eugenics. As humans usually prefer to choose their own partners, some form of reward, coercion, or indoctrination is often required. Since the process will take many generations, a very stable organization or culture must be founded which can oversee the program through many generations.

Fictional eugenics programs are often devoted to designing a master race with superior physical and mental traits, a super-being with exotic psi powers, or specialized

humans for a biological caste system modeled on an insect hive. Often, these programs are directed by authoritarian governments, secret societies, hereditary aristocracies, or religious orders. The Nazis made half-hearted efforts in the field of eugenic breeding programs. Had the Reich really lasted a thousand years, they might have been successful; fortunately, they had less than a generation.

But can you *really* breed a "better" race with eugenics? A major problem would be the danger of inbreeding, with an increased possibility of recessive metabolic diseases. In **GURPS** terms, this would manifest as disadvantages such as Epilepsy or Hemophilia and various forms of insanity. This comes from keeping the genes within a small population without the benefit of genetic engineering to counter such problems.

In theory, a eugenic breeding program could eventually produce racial templates that include any hereditary advantage or disadvantage within the species' original genome (see *Eugenic Germline Engineering*, p. 36). It could only bring out and emphasize features that are latent in existing genes, not create completely new capabilities ("species modification").

There's no easy way to predict how long this process would really take. GMs who want hard numbers could assume that a large, intensive, and ruthless breeding program just might be able to put 1d-4 (at TL1-5), 1d-3 (at TL6-7) or 1d-2 (at TL8+) character points toward creating a specific genetic template every generation. Keep track of negative points as well – apply them toward *unintended* hereditary disadvantages, representing inbred traits. At TL8+, this averages 1.5 character points per generation; so, for instance, breeding a “warrior caste” who all possessed Combat Reflexes (15 points) would take about 10 human generations. These represent total points of change, including *intentional* disadvantages, so deliberately breeding a combination such as High Pain Threshold [10] and Berserk [-10] is 20 points, not 0 points.

Alternately, it could be argued that the time required depends only on the number of traits to be selected rather than their point costs. Roll 3d-(TL/2) for each advantage or disadvantage; the result (minimum 1) is the number of additional generations required to fix that trait into the template.

Any eugenics program will probably also produce several failures, who may have interesting but unplanned

advantages or disadvantages – the plot of Frank Herbert's classic *Dune* hinges on such a development.

Someone who is the living product of an ongoing eugenics program might represent centuries or millennia of effort by a powerful organization. As such, they might well be the victims of subversion, kidnapping, or assassination. The Social Stigma (Valuable Property) is appropriate for any eugenics subject.

Eugenics programs are especially suitable for settings where secret societies may indeed have long-running and manipulative interest in certain bloodlines, which might translate into eugenics. In alternative histories where the Axis won World War II (see the Infinite Worlds background), long-term eugenics programs may also be underway, if not replaced by more sophisticated eugenic genetic engineering technologies. Finally, while eugenics takes a long time, it may not *seem* long to a long-lived or immortal race or being. Fantasy is full of dark lords who use eugenics to produce nastier breeds of orcs or other monsters. A long-lived alien might be raising a line of humans . . . if the manipulation is subtle, the subjects might not be aware they're part of such a project.

GENETIC ENGINEERING

Genetic engineering, or “gengineering,” is the practice of manipulating genes to produce desired changes in an organism. The discovery of the structure of DNA and early experiments are TL7 developments; practical genetic engineering requires TL8.

Historical Development

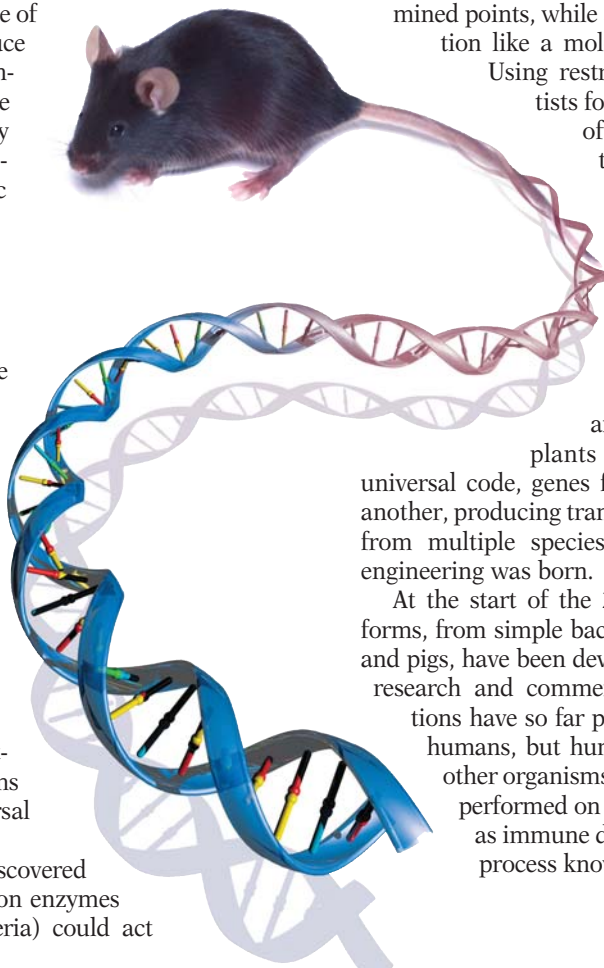
Scientists gradually came to the realization that DNA (rather than proteins) was the agent of genetic change between 1920 and 1940; Oswald Avery and his group published the central paper on this in 1944. Watson and Crick, working from research data provided by Franklin and Chargaff, described the structure of DNA (1953) and demonstrated that all terrestrial life forms seemed to share a universal genetic code.

In the 1970s, it was discovered that proteins called restriction enzymes (derived from certain bacteria) could act

like molecular knives, slicing DNA molecules at predetermined points, while another enzyme, ligase, could function like a molecular glue to rejoin these pieces.

Using restriction enzymes and ligase, scientists found they could chop fragments out of one organism's DNA and splice them into another, resulting in *recombinant DNA*. Since all life on Earth has the same genetic code, the genes are, in a gross but wonderful sense, a box of interchangeable parts. At first, only simple bacteria could be engineered, but by the 1980s, scientists had learned how to cut and paste genes into more complex plants and animals. Since DNA is a universal code, genes from one species can be added to another, producing transgenic life forms that possess traits from multiple species. Thus the discipline of genetic engineering was born.

At the start of the 21st century, many transgenic life forms, from simple bacteria to higher mammals like mice and pigs, have been developed and even patented, for both research and commercial purposes. Ethical considerations have so far prevented the creation of transgenic humans, but human genes have been inserted into other organisms. Genetic engineering has also been performed on humans to fix genetic defects (such as immune deficiency or cystic fibrosis), using a process known as gene therapy.



GENETIC ENGINEERING PROCEDURES

So how does engineering work?

Sophisticated chromosome-mapping techniques are used to determine which genes do what. The desired genes can then be cut out of cells (using restriction enzymes) and placed into bacteria, where they are copied as the bacteria reproduce. Since the 1980s, however, the favored method has been a technique known as the polymerase chain reaction, or PCR (see *PCR Machine*, p. 7). A genetic engineer can create a computer model of the genetic sequences he wants, then mix together the basic building blocks to copy the sequences of existing genes. Thus, genetic engineers can produce genes that they suspect will be functional. Alternatively, they can analyze proteins and use that information to devise genes that will produce those proteins.

Strands of DNA don't do any good just sitting in a test tube, though. If the DNA is to be added to a different species, it must be further modified so that it will actually do something ("express itself") when inserted into the host organism's cells. To do this, genetic engineers must construct a partially artificial gene that obeys the regulatory mechanisms of the host species. Altered DNA also needs a way to enter the cells of the organism it is to modify. Some of the methods used by engineers to accomplish this are microinjection, bacterial plasmids, retroviruses, artificial chromosomes, and nanoviruses, described below.

Applications for genetic engineering include gene cloning (below), germline engineering (p. 13), and genetic surgery (p. 14).

Microinjection

An early method used for animal cells is to inject genetic material into target cell nuclei, either with a tiny needle or by using a "gene gun" which uses compressed gas to fire very tiny pellets (often gold dust) coated with genetic material. Microinjection may be used when genes need only be delivered to a single cell (such as a bacterium or egg cell) in a lab dish.

Bacterial Plasmids

Plasmids are small rings of DNA found in bacteria outside their chromosomes. Some types of soil bacteria, such as *Agrobacterium tumefaciens*, have the habit of inserting pieces of their plasmids into plants, transferring some of their DNA to the plant's chromosomes, resulting in tumors. Scientists have modified plasmids into vehicles for the transport of recombinant genes, and they are useful tools for engineering many plant species. However, this method is ineffective on animals and doesn't work on all plants.

Retroviruses

In their natural state, retroviruses ("RNA viruses"), such as HIV, enter a living cell and take over its metabolism. They inject their RNA into the cell, taking over its cellular machinery and forcing it to make copies of the virus. Genetic engineers have turned this ability to their advantage. They modify the retrovirus so that instead of hijacking the cell to make viruses, it deposits the new gene. One pitfall of this method is that viruses are hard to selectively

target – this procedure often produces many failures for each success, and there is a very slight but real danger that the virus will deposit genes in the wrong place, or damage existing genes, resulting in unintended defects or even cancer. However, retroviruses have the advantage that they can be used to deliver genes to many cells at once, which makes them useful for gene therapy (see p. 181). In the future, "smarter" tailored viruses with greater discrimination may be developed.

Nanoviruses

At present (TL8), retroviruses and microinjection are the most common ways of inserting genetic material. However, TL9 engineering may use more exotic techniques. One possibility is the use of artificially engineered biological nanomachines capable of performing sophisticated molecular and cellular engineering. Such "proteus viruses" or "nanoviruses" may be radically engineered retroviruses or white blood cells, or completely artificial constructs. They pass harmlessly through cell membranes and take over cellular machinery using their own artificial enzymes, then alter or insert genetic material or other chemicals. They communicate with each other using specialized enzymes, and even cooperate, coordinating their operations. Nanoviruses are powerful tools, and are the basis of many ultra-tech engineering projects, taking over from clumsier tailored viruses in tasks such as germline engineering.

Artificial Chromosomes

One problem with inserting new recombinant genes into an organism is that the interactions between genes is complex and new ones can interfere with the working of neighboring genes in unpredictable ways. One way to solve this is to create completely synthetic chromosomes, first produced in 1997. An organism so modified will have more chromosomes than a baseline member of its species (which will easily show up on genetic tests), but this makes no real difference beyond the effects caused by the new genes. Since they're separate from the natural chromosomes, they're less likely to cause unintended defects. (They won't interfere with the operation of existing genes at the transcription level, although there is still a chance of interactions at the protein level.) The extra chromosomes will be passed on to offspring if both parents share them. See *Genetic Surgery Biomods* (p. 181) for additional uses for synthetic chromosomes.

GENE CLONING

Genetic engineering techniques can be used to isolate the particular gene that produces a given protein. That gene can then be inserted into a fast-reproducing bacterium, creating a transgenic species. What good is that? We'll demonstrate with an example:

The protein insulin is vital for treating diabetes. It's produced naturally in the human pancreas, but harvesting it from humans is not practical. Before gene cloning, insulin was harvested from other animal species, but this required expensive purification and sometimes had side effects. What was needed was a way to mass-produce pure human

insulin in large quantities. This was accomplished by using recombinant DNA techniques to splice the gene that makes human insulin into a bacterium. If the genetic engineering is properly performed, the bacterium will accept the foreign gene. The human gene will then “express itself” by telling the bacterium to manufacture the desired protein.

Commonly used bacteria can reproduce every half-hour or so (although this can vary a lot depending on the species) if they are supplied with the proper nutrients and their temperature is carefully regulated. Each time they reproduce, they double their population; in a day, there might be trillions of them. When a large enough mass of bacteria exists, it can be processed to extract the protein. A little more finesse in the genetic engineering may even produce a bacteria that excretes the protein itself. If a large enough vat is used, tons of commercially useful proteins can be produced.

This process has been used successfully since the 1980s. While TL8 gene cloning techniques of this sort focus on compounds that are medically useful (such as insulin or growth hormones), TL9+ techniques may widen this to include numerous proteins with exotic industrial applications. As genetic engineering labs become more widespread, it’s possible to imagine gene cloning being used to produce substances such as illegal drugs.

In addition to naturally occurring, medically useful proteins, engineering has spurred the design of new ones with novel characteristics, such as tailored enzymes designed to perform specific chemical reactions more efficiently than conventional catalysts. At present, only a few dozen enzymes are used for industrial purposes, such as detergents or food sweeteners, but enzyme engineering is on the verge of becoming a major industry. Many future products, from superior plastics to new foods and wonder drugs, may use genetically modified (“genemod”) enzymes in their manufacture, and such enzymes may be the first step toward building nanomachines.

GERMLINE GENGINEERING

This is what most people think of as genetic engineering. Using any of the genetic engineering techniques described above, genes are inserted into the reproductive germ cells of a plant or animal, such as its fertilized eggs. Modifications to the single, fertilized germ cell will be passed on to all successive cells in the organism, as the egg cell grows and divides. Moreover, if the process is performed correctly, the altered genes will be put in the right places and be accepted by the cells’ regulatory mechanisms. This will cause the cells to produce different proteins, which will lead to the organism developing in a different way than it otherwise would. The result? A permanent change in the species, and one that can be passed on to successive generations.

Germline gengineering can create enhanced or modified organisms. These include transgenic plants and animals with numerous commercial, medical, or even military uses (see Chapter 3) and altered humans or other intelligent species (see Chapter 2).

Horizontal Gene Transfer

Genetic material normally transfers vertically through generations of organisms, from parent to child. *Horizontal* transfer is the incorporation of genes into a cell from a source other than its parent. This is the basis of genetic engineering techniques, as the whole goal is to modify the genome of the target cell. For a long time, genetic researchers believed this could not occur naturally, but in recent years they have discovered that it is common among bacteria and archaea. Horizontal gene transfer is now known to occur in eukaryotic organisms as complex as plants and nematode worms. It can happen in three ways:

Conjugation is when two bacteria meet and exchange genetic material, first demonstrated by Frederick Griffith in 1928. This is a one-way transfer, from a bacterium carrying an enabling plasmid to one without. The plasmid transfer can also carry some or all of the donor’s own genome. Conjugation is an important mechanism for the spreading of mutations between bacteria – such as resistance to antibiotics.

Transformation is the uptake and incorporation of bare genetic material from the environment. This was first shown to be possible with bacteria in 1944 – nine years before Crick and Watson published the structure of DNA. This is the method commonly used for genetic research on bacteria, using plasmids as packages of DNA to be incorporated.

Transduction is when a virus or bacteriophage enters a cell and inserts part of its genetic material into the cell’s genome. This method is used for engineering eukaryotic organisms, since few of their cells take part in transformation.

Dangers of Horizontal Transfer

Although artificial horizontal gene transfer is a basic engineering technique, natural horizontal transfer may be a problem for a biotechnological society. Decaying organisms and bodily wastes release free DNA strands that can remain intact for up to a day in soil or 10 days in the ocean before being destroyed by environmental enzymes. Bacteria take up these fragments and incorporate the material into their genomes. This means that engineered genes in crops, livestock, and even human sewage will find their way into wild populations of bacteria. This could be exploited for biowarfare purposes, spreading genes designed to cause new types of cancers or even perform unwanted gene therapy on anyone who catches an infection. In a horror scenario, this could even happen by accident!

Changes made as a result of germline genetic engineering can reach a threshold at which reproduction with unmodified (or differently modified) individuals becomes impossible. At this point, the new germline is a different species. In *GURPS*, human variants incapable of interbreeding with baselines are called *parahumans*.

SELF-MODIFYING GENETIC CODE

It is possible for proteins to “edit” the gene sequences in a strand of DNA, physically cutting out sections of the molecule and inserting new nucleotides. A genetic code that produces such proteins has the capability of modifying itself into a new code. This capability can be used to produce cells or even give rise to offspring that do not share the genome of the parent.

If such editing is dependent on environmental factors, this could be a direct way of producing mutations and adaptations, providing a more rapid means of evolution than sexual reproduction. Such a system may evolve naturally, but could also be produced by deliberate engineering, to provide adaptable species for colonizing hostile environments or terraforming, for example.

Another use is to set up an initial colony of organisms that reproduce rapidly, and then after a set number of generations mutate into a slower-developing form. Self-modifying genetic code can also be used to grow biological products with desirable properties from a parent breeding stock with different properties – see *Non-GM GM Crops* (p. 79) for an example.

GENETIC SURGERY

Humans begin as single cell – a zygote. As we grow out of the germinal stage, our cells differentiate. Every cell now carries the full complement of genes, but only uses some of them, depending on where it is in the body. This is what distinguishes skin cells, brain cells, blood cells, and so on. The function of the genes in a cell may also change over time; for instance, after we stop growing, many cells switch off.

Genetic engineering can be performed after the germinal stage, but it's trickier. Instead of working on changing a single germ cell and then having those changes spread through the entire organism as the cell grows and multiplies, the body now has billions of individual cells, each with a different function, locked into a specialized role. Post-germ cell genetic engineering is known as genetic surgery.

Genetic surgery experiments on humans began in the 1980s with *gene therapy*. This process uses retroviruses or other methods of gene insertion to replace defective genes with functioning ones in specific cells. While it is very difficult to add genes that alter the way an organism has already grown, gene therapy can be used to correct hereditary defects.

Early attempts at gene therapy sometimes encountered problems getting the added gene to properly interface with the body's regulatory system – that is, making sure it

switched on or off when it was supposed to. Often, inserted genes either failed to make the necessary proteins or made too much of them. Today, many of these problems have been overcome. At TL9+, with the availability of more advanced tools like nanoviruses, genetic surgery may become a means of not only healing but also augmenting or transforming living beings. Individual gene therapy and gene surgery modifications are covered in Chapter 7 – see *Genetic Surgery Biomods* (p. 181).

GENETIC RECONSTRUCTION

A popular conception is that living organisms – particularly extinct creatures – can be “reconstructed” from a sample of their DNA. Even if the sample is incomplete, missing segments might be filled in by sections taken from more or less similar species. Once the DNA sequence is complete, it can be injected into a host egg cell taken from a species that produces its young in a similar way, with its original genetic material removed. Voilà, instant dinosaurs!

The reality is neither this simple nor this achievable. Once again, the biochemical context of a developing embryo containing the DNA is crucial (see *Genetic Simulation*, p. 10). Genetic scientists of today or the future don't have ready sources of cells even remotely as close to dinosaur ova as rats are to mice. If you put dinosaur DNA into an ostrich egg, as in *Jurassic Park*, you'll end up with a scrambled egg, not a *T. rex*.

That's assuming you have the entire DNA sequence. If you only have fragments, the situation is even more hopeless. Even if you could determine how the fragments fit together, how long the missing sections are, and what sort of genes in other species might be used to fill the gaps, those genes in the different environment of the rest of the DNA will interact in new and unpredictable ways. Splicing frog genes into incomplete dinosaur DNA does not give the resulting dinosaur frog-like traits; it produces random mutations, most likely killing the cell before it can begin growing.

The final nail in the coffin is that eukaryote DNA is inherently unstable over geological time periods. It breaks down within 100,000 years. Quite simply, there is no dinosaur DNA to be found; it all fell apart over 60 million years ago.

Archaeobiology

All is not lost, however. Many important and interesting species became extinct within recorded history, and for some of them we have preserved tissue containing plenty of DNA. Such recently extinct species are likely to have close living relatives that may provide compatible ova and form suitable surrogate mothers. So while dinosaurs are out of the question (unless time travel or parachronic travel can come up with the DNA!), we might reasonably expect Tasmanian tigers and great auks to be resurrected.

At high tech levels, it may be possible to provide a suitable biochemical environment for development of an embryo even if no workable surrogate is available. After all, the DNA does provide the blueprint for making the environment – if it has the right environment to begin with.

Bioengineering Equipment

Biotechnology requires high-tech equipment, although much of it can be abstracted out as standard gear in a fully equipped biotech laboratory.

Equipment Quality Modifiers

GURPS Bio-Tech includes examples of basic, good, fine, and best-quality equipment in terms of *Equipment Modifiers* (p. B345). Better quality biotech and medical equipment is *generally* also heavier and more expensive. A gadget's quality grade is always followed by "(quality)" in item descriptions, e.g., "provides a +2 (quality) bonus to Diagnosis skill." Quality is basic if there is no bonus, good if the bonus is +1, fine if at least +2 but less than +TL/2, and best if +TL/2.

Gadgets may also add a bonus to skill because the underlying technology is easy to use or realistically doesn't fail very often; an example is the bonus that higher-TL surgical instruments provide (p. B424). This is comparable to a ranged weapon's Accuracy. Any bonus that *isn't* marked "(quality)" is an intrinsic bonus like this. It has nothing to do with quality, and applies

whenever you use that variety of gadget. This bonus "stacks" with the quality modifier, if any.

Biotech Equipment Costs

Biotech and medical equipment can be expensive! Prices can also vary significantly, depending on features of the item and how new it is. The listed prices are averages for new equipment, which may vary by up to 50% in either direction.

Second-hand or reconditioned equipment is often *much* cheaper, as it's obsolete and doesn't have to pass stringent manufacturer safety checks. Such equipment has -1 to -3 to its HT score and the GM may rule that it requires an equipment failure check (p. B485) each time it is used.

Second-hand biomedical suppliers will sell equipment a few years old for just $(1d+1) \times 5\%$ of the full price – if they have it in stock. If you're on a budget and need an automed for your starship, this is the place to get it. Just remember, they don't offer any guarantees.

Genetics labs and many of the medical gadgets found in Chapter 5 also require reagents, sterile needles, or other consumables to keep running. Assume operating costs of such a piece of equipment are 1% to 5% of the listed price per month. Most equipment that requires power runs on building or vehicle power; portable powered devices typically have batteries that allow 12 hours of continuous operation. Solar or exotic power sources may be an option in some campaigns.



Biochemical or computer simulations could bootstrap the process, getting around the chicken-and-egg problem by iteratively converging on a solution that works. On the other hand, there may be more than one solution that produces a live organism, so there's no guarantee that the resurrected creature will be *exactly* like its extinct DNA cousins.

Not having a complete DNA sequence is a much more serious problem. Genes may be interpolated from a mixture of related species, theory, simulations, and outright guesswork, and a viable organism produced, but the chances are that it will be so incompatible with the original source as to be a different species, with unpredictable variations in physiology and behavior. The result may be essentially a chimera (see p. 38).

Alternately, a superficially similar existing species can be modified through genetic engineering or created using biogenesis (p. 26) to have the presumed appearance and behavior of the extinct creature, without needing *any* of its DNA at all. This will be a different species from the original

organism, and can't teach us as much about the original species, but is perfectly adequate for entertainment and display uses. As long as its behavior is fairly close to that of the real animal – or at least, how people *expect* it to have behaved – it will generally be adequate for filling its ecological niche. This may be the best route for recreating a "dinosaur park," short of time travel!

BIOTECH FACILITIES

Genengineering isn't something that can be done on the kitchen table – specialized equipment is necessary.

Lab Facilities

These are necessary to fulfill the basic equipment requirements for genetic engineering tasks. Weight and cost are not reduced at higher TLs – instead, sophistication increases. Modifiers are given for both minor and major tasks. Minor tasks are things like genetic testing, or synthesizing a known protein. Major tasks include cloning, chromosome mapping and sequencing, genetic reconstruction, and genetic engineering.



Full Genetics Lab (TL8)

This lab contains sufficient equipment and work space for one researcher and up to four assistants to perform advanced bioengineering. It contains tables, lab counters, and refrigerators, as well as high-tech (and fragile) gear such as several PCR machines, incubators, culture vats, microscopes, and other imaging systems. It provides a +2 (quality) bonus to Bioengineering skill but no bonus if used for complex genetic engineering research projects that need a state-of-the-art lab. A big lab complex will contain multiple labs, allowing several research teams to do work at the same time. \$1 million, 20,000 lbs. LC4.

Standard Genetics Lab (TL8)

Found at small biotech companies or average universities, this is a less costly and more compact version of the full lab (above). It provides a +1 (quality) bonus to Bioengineering skill. \$200,000, 4,000 lbs. LC4.

Small Genetics Lab (TL8)

A work table or counter, fridge and basic genetic engineering equipment. This is typical of community colleges, reclusive geniuses, and amateur bioterrorists. It is basic equipment (no modifier to skill). \$50,000, 500 lbs. LC 4.

Suitcase Genetics Lab (TL9)

A miniaturized, man-portable genetics lab. For all but the most simple tasks, it is improvised equipment (-5 to skill). It takes 10 minutes to pack or unpack. \$12,000, 20 lbs. LC4.

Hellkitchen (TL9)

This is a suitcase genetics lab optimized for producing biological weapons. It contains the necessary precision scientific equipment (including a miniaturized gene-splicing and PCR machine), cell cultures, and genetic engineering computer software to transform an ordinary kitchen into a

biowarfare laboratory. A hellkitchen counts as a suitcase lab for most tasks, but as a small genetics lab for developing disease cultures and similar bioweapons. It can also manufacture additional doses of a germ from an existing or modified culture at a rate of one dose per hour; an unmodified skill roll should be required to set this up.

The hellkitchen is so compact because it lacks even rudimentary safety features; any critical failure results in some form of disaster (e.g., the user becoming infected or releasing a plague). This applies whether trying to modify a disease or find a cure for one. Packing or unpacking it takes 10 minutes. \$50,000, 20 lbs. LC2.

Containment Tubes (TL9)

These resemble giant, vertical test tubes, large enough for a person to stand upright in, resting atop a base platform containing a life-support system and powerful vacuum pumps. They are used for containing human-sized specimens. Any super-scientist's lab will have a few of these for holding captured supers or experimental subjects!

The tubes are sealed, but are connected to an external air conditioner that recycles the air within them. They can also be pumped empty of air in 30 seconds. Canisters may be attached to the tubes to allow gases or liquids to be pumped into them (e.g., sleep gas, nerve gas, germs, or proteus virus), or to maintain a different atmosphere within the containment tube. A gas canister suitable for flooding the tube (requires five doses of whatever gas or other agent is used) is 5 lbs. and \$300. It can hold 100 doses of gas.

Access to the tube is provided by a transparent sliding door, which causes part of the tube to slide open. The door's lock cannot be picked from inside the tube. Opening or closing the door, or controlling life support in the tube, is accomplished using either controls on the base or an external computer terminal. The containment tube itself is made of a plexiglas-like material with DR 30 and HP 55 (it is also Brittle). Increase DR at higher TLs: DR 45 at TL10, DR 60 at TL11, DR 90 at TL12.

Each containment tube is \$20,000, 400 lbs., LC4. It runs off building power.

For double cost, the containment tube can have twice the DR; at four times cost, three times the DR. Containment tubes for beings larger than humans are possible; multiply cost, weight, volume and power requirement by relative weight compared to an average human. Growth tanks, forced-growth tanks, and chronowombs may be outfitted as containment tubes; add half the weight, cost and volume of the tube to the weight, cost and volume of the growth tank or womb. This is useful if growing dangerous beings.

Lab Biohazard Precautions

Biotech labs are rated for the level of biohazard safety that is practiced in them:

P1 – Ordinary microbiological lab procedures, such as using absorbent mats to catch spills and ultraviolet lamps to kill contaminants, and wearing protective gloves.

P2 – As above, but restricting access (i.e., a lock and a "Keep Out" sign). This is the highest level possible for a suitcase lab or hellkitchen (above).

P3 – As above, but lab air pressure is lower than its surroundings, so that airborne microorganisms blow in rather than out. Triple the size, weight, and cost of the lab facility. Any critical failure that would result in the escape of biohazardous material should be confirmed by a second failure; if this second roll succeeds, the accident merely contaminates the lab itself.

P4 – Sealed lab. Lab workers change clothes and shower, and there will be an airlock between the lab and the outside world. May have security guards. Multiply size, weight, and cost by 10. A critical failure that would result in the accidental escape of biohazardous material should be confirmed by a second critical failure (e.g., something else went wrong, like the airlock door malfunctioned). Deliberate sabotage can still circumvent these precautions!

Maximum-security labs are relatively rare. In 2005 there were four P4 laboratories in the United States (with six more planned) and 50 laboratories at P3 (with 19 more planned).

GENETIC ENGINEERING IN PLAY

If the GM wants to game out the process (e.g., a PC is the engineer), this version of the New Inventions rules (p. B473-477) can be applied to genetic engineering.

First, the engineer decides what traits or changes to produce in an organism, within the limits possible at his TL. This involves describing the modification in game terms, often as a racial template. Chapter 2, Chapter 3, and Chapter 4 detail the various traits it may be feasible to engineer into humans, animals, plants, and microorganisms at particular TLs. If the player's description is especially clear or clever, the GM should give +1 or +2 to all related skill rolls.

Required Skills

The invention skill required is Bioengineering (Genetic Engineering). Bioroids and similar constructs may also require Bioengineering (Tissue Engineering); if so, use the lower of the two skills.

Complexity

Determine the "complexity" of the invention using the table and guidelines on p. B473. This requires knowing the retail price of the organism or modification; see *Life's Price Tag* (p. 65) for a specific formula and Chapter 2, Chapter 3, and Chapter 4 for examples of retail prices. Complexity can be increased or reduced for individual cases.

Complexity	Required Skill Level	Retail Price
Simple	14 or less	Up to \$100
Average	15-17	Up to \$10,000
Complex	18-20	Up to \$1,000,000
Amazing	21 or more	Over \$1,000,000

Concept

After determining complexity and required skills, the GM makes a secret "Concept roll" against the inventor's invention skill to see whether he comes up with a testable theory.

Modifiers: -6 if the invention is Simple, -10 if Average, -14 if Complex, or -22 if Amazing. +5 if you have a live or well-preserved specimen of an existing species you're trying to copy, or +2 if the species already exists but you don't have a model; +3 if performing eugenic (rather than species) engineering, i.e., if all traits being added to a template are ones that can occur naturally in the organism's genome; -5 if the basic technology is totally new to the campaign (*regardless* of TL); -5 if the required trait is one TL above the genetic engineer's TL. A "model" is a live or well-preserved specimen.

The lead genetic engineer may roll once per day. On a success, proceed to the next step. On a failure, he may try again the next day at no additional penalty. On a critical failure, it's a flawed concept that *looks* good but that will never work in practice – go on to the next step, but note that it is doomed to failure. (If the genetic engineer already has obtained a complete genome and proteome, he can skip this stage altogether.)

Prototype

A success – or critical failure – on the Concept roll gives the genetic engineer the detailed concept he needs. Now he must perform the actual genetic engineering. This requires a second roll against invention skill, and an appropriate genetics laboratory (p. 16). Genetic material is also required. In humans and other animals, this means the eggs and sperm, collectively called gametes. These may be taken from a donor (half might come from the genetic engineer, if he wants to work on his own genetic material). Banks of frozen germ cells may also exist. In most societies, traffic in genetic material, especially from sapient beings, is regulated, but donors are relatively easy to locate.

The GM makes this "Prototype roll" in secret.

Modifiers: All modifiers listed for Concept rolls; +1 per assistant with Bioengineering (Genetic Engineering, or, if appropriate, Tissue Engineering) or with Electronics Operation (Medical) skill 20+, to a maximum of +4; -1 to -10 (GM's discretion) if the genetic engineer must make do with anything less than the most advanced tools and facilities for his TL – a full genetics lab.

On a success, he creates a prototype – a test tube of microorganisms, a bit of plant tissue suitable for culture, or a viable early embryo ready to be implanted. On a failure, the result is non-viable and is discarded; he may try again, provided he has the time and money (see p. 18). On a critical failure, a lab accident of some sort occurs. This may mean one of two things: either a seemingly viable prototype with a hidden fatal flaw that won't be detected by testing (a "Frankenstein"); for microorganisms, it may optionally result instead in accidental exposure or release – but see *Lab Biohazard Precautions*, p. 16.

If the genetic engineer was working with a flawed concept (due to a critical failure on the concept roll), he will never create a working prototype (this is why the GM rolls in secret!), but a *critical success* on the Prototype roll lets him realize that his idea was bad and start again.

Time Required: Each Prototype roll requires 1d-2 days if the invention is Simple, 2d days if Average, 1d months if Complex, or 3d months if Amazing. Divide time required by the number of skilled people working on the project. Minimum time is always one day.

Cost: The only cost is the personnel costs and the purchase and upkeep of the lab. A suggested cost per attempt is equal to the retail price of the genetic construct being built times the number of embryos, tissue cultures, or doses of the microorganism that will be created on a successful attempt. Usually several are created at once, since that allows some to be destroyed in testing.



Defects and Testing

Most initial prototype life forms have bugs or shortcomings, referred to here as defects. These are genetic errors that crept into the genome, or inadvertent negative consequences of combining particular genes. Critical success on the Prototype roll means there are no defects; success by three or more gives 1d/2 minor defects; and any other success gives 1d/2 major defects and 1d minor defects.

Minor defects are annoying, but not critical. In animals or people, each is a racial disadvantage worth up to -10 points, or an unplanned limitation on an advantage in the template, or an unfortunate feature such as Sterile. See *Unintended Disadvantages* in Chapter 2 (p. 61) for guidelines. In bacteria or plants, they may be changes that make the construct less useful than was hoped for, e.g., a new food plant may turn out to be viable only under certain climatic conditions, or be vulnerable to a particular pest.

Major defects are potentially catastrophic. In animals or people, each is a racial disadvantage worth more than -10

points. Common problems include racial Attribute penalties, low Appearance (even Monstrous), Stress Atavism, Susceptible to Disease, and Unusual Biochemistry. In microorganisms or plants, major defects may include organisms only viable under careful lab conditions, that pose health risks to consumers (if intended to be beneficial), mutate rapidly "in the wild" or other crippling defects.

Testing

To find defects requires careful testing. In the case of bacteria or tissue cultures, the organism is allowed to sprout or reproduce while being tested; for embryos, especially those of sapient species, each test sacrifices an early embryo, although non-destructive testing may be carried out at -5 to skill. One roll is allowed each week, using either Bioengineering (Genetics) or Diagnosis skill. Each success finds one defect; a critical success finds *all* defects. A critical failure means the user believes he's found, possibly erroneously, that no defects remain, or thinks he's found major defects even if there aren't any, which might cause him to start over.

If a genetic engineer tests and finds defects, he may discard the prototype bacteria, tissue cultures, or early embryos and attempt another prototype roll, hoping for a better result, or he might decide the problems are minor enough to ignore, and proceed anyway. Discarded "defective" prototypes might be destroyed, but they could also be preserved (e.g. embryos might be frozen or placed in stasis). Science fiction is full of situations where people stumble on old bacteria samples, preserved embryos, or the like and decide to use them, not realizing they had some hidden and potentially deadly flaw!

Growth

Microorganisms can be simply allowed to reproduce in test tubes or vats, injected into hosts, etc. The cost of growth depends on the quantity required and whether it requires any special environment.

Plants are grown in tissue-culture medium until they are ready to root, just as commercial greenhouses do when cloning plants for sale to gardeners.

Embryos can be grown in growth tanks (p. 20) or transplanted into an appropriate host mother – possibly enough the donor of the original genetic material. (See *Reproductive Technology*, p. 19). They can then develop progressively into a fetus and baby. Physical defects may be noticed as the embryo grows into a fetus, especially if they're obvious. This might also prompt a decision to abort the fetus, or an attempt to mitigate the problem using gene therapy (p. 181) before or after birth. More subtle problems may not be noticed until childhood or even maturity.

Viable organisms can also reproduce through their usual means (unless sterile), although in the case of sexual reproduction, species modification may render genetic constructs unable to crossbreed with normal examples of the race. Cloning (p. 22) is another possibility, and may be commonly practiced to prevent dilution of any special traits produced by genetic engineering. Clones of both sexes are possible through minor tinkering; no special rolls are required for this.

REPRODUCTIVE TECHNOLOGY

Some individuals suffer from genetic conditions, illnesses, or accidents that hinder the processes of natural reproduction. Others wish to have children without the restrictive biological requirement of exactly one mother and one father.

All the methods discussed below can be used on animals as well as humans. Controlling animal reproduction is common in agricultural applications and will be important for extraterrestrial colonies.

BIRTH CONTROL

One major aspect of controlling reproduction is *preventing* it. Prophylactic barrier methods have been available to prevent human conception since ancient times (TL1), but are unreliable.

Hormone-based oral drugs designed to prevent ovulation were first marketed in 1960 (TL7), providing a reliable temporary method of contraception, but a daily dose can be forgotten. Ovulation-preventing drugs such as progestin can also be encapsulated in slow-release implants; a simple procedure will prevent conception for times ranging from a few months to five years. Similar drugs for men have taken longer to develop and are not yet commercially available, but should be established by TL9. For “birth control pills” of various types, see *Drugs and Nano*: oral contraceptive pills (p. 157) and male contraceptive pills (p. 158). Abortifacient drugs (p. 149) allow people to be careless until after a sexual encounter.

Intra-uterine devices are very reliable, but require a Physician+4 roll to insert properly. The permanent solution is sterilization. The requisite surgery on men is an outpatient procedure taking an hour; for women it is a multi-hour operation requiring a hospital stay. At TL8+, a reversible laser treatment for males becomes available.

FERTILITY TREATMENTS

On the other side of the coin, some people require assistance in conceiving a baby. People can have reduced or impaired fertility due to genetics, disease, injury, or chemical exposure. As long as the body is still capable of producing gametes, medicine can assist in reproduction, and even that isn’t a barrier with high enough technology.

In Vitro Fertilization (TL8)

In vitro (“in glass”) fertilization (IVF) allows pregnancy without sex. A woman’s ova are collected, then fertilized with sperm in a fluid medium. The resulting embryo is implanted into her uterus, into that of a surrogate mother, or (at TL9+) into an artificial womb such as a growth tank or forced-growth tank.

The first IVF was performed in 1978. It is most often used when it is impossible for a couple to conceive naturally. Today, IVF is relatively common but somewhat tricky

and expensive. It is growing in popularity in wealthier countries: at the start of the 21st century, over 100,000 babies had been born in this fashion.

The fertilized ova grow in an incubator for 60 hours to a pre-embryo state, where they are ready to be implanted in a mother. The success of the procedure is known in two weeks. The would-be host mother will often take the hormone progesterone to thicken the uterus lining, increasing the chance of successful pregnancy.

One advantage of IVF is that it makes it possible to perform very early genetic testing. If genetic problems are suspected in the parents, IVF may be preferable for this reason alone. Sperm, ova, and pre-implantation embryos can easily be frozen and thawed for use later – sometimes *much* later – leading to ethical questions when the donors die.

Statistics: There is only a 1-in-6 chance of success per IVF attempt at TL8; each attempt takes at least 4d weeks. At TL9+, this chance increases to 5 in 6. In humans, each attempt costs \$10,000 at TL8, \$5,000 at TL9, and \$2,500 at TL10+.

Artificial Sex Cell Production (TL9)

When infertility is caused because the patient cannot produce viable gametes, cloning technology can come to the rescue. Rather than cloning an embryo using one parent’s DNA, this procedure uses adult cells to produce haploid sex cells, containing half of the parent’s DNA. This can be combined with a normal sex cell from the partner (or another artificially produced gamete) to produce a fertilized zygote.

This method allows otherwise infertile individuals to reproduce sexually, i.e. by combination of their genes with those of a partner. Many people would view this as more natural than the option of cloning. This procedure doubles the cost of an IVF treatment.

Alternative DNA Mixing (TL9)

I have my first Daddy’s hazel eyes and my second Daddy’s red hair, but they bought my sense of direction from the gene bank.

– Chance Mackintosh

Same-sex partners can use genetic engineering to blend their genetic material together. Women don’t need to involve men at all; men will still need a female egg donor, although the genetic material from the egg nucleus could be removed and replaced with genetic material drawn from the male partners. If it is important for the men involved to provide the mitochondrial DNA as well, the donor egg can come from a matrilineal relative (anyone descended from one’s mother, mother’s mother, etc., will share the same mitochondrial DNA). Splicing genetic material from same-sex partners together costs an extra \$10,000 and takes a week. Halve the cost at TL10 and again at TL11+.

At TL9 it is also possible to blend the DNA of up to 46 partners (the number of chromosomes in a human) into a single zygote. This involves selecting particular chromosomes from each contributor's DNA to form one complete genome. The child would inherit some features from each of the multiple parents. By TL10, individual genes (parts of chromosomes) can be blended from any number of parents; they can either be chosen deliberately for particular genetic characteristics or at random.

TL10 also allows male parents to replace mitochondrial DNA in any donor egg with their own. Finally, at TL 11 males can do away with females altogether, producing a viable embryo without needing a donor egg through techniques similar to neogenesis (p. 27).

SURROGATE MOTHERHOOD

A fertilized egg or early embryo can be transferred to a human host mother to grow to term within her. This has the advantage of not requiring a bulky, ultra-tech growth tank (see below). Some people believe it might also be better for the mental or physical health of the child. The disadvantage is that surrogate motherhood, especially for pay, is often considered unethical or even illegal, and hence can be expensive.

In areas where the practice is legal, a host mother can be hired for \$20,000 to \$30,000 plus payment of medical bills. Usually, a potential mother has to undergo a medical examination to certify she is healthy, and sign a contract agreeing to refrain from activities that might put the developing fetus at risk (e.g., drug abuse, dangerous sports). In some areas, professional associations of surrogates may exist.

If surrogate motherhood is illegal, the fee could be much higher. Cheaper host mothers could be hired in impoverished regions, such as slums or Third World nations. However, employers might balk at this, partly due to fears that a desperate and impoverished mother might be more likely to suffer from ill health or substance abuse, and partly due to snobbery.

There is a chance that the mother will become attached to the child and try to keep it, or change her mind and decide to terminate the pregnancy. This risk is increased where surrogate motherhood is considered illegal, since there is little the employer can do in such circumstances without admitting guilt. In any such disputed circumstance, the exact legal status of surrogate motherhood, and the nature of the transaction involved, will usually influence the decisions of the court in determining whether the rights of the host mother, the employer, or the developing fetus take precedence.

Rules for pregnancy and childbirth are beyond the scope of this book. Assume a pregnancy proceeds normally unless the GM decrees otherwise for dramatic necessity. Unusually modified babies may carry a greater risk of abnormal pregnancy.

Nonhuman Surrogates

Females cannot normally carry embryos of other species, but genetic modifications can make this possible.

This allows brood animals to carry human babies to term, either to boost population growth or free up human mothers for strenuous jobs. This technology might be used if growth tanks (see below) are infeasible or poorly regarded. The other possibility is modifying humans to gestate other species . . .

GROWTH TANKS

Sometimes called an "artificial womb" or "exowomb," the growth tank is a basic tool of ultra-tech bioengineering. Programs to develop artificial wombs are underway at TL8; they should be available by TL9. The main impetus driving this technology is not so much the desire to do away with the womb as the need to create incubators for very premature babies. Currently, babies born less than six months after conception have a low chance of survival, because their lungs aren't ready to breathe air. Artificial wombs that use oxygenated fluids such as perfluorocarbons (the same chemical used in *Perflubron Blood*, p. 131) can enable much younger infants to survive, and may lead to practical growth tanks.

An artificial womb contains the necessary facilities for growing a multicellular animal from gametes to healthy birth, eliminating the need for surrogate mothers. Growth tanks may be used to grow clones, genetic constructs, or unmodified human embryos. This is no faster than natural growth – growing a human from germ cells to a baby requires nine months; adulthood takes 18 years.

Growth tanks are enclosed, but may have windows or cameras so that observers can see the developing organism. Most are big enough to allow the organism within to grow to normal birth size, but some are larger to allow growth to adulthood.

An organism developing in a tank has the same degree of awareness as a baby in its womb. Individuals kept in the tank past the fetal stage and into childhood will be conscious, but will not develop mentally in the absence of stimuli. Electrodes attached to muscle groups can keep them stimulated in the tank, the body twitching constantly in an unconscious exercise program that maintains muscle tone.

It is safe to remove a creature from the tank before its intended "birth" date, provided it has developed past the fetal stage. If the organism has been in there for less time, it will not be able to survive outside the tank without medical care (and prompt transfer to another growth tank or surrogate mother).

Destroying a growth tank and severing the artificial umbilical cords will free the organism. This will kill it if it has not developed enough to be born, but is no more traumatic than a normal birth otherwise.

Growth Tank (TL9)

Normal growth tanks can be used to grow any single organism up to the size of a human baby. For larger growth tanks, multiply the weight and cost by the weight of the organism relative to a 10-lb. baby; e.g., a growth tank for a 100-lb. foal is 10 times the cost and weight. Raising a 10-ton dinosaur to adulthood requires a tank 2,000 times as big as normal! A tank for a human baby: \$10,000, 10 lbs. LC3.

Forced-Growth Tanks

These are growth tanks equipped to tremendously accelerate the development of the organism within it without doing it any harm. At present, it is unclear whether this is even possible, so forced-growth tanks are superscience – the GM must decide at what TL, if any, this technology becomes available.

Without forced-growth tanks, many of the dramatic possibilities of cloning are rendered moot due to the time it takes a human being to develop to adulthood. With a forced-growth tank, it is possible to take a cell sample from someone, make a clone and force-grow it to maturity, or even the same age as the cell donor, effectively allowing the creation of clone doubles. It's also possible to mass-produce armies of cloned or genetically altered people.

A forced-growth tank is like an adult-sized growth tank, with the difference that the organism within it develops *much* more rapidly. A typical forced-growth tank takes a minimum of three weeks to mature a human from a cell into a baby that can survive outside the womb. If not removed from the tank, the growth can then be accelerated to the even more rapid pace of just over one physiological year per day until the organism reaches age 25.

The force-growth process can be deactivated, allowing the person to grow in a normal fashion, exactly as within a growth tank. Once it is stopped, it cannot be restarted without killing the organism. Alternatively, the organism can be “stabilized” using an artificial hibernation process to keep it unconscious and at the desired physiological age for as long as it remains in the tank.

While someone is being force-grown, he is unconscious. A person newly awakened from a forced-growth tank is a blank slate, with no memories or skills.

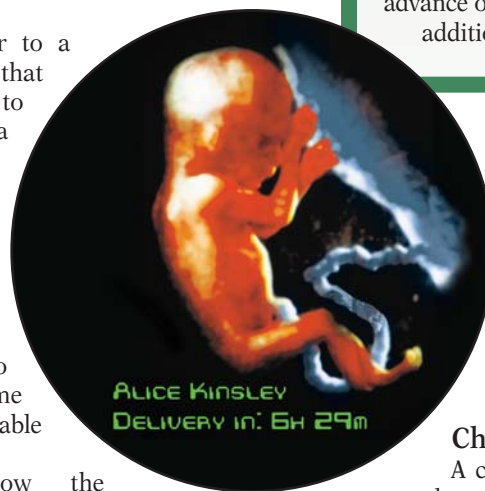
Forced-Growth Tank (TL[^])

A forced-growth tank has 10 times the cost and twice the weight of a growth tank: \$100,000 and 20 lbs. for a standard tank. LC2.

Chronowombs

A chronowomb is similar to a forced-growth tank, except that instead of using chemicals to accelerate growth, it creates a pocket of accelerated time within the tank. The GM should set available time dilation ratios based on campaign needs. A suggested ratio is roughly 700:1 – a day of growth every two minutes, a month every hour, or two years every day. Some chronowombs may have variable time dilation controls.

External controls allow the chronowomb to be set to operate for a specific amount of time. When not being used in chrono-acceleration mode, it functions as an ordinary growth tank.



Universal Growth Tanks and Wombs

Growth tanks, forced growth tanks, and chronowombs are for use on a single species or group of closely-related species (such as humans and variant parahumans) only. *Universal* growth tanks and chronowombs can provide suitable growing conditions for any species able to fit inside, given a DNA sample or database containing biochemical data for the species. These appear one TL later, and cost twice as much.

Growth and Forced-Growth Tank Fees

An institution that provides growth tank services will usually charge the following fees to its customers:

- \$1,000/month to grow an embryo in a growth tank (or a forced-growth tank without using forced-growth). Growing a human embryo to a baby would thus cost \$9,000 and take the usual nine months, while leaving him in the growth tank and growing him to age 25 would cost a further \$300,000 and take 25 years.

- \$1,500/week, for six weeks, to force-grow a human to maturity (or to any earlier stage of development).

For species that mature earlier or later, modify the times and costs appropriately. For larger-than-human organisms, multiply the cost by the relative size (use average racial weight as a guide). The GM may decide that different species require specialized tanks. In this case companies may spring up to provide pet and livestock facilities. The only places likely to be set up for growing unusual organisms are major biotech corporations. Persuading them to tie up their facilities requires either a large advance order, inside connections, or a substantial additional fee of perhaps 10 times the cost.

Unlike forced-growth, developed individuals (or even adult humans) can use chronowombs – but they should be careful with the setting or they may end up aging to death! A side effect of the time-acceleration process is disorientation followed by unconsciousness: individuals can't climb into a chronowomb and study skills or the like, but they can use it to heal (regenerating 1 HP per 2 minutes).

Chronowomb (TL[^])

A chronowomb is a growth tank with an integrated stasis field generator. The generator costs \$5,000,000 and weighs 500 lbs. Add the cost and weight of the tank; \$200,000 and 200 lbs. for a human adult-sized tank. LC2.

Stem Cells

Stem cells are undifferentiated cells with the potential to grow into any of several different specialized cell types found in a multicellular organism. This makes them useful for many biotech purposes, including tissue engineering, cloning, cancer treatment, tissue repair, and genetic engineering.

Stem cells can be collected from many organs in adults, as well as the blood in umbilical cords and placentas. These can differentiate into a limited selection of specific cell types. For example, bone marrow stem cells can become any of several types of blood cells, liver cells, or muscle cells – but not skin cells. Such cells have uses for therapeutic purposes, but these are limited.

More useful are stem cells collected from embryos, because these still have the ability to differentiate into any of the over 200 cell types in the human body. Under the right conditions, they can divide and grow into an entire human. Embryonic stem cells *can* be collected from an adult, by growing a clone and taking the cells from the blastocyst before cell differentiation occurs. The disadvantage to this is an ethical one: the cloned embryo has the potential to grow into an entire human being, so some people consider turning it into a cell culture to be destroying a human life. Current research

indicates this ethical dilemma may be solvable by inducing *dedifferentiation* of adult cells into “embryonic” stem cells without growing them as a clone, but whether this will ever work remains to be seen.

Uses of Stem Cells

Stem cells can be used therapeutically simply by injecting them into their usual site in the body. Bone marrow and blood stem cells have been used in this way since the 1970s for treatment of the aftereffects of chemotherapy, as well as spinal cord injuries and Parkinson’s disease. The cells replenish the body’s normal supply and grow to regenerate the damaged tissue. Research promises to apply similar techniques to regenerating heart tissue after heart attacks and to fighting brain tumors.

By TL9, embryonic stem cells hold the promise of wholesale regeneration of the simpler organs, including the spinal cord of paralysis victims. Stem cells can also be used to grow spare organs outside the body, for later transplantation – see *Tissue Engineering* (p. 26). Which method will prove to be easier is still a matter for debate. Research and treatment using embryonic stem cells may, however, be stifled by ethical concerns and legislation.

CLONING

Unlike bacteria, species that reproduce sexually receive chromosomes from both parents, and each child is different. Cloning is a way around this. It is a bioengineering technique that is used to produce multiple, genetically-identical offspring.

THE HISTORY OF CLONING

Cloning was a long-established process in horticulture before anyone thought of applying the process to animals.

Cloning is easy with plants – it’s done by making a cutting and planting it. Farmers and gardeners create clones all the time. It’s not so easy with animals, but it is possible.

Cloning from Embryonic Cells (TL7-8)

Animal cloning technology was first explored in the mid-1960s with frogs and fish, whose egg cells are very simple in design. These early clones were made by transplanting the nucleus (containing the chromosomes and genes) of an embryonic animal cell into an egg cell whose genetic material had been removed. With electrical stimulation, the modified egg then developed normally into an embryo, a fetus, and finally a baby, genetically identical to the nucleus donor.

However, while scientists could make clones, there seemed to be a catch – a process known as cell differentiation. As an embryo develops into a fetus, certain genes in

each particular cell activate, depending on the cell’s role in the developing organism. The cells become much more specialized; for instance, they turn into skin cells, heart cells, brain cells and so on. The unused genes “switch off,” and the now-specialized cells lose the ability to replicate in the fashion that cloning requires, because the genes required to make a complete animal are no longer functioning. The only way to avoid this problem seemed to be to take a cell from the early embryo (a stem cell), before it had differentiated.

During 1980s and 1990s, cloning experiments were applied to mammals. Human embryos were first cloned in 1993, but they were not allowed to develop into fetuses. Researchers figured out how to make multiple clones by culturing several cells from the same embryonic cell. One can also split an embryo at the 2-, 4-, 8- or possibly 16-cell stage to produce artificial twins, quadruplets, etc.

This technique is especially useful for cloning animals like livestock, but it has its limitations. The decision to clone an animal – or a human – has to be made before it’s born. However, combined with engineering, embryonic cloning allows genetically-engineered species (human or animal) to be mass produced, even if the engineering was so extensive that they could no longer interbreed with normal specimens. It is especially popular in animal husbandry: a genetically-engineered cow embryo, for example,

can be cloned many times, ensuring its modifications are not lost through normal interbreeding.

In addition to ensuring the duplication of particular gene lines, humans might use embryonic cloning for other reasons:

Deliberate Twins (or Triplets, etc.): A mother who wanted multiple children might choose to carry two (or more) at once, if she lacked time or inclination for multiple pregnancies, or simply wanted to bear twins, triplets, etc.

Therapeutic Cloning: Cloning techniques may be used to create early embryos as a controlled source of high-quality human stem cells (p. 22) for medical research or treatments.

In Vitro Fertility: Some women can only supply a single egg for in vitro fertilization (p. 19), resulting in a low chance of success; by using embryonic cloning, that same egg can be divided before implantation, increasing the chance of a successful pregnancy (Add +1 to the success roll; double the cost).

Spare Parts: One clone is allowed to develop; others are removed and frozen. If necessary, the embryos can later be allowed to develop as a source of transplant material. In some cases, such as bone marrow transplants, this would be possible without injuring the donor, although the ethics of such a procedure are troubling.

Cloning from Post-Embryonic Cells (TL8)

This is much more difficult: it is the creation of a genetic duplicate of an adult animal (or human). Take a DNA sample from anywhere (skin, breast, blood, etc.), load it into an egg whose DNA has been removed, and grow it into a baby who is a perfect genetic copy of the original cell donor. It seemed like an impossible dream – but in 1997, Scottish scientists led by Ian Wilmut proved that it wasn't: Dolly, a female sheep cloned from adult cells, was born! Since then, many other animal species (cats, horses, dogs, etc.) have been cloned.

How is this accomplished?

First, cells (in the case of Dolly, udder cells) are removed from an adult animal and allowed to replicate in nutrient dishes. Then, the nutrients are scaled back dramatically, and the starving but still-living cells become quiescent. This crucial additional step of making the cells inactive is enough to allow their genes to receive signals to start making an embryo, given the correct environment.

This environment is provided by an egg taken from a female of the same species (who can also be the cell donor). Using techniques similar to embryonic cloning, the nucleus of the unfertilized egg is scooped out, removing the genetic material but leaving the rest intact. An electrical spark is used to fuse the quiescent donor cells with this egg, “awakening” the cell. The egg and nucleus then begin to form embryonic cells; about a week later, they're ready to be implanted into a surrogate mother. The offspring that results is a clone of the original cell donor, with no relation to the egg donor or the surrogate mother.

While cloning of adult organisms is quite possible with mid-TL8 technology, there are still some real and potential problems:

Inefficiency: The methods used to produce adult clones at mid-TL8 are very difficult and labor intensive. In Dolly's case, out of 277 attempts to fuse adult cells with eggs, only 13 pregnancies resulted, and only one was born alive. Nevertheless, the odds are improving as further research and development has been financed.

Side Effects: There are some difficulties with producing viable organisms from cloning (see *Risks of Cloning*, p. 24). Even though all the genes are transferred, some do not appear to “switch on and off” as they should, resulting in an increased number of abnormalities in many cloned animals. At TL8, any clone, human or animal, is likely to have hereditary disadvantages. Problems noted in animal clones have included a level of Short Lifespan (p. B154), a tendency toward obesity (e.g., Overweight, Fat, etc.), and problems with the immune system manifesting as Susceptible to Disease (any HT penalty) (p. B158). It is unlikely that there will be much support for human cloning until safer methods are developed, although that does not rule out the possibility of clones (successful or otherwise) being attempted. TL9+ cloning techniques are assumed to overcome these problems, but success is not guaranteed!

CLONES AND UNIQUENESS

Genetically, a clone is much the same as an identical twin. A newborn clone will be a baby, without any of the original person's memories or skills. However, various forms of ultra-technology may change this – e.g., deep learning (p. 143) and forced-growth tanks (p. 21).

All other factors being equal, a clone will have an identical physique and appearance to the original (unless there are any genetic abnormalities as a result of cloning problems). A clone is physically the same as the original at the same stage in its life. Thus, a nine-year-old clone will look like the original did at age nine. While a clone will not have the original's memories, it will share any genetic influences on body and mind. In game terms, this means it will have any advantages and disadvantages that the GM rules are genetically inherited, and should have similar attributes to those of the original at the same age.

However, everything is not always equal. Diet, exercise, and environment can have a dramatic affect on characteristics, from looks and build to behavior and intelligence. These changes can begin even before the clone is born. For example, if the clone is carried by a healthy surrogate mother, but the original was born to a mother who was malnourished during her pregnancy, the clone may well grow up to be taller and healthier!

If forced-growth tanks are available, they may be able to regulate the fetal environment to ensure that a clone is identical in appearance to the original, assuming this is desired. Without this technology, ensuring that a clone is completely identical requires ensuring that the clone's nurture and environment – from womb onward – simulate the original's. In some cases, this may require exhaustive research into the original's childhood.

Risks of Cloning

Despite having cloned several mammal species, researchers are still battling a problem inherent in the structure of the genes. The telomeres of any adult cell used for cloning have already been degraded (see *The Genetics of Aging*, p. 183). This means the cells in a newly cloned body start their lives effectively as old as those in the original donor. Even though the overall body is young, the cells begin to display the effects of old age prematurely.

This occurred with Dolly the sheep, who developed arthritis at the unusually young sheep age of six years. At present, scientists agree that a cloned human would likely suffer a similar fate. Before human cloning can become viable, this problem must be overcome, possibly by treating donor cells with telomerase before generating the clone.

Clones (and identical twins) may look alike, but fingerprints, palm prints, freckle patterns, and retina prints will not match, at least not without surgical modification. They may be quite similar, however, requiring an expert to tell them apart.

Also, the genes for a cell's mitochondria (its energy source; see *Organelles*, p. 103) – are contributed by the egg donor rather than genetic donor; the mitochondria exist outside the cell nucleus. Thus, unless both the egg cell and the genetic material (the mature cell nucleus) are donated by the same person (who'd have to be female), the clone won't be exactly identical – there will be slight differences in the tiny genome of the mitochondria.

UTILITY OF POST-EMBRYONIC CLONING

Why clone people at all? There are several possible reasons:

It is an alternative method of reproduction when natural methods fail. Many people want to have children – it is after all a biologically programmed imperative, for the good reason that if most people don't have children the species will die out. But some people can't, even with the help of conventional reproductive technologies (p. 19). Someone unable to produce ova or sperm has no way of

passing on genes to the next generation, except by cloning. Using cloning to have children is in many ways preferable to adoption or using donor sperm or ova. The children will share a genetic heritage with the parent, making social situations easier to manage. And there is no risk that a genetic parent will come looking to reclaim custody of "his" child, or that the child will grow up unsatisfied with not knowing who his genetic parents are.

Cloning is also an alternative when a prospective parent simply doesn't *want* to have a reproductive relationship with a person of the opposite sex. Homosexuals or loners can use the technology to fulfill a desire for children.

Cloning might be the only way for a couple to have *healthy* children. If one parent suffers a terrible genetic condition, cloning the other partner will produce a child who doesn't inherit it.

The cloning of humans is on most of the lists of things to worry about from science.

– Lewis Thomas

Then there are reasons for cloning that involve helping others. A cloned sibling may be the only chance a patient has of receiving a matching tissue transplant to cure a disease. This can be done benignly, where the clone loses nothing from the donation (such as bone marrow to cure leukemia). On the other hand, unscrupulous individuals may want clones for their vital organs, replacing worn-out hearts, kidneys, or even the entire body in an attempt at eternal youth (see *Head Transplant*, p. 143).

Finally, clones may be created for social reasons. Even though a clone is not mentally identical (and may have physical differences), people may seek to clone a dead pet, deceased child, or former lover, for sentimental reasons. Having a twin of a person can be useful for all sorts of illicit activities, ranging from "celebrity" prostitution to training a replacement for infiltration purposes. Cloning may also be used for eugenic reasons, such as to reproduce valued genetic traits (whether natural or engineered).

Some of these reasons are worthy; others are distasteful or criminal. The ethical repercussions of cloning for these purposes are discussed in Chapter 8 (*Playing God*, p. 195).

BIOMETRICS

Biometrics is the science of measuring and statistically analyzing biological data. It includes technologies for personal identification by analyzing physiological characteristics such as fingerprints, facial patterns, or DNA. Uses include security systems, computerized face and voice recognition, and forensic identification, both for catching criminals and identifying dead bodies.

Bertillonage (TL6)

Alphonse Bertillon developed one of the first practical biometric systems for identifying people in 1882, by recording the precise lengths and widths of various features of the head and body. Bertillonage proved useful to English and French law enforcement, until the more reliable method of fingerprinting took over.

A person's Bertillon measurements change slowly with age or injury. Measurements for twins and clones will match – assuming they have not had discrepant bone-modifying surgery or injuries, and their growth stage is the same (clones or frozen embryo twins may be different ages!). There is, however, a chance that the person taking the measurements will make an error; correctly recording all 11 figures requires a successful Forensics/TL6 or Criminology/TL6-2 roll. The chance of two random sets of Bertillon measurements matching is one in several thousand. Forensics/TL7+ does *not* include a working knowledge of Bertillonage.

Blood Typing (TL6)

Blood is often found at crime or accident scenes. Historically, blood types (p. 130) were recognized in 1909, but they required a fresh sample. Forensic investigators could not determine the type of a dried blood sample until 1932. Blood typing can rule out a person as having left a particular sample, but it cannot make a positive identification because many people share each blood type. With a premixed test solution kit (TL7) or an antibody-impregnated card (TL8+), anyone can identify a blood type on a successful IQ+6 roll.

Fingerprinting (TL6)

Although there is some evidence that fingerprints have been studied throughout history, their use in modern biometrics began when the London Metropolitan Police adopted fingerprinting in 1901 as a method of uniquely identifying criminals. Although fingerprints are unique in their details, there is a small chance of an analyst making an interpretive error when comparing prints (on a critical failure on a Forensics roll). Prints of identical twins or clones are very similar, giving -1 to Forensics rolls to distinguish them. Prints lifted from crime scenes may be more or less smudged or incomplete, giving penalties anywhere from -1 to -8 depending on circumstance.



Facial Reconstruction (TL7)

Given a human skull, it is possible to model the shape of facial muscles and tissues using anatomical knowledge to reconstruct an image of the person's face. This is useful for identification of decayed bodies, but is not 100% reliable and is quickly made obsolete by DNA profiling methods. It also has applications in archaeology. Creating a realistic reconstruction requires a successful roll on Artist (Forensic), or Forensics-4 skill.

Aging Simulation (TL8)

Missing persons, particularly children, change in appearance as they age. To provide a current target for investigation, a computer simulation can artificially age the missing person's physical features. This produces an image that matches closely enough for a rough identification,

which in many cases is all that is needed for further investigation to uncover the truth. Writing such software requires Computer Programming and Physiology skills, but running it is simply Computer Operation. The software is Complexity 4, \$5,000. LC4.

Genetic Fingerprinting and RNA Sample Dating (TL8)

See *DNA Testing* (p. 8).

Forensic Equipment

Forensic criminologists use an array of specialized chemicals when investigating crime scenes.

Suitcase Forensics Lab (TL5-12).

Basic equipment for using Forensics skill to gather samples. \$3,000, 10 lbs. LC4.

Luminol (TL6)

This chemical, invented in 1937, reacts with the iron in hemoglobin, forming a compound that fluoresces under ultraviolet light. Forensic investigators can spray it over a suspected crime scene to locate where any blood has been spilled, even if obvious stains have been removed. Such traces are enough to gather for DNA profiling, but luminol destroys antibodies, so the blood cannot be typed below TL8. Luminol gives a +3 (quality) bonus to Forensics skill when searching for traces of blood. \$10 for a vial of powder that makes up a pint of solution with water. LC4.

Ninhydrin (TL7)

Invented in the 1950s, this chemical reacts with the amino acids left behind by latent fingerprints, even years after the prints have been deposited, forming an easily visible purple image. It works especially well on paper and other organic surfaces. Ninhydrin gives a +3 (quality) bonus to Forensics skill when searching for fingerprints. \$5 for a vial of crystals that make up a pint of solution with methanol; \$10 for a pint of premixed solution. LC4.

Cyanoacrylate (TL7)

Eastman Kodak developed this adhesive in 1958; today it is commonly sold under the trade names SuperGlue or Krazy Glue. It has two distinct biotech uses. Firstly, it is an exceptionally rapid-setting and strong adhesive, polymerizing quickly in the presence of moisture to form a fast bond. It binds body tissues tenaciously and is non-toxic, making it useful for closing wounds without sutures, although it needs to be applied with care to avoid glue in the wrong places! It also works well on non-porous materials, so it is frequently used to glue metal implants (such as artificial joint appliances) to bones. Its second use is in forensics, as cyanoacrylate vapor polymerizes in the presence of the traces of water left behind by a latent fingerprint, forming a white print that is easily visible on dark surfaces, and enhancing the print structure so that secondary powders or dyes work more effectively. \$5 for a 1 oz. bottle. LC4.

ARTIFICIAL LIFE

The ultimate expression of biotechnology is to *create* life from non-living matter. At a reductionist level, there seems to be no barrier to this; if we can line up all the molecules in the right configurations, it would be impossible to distinguish a natural organism from a created one. This would take superscience technology, as the number of molecules to be arranged will defeat anything less. There are shortcuts, though.

TISSUE ENGINEERING

Tissue engineering is the first step in producing artificial organisms. It uses stem cell cultures (p. 22) grown on biodegradable scaffolds in a suitable biochemical environment to produce organs without having to grow an entire clone body.

Transplant Organs (TL8)

Tissue engineering can be used to grow organs suited for transplantation (p. 141). The patient donates a sample of DNA, which is then used to grow the required organ. At TL8, organs must be grown attached to a living animal so they are supplied with the required nutrients, but smaller versions of cloning tanks may ultimately replace them at TL9. Cosmetic tissue such as ears and noses is the simplest to grow (TL8), followed by simple organs such as kidneys and livers (TL9). These would take four weeks to grow. Entire limbs and complex organs like hearts, lungs, and eyes would become available later, and take up to eight months to grow.

Fauxflesh (TL9)

NAPANEE (AP) – Acting on an anonymous tip, Ontario Provincial Police raided a factory building on the outskirts of Napanee. They found what one officer called a “disgusting scene, right out of the 20th century”: live pigs and chickens being slaughtered and packed by modified agribots for the black-market meat trade. “I thought I’d seen everything in my 10 years on the force,” said OPP officer Bill Mackenzie, “but this really turns your stomach, eh?” Police made six arrests.

Gengineered cells from livestock are cultured in growth tanks and supplied with nutrients. This creates a continuously growing biomass of lean meat tissue, which is harvested whenever food is required or it gets too big for its vat. Fauxflesh meat comes in oddly regular shapes, but is otherwise indistinguishable from natural meat.

Initially there is likely to be consumer resistance to fauxflesh as “unnatural,” but this may be overcome by relative cheapness, concerns for animal welfare, or a population outpacing its food supply. Once established, fauxflesh may ultimately make raising animals for meat socially unacceptable or illegal.

MIMICKING BIOLOGY

For most of our scientific history, we’ve thought of life as plants and animals and, more recently, microbes. These provide plenty of patterns on which we could base artificial living organisms.

Biogenesis (TL10)

Biogenesis is tissue engineering (above) taken to the point where biological molecules can be assembled into a viable organism. Nanomachines lay down a polymer or carbon composite scaffolding and assemble bone, muscle, nerves, and other tissues on this framework. The cells are controlled by artificial chromosomes, designed to produce the proteins and enzymes needed by the resulting organism. Often the designers will take shortcuts, using clusters of nanofactories to produce required proteins that couldn’t be coded into the genes, either because of lack of understanding or development time. The result is that the organism is a mixture of biological parts and artificial components.

Biogenetic organisms come in all sizes, from insect-sized up to building-sized or larger. Since construction throughout the organism is simultaneous, they all take around the same time to build: four to six weeks. Larger organisms require more nano and raw materials, however, and thus are proportionately more expensive. Biogenesis can be used to create a wide variety of organisms, including copies of animals, designer lifeforms such as the skullcat (p. 96), and biogadgets (p. 95).

Any biogenetic organism will have Unusual Biochemistry (p. B160).

Bioroids (TL10)

Bioroids (short for biological androids) are humanoid beings created using biogenesis. Although they can be made to resemble humans, deep differences will be apparent if the cells are examined. Baseline bioroids are designed to accept artificial chromosomes, with “slots” into which genetic engineers can easily plug specific modules of genes. Much redundant material, such as introns, is left out of bioroids.

A basic bioroid design is similar to a genetically upgraded human. Initially they will be sterile, though some female models will be able to act as surrogate mothers. This limitation can be overcome with implanted or *in situ* tissue-engineered reproductive organs grown from human DNA.

Early bioroids will have limited intelligence, restricted to instinctive actions, but as the technology matures designers will be able to produce learning and reasoning capability. Since bioroids are produced in a fully grown form without passing through childhood, they will require intensive learning programs to achieve human levels of intelligence in a reasonable time; they would be ideal candidates for deep learning technology (p. 143).

Due to their resemblance to human beings and their potential for intelligence, bioroids would be the subject of intense ethical debate and legal regulation; see *Bioroids and Parahumans*, p. 199.

Cost: Usually about \$25-50,000 for production, plus at least \$1,000 per character point of the model template, for design, marketing, and education.

Statistics: Bioroid characters all possess the *Bioroid* meta-trait (p. 214). See also the Bioroid box in Chapter 2.

Biofab (TL10)

This is a specialized wet nanofactory that can assemble organs or even complete life forms (bioroids). A biofabricator can assemble living things rapidly (a year of growth every week). Thus, it takes 18 to 20 weeks to make an adult human. A biofab costs \$20,000 and weighs 5 lbs. per pound of capacity. One big enough to hold a human is \$400,000, 1,000 lbs. LC2. Necessary raw materials for biogenesis are usually \$100-\$500 per lb. (\$20,000 per ton) for production, plus any design and marketing costs.

Neogenesis (TL11)

The next step beyond biogenesis is to design fully biological organisms without the need for residual nanotechnology systems to keep them functioning. This requires an advanced theoretical understanding of the interactions between DNA, RNA, amino acids, proteins, and enzymes. Designs would require a vast database of biomolecular data and accurate simulations of their interactions.

Getting all the complex interactions right may be so difficult that it is the province of specialized AIs – or it might be accessible by a point-and-click interface built on top of a vast expert system, allowing anyone to design their own life forms. At high enough tech levels, designing life might be a children's educational tool.

Once you have the design for a new life form, bringing it into reality can be done in two ways:

Nanoassemblers could build viable creatures from scratch, perhaps using DNA as the template, in a method similar to biogenesis. Assembled organisms would be essentially equivalent to bioroids, with no mechanisms for reproduction. The molecular mechanisms for sustaining their bodies, allowing growth, metabolism, movement, and possibly intelligence, may be encoded in relatively short sections of genetic material. Leaving out the genes for reproduction and growth from an embryonic form will save considerable amounts of development time and be achievable with lesser technology.

The ultimate expression of biogenesis (at TL12) would be to create an entirely new viable *species*, fully capable of self-reproduction. Individuals could either be assembled from scratch or, more efficiently, grown from assembled embryos provided with a suitable biochemical environment, allowing the genome to control the growth process. This is a simpler procedure at the assembly stage, but requires a far greater theoretical understanding during the design phase.

Non-Biological Life

Going beyond the DNA/RNA/protein complex as the basis for artificial life, designers could use other biochemical bases on which to build organisms (see *Different Biologies*, p. 35). This results in biogenetic organisms with vastly different biochemistry, which may require special food designed so that they can digest it. More fancifully, those seeking to emulate life might choose inorganic chemistry, or even electromagnetic interactions, as the basis for their research. This leads to machine-like beings and the worlds of artificial intelligence, which are discussed in *GURPS Ultra-Tech*.

Lifebanks and Genome Libraries

A lifebank is an indexed collection of tissue cultures, eggs or embryos. A well-stocked lifebank will have examples of many different genotypes within a particular species, to ensure genetic diversity. About 50 individuals per species would be the minimum breeding population needed to allow that species to be reintroduced successfully, while 1,000 could preserve most of a species' genetic diversity.

The simplest stable ecosystems (e.g., an isolated lake) might have under 1,000 species, but most have 10,000 or so. Earth may have as many as 80 million species – 2-4% of all the species it has ever had. Extensive lifebanks are already being established as a safeguard against extinction. At higher TLs, they can be found aboard colonizing “seed-ships.” Lifebanks require \$500 and 5 lbs. per embryo stored. A live bacterial culture, or large quantities of germ cells (hundreds of human gametes, plant seeds or bacterial spores), can be stored for the same amount of money and weight.

A genome library stores the data for a mapped and sequenced genome in digital form. This information can then be used to synthesize DNA, although growing a complex organism like a human with nothing but a digital genetic code requires TL10+ technology and is far more time-consuming than if actual samples existed. (See *Genetic Reconstruction*, p. 14). A complete genome database (plus Complexity 2 indexing programs) for a particular species genome is \$5,000 (and 5 gigabytes) for microorganisms or plants and \$20,000 (and 20 gigabytes) for other life forms.

A common trope in science fiction is the idea of a colonizing “ark,” with DNA samples of the various animals and plants the colonists will need when they reach their (usually interstellar) destination. Such an ark will also need technology capable of reproducing the right growing environments for the embryos of all those species. At TL10, this sort of universal womb machine is feasible, if programmed with data on the right biochemistry for each species – see *Growth Tanks* (p. 20).

BIOMATERIALS

Another application of biotechnology is to materials science. Rather than rely on the metals, ceramics, and polymers of our forebears, the future will be a world in which biologically produced materials play an increasingly important role.

BIOMIMETICS

Biomimetics is the branch of materials engineering that deals with the development of synthetic designs modeled on biological materials. Natural materials often have extremely complex molecular structures. Rather than copying these directly, biomimetics seeks to improve on nature by using them as templates for synthetic molecular designs.

Designing synthetic versions of natural polymers – like snail shells, wood, or insect chitin – could lead to stronger and tougher materials. Since many biomaterials can sense and respond to their surroundings, a major goal of biomimetic technology is to develop “smart” materials capable of altering texture, color or shape, sensing and repairing stress and damage, or even growing. Primary applications include fabrics, (such as flexible body armor derived from spider silk), cybernetics, sensors, textiles, and waterproof, weatherproof, “chameleon,” or “stealth” coatings.

Many TL9+ items will employ biomimetic materials. As a single example, some archaeobacteria (see *The Domains of Life*, p. 103) live at very high temperatures in ocean thermal vents. Their heat-stable molecules could be adapted for many industrial and pharmaceutical processes, ranging from detergent additives to beam-resistant ablative armor. Another widespread biomimetic technology might be “bioglue” – a range of biodegradable, waterproof adhesives based on the naturally-secreted, protein-based glue used by limpet mollusks. Bioglue may be found in many surgical kits, replacing conventional surgical sutures, since it does not need to be removed; it is also the adhesive base for plastiskin patches. Besides its medical uses, bioglues may also be used to assemble composite materials or in ultra-sticky tangler strands (see *Web Gun*, p. 227).

BIOTRONICS

This technology uses protein-based systems for information storage and processing. Here are just a few of the biotronic technologies on the horizon.

Biosensors (TL8)

A biosensor is an electronic device that consists of a ordinary computer chip coated with a layer of biological molecules that selectively bond with a specific, known compound. When this occurs, the chip sends a signal that these molecules are in the area. Depending on the design, a biosensor can be used as a contact sensor to identify specific chemicals or biological substances, or as a ranged sensor to detect airborne molecules such as toxic gases or explosive vapors. The main limitation of biosensors is that they don't detect “unknown” compounds. However, they can be easily updated by plugging in a new biosensor chip. At TL9+, more sophisticated biosensors may work as “electronic noses” with bloodhound-like odor detection capability.

Smart Sensors (TL9)

These are the next generation of biosensors. While a biosensor is designed for a particular application and requires a chip upgrade to add new capabilities, smart sensors contain synthetic neural material. This is capable of reconfiguring its structure and learning from experience, flagging new sensations and giving them different labels so that they can be recognized in the future and passed on to the interfacing software. With suitable software controllers, a smart sensor can be trained from scratch, rather than having to be redesigned for each application.

Vatbrain Computers (TL9)

A vatbrain biocomputer, or “meat matrix,” is a computer whose processing capabilities have been enhanced with living nerve tissue. Vatbrains are good at mimicking human neural systems, and are a possible shortcut to artificial intelligence. The down side is that the life-support facilities for their organic central processing units are heavy, requiring precise environmental controls and nutrient feed systems.



The neural tissue used might be scavenged from living brains or grown in vats, to create self-organizing logic connections. Biocomputers require a life-support system to bathe the neural structures in nutrients; maintaining a biocomputer requires both Electronics Repair (Computers) and Electronics Repair (Medical).

In some settings, vatbrain biocomputer neural tissue might have to come from sapient brains (such as those of humans), or there may be even more ghoulish requirements, such as fetal tissue or tissue from brains that are still developing. This could lead to a market demand for scavenged brain tissue to supply the biocomputers. Cheap tissue engineering technology would likely remove the need for such a market.

The software Complexity required for any artificial intelligence programs or mind emulations are reduced by one Complexity level when running on a vatbrain biocomputer. Vatbrains might also permit special capabilities, such as computer systems that can develop psi powers.

A vatbrain biocomputer has twice the usual weight, cost, and power requirement of a normal computer, due to the extra requirements of its life support system. LC3.

Gestalt Brain Matrix (TL9⁺)

Once it is possible to form neural connections between human brains, someone will consider wiring lots of them together to form a computer. Realistically, this will be slow and unwieldy, easily outperformed by conventional computing technologies. Procuring brains to build a gestalt matrix will also be ethically questionable and probably illegal. Still, there's no reason it couldn't be done, and it would make a suitable project for a mad villain.

A more enlightened variant could be built using neural interfaces to unite brains via a distributed network. People might volunteer to be part of such a project, something like SETI@home and similar efforts today, but they would be allowing the project to run programs using their brains. People jacking into a neural network might have parts of their brains utilized without their knowledge.

Physically, the gestalt looks and operates like a normal computer . . . except for the people or bodiless brains in the server room! Each "component" brain must have some way of interfacing with the computer. This may be a temporary connection, such as a jack that plugs them into the computer, or it may be a more permanent connection. The human components may have their entire bodies integrated into the computer and sustained by a life support system, or, more ghoulishly, just their brains and nervous systems; see *Brain Transplant* (p. 143) and *Brain Pod* (p. 147).

When interfaced with the computer's gestalt processor, the components are effectively asleep (although the time spent does not count as sleep for the purpose of recovering fatigue, etc). They cannot themselves use the computer system, and afterward will have no conscious recollection of what the gestalt computer is doing.

At the GM's option, some of the component brains may retain some subconscious residue of the work or data they are handling. This could come out in dreams, under hypnosis, or only through the use of specialized brainscanning equipment; the GM may wish to treat this as a Flashbacks

(p. B136) or Nightmares (p. B144) disadvantages, or even as a Racial Memory (Passive) advantage (p. B78). This could create difficulties if the gestalt computer was engaged in classified or illegal activities using components who were working remotely through neural interfaces, and it is suspected that some of these individuals have started to recall what these activities were.

This leakage could also be two-way: if the computer itself is sapient it may, after a time, absorb memories or personality traits shared by a large percentage of its components, or by particularly high-IQ or high-Will individuals.

The number of people in the gestalt array determines the computer's effective Complexity. The gestalt "components" must be sapient (IQ 6+) beings with no significant brain damage. One linked mind gives it a base Complexity 9; for each tenfold increase in the number of minds in the gestalt, add one to its Complexity. An IQ 6-7 component counts as only half a mind; IQ 15-17 as two, IQ 18-20 as three, IQ 21-23 as four, etc. Optionally, the computer may also gain mental advantages, if they are possessed by the majority of its components. Each component mind can also be used as a unit of removable media, storing (TL-8) TB of information even when removed from the gestalt (this information is not consciously available, but may interfere with memories). A basic gestalt computer is \$100,000 and 500 lbs. Modular "brain connectors" for extra components can be added for \$1,000 and 50 lbs. each. LC2.

Sponge Computers (TL10)

Sponges have a homogeneous macroscopic structure suitable for hosting neural networks, but the natural animals do not take advantage of this to perform complex thinking. With some genetic tinkering, sponges can be made to grow electrically active neurons in configurations responsive to external stimuli. As these develop, they become effectively "artificial brains," that can be connected to biosensors or other electronics. Sponge computers incorporate memories and make logical connections much like a real brain, with the advantages that the structure allows the permeation of nutrients and oxygen and that they can keep growing as long as these are supplied. They are thus much more robust than vatbrains and easier to grow.

At TL11, sponge computer implants can be made with discriminatory growth patterns that let them grow into small crevices and infiltrate biological material. Implanted into a sinus cavity, it could grow into and either supplement or take over the brain of a person. Use the rules for vatbrains (p. 28) but halve the cost and weight. There is no practical upper limit to how large a sponge computer can be – they can be housed in the open ocean if necessary.

TL11 infiltrative sponge computer implants most often suppress higher brain functions, giving the subject both the AI and Automaton meta-traits (p. B263). They are about the size of an apple seed and can be easily implanted in food, etc. They take a day to grow; a HT-4 roll means the subject's immune system fended them off. Removal requires brain surgery, much like removing a tumor; roll at -3 if they're half-grown or -6 if full-grown.

VARIANT BIOTECH

We tend to think of biotechnology as a modern science, using the latest discoveries in biochemistry and genetic engineering techniques and their extrapolations into the future. But depending on the genre of a game, there may be other ways of manipulating the forces of life.

Imprinting

Widespread myths from the ancient Greeks to Renaissance Europe have held that a female who sees or imagines someone other than her sexual partner at the moment of conception can imprint that image on the child. Greek stories tell of women falling in love with statues, and producing children who resemble them.

On a practical level, this belief leads to two avenues of distrust against suspected adulteresses. Firstly, if a woman is physically faithful, but fantasizes about another man, a child may end up looking like the object of desire rather than the father. Secondly, a woman might deliberately think of her husband while in the embrace of a lover, making the love-child resemble her spouse. So whether the child resembles the husband or not, it can be construed as grounds for suspicion! In a game world, rather than simply being a projection of male paranoia, this myth may have some truth to it.

A mother who has suffered some psychological shock or trauma at any time prior to conception may also imprint the child. A woman threatened with a knife could give birth to a child with a knife-shaped birthmark, or who resembles her assailant.

What's more, it works with animals too; the story of Jacob in *Genesis* mentions showing ewes black-spotted rods so that they give birth to spotted lambs. In a mythic campaign, this power could be harnessed for eugenic purposes, to produce offspring based on idealized statues, or for twisted experiments producing half-human chimeras.

MAGICAL BIOTECH

Fertility magic is nearly as old as humanity itself; wizards in fantasy literature are forever brewing up strange creatures in their vats, and fairy godmothers often bestow gifts or curses on unborn children. And in a setting that harbored both magic and high technology, who knows what strange hybrids the combination of biotechnology and sorcery could spawn?

The spells described here can form the arsenal of any mage who specializes in bio-magic. The colleges they belong to are:

Body Control: Accelerate Pregnancy, Ease Labor, Remove Fetus, Transfer Pregnancy, Warp Fetus.

Enchantment: Create Chimera, Spellgraft

Healing: Ease Labor, Remove Fetus, Sense Disease.

Knowledge: Analyze Heredity, Genomancy.

Movement: Remove Fetus, Transfer Pregnancy.

Necromancy: Hellspawn.

Technology: Alter Nanovirus, Manipulate DNA, Sense Nano, Sequence DNA.

The Technology College and some prerequisites are described in *GURPS Magic*, but all spells may also be learned using prerequisites found only in the *Basic Set*. The spells in the technology college are unlikely to appear before TL7, but you never know!

Accelerate Pregnancy

Regular

This spell speeds the safe development of an unborn baby.

Duration: Permanent (until baby is born).

Cost: 20 to double rate of development, plus 10 more for each additional doubling of speed. Thus, a baby developing at 16 × speed (50 to cast) would come to term in only two weeks.

Time to cast: 20 seconds.

Prerequisites: Ease Labor and Haste.

Alter Nanovirus

Regular

This spell alters the nature of a particular nanovirus (see p. 12) that is either dormant (e.g., stored in a vial) or is within a host but has not yet finished transforming its subject. Each casting allows the mage to add or subtract one advantage or option from the virus.

Cost: (T-8) × 10, where T is the higher of 9 or the minimum TL required to add that option or ability to a nanovirus.

Prerequisites: Sense Nano, Manipulate DNA.

Analyze Heredity

Information

This allows the mage to ask a question regarding the heredity of the subject, within the limits of his TL's knowledge. For example, a TL3 mage who isn't a biologist could ask "is he a son of King Richard?" or "will this mare pass on the blood sickness to her foals?" and get a true answer; at TL7+ a mage could get answers equivalent to those available from a DNA test (see *Genetic Profiling*, p. 9).

Cost: 3.

Prerequisites: Seeker or Sense Life.

Create Chimera (VH)

Regular

This enchantment fuses together two or more very early embryos (no more than week-old if human) of different species into a single organism. The subject may be a live host or a growth tank (p. 20). If the subject was already pregnant with an early embryo, the other embryos must be implanted as part of the process using surgical means or a Transfer Pregnancy spell (p. 32). Otherwise, at least two embryos must be implanted via these means, and if using a live host, at least one of the embryos must also be the host's species. The resulting chimera will blend all species' traits, with appropriate advantages and disadvantages (see *Chimerization*, p. 38); the details are up to the GM.

Modifiers to skill roll: 0 if very close cross (e.g., wolf-dog), -3 if closely related (e.g., ape-human, sheep-goat or tiger-lion), -6 for distant hybrids (e.g., fox-human or alligator-viper), -8 for radical hybrids (e.g., crocodile-bat or human-hummingbird). Add +4 if trying to duplicate a previous success using the same mix, -4 if mixing three species, -8 if mixing four, -12 if mixing five, etc.

Success means a viable chimera forms but (especially if the caster got very ambitious) it will not be perfect: the GM should give it several unplanned disadvantages. Critical success means an excellent mix of advantageous traits and mild disadvantages.

Failure means the spell fails to work, terminating any natural pregnancy in the process. Optionally, failure by 1 means the implanted embryos fail to fuse, but do not die unless the host could not reasonably sustain them; otherwise it's a multiple pregnancy (e.g., an attempt at an elf-dwarf fusion results in elf and dwarf fraternal twins).

On a critical failure, the creator gets something that appears to be viable enough to carry to term, but which proves to be either horribly deformed, life-threatening to the mother (if using a live host), or both.

If the spell works, it also ensures the embryo will be carried safely to term. The size of the fetus will usually be appropriate to the host mother, e.g., a whale-human carried by a human mother (or appropriately-sized growth tank) might be larger than her normal baby, but not by much. It is also possible to remove a developing chimera and implant it somewhere else – see *Surrogate Motherhood* (p. 20) and *Growth Tanks* (p. 20).

Cost: 20 per embryo in the fusion.

Prerequisites: Analyze Heredity, Enchant, and either Alter Body or Lightning.

Divination

Information

Genomancy is divination by examining the pattern of introns in someone's DNA. A blood sample and some means of viewing the introns (e.g., a genetics lab) is required.

Prerequisites: Analyze Heredity, two Healing, and two Body Control spells.

Ease Labor

Regular

Cast on a mother who has gone into labor, this spell eases the pains and ensures a relatively trouble-free birth. If using the rules for birth in the *Surrogate Motherhood* rules (p. 20) it gives a +2 on HT rolls to avoid problems if maintained for the duration of labor, or +1 if maintained only for the last half.

Duration: 1 hour.

Cost: 4 to cast; 2 to maintain.

Time to cast: 6 seconds.

Prerequisites: Lend Vitality.



Hellspawn

Regular; Resisted by mother's Will

Conjures a malign demonic spirit to replace the soul of an unborn child. The result will usually be born as a demonic familiar if conjured into a non-sapient animal, or a cursed half-demon (give the character lots of supernatural disadvantages) if a sapient race.

Critical failure may conjure a real demon outside the mother's body, or accidentally summon some other entity to possess the developing fetus – maybe an angel?

Cost: 20.

Time to cast: 5 minutes.

Prerequisites: Summon Demon.

Manipulate DNA (VH)

Regular

Lets the caster magically splice genes and manipulate DNA to produce specific traits. Successful use gives the caster a +10 to Bioengineering (Genetic Engineering) skill to the Prototype when performing genetic engineering (see p. 17). This bonus adds to other modifiers in the genetic engineering rules; the spell also allows working with improvised facilities (e.g., a kitchen) at a -10 "lab quality" penalty (which exactly cancels the +10 bonus the spell provides for no net modifier). Only one try is allowed per weekly attempt at genetic engineering; the GM should roll secretly for success.

Duration: 1 week.

Cost: 8.

Time to Cast: 5 minutes.

Prerequisites: Sequence DNA and Apportation, or Create Chimera.

Remove Fetus

Regular; Resisted by mother's HT

Cast on a pregnant mother, this spell allows the mage to reach through the mother's belly and into her womb and safely detach the fetus. If the fetus is old enough to survive (or can be rapidly transferred to a growth tank or incubator), this is effectively a painless alternative to Caesarean birth. Otherwise, it serves as a means of abortion.

Cost: 3

Time to cast: 3 seconds.

Prerequisites: Ease Labor, and either Minor Healing or Apportation.

Sense Disease

Information; Area

This spell tells the caster if the area contains substances or organisms likely to cause disease symptoms – such as contagious bacteria or viruses, parasites, carcinogens, allergens, foul air, disease spirits, or hostile nanomachines. The

caster may specify he is looking for a particular type of agent, or for something able to cause a particular symptom.

Base Cost: 1/3 (minimum 1).

Prerequisites: Sense Life, or any two Healing spells.

Sense Nano

Information; Area

Tells the caster if there are any nanomachines in the subject area, and gives a general impression (on a good roll) of what kind. The caster can also specify he is looking for a specific type of nanomachine, or even a named brand he is familiar with.

Base Cost: 1.

Prerequisites: Sense Disease and IQ 15+, or Seek Machine and Small Vision.

Sequence DNA (VH)

Information

This spell allows the caster to magically determine the correct DNA sequences needed to produce specific traits. Successful use of this skill gives the caster a +10 to Bioengineering (Genetic Engineering) skill at the concept stage of genetic engineering (see p. 17). Only one try is allowed per week; the GM should roll secretly for success.

Duration: 1 week.

Cost: 6.

Time to Cast: 5 minutes.

Prerequisites: Magery 2+ and either Genomancy or Analyze Heredity.

Spellgraft (VH)

Enchantment

This gives an unborn child inherent magical ability. This spell is thus a favorite of genetic engineers, fairy godmothers, and pagan deities.

A spellgraft can be made using any spell known to the caster at skill-15 or better. When the child is born, he will possess the ability to use that spell as racial magic – use the *Racially Innate Spells* (p. B453) rules. Only one try is allowed to give a child a particular spellgraft. A critical failure adds an extra curse as a side effect – the child will be born with a supernatural disadvantage such as Cursed or Weirdness Magnet.

Cost: Half the energy cost of an equivalent magic-item creation, but can only be cast on a developing fetus.

Prerequisite: Enchant.

Transfer Pregnancy

Regular; Resisted by HT

This spell transfers an embryo or fetus from the mother to the mage's own womb, or from the mage to another female's womb. At double energy cost, the mage can transfer from an artificial container (such as a vat or growth tank); the mage must be touching the container if he wishes to



transfer its contents into a host. At even higher energy cost, the spell can transfer to a male, creating an artificial pocket womb, although any birth must be through Caesarean section, this spell, or the Remove Fetus spell.

The subject of the spell (not the fetus or embryo) resists, whether the baby is being transferred to or from it.

Cost: 4 for an embryo, double for a fetus. Double energy cost to transfer to or from an artificial container. Triple energy cost if person receiving the fetus is male.

Prerequisites: Remove Fetus and Magery 2+.

Warp Fetus

Regular; Resisted by mother's HT

If cast on a developing embryo or fetus, it will be born deformed. The child will be born with 10 points of mundane physical disadvantages (caster's choice) for every energy point put into the spell. Only disadvantages that could conceivably be the result of birth defects or hereditary diseases are possible, e.g., Epilepsy or One Arm.

Warp Fetus may also be used to give the subject supernatural physical disadvantages, such as Draining or Supernatural Features, but these cost double, i.e., 1 energy point per 5 points of disadvantages granted.

Cost: variable

Time to cast: 10 seconds.

Prerequisite: Strike Barren or Wither Limb.

STEAMPUNK BIOTECH

The science of the Industrial Revolution and the Victorian Age had its own views on the processes of life and what might be achieved with it by experiment and manipulation. In a steampunk world where the visions of Verne and Wells are reality, the scientist who dares to tinker with living creatures is one step from playing God. His creations are often abominations that serve as a lesson that there are still places where mankind's apparently limitless power must not be used.

This has been the traditional role of biotechnology in the steampunk genre, but it is also possible to imagine a bright future for the fledgling sciences of evolution and heredity, as well as the germ theory of disease and vaccination. In such a world, biologists would use scientifically directed selective breeding to produce fantastic new crops and livestock with many of the properties of engineered organisms, while doctors would be heroes developing vaccines against all diseases, and creating drugs to grant effective immortality.

Breeding

With the discoveries of heredity and evolution, 19th-century science suddenly saw great possibilities for the advancement of living beings. A systematic approach to selective breeding – which had been practiced informally by farmers for centuries – might make sweeping changes to species in a matter of a few generations. The (now discredited) theory of Lamarckism – that parents can pass on features acquired during their lives to their offspring –

Biotech Development Pathways

Like the ultra-tech development pathways described in *GURPS Ultra-Tech*, biotech can develop in several different speeds in alternate directions. To an even greater extent than other technologies, biotech is as likely to be held back by public opinion, ethical concerns, religious condemnation, and legal restrictions as by technical difficulty . . . if not more so. A biotech campaign setting can be customized in various ways by “twiddling the knobs” on the pace of development in different areas, as well as the reasons for the differences. A world in which human clones don't exist because there are insuperable technical difficulties is very different from one in which they are demonstrably possible, but outlawed.

Slow Nanotech

The development of biological “wet” nanotechnology is more difficult than expected or held back by societal pressures. This retards development of techniques that rely on medical nanobots and prevents the invention of bioroids. Variant human races must be built by germline genetic engineering, while technologies like diagnostic nano, nanoviruses, and biogenesis remain nonexistent, experimental, or illegal.

Slow Gengineering

This posits that genetic engineering techniques will hit a major stumbling block, either theoretical or imposed by society. This restricts the generation of human clones, tissue-engineered implants and biomods, and genetically upgraded or modified variant human races. Germline modifications to the human genome will be nonexistent or rare, and any variant humanoids encountered will be bioroids. Biogenesis and biogadgets may provide items that make up for the lack of parahuman species capable of colonizing hostile environments, making them dependent on this technology to survive.

provides a method by which breeders can direct such changes and hope to see gross changes in anatomy within a reasonable time.

In order to explain the apparent massive differences between species that presumably evolved from common ancestors, Dutch biologist Hugo de Vries proposed that species could undergo sudden and massive changes in a single generation, becoming a new species all at once. Triggering such macromutations either through deliberate breeding or by using drugs gives steampunk biologists an even faster way of transforming life.



Xenotransplants and Surgery

This is the modification of living animals through surgery and transplants – the classic examples are *Frankenstein* and *The Island of Doctor Moreau*. The goal is often to make animals more human-like, giving them upright postures, the ability to speak, and so on. It can also be used to make chimeras (p. 38), assembling monsters out of the parts of various animals. This is useful when you don't have the patience to breed for desired traits (most mad scientists don't). For an extra tinge of horror, the operations can be carried out without anesthetic.

On the positive side, it could be the steampunk version of biomodification, allowing many of the enhancements listed under *Biomods* (Chapter 7), with similar times and costs. The main difference is that parts from appropriate animals would be used to achieve many of the enhanced effects. Such operations would be carried out with the patient under ether or chloroform, and may lead to a world in which most people are so enhanced.

Atavism

In the late 19th century, Ernst Haeckel proposed his theory of *recapitulation*: that animals pass through embryonic stages similar to the path their species took through evolution. This was somewhat supported by evidence of gill-like structures on bird and mammal embryos, among other features. Although not accepted as part of modern biology, recapitulation could be true in a steampunk world, leading to the possibility that selective breeding or drugs might halt

some part of the “evolution” of an embryo, giving the resulting creature some features of evolutionary ancestors. Through this process of *atavism*, humans could thus be granted the strength of apes, or the gills of fish. In other genres, atavism based on different theories may also be appropriate for alien races!

Revivification

With discoveries such as the electrical and chemical activities of animals in the late 18th century, it seemed that it might be possible to grant life to inert matter. Mary Shelley's classic novel *Frankenstein* showed how it might be done, using parts of cadavers sewn together, and in film adaptations revived using the power of electricity (though the novel does not specify this). Other approaches include using a vitalizing elixir, known as *élan vital*, which contains the distilled essence of life. The source of *élan vital* might be rare orchids, mystical rituals, or boiled-down babies. This may also represent a steampunk way to create bioroids (p. 26). It may even be possible to raise the dead by similar injections, as in H.P. Lovecraft's *Herbert West, Reanimator* – the rules for Necromorphosis (p. 188) but as a TL(6+6) procedure, would be appropriate.

“Jekyll/Hyde” drugs

In a steampunk world, the rapid advancements in medical technology could lead to miracle drugs capable of transforming people in various ways. Partial atavism is a logical possibility, given 19th-century understandings of

biology, as well as gross changes in body anatomy and/or behavior. These changes may naturally reverse when the drug wears off, or may be permanent. This is another method through which biomods may be gained, although the process is likely to be painful and carry risks of adverse reactions.

*Millions long for immortality
who do not know what to do
with themselves on a rainy
Sunday afternoon.*

– Susan Ertz

HORROR BIOTECH

Horror biotech begins with the nastier parts of steam-punk biotech taken to extremes. It is easy to imagine splatter and gore laid on a biotech foundation. The vivisection of conscious beings, trade in body parts, and the creation of unnatural monsters by various means are obvious routes to horror with a biotech basis. There are also more subtle methods.

Supernatural Horror

The distinguishing feature of supernatural biotech is that things that should otherwise be dead can be animated by forces of evil or sheer bloody-mindedness. Such biotech defies logical explanation and gives rise to creeping things that should not be. Whether such supernatural power over life and death can be tamed is an open question. Imagine a scenario in which a supernaturally powerful psycho killer is apparently defeated, and the remains taken to a government lab for analysis. The army may soon be fielding soldiers whose limbs still operate when severed, or the horror may begin stalking the halls of power . . .

Technological Horror

Technological horror is more subtle, and can be created by extrapolating the instinctive reactions of many people to the possibilities of today's real biotech. The threats of targeted genetic viruses, creeping nanotech with the ability to change morphology or psychology, the spread of engineered diseases, and weird transgenic things in our food are among the items of biotech that can be used to generate feelings of paranoia. Slightly weird biotech can produce the classic disembodied brain in a jar, as well as other horrors on the edges of possibility. In a soft-science setting, the veneer of technology can provide a terrifying excuse for any sort of biological monstrosity.

Different Biologies

This chapter discusses terrestrial biology – the only sort we know about. But that's not the only *possible* biology. Any truly alien life forms will not share the same details of DNA, RNA, and amino acids as Earthly life. (The main exception is if terrestrial and extraterrestrial life share a common origin, which is intriguing in itself.)

An alternative biochemistry can be based on any of several differences:

- *Chirality* is the “handedness” of the many biological molecules that come in two different and incompatible shapes. Terrestrial life uses only one chirality. Life that uses the other may seem very similar, but will be mutually incompatible (and indigestible).

- *Alternatives to DNA* can encode genetic information using slight variants (different base pairs) or completely different molecules. One example is polysaccharides – branching chains of linked sugars.

- *Additional amino acids* from the over 500 discovered so far could be added to the mere 20 that terrestrial DNA uses.

- *Silicon and metallic chemistry* could potentially produce enough complexity to foster life at temperatures where these elements are molten, inside tectonically active worlds.

- *Neutronic compounds* such as those found on the surface of a neutron star might form nuclear chemistry capable of nurturing the emergent complexity of life. Since nuclear reactions are rapid, such life would evolve incredibly quickly.

- *Magnetic vortices* in plasmas such as stellar atmospheres or around large planets could conceivably form into self-sustaining and evolving systems. “Genetic” information could be encoded in tight bunches of magnetic fields. This is not as far-fetched as it sounds; we do it ourselves in our computers.

Bioengineers can use these different bases for biology to design ever more exotic bioroids or artificial life forms. (They are also useful for GMs designing aliens; see *GURPS Space* for a more thorough treatment of these concepts.)

A being using even the least radical of these different biologies does not qualify for Unusual Biochemistry (p. B160) – it is too different for that and may need Restricted Diet or Dependency instead. It will be unable to interbreed with or supply transplant organs for terrestrial life without TL12 technology or superscience. And don't even think about combining the biochemistry of humans with metal-alloy beings!

CHAPTER TWO

HUMAN GENETIC ENGINEERING

Yesterday, the Mokoto twins started laughing and teasing me 'bout my genemods again, calling me Girl Dracula and stuff. I bit one of them, but she beat me up – ain't no room to fly in the ship; it's hard to fight back proper when your bones aren't strong as theirs. I can't wait for planetfall on Darktree. Soon we parahuman kids be gliding from tree to tree, while them crew-brats be stumbling around in the groundfogs in their chillsuits and respirators. Then we see who's laughing.

– Tizbeth Sung-Morton (age 9), Darktree Colonization Fleet

Everyone thinks that they're the end product of evolution. *T. rex* probably thought that way just before he saw the comet flash. But with genetic engineering, we can take control of our own cells, making our children brighter, faster, and immune to hangovers. We can even redesign people to live in space, so the next time some big rock hits, some of us won't be here.



GENGINEERING AT CONCEPTION

A genetic engineer can insert recombinant DNA or RNA into a newly-fertilized human egg cell (a zygote) to alter its genes. Those genes will express themselves by producing slightly different proteins. As the zygote develops into an embryo and then a fetus, the new proteins will make up different cells, and a child will be born with traits it would not have possessed had it remained unmodified. These changes will be passed on to its descendants. This process is known as “gengineering at conception,” or more technically, germline genetic engineering.

EUGENIC GERMLINE GENGINEERING

“We'd like our Katiana to be petite and beautiful, with big, violet eyes and jet-black hair. Could she have a tendency toward musical aptitude, with long fingers for playing the

piano? We also want her to be good at sports – an athletic body type would be nice, so she could be a gymnast. Oh, and we want the standard features, of course: boosted immune system and genefixed heredity.

“Now, how much will all that cost?”

– Mr. and Mrs. Arlington

“Ever since my teens, I've really wished my parents had designed me for something practical. At least I don't get sick.”

– Katiana Arlington III

This is what most people think of when they hear the term “human genetic engineering.” Eugenic germline gengineering is the process of selecting gene combinations that ensure the appearance of traits the gengineer considers desirable, such as good looks, high intelligence, or perfect vision.

The abilities and disabilities of each of us result from traits inherited from our parents' genes, modified by

environmental factors such as diet, experience, and education. Eugenic engineering (“eugeneering”) involves determining what genetic combinations favor certain traits, then using gengineering at conception to make it likely they appear. It does not add anything new to the human genome, so a eugeneered person will still appear human to genetic tests or scanners.

The major stumbling block in the road to eugenic modification is that desirable traits can result from the interaction of hundreds of different genes. Moreover, one gene may be involved in multiple traits – change it to produce one effect and there may be unintended consequences for the others.

The capability to perform eugeneering rests on possessing a complete map of the human genome (see *The Human Genome Project*, p. 8) and a detailed understanding of how specific gene sequences code for proteins that affect human development. Completing a racial genome map is a TL8 achievement, and the ability to use this knowledge to perform complex eugenic selection is TL9+.

Efforts to determine the effects of specific gene sequences often proceed by tinkering with the DNA of individual genes, using animal subjects. Since mammals such as mice share much of our DNA, and produce successive generations in a short period of time, animal testing can provide insight into the effects on humans, especially if the test animals are gengineered to possess additional human genes. As more data is gathered on each gene’s role in human development, computer simulations may supplement or replace experimentation, making eugenic selection more practical, and allowing a designer to work with a standard “tool kit” of genes known to produce certain effects.

Once this capability is achieved, eugeneering can create “designer people” whose potentials are enhanced or skewed toward a specific physical or mental ideal. Changes may range from the obvious (good looks, muscular build, 20/20 vision, or “double-jointedness”) to the subtle (higher IQ, or gengineering of the adrenal glands to give someone a positive stress response).

GERMLINE GENGINEERING FOR SPECIES MODIFICATION

The human/rabbit genesplices were originally developed as bioroids by Novabody in the last century, apparently for the domestic, secretarial, and pleasure market. A century later, after the War, the Bureau of Colonization resurrected the genotype. BuCon’s mandate was to establish “facts on the ground” by reclaiming some of the border worlds depopulated during the War, and by colonizing as much territory as possible. The idea was to send over a seedship with a few hundred pubescent “rabbitoid” settlers and a colonial governor’s cadre, and within a few years these fast-breeding parahumans would give Earth a thriving agri-world.

That was the plan, anyway. Of course, we all know how it turned out.

– Darin Skay, *Shattered Genomes: The Colonial Revolution*

Genetic Engineering and Other Species

While this chapter focuses on human genetic engineering, the guidelines given here can also be applied to humanoid aliens, elves, and other fantasy folk, or, adjusted on a case-by-case basis, to even less-human species.

Some species may be easier or harder to genetically engineer. GMs can simulate this by making certain categories of modifications require a lower TL for one species, or a higher TL for another.

Species may even seek out other races to assimilate useful traits from their genomes. What is mundane for one species may be exotic to others, and aliens might seek to acquire human specimens for seemingly mundane traits (immunity to terrestrial diseases, an ability to dream, etc.) they wish to use.

Species modification involves gengineering for complex traits that never existed within the species’ original genome, such as gene sequences that produce modifications to anatomy. Some changes may be internal, like a modified liver that’s better able to filter toxins. Others might be obvious, like a coat of fur or a pair of functional extra arms. Again, the difficulties lie in predicting how the effects of a specific genetic change will cascade over the entire genome, and in making major changes in hundreds or thousands of genes at once. The tools to do this become available at TL9 – supercomputers for running extremely complex genetic simulations, and early bio-nanotech, such as tailored retroviruses or nanoviruses.

Gengineers might synthesize genes for totally new abilities, but it may be easier to enhance existing human traits, or design nonhuman abilities by basing them on the genes of terrestrial animals. This can be background information (“if you look closely at my chromosomes, I’m part bat”) or imply colorful physical traits (someone whose bat DNA sequences give them sonar and wings may have other chiropteran features, such as fangs and pointed ears). These may be the unintended results of cross-linked genes, or necessary for a given trait (e.g., pointed ears for ultrasonic hearing).

This sort of transgenic gengineering is already being experimented with at TL8, with small numbers of human genes being inserted into “pharm animals” (see p. 88) so that their metabolisms produce necessary proteins or can be used to grow human-compatible xenotransplants. Once the human genome and several nonhuman genomes are mapped and sequenced, complex human transgenic engineering could become a reality, limited mainly by ethical considerations.

The guidelines under *Designing Variant Humans* (p. 41) suggest TLs at which various advantages and disadvantages can be produced by gengineering.

Alien Hybrids

A popular theme in fiction is the possibility of humans and aliens interbreeding, either naturally or by genetic hybridization in the laboratory.

In “rubber science” settings, aliens with appropriate anatomy might be able to breed with humans simply by engaging in sex, or via relatively simple procedures such as artificial insemination. Typically, offspring of such encounters superficially resemble humans, but have some distinctive physical or mental features of the alien species. Offspring resembling aliens with a few human features would make an interesting turnaround. Half-aliens can be good archetypes for protagonists who work against the background of a culture clash, struggling to reconcile their two heritages.

Hybridization in a realistic setting may require a combination of chimerization, genetic engineering or biomods (e.g., *Alternate Gamete Production*, p. 184), or be only possible through a form of biogenesis (the offspring is basically a bioroid). However, these considerations may be moot if humans and aliens share a common ancestry. The discovery of this fact – either in the lab or the bedroom – would raise some interesting questions of its own!

Fantastic Hybrids

In a fantasy game, the rules can be looser. Myths contain many stories of humans interbreeding with gods, spirits, and animals, producing outstanding individuals, new races, or monstrous chimeras. This is a useful justification for the existence of such beings, but the GM should consider if they are unusual occurrences or a “law of nature” that individuals may be able to exploit.

Chimerization

Technically, a chimera is an entity created when the cells of two dissimilar blastocysts (very early embryos) are fused together so that they form a single organism. If the blastocysts are from different species, the result – if it survives – will be a new creature with traits of both. Such a chimera will usually tend more toward one species than the other.

Chimeras that are basically nonhuman animals, but contain some human traits, can be treated as genetically-engineered animals, and used for similar purposes; see Chapter 3. Human-like chimeras that incorporate cells from other species are also possible. In addition to animal-human chimeras, human-alien fusions – “alien hybrids” (above) – are a staple of space opera and UFO mythology.

While a “classic” chimera is not too difficult to achieve with bacteria, plants, or very closely related animals (e.g., between dog and wolf blastocysts), the likelihood of a viable chimera declines as the species become more

diverse. To produce more exotic chimeras, such as human/wolf or human/alien, the germ cells from each embryo often need to undergo genetic engineering to improve their compatibility. Additional cell grafts or microsurgery are used to ensure the correct mix of cells and to correct any resulting deformities in the developing embryo. Cross-species chimerization is unlikely to be easy. The path to success will be littered with failed fusions, resulting in dead embryos and aborted, defective, or monstrous fetuses. Even a successful chimera may have genetic flaws, or be born with hormonal imbalances that can cause psychological problems.

In game terms, there isn’t that much difference between chimerization and germline engineering, especially since the techniques are likely to blend together. As such, chimerization uses the germline engineering rules – design the species as a engineered animal or human, with appropriate cross-species characteristics. Since a chimera’s fusion occurs on the cellular level rather than the genetic level, it is less of a “complete” organism. To reflect this, all chimera templates created at TL8-9 should have the Chimera meta-trait (p. 214) as an unintended defect. A lower HT is also reasonable. The Chimera meta-trait is not mandatory at TL10+, but may be common.

OBJECTIVES OF HUMAN GENENGINEERING

Once we have the technology to radically redesign a human, would we want to do it? Here are some reasons that might drive engineers:

Pantropy

From Greek, meaning “grow anywhere,” this is the practice of adapting humans to live and work in hostile or alien environments. People designed to survive without an artificial environment may be safer (due to reduced risk of accidents) and, in the long run, less expensive – atmosphere plants, artificial gravity, space suits, and domed cities don’t come cheap, and terraforming is a massive expense.

Moreover, if long-term colonization is planned, a colony is more likely to be psychologically stable if the colonists and their children can live on “their” world without the constant threat of death by technological failure. If there is a local or widespread breakdown of civilization, such as a war, blockade, or “long night” interregnum, colonies of altered people are far more likely to survive the loss of their infrastructure. Pantropy may also be preferred due to ideological opposition to terraforming: instead of changing a world to fit people, it may be considered more ecologically friendly to change people to fit a world.

Homo superior

Engineering may be driven by the desire to create “better” or “super” people. This is the major goal of eugeneering, but it can also be taken farther via species modification.

Typical goals include improved health, longer life (even immortality!), mental enhancements like improved intelligence or memory, and superior physical abilities such as enhanced strength or speed. Other objectives may be to gengineer away human dependencies, such as the need for sleep.

Homo superior may have improvements in many areas, or be more specialized, gaining some abilities at the expense of others. Unmodified humans may react with fear or envy to a gengineered super-race, especially if they can't afford to give their children the same kinds of modifications.

On the other hand, extensive or limited gengineering of this sort may be applied to an entire society. For example, a society may embark on an effort to ensure every child is gengineered with an enhanced immune system, or a higher level of intelligence. Of course, conflict can arise over exactly what sets of traits *should* be standardized by such a society. The concept of a "superior" person is likely to be driven by ethical and ideological considerations. A utopian commune might consider *Homo superior* to be a peaceful race, and choose to delete genes linked with aggression. There could also be a yawning "generation gap" between the adults who chose such traits, and the enhanced children who were the first to express them.

Slave Species

Gengineering may be used to create a more tractable proletariat, underclass, or slave caste. Slave species are usually designed for jobs that humans find dangerous, boring, or demeaning, such as work in hostile environments, soldiering, manual labor, domestic servitude, or concubinage.

Gengineered slave species often possess highly specialized physical and mental modifications to make them more effective workers, or condition them to accept their role. For example, pleasure models may be grown with stunning looks and glandular modifications that keep them constantly "in heat," while a janissary warrior could be gengineered with enhanced speed, a high pain threshold, and boosted aggressiveness. These changes can leave members of a slave species more effective than humans within a limited sphere, while circumscribing their free will. This might result in simultaneous feelings of inferiority and superiority with respect to normal humans. Gengineers sometimes try to create a slave species so perfectly adapted to its role that it can't conceive of freedom. They don't always succeed.

Slave species are sometimes deliberately gengineered to look physically distinctive. For example, all slaves may have blue skin, or be gengineered human/animal hybrids. This might be done for cosmetic reasons, but it also makes it more difficult for people to see them as "human," and harder for them to escape. It's even possible that differences will accrue because the law states that having a certain percentage of nonhuman gene sequences makes someone legally an animal or living artifact (which can be owned) rather than a human being (who is a free citizen). Gengineers may have to make a slave species less human in order for it to be considered a slave species.

A slave species may not always remain in slavery. Changes in circumstances or social attitudes, or an unforeseen mutation, might lead to emancipation or revolt. Of course, if the species has been specialized for a limited role, this may limit its ability to enjoy its new-found freedom . . .

Why Make Übermenschen?

Genetic engineering to allow superhuman physical feats is useful for many physically-demanding jobs, but especially for covert operations, where cybernetics or powered armor might be too easy to detect. Modern military forces may also find biological enhancement easier on logistical grounds – a gene-enhanced soldier may not be quite as strong as a robot or a trooper in a battlesuit, but at least he doesn't require any special maintenance.

Since modifications to ST and DX are purely physical, they would be amenable to animal testing. Several models of enhanced "super-animals" will probably be designed before any super-humans are. Even if the animals weren't put into production, a few prototype super-critters might be found in (or escape from) labs.

Many species modifications (and to a lesser extent, almost all genetic modifications) produce effects that can be replicated more cheaply by technology. Why bother to use feline genes to give someone fur or claws when you can get the same or better effect with a weatherproof jacket and a knife?

First, parahumans may be designed as frontier colonists or workers on worlds with harsh environments.

A biological edge may be useful if disaster leads to a technological breakdown. Even if it doesn't, being able to survive outdoors (even briefly) without artificial aids brings a welcome sense of security, contributing to the psychological health of the community.

Second, some cultures may prefer "softer" biotech to inorganic devices, or create transgenic people for aesthetic reasons.

Third, biological abilities are more convenient. Someone with super-acute senses doesn't need to stop to look at an instrument to know if someone's sneaking up on him. Likewise, you don't have to worry about changing the batteries. If you have retractable claws, you'll never forget your knife, or puzzle over concealing it in different types of dress or undress. Sure, you can get the same effect with cybernetics, but that's as expensive as riding the genemod train.

Fourth, transgenic modifications can be augmented as well. If you've got natural claws, you can add a diamond layer to them. If you have super-sensitive hearing and smell, you can use them at the same time you're wearing that sensor visor. It's not an either/or proposition – it's a wider range of capability.



Specialization and Genetic Castes

Gengineered people may be optimized for specialized tasks from birth, without ever having been intended as slaves. This may be the decision of parents (“I want my baby to be a scientist”) or of a community, or could follow the emancipation of slave races.

Taken farther, this could lead to a caste-based communism similar to the one in Aldous Huxley’s novel *Brave New World*, or the end result of a fascist “master race” breeding program. In this type of hive-like society, citizens are designed from birth for specific jobs. There may be a drone-like working class indistinguishable from a slave species, managed by an upper class of unspecialized people (normal humans or a *Homo superior* race) to give orders and handle unforeseen emergencies.

Such a society may dispense with sexual reproduction and reproduce through growth tanks or cloning. Ordinary citizens may be gengineered to be non-aggressive workers; faced with an external enemy, such a state might alter its birth programs to grow (or clone) a crop of super-soldiers.

HIDDEN DANGERS

The obvious problems of genetic engineering are short-term hazards – an error that threatens the life or well-being of modified individuals or their children. But if genetic engineering is aimed at creating a viable *race* that’s capable of reproducing without further technological assistance, there are additional issues to consider. These may be of little concern to individuals, but they can have long-term implications, especially if variant races are being used for planetary colonization.

One risk is that the pool of diverse genotypes in an engineered race may be relatively shallow (or nonexistent, if they reproduce via cloning and eschew further modification), at least for several generations. A real-life example of

Nature Versus Nurture

There is an ongoing scientific debate over the degree to which human traits and behavior are influenced by genes (“nature”) and by environmental factors (“nurture”), including fetal conditions, child care, nutrition, education, and other life experiences.

Events in the womb have a profound effect on the physical and mental traits of a person. While genetic disorders can cause many physical disadvantages, many other physical abnormalities – including many gross deformities – result from problems that arise during fetal development, such as the lack of oxygen at a crucial time, or the presence of radiation or chemicals.

The childhood environment is also influential. For instance, there is a convincing body of research that suggests the trait of “shyness” is genetic. Certain genes do make people extra-cautious and anxious, leading to high heart rates when responding to new stimuli. This influences behavior through a kind of feedback loop. To escape these feelings of anxiety, children with these genes avoid new situations where these kinds of stimuli occur – they act “shy.” However, studies also indicate that parents who encourage their shy kids to play with others at an early age will alter these biochemical systems, modifying the way the body reacts to stimuli. In other words, nurture triumphs over nature through deliberate action.

Likewise, while it is possible to edit out genes believed to influence mental instability, many mental disadvantages result from childhood trauma. Thus, while someone may not have the genetic predisposition toward lecherousness, he may have grown up in an emotionally deprived environment, leading him to adopt promiscuity as his sole means of expressing affection. Similarly, someone who saw his parents massacred in a war may be prone to fits of uncontrollable rage, or manic-depressive episodes.

In short, it’s hard to eliminate common mental and physical problems just by fixing genes. If gengineered people are grown in an artificial womb (growth tank or forced-growth tank) and educated under controlled conditions, then they may turn out exactly as planned. If they grow up in the real world, there is a fair chance that they’ll have the same sorts of problems as everyone else.

In game terms, this means that most mental advantages, mental disadvantages, and even some taboo traits in a genetic racial template should be considered guidelines rather than hard-and-fast rules. If the subject was raised in controlled conditions, and no mistakes were made, he’ll generally “live up to spec.” It’s also possible that the genes of a human who is gengineered for a specific trait will make it almost certain that he’ll develop that trait.

this danger is the cheetah. Some time in the prehistoric past, this cat species suffered a genetic “bottleneck” in which a large amount of the breeding population died. Modern cheetahs are descendants of a few individuals. As a result, as a species cheetahs are highly vulnerable to epidemics (since if one cheetah catches something, the others are unlikely to have any immunity to it), and suffer many birth defects due to inbreeding. This could be equally true of a genetically-homogenous variant race.

Similarly, it’s all well and good to transform everyone into a race of “beautiful” people by, say, deleting gene sequences for excess body fat. However, if a disaster (comet strike, nuclear winter or whatever) triggers the next ice age and causes the collapse of technological civilization, the super-slim, fashion-model beautiful *Homo superior* will all starve or freeze to death – and since the gene for obesity is now gone, there will be nothing to select for in future generations.

DESIGNING VARIANT HUMANS

A gene-altered person is a “sub-race” (see p. B454) of humanity, even if he represents the first (or only!) member. However, since the parent race is human (which have no racial templates), variants are usually described with templates.

A variant human racial template should be created using the *Racial Templates* rules (p. B450) and the guidelines in this section. Ideally, it should be designed around a specific theme, depending on the intent of the designer and the kinds of genetic material used. It will have its own racial traits (see *Selecting Traits*, pp. B451-452).

The traits chosen should have a scientific – or at least pseudo-scientific – rationale (e.g., extra Fatigue Points and Combat Reflexes could be justified by “enhanced lungs and built-in war drug glands”). Others may be based on “xenogenes” from other species (e.g., Night Vision derived from cat genes).

A variant human racial template can have any traits the GM feels could be logically produced through genetic engineering. This includes basic attributes, secondary characteristics, build, and physical appearance. Most physical advantages and disadvantages are appropriate; so are many mental ones.

Genetic engineering is not a neutral technology. It is by its very nature too powerful for our present state of social and scientific development.

– Linda Bullard

Inappropriate traits include anything that can only be explained by post-natal experiences or events: this includes Fashion Sense, all traits under *Social Background* (p. B22), *Wealth and Influence* (p. B25), all social advantages and disadvantages, all self-imposed mental disadvantages, and any traits that represent relationships, possessions, wealth, or training. The GM can rule that some mundane traits, such as Luck, are too abstract, weird, or difficult to engineer (although even that might be possible if these traits are explained as genetically-linked psionic powers). Genetic engineering of exotic traits not found in nature, such as

Experimental Procedures

Biotech may be available at one TL earlier than listed, as an “experimental procedure.” This includes early human trials of specific biomod processes, experimental engineering projects, and so on. In general, an experimental process will cost at least 10 times as much as normal. This is very common in cinematic genetic engineering. For example, cinematic TL9 genetically-engineered “super agents” often have TL10 modifications.

It’s likely that any such newly-invented process will have bugs in it – the GM should apply Tech-Level Modifiers (p. B168) to skill rolls for surgery or engineering tasks, or assign additional side effects (usually disadvantages) to anyone or anything that has undergone the process, or been created by it.

Invisibility or Shadow Form, may only be possible if “mutant super-powers” exist in the setting. Similarly, supernatural traits such as Magery can only be engineered if these traits both exist, and are hereditary.

The rest of this chapter is devoted to discussing what genetic engineers might plausibly produce at various TLs, and how they might do it. Lists of traits have been assigned TLs based on how difficult they might be to produce through engineering.

GMs should feel free to modify the TLs, effects, and rationales suggested for various modifications – they are only intended as guidelines, not hard and fast rules. Not every trait has been included, only those that seem likely or interesting.

In space-opera, supers, or horror settings, variant racial templates can include *any* ability that can be rationalized as “genetic,” from mouse-sized humans to the ability to throw lightning bolts or fly faster than light. In that sort of campaign, genetic engineering of this sort is simply super-science. Don’t feel bound by tech levels – after all, in the comics, a genius grad student working in a TL7 lab might be capable of splicing “spider genes” into human germ cells to grow a human/spider chimera with ST and DX bonuses, Binding, Clinging, or even Extra Arms.

GENGINEERED TRAITS

The following sections discuss different categories of changes that might plausibly be bioengineered into a variant human race. The assignment of TLs and association of advantages with various traits (e.g., Hard to Kill under Cardiovascular Modifications) are suggestions only, and may be altered by the GM as desired.

Not all gengineered traits will be advantages. Some variant races are designed with deliberate physical defects. For example, a wealthy sadist might want his latest concubine to be a beautiful albino with Low Pain Threshold, while the eccentric Sultana of Gideon Prime might desire her bodyguard of gene-enhanced janissaries to have both Gigantism and Mute.

Gengineered Traits Tables

Trait: The name of the attribute, advantage, disadvantage, feature, ability, or meta-trait.

Cost: The point cost of the trait. Some traits are 0-point features, but may still require complex or even radical genetic engineering.

TL: The minimum TL at which the trait may be *deliberately* engineered. It is possible that a trait may be produced by accident at a much earlier TL, and GMs are free to use this to justify templates with abilities in excess of those normally available. Modifiers to attributes, secondary characteristics, or other leveled traits that have two quite distinct justifications can be combined, unless otherwise noted. For example, immune system modifications and lifespan and self-repair modifications can each justify a +1 to HT at TL9, for a total +2 HT.

Page: The page on which the trait is described in the **GURPS Basic Set** or this book.

Eugenic vs. Species Modification

Whether added DNA sequences are human or not may be very important if society bans or stigmatizes parahumans. Also, species modifications are more likely to be coupled with nonhuman features. Those genetic traits that would require departing from the human genome have been labeled as requiring “species modifications.” Human genetic engineering that involves species modifications also has a higher dollar cost.

A few traits are described as requiring “radical species modification.” Such modifications significantly increase the dollar cost and the difficulty of a genetic engineering project; a template with radical modifications is very likely to have a number of unintended genetic defects, especially at the TL that trait first becomes available.

BRAIN MODIFICATIONS

Our competitors at Matsai gengineered their 3000-series megabrights for hyped-up creative, intuitive, and mathematical faculties. Turned out the engineers didn't know as much

as they thought they did about brain chemistry, and ended up with three super-bright, high-strung, delusional schizophrenics. Two killed themselves. The third is convinced God is behind the event horizon of the black hole in the galactic core, and devotes all her time to trying to figure out how to get him to answer back. She's managed some useful astrophysics and hyper-mass experiments, but that isn't what Matsai hoped for. Still, Matsai corporate ideology keeps them trying to develop 'super-thinkers.' I admit they did a better job with their more modest Pandora-series, although these sure aren't bug-free either – ever try talking to one?

– Doctor Sayyid Iqbal, Biotech Euphrates

The adult human brain weighs only three pounds, but has been described as the most complex object known to science. It contains some hundred billion nerve cells, including specialized neurons devoted to higher cognitive functions such as reasoning, emotion, and language.

The brain consists of two large, wrinkled, dome-shaped cerebral hemispheres that together form the cerebrum, the site of reasoned mental activity. At the lower rear is the cerebellum, which coordinates the body's movements. The central part of the brain includes the thalamus, which controls sensory awareness, the limbic system, which affects glandular functions and emotions, and the hippocampus, associated with memory, personality, learning, and will. The lower part of the brain, the “primitive” brain stem, controls automatic body processes including the heartbeat, respiration, and digestion.

Engineering mental traits such as intelligence, alertness, memory, or specific aptitudes is difficult, because these traits are more abstract than physical ones. Exactly how much of “intelligence” is genetic and how much is environmental is not only controversial, but any answer also depends on how you measure and define intelligence.

However, traits ranging from self-control to high intelligence appear to be connected to specific gene sequences that govern the exact mix of hormones and other neurotransmitters produced by the body. Scientists have found human genes that appear to correlate with mental stability, shyness, impulsiveness (which, through mitigation, may lead to Common Sense) and memory, among other characteristics.

In this realm, engineering works hand in glove with neurology and molecular neuropsychology. Today, radioisotope-labeled monoclonal antibodies are used to locate neurotransmitters in the brain, and imaging systems have begun to observe the brain's neurochemical activity as it occurs. As these techniques are refined at TL9+, neuro-geneticists can study the molecular changes that occur while people stay awake, endure pain, memorize, solve math problems, and so on. Then they can design nucleotide sequences that will optimize the brain's neurochemistry or structure toward specific activities.



Brain Modifications

<i>Trait</i>	<i>Cost</i>	<i>Page</i>	<i>TL</i>
3D Spatial Sense	10	B34	10
Ambidexterity	5	B39	10
Autotrance	1	B101	10
Common Sense	10	B43	10
Compartmentalized			
Mind 1-2	50/level	B43	11*
Eidetic Memory	5	B51	9
Intuition	15	B63	10
Intuitive Mathematician	5	B66	10
IQ -1 to -4	-20 per -1 IQ	B15	9
IQ +1	20	B15	9
IQ +2	40	B15	10
IQ +3	60	B15	11*
IQ +4	80	B15	12*
Language Talent	10	B65	10
Lightning Calculator	2	B66	10
Mathematical Ability	10/level	B90	9
Musical Ability	5/level	B91	10
Perception +1	5	B16	9
Perception +2	10	B16	11
Photographic Memory	10	B51	10
Single-Minded	5	B85	9
Versatile	5	B96	10
Will -1 to -3	-5 per -1 Will	B16	9
Will -4 to -5	-5 per -1 Will	B16	10
Will +1	5	B16	10
Will +2	10	B16	12

* Species modification.

Behavioral Modifications

We must ensure that the bioroids we create are happy in their jobs. A happy worker is a productive worker. We can point to the success of the Eros-5's hormonal imbalance: To be crude, the E-5s are always in heat, hence eager to please.

– Internal memo, Biotech Euphrates

It's possible to eugeneer a careful imbalance of neurotransmitters and glandular hormones to result in a predisposition toward certain distinct mental states, such as aggressiveness or lecherousness. These may result in hereditary mental disadvantages . . . but what might be a disadvantage to the individual can suit the purposes of the genetic engineer.

Changes may be intended to suit a person to his job, for example, instilling Lecherousness in a pleasure model or Bloodlust in a soldier. They may also be intended to benefit society, e.g., by making everyone Chummy or even Selfless. Sometimes, the goal is a more tractable variant race: a slave with Combat Paralysis will be less likely to rebel, and one with Hidebound is less likely to develop dangerous new ideas.

By tinkering with the genes that regulate behavior-modifying neurotransmitters, like MAO inhibitors, an unspecified mental instability can be engineered. This is usually intended as a form of genetic booby trap; e.g., someone orders or awakens a clone, but a saboteur has secretly gene-modified it to go crazy after it awakes. In game terms, the template is not given specific mental disadvantages to represent this, but is assigned several points of Secret

Disadvantages (p. B120). These differ from individual to individual, and are chosen by the GM and imposed during play, usually from among Berserk, Chronic Depression, Delusions, Manic-Depressive, Megalomania, On the Edge, Paranoia, and Split Personality. This would be recorded in a template as Secret Disadvantages (Mental Instability) and the point value (at least -10 points); the actual disadvantage will be worth five points less. It's quite possible someone could learn they have genes tending toward mental instability . . . but not how it or when it will manifest!

Another form of tinkering is to design someone so that exposure to a physical taste or scent triggers a release of endorphins, or simply tastes/smells good to them. This might be a 0-point feature (e.g., engineering children so they *always* like the taste of spinach) or more manipulative (e.g., a servant race designed to like the scent of a master race, etc.). This might count as a Minor Addiction.

The most common behavior modifications likely to be *deliberately* engineered are shown below.

Behavioral Modifications

<i>Trait</i>	<i>Cost</i>	<i>Page</i>	<i>TL</i>
Attentive	-1	B163	9
Bad Temper	-10*	B124	9
Berserk	-10*	B124	9
Bloodlust	-10*	B125	9
Broad-Minded	-1	B163	10
Bully	-10*	B125	9
Careful	-1	B163	9
Callous	-5	B125	9
Congenial	-1	B164	10
Cowardice	-10*	B129	9
Curious	-5*	B129	10
Dull	-1	B164	9
Dyslexia	-10	B134	9
Gluttony	-5*	B137	9
Hidebound	-5	B138	9
Humble	-1	B164	10
Impulsiveness	-10*	B139	9
Incurious	-5*	B140	10
Lecherousness	-15*	B142	9
Loner	-5*	B142	9
Low Empathy	-20	B142	9
Minor Addiction	-1	B165	9
Nosy	-1	B164	9
Overconfidence	-5*	B148	9
Personality Change	-1	B164	9
Proud	-1	B164	10
Responsive	-1	B164	10
Secret Disadvantage (Mental Instability)	variable	43	9
Selfless	-5*	B153	11
Shyness	-5, -10, or -20	B154	9
Slave Mentality	-40	B154	11
Split Personality	-15*	B156	10
Staid	-1	B164	9
Stubbornness	-5	B157	9
Uncongenial	-1	B165	9
Workaholic	-5	B162	10

* You must select a self-control number; the cost given is for a self-control number of 12.

Sleep-State Modifications

The biochemical mechanisms behind sleep remain murky. Many researchers believe that animals (including humans) sleep and dream because the body or brain needs time to rest and regenerate itself. However, some scientists lean toward the idea that sleep is not a metabolic necessity, but rather an evolutionary quirk. That is, our brains are programmed to make us sleepy because being dormant for a certain length of time reduces food requirements and, for humans, prevents us from stumbling into predators we can't see. If that's the case, sleep's been obsolete since we invented fire – but the only way to tell our bodies otherwise may be genetic engineering.

Careful tinkering with sleep-regulating structures in the brain, such as the caudal brain stem, basal forebrain, the serotonin-producing raphe nuclei, and the suprachiasmatic nuclei (which appear to govern circadian rhythms) may modify or eliminate the need for sleep. Other modifications may affect the way humans dream by interfering with the flow of images to the cortex from the limbic centers (the older part of the brain).

Sleep-State Modifications

Trait	Cost	Page	TL
Deep Sleeper	1	B101	9
Doesn't Sleep	20	B50	11*
Dreaming +1 to +3†	2/level	B188	10
Less Sleep 1	2	B65	9
Less Sleep 2-4	2/level	B65	10

* Species modification.

† Racial skill bonus (p. B452).

CARDIOVASCULAR MODIFICATIONS

Cardiovascular modifications are made to the heart, blood, and circulatory system.

The human heart is a pump with four chambers in two pairs: the right pair sends blood to the lungs to pick up oxygen, the left delivers the now-oxygenated blood. The heart may be strengthened with enhanced muscle tissue so it can better withstand trauma and stress, providing extra HT and HP and the advantages Fit, Very Fit, or Hard to Kill.

Mammals, including humans, have about a pint of blood for every 15 pounds of body weight (a "unit" of blood, as used in medicine, is also about a pint). Blood itself is a complex liquid composed of plasma and blood cells. Plasma is a watery liquid containing the glucose (blood sugar) that powers the body, various dissolved nutrients, hormones, and waste products. Blood cells are white cells that fight disease, platelets that clot and seal wounds, and red cells that carry oxygen. Bone marrow cells may be modified to produce engineered blood cells with improved capabilities. The hemoglobin in red blood cells (erythrocytes) can be redesigned for greater oxygen transport capacity (extra Fatigue Points). Extra red blood cells can be stored in the spleen (as in a dog) for additional release when necessary.

The circulatory system includes arteries that carry blood from the heart to the body, veins that return it, and tiny capillaries linking the two, where oxygen and nutrients are exchanged. Arterial tissue may be engineered so it does not lose its elastic property with age (which could provide Longevity). More specialized cardiovascular genemods are also possible. For instance, as high-g acceleration causes blackouts when the blood pools in the lower body rather than reaching the brain, arteries feeding the lower body may be redesigned to react to g-forces by pinching off blood flow to legs and abdomen while enhancing it to the brain (Resistant to Acceleration). Related modifications may produce faster recovery from unconsciousness (Recovery) or adapt the circulatory system to lengthy periods in higher or lower gravity (Improved G-Tolerance).

To design cardiovascular genemods, use these secondary characteristic bonuses and advantages:

Cardiovascular Modifications

Trait	Cost	Page	TL
Fit	5	B55	9
FP +1 to +3	3 per +1 FP	B16	9
FP +4 to +5	3 per +1 FP	B16	10*
FP +6 to +10	3 per +1 FP	B16	11*
Hard to Kill 1-2	2/level	B58	10
Hard to Kill 3-5	2/level	B58	10*
Hard to Subdue 1-2	2/level	B59	10
Hard to Subdue 3-5	2/level	B59	10*
Improved G-Tolerance (0.3 G)	5	B60	9
Improved G-Tolerance (0.5 G)	10	B60	10
Improved G-Tolerance (1 G)	15	B60	10*
Improved G-Tolerance (5 G)	20	B60	11*
Longevity	2	B66	9
Rapid Healing	5	B79	9
Recovery	10	B80	10
Resistant to Acceleration (+3)	1	B80	9
Resistant to Acceleration (+8)	3	B80	11*
Very Fit	15	B55	10

* Species modification.

COSMETIC AND MINOR TRANSGENIC MODIFICATIONS

Eye color can be specified quite easily, as this is a simple multigenic trait. Hair color, as well as skin pigment (melanin) and other traits that make someone racially black, Caucasian, and so on, are somewhat more complex, but all can be selected at TL9+ to give whatever eye, hair, skin color, or other ethnic features are desired, or to deliberately blend several types.

Good or bad looks can be selected by choosing a particular bone structure and metabolic factors that encourage a specific type of build, while working against acquiring blemishes, acne, and so on. Left unspecified, a person's looks are whatever is randomly inherited from the original genetic material used, i.e., it depends on the parents, and it's up to the player or GM. Other traits, such as a tendency toward a particular build, are also possible.

Species engineering can create designer genes for distinctive exotic features like green hair, blue skin, or gold-flecked eyes.

Genetic Tattoos: These are images or symbols formed from skin pigmentation, bumps or ridges. They might be artistic, or show clan or company affiliation – a slave race might even have a tiny company logo and trademark symbol on their body.

Intron Messages: Introns (p. 7) can be modified to “spell out” specific messages when someone sequences the engineered DNA.

Skin, Hair, and Body Coverings

The skin itself is the body's largest organ, designed to protect softer internal tissues from harm and (through sweat glands) keep it cool. The outer skin, or epidermis, is composed of a surface of hard, dead tissue (keratin) atop a basal layer of live skin cells that are constantly multiplying, growing, filling up with keratin, dying, and flaking off; the cycle takes about four weeks. Below the epidermis is the dermis, a thicker layer formed from the protein collagen, that also contains blood vessels, nerves, sweat glands, and hair roots. Modifications may change the way skin cells grow, alter pigments, or cause the growth of a thicker hide, fur, or even scales.

Chameleon Skin: Natural chameleons such as the cuttlefish have layers of dermal chromatophore cells. These consist of a pigment sac (there are usually three different pigments) encased in muscle and nerve tissue. By contracting these muscles, the colored cell is flattened into a wide disk, increasing its visibility; by relaxing the muscles, it contracts to a dot. By relaxing chromatophores containing one pigment and constricting those containing others, a wide range of colors and patterns can be generated. Chameleon could also be extended to cover Infravision through pigments that absorb infrared radiation, or its masking via thick fur.

Fur, Scales, Spines, etc. These are usually intended for aesthetic effect, but can serve more practical purposes, such as protecting colonists engineered for harsh climates. They may also be effects of blending human and animal genes in search of other advantages like xenosenses. *Thick fur* may also provide DR 1-3 and Temperature Tolerance 1-2. Scales or a thick leathery hide may provide DR 1-4; a tortoise-like shell, DR 4-5.

Other Transgenic Traits

Amphibious: This requires engineering for webbed fingers and toes, and is often associated with a sleek coat of fur like a seal, or very light scales.

Bioelectric Organ: An exotic modification that uses modified plates formed from muscle tissue, derived from electric eel genes. It can deliver a localized but powerful electrical shock: Burning Attack 1d (Melee Attack, Reach C, -30%; No

Incendiary Effect, -10%; Side Effect, Stunning, +50%; Surge, +20%; Takes Recharge, 5 seconds, -10%; Variable, +5%) [7]. The Variable enhancement allows it to be used at a lower power level, e.g., to act as an emergency defibrillator (p. 124).

Clinging: This may be achieved via tree-frog suckers or gecko hairs on hands and feet.

Claws, Talons, etc: Claws, hooves, teeth, etc. are based on animal models. They all may be given the Switchable (+10%) enhancement to represent retractable features. Weak Bite could represent changes in jaw structure, or softening or removal of the teeth – possibly a deliberate modification in a pet or pleasure bioroid; this may limit available food choices, but is not severe enough to count as Restricted Diet.

Payload: This represents natural pouches, like those of marsupials, which may be useful for carrying tools or concealing weapons, as well as holding babies.

Nictitating Membranes: These reptilian “second eyelids” are designed to protect the eyes. This modification may be common in pantropic parahumans designed for worlds with hostile atmospheres or perpetual dust storms, or for vacuum.

Prehensile Tongue: This is a long (sometimes forked) retractable tongue. Acute Taste +1 [2]; Racial Skill Bonus: Erotic Art +1 [2]; Extra Arms (Third Arm; Extra-Flexible +50%; Short, -50%; Switchable, +10%; Weak, 1/4 ST, -50%) [6]. 10 points.

Temperature Tolerance: This may be combined with fur, but could also represent a sub-dermal layer of adipose or blubber, or special insulating glands.

Cosmetic and Minor Transgenic Modifications

Trait	Cost	Page	TL
Appearance Levels	Variable	B21	9†
Distinctive Features	-1	B165	9
Genetic Tattoos	0	45	9*
Intron Messages	0	45	10*
Pitiable	5	B22	10

Other Transgenic Traits

Amphibious	10	B40	9*
Chameleon 1-2	5/level	B41	10*
Chameleon 3-4	5/level	B41	11*
Clinging	20	B43	10*
Damage Resistance 1-3	5/level	B46	9*
Damage Resistance 4-6	5/level	B46	10*
Fur	1	B101	9*
Long Spines	3	B88	10*
Nictitating Membrane 1-5	1/level	B71	9*
Payload 1-5	1/level	B74	9*
Prehensile Tongue	10	45	10*
Short Spines	1	B88	10*
Temperature Tolerance 1	1/level	B93	9
Temperature Tolerance 2-5	1/level	B93	9*
Temperature Tolerance 6-10	1/level	B93	10*
Temperature Tolerance 11-20	1/level	B93	11*
Unnatural Features 1-5	-1/level	B22	9*

Transgenic Natural Weapons

Trait	Cost	Page	TL
Bioelectric Organ	7	45	11*
Claws			
– Blunt Claws	3	B42	9*
– Hooves	3	B42	10*
– Long Talons	11	B43	10*
– Sharp Claws	5	B42	9*
– Talons	8	B43	10*
Teeth			
– Fangs	2	B91	9*
– Sharp Beak	1	B91	10*
– Sharp Teeth	1	B91	9*
Weak Bite	-2	B161	9*

* Species modification. In some cases, these may qualify as Distinctive or Unnatural Features, depending on how common parahuman species are.

† Any level except Horrific or Transcendent is possible; these may optionally be possible with TL11+ biotech. Appearance may be engineered with the Androgynous (p. B21) or Impressive options, and the -50% limitation Off-the-Shelf Looks (p. B21) is appropriate for templates that involve mass cloning or identically-manufactured bioroids.

DIGESTIVE AND FILTRATION MODIFICATIONS

Chronos-series long-range recon patrol bioroids have a stomach like a grasshopper mouse's and hyperactive digestive enzymes that can digest anything. Supposedly, that frees them from dependence on the supply system, especially in harsh environments where there isn't much food around. In the Andes conflict, I saw them ambush an enemy patrol, then swallow them up and grind them down, bones and all. Even ate their own dead. Creepy.

– Captain (ret.) Dana Martello, Marine Force Recon

The body's digestive system is designed to transform food into protein, vitamins, minerals, carbohydrates, and fat which can be absorbed into the bloodstream to power the body. After being chewed and moistened by saliva, food goes down the esophagus into the stomach, where it is digested by stomach acids. It then passes into the small intestine (the longest part of the digestive system), where it is transformed into nutrients and absorbed into the bloodstream along its vast surface area.

Nutrient-rich blood enters the liver for processing. It filters out harmful substances or wastes, turning some of the waste into bile (which is used to break down fatty foods). The large intestine handles the remaining waste. It absorbs water and any remaining minerals, concentrating the remaining soup into solid waste and storing it in the rectum. The large intestine teems with symbiotic microbes which assist the process.

Modifications to the liver are usually aimed at selectively improving its metabolic and detoxification abilities, giving better resistance to blood toxins (including alcohol), usually in conjunction with modifications to the spleen and kidneys. This is represented by being Resistant to Poison or

perks such as Alcohol Tolerance. It may also be possible to rebuild the liver so its tissues store oxygen, in the manner of some marine mammals (see *Respiratory Alternatives*, p. 55).

General improvements to the digestive and urinary system can give the advantage Reduced Consumption; digestive improvements provide Reduced Consumption (Food).

A common modification, especially for pantropic parahumans who are adapted to an alien world or post-holocaust environment, is Immunity to a specific poison, where the poison is a particular environmental condition in air, water, or food. This is usually TL9, although some conditions might require higher-TL modifications.



Colonists, scouts or soldiers who have to live off the land might have an intestinal tract redesigned to function like that of a ruminant animal (e.g., a cow), with symbiotic bacteria that can digest cellulose, allowing them to eat almost any plant matter. This ability is Reduced Consumption (Cast-Iron Stomach) (p. B80). Going the other way, it might be desirable to remove as many parasitic and symbiotic bacteria as possible from the human body, giving Sanitized Metabolism (p. B101). Spacers may take this route to reduce the risk of bacterial infection or mutation in fragile and radiation-exposed space ecosystems. If so, the newly-sanitized intestines will need to be modified to produce enzymes that handle the functions of intestinal bacteria, such as vitamin synthesis.

The appendix is a vestigial growth on the end of the intestine. In humans, it doesn't do much except become

infected; human engineers may remove it in the interests of boosting overall health and resistance to disease. In and of itself, No Appendix is only a feature, but it is often taken in conjunction with an overall increase in HT.

Kidney Modifications

"Uh, should all of us be drinking? I'm out of Sober-Ups, and we don't have a designated driver."

"Hey, it's cool. I'm an Ishtar-sequence upgrade. With my genemod liver, I can drink all night and never get wasted."

"Well, I hope you've got a boosted kidney, too. It's 20 miles to the nearest rest stop, and I'm not going into this place's washroom without a gun."

The body's water processing system is the urinary system; its main organs are the kidneys, which contains a million tiny filters (nephrons) that remove waste products including excess salt and water from the blood into the bladder, for release. The kidneys could be remodeled after a desert animal's to conserve water via super-concentration of the urine (which would also reduce the need for bathroom breaks). This results in the need for only 2/3 to 1/3 as much water. This ability provides Reduced Consumption (Water Only).

Digestive and Filtration Modifications

Trait	Cost	Page	TL
Alcohol Tolerance	1	B100	9
Immunity to a			
Specific Poison	1	B80	9
No Appendix	0	46	9*
No Hangover	1	B101	10
Reduced Consumption 1-2	2/level	B80	10*
Reduced Consumption 3	6	B80	11*
Reduced Consumption 4	8	B80	12*
– Food Only	-50%	B80	-1
– Water Only	-50%	B80	-1
Resistant			
– to Ingested Poison (+3)	3	B80	9
– to Ingested Poison (+8)	5	B80	10*
– to Poison (+3)	5	B80	10
– to Poison (+8)	7	B80	11*
Sanitized Metabolism	1	B101	9*

* Species modification.

GLANDULAR MODIFICATIONS

Well, sir, we've been grown with the Gen-Five supergland. Whenever our model goes into overdrive, we get these cravings afterward. No, sir, we didn't mean to do that to the prisoners, but we just couldn't help ourselves. Usually the MPs are on hand, but – yes, sir, I'm sorry, sir.

– Corporal NB-SEK-0172, 152nd Paratroop Regiment, Felicia bioroid

A network of internal glands, the endocrine system, secretes hundreds of different hormones into the bloodstream. The tiny pituitary gland (under the brain) is in overall command of the endocrine system. Other glands –

the adrenal, thyroid, parathyroid, pineal body, pancreas, thymus, ovaries and testes – release hormones into the bloodstream to regulate the body's growth, development, and routine metabolic processes, as well as emergency, emotional, and sexual responses. For example, the adrenal gland (above the kidneys) regulates how the body consumes water and reacts to stress; in stressful situations, it tells the liver to release more glucose (for extra energy) and the heart to beat faster (increasing blood flow to the muscles).

Selective glandular biomodification can optimize the body's hormonal balance so that a person will develop in a certain way (more muscular, for instance), perform differently under stress, or experience stronger or weaker passions.

Gengineering of the pituitary and thyroid glands, or designing new, voluntary regulatory glands that produce similar hormones, could adjust metabolic processes such as growth and maturation, and possibly allow control over involuntary biological functions like respiration and digestion. This can grant a tendency toward or away from particular builds, e.g., Taboo Trait (Fat). Deliberately engineering Skinny or Overweight may even be desirable, depending on prevailing ideals or other purposes, e.g., reduced weight for engineered flyers or extra fat for cold weather.

It may also be feasible to engineer for short-term "emergency performance," or to improve pain or stress response. This can provide advantages such as Combat Reflexes and Fearlessness. An ambitious goal is the voluntary control of the sudden bursts of "hysterical" speed or strength that some people are capable of in emergencies. This might require genetic tinkering to modify the adrenal glands or, as with metabolic control, the creation of new voluntary glands that produce similar hormones. This is Combat Reflexes, or for superhuman levels of performance, the meta-traits Burst Speed (p. 48) or Explosive Strength (p. 48). The reverse of this is also possible, creating someone who will usually freeze in a combat situation (Combat Paralysis).

In micro- or zero gravity, the lack of weight seems to affect development, causing brittle bones. Gengineering may be aimed at modifying the parathyroid gland to restore calcium levels, and otherwise adjusting the metabolism to life in zero-G.

By tinkering with hormones, the gengineer can also adjust human behavior, creating a being whose emotions are skewed in a desired direction. Modifications of this sort usually center on the adrenal gland, the gonads (which control influential sex hormones such as estrogens – e.g., estradiol – and androgens – e.g., testosterone) or the pituitary (which produces hormones that influence other glands). The strongest influence will be on the three "primal" human responses: fear, aggression, and sexual behavior.

Early Maturation: This feature reduces the age of maturity at the same rate as Short Lifespan (p. B154) without reducing lifespan. See p. 212.

Hibernation: This ability is Metabolism Control (Hibernation, -60%) [2/level]; see *Metabolism Control* (p. B68).

Glandular Modifications

Trait	Cost	Page	TL
Basic Speed†	20 per +1.00	B17	9
Combat Paralysis	-15	B127	9
Combat Reflexes	15	B43	9
Early Maturation 1	0	212	9
Early Maturation 2	0	212	10
Early Maturation 3	0	212	11
Early Maturation 4	0	212	12
Enhanced Muscle 1-5†	8/level	213	9*
Fearlessness 1-5	2/level	B55	9
Hibernation 1-4	2/level	47	9*
High Pain Threshold	10	B59	9
Improved G-Tolerance (0.3 G)	5	B60	9
Metabolism Control 1-2	5/level	B68	9
Metabolism Control 3-4	5/level	B68	10*
No Degeneration in Zero-G	1	211	9*
Overweight	-1	B19	9
Skinny	-5	B18	9
Taboo Traits (a particular Build)	0	64	9
Unfazeable	15	B95	10

* Species modification.

† This advantage *must* be taken in conjunction with one or more of these limitations: Aftermath (p. 215), Cardiac Stress (p. 215), Costs Fatigue (p. B111), Emergencies Only (p. B112), or Temporary Disadvantage (p. B115); Aftermath or Temporary Disadvantages are usually based on Bad Temper, Berserk, Gluttony, or Lecherousness.

Here are two examples:

Burst Reflexes (TL9): A controlled release of adrenaline lets you react quickly. This is Basic Speed, +1.00 (Costs Fatigue, 2 FP, -10%) [18].

Explosive Strength (TL9): In emergencies, your body can trigger an explosive burst of adrenaline-fueled “hysterical” strength for a very short period. This is Enhanced Muscle 5 (Costs Fatigue, 1 FP/second, -10%; Emergencies Only, -30%) [24].

For another example, see the Felicia (p. 73).

Pheromone Modifications

I believe that we can gain further control over the next generation by restoring the vestigial vomeronasal system, which reacts to airborne pheromones. Unlike lower animals, whose pheromone vulnerability is limited by mating seasons, humans with this genemod may experience irregular, heightened states of arousal. More important for our purposes, they will become far more vulnerable to enhanced pheromones, such as those produced by the pheromone glands and aerosols we have developed.

– Dr. Tse Chang, Report to the Genetic Planning Council

Pheromones are chemical signals given off by the body’s natural secretions. Animals use pheromones to attract mates or, to a lesser extent, warn others of danger, identify each other or establish dominance. For game purposes, this term can also be extended to the production of other airborne hormones.

Susceptible to Pheromones: Many animals have a vomeronasal organ that lets them perceive pheromones as a feeling rather than a smell: detecting another’s pheromones can induce arousal, attraction, respect, nervousness or whatever. In humans, the vomeronasal organ has atrophied to the point where people probably can’t detect pheromones . . . but that might change. In the case of pheromones that provide a reaction bonus (Xeno or Dominance), increase your bonus by your level of susceptibility. This is Susceptible (Pheromones) 1-5 [-1-5].

Sex Pheromones: Modified human glands could produce sex pheromones (or other chemical aphrodisiacs) powerful enough to influence humans. The user exudes an invisible chemical cloud that inspires attraction in those exposed to it. Victims must be within two yards and breathe it in – this ability doesn’t work by touch or sight. This ability is Affliction 1 (HT; Lecherousness (12), +15%; Accessibility, Only on those attracted to your gender, -20%; Area Effect 1, +50%; Emanation, -20%; Scent-Based, +150%) [28]. 28 points.

Trust Hormones: Airborne production of hormones such as oxytocin that inspire levels of trust may justify Affliction 1 (HT; Gullibility (12), +10%, Area Effect 1, +50%; Emanation, -20%; Scent-Based, +150%) [29]. 29 points.

Xeno-Pheromones: Modified organs for producing pheromones capable of influencing a non-sentient species could justify the advantage Animal Friend 1 (Accessibility, One species only, -40%; Scent-Based, -20%) [2]. 2 points.

Dominance Pheromones: These sophisticated pheromones cause people to admire or react with awe to the user – though they don’t know why! This is Charisma +4 (Accessibility, no effect on nonhumans, -5%; Scent-based, -20%) [15]. 15 points.

The user is assumed to be possess an immunity to his own chemical emissions, but this need not always be the case. If not, adding an appropriate Temporary Disadvantage limitation (e.g., Lecherousness or Gullibility, or possibly Chummy for Dominance pheromones) might be appropriate.

Certain disadvantages might also be *activated* by pheromones – this is the Trigger limitation.

Pheromone Modifications

Trait	Cost	Page	TL
Dominance Pheromones	15	48	11*
Sex Pheromones	28	48	10*
Susceptible (Pheromones) 1-5	-1 to -5	48	9*
Trust Hormones	29	48	10*
Xeno-Pheromones	2	48	10*

* Species modification.

Xeno-Glands

Today’s featured company expose is Onokage Labs. This shadowy Kyoto-based corporation has carved out a niche for itself in custom gengineering for the rich and decadent of Asia-Transpacific. Their living products are well known among connoisseurs of the bizarre – and not always what

they seem. Take their Fugu-series pleasure bioroid: an exotic beauty with lavender skin and white hair; she also possesses genemod venom sacs capable of delivering endorphins. Her 'love bites' can make you high, but too much of a good thing can kill you.

– Noriko Hayakawa, host of *Cyberia Beat*

The most common exocrine glands derived from non-human species are venom sacs based on those of reptiles or amphibians. A huge array of toxic and drug-like effects are possible, generally bought as a follow-up Affliction or an Innate Attack doing Toxic damage, usually in conjunction with Sharp Teeth or Claws (p. B42).

Symbiotic bacterial or glandular bioreactors capable of producing or excreting various substances or drugs for later harvest are also possible, although these are much more for animals than humans; See *Pharm Animals* (p. 85) for examples.

Gengineering of these, or of modified hormone glands, may permit chemicals produced in the body (including exotic, new ones) to be secreted externally.

At high TLs, glands (such as spinnerets) capable of secreting enzymes and proteins derived from insect or arachnid genes may allow Clinging or web-slinging (Binding). Other exotic possibilities are enhanced sweat glands to provide Slippery or Temperature Tolerance, or squid-like ink glands giving the Obscure (Vision) advantage in water.

Xeno-glands often have Limited Use or Takes Recharge limitations and are sometimes limited to Emergencies Only.

Xeno-Glands

Trait	Cost	Page	TL
Affliction 1+	10/level	B35	9*
Binding 1-20	2/level	B40	12‡
Clinging	20	B43	11
Obscure (Vision) 1-10	2/level	B72	11†
Slippery	2/level	B85	10
Temperature Tolerance 1-2	1/level	B93	10
Toxic Attack 1+	4/level	B62	9*

* This should have either the Blood Agent (p. B110) or, for musk, Sense-based (p. B109) (usually in conjunction with either Melee Attack or Jet) or Follow-Up modifiers (p. B105).

† This should have the limitation Accessibility, only in water, -30% (p. B110).

‡ This should have the modifiers Area Effect (p. B102) and Persistent (p. B107), and possibly Sticky (p. B40) and Wall (p. B109).

All xeno-glands are species modifications.

Toxic and Affliction Abilities

There are numerous possible Toxic and Affliction attacks that could be produced with advanced genetic engineering. Three examples are given below:

Deadly Venom (TL9): Toxic Attack 1d (Cyclic, 1 hour, 4 cycles, Resistible, +30%; Follow-Up, Teeth/Striker/Claws,

+0%; Onset, 1 minute, -10%; Resistible, HT-4, -10%; Symptoms, 2/3 HP, -2 ST, DX, IQ, and HT, +60%) [8]. *Notes:* The victim must make a HT-4 roll a minute after injection and hourly for three hours. Each failure inflicts 1d injury. Those who lose 2/3 HP or more become seriously ill: -2 to all attributes until healed. 8 points.

Ecstasy Glands (TL10): Affliction 1 (HT; Blood Agent, -40%; Onset, 1 minute, -10%; Ecstasy, +100%; Emergencies Only, -30%; Melee Attack, C, -30%; Secondary Heart Attack, +60%) [15]. *Notes:* The attacker's bodily secretions contain a powerful drug, released when sexually excited or when frightened; a victim must make a HT roll a minute after being exposed. Failure means he's incapacitated by ecstasy for minutes equal to his margin of failure; failure by 5+ means a heart attack. 15 points.

Venomous Spit (TL10): Toxic Attack 1d+1 (Blood Agent, -40%; Cyclic, 1 hour, 4 cycles, Resistible, +30%; Jet, +0%; Onset, 1 minute, -10%; Reduced Range, $\times 1/2$, -10%; Resistible, HT-3, -15%; Symptoms, 2/3 HP, -3 DX and IQ, +60%) [7]. *Notes:* This jet of venom must hit the eyes or open mouth, or an open wound, to have any effect. Victims must make a HT-3 roll a minute after exposure and hourly for three hours. Each failure means 1d+1 injury. Those who lose 2/3 HP or more grow feverish: -3 DX and IQ until healed. 7 points.

IMMUNE SYSTEM MODIFICATIONS

The body responds to infection using a combination of blood proteins (the complement system) and white blood cells (leukocytes). The latter include killer T-cells, which destroy infected cells in the body; B-cells, which produce antibodies that tag pathogens; and phagocytic cells, which engulf and destroy tagged pathogens.

Improved disease resistance may result from gengineering the spleen and bone marrow to manufacture more discriminating and aggressive leukocytes. Ultimately, they may be engineered into bio-nanomachine factories, creating cells that can do everything from binding with and destroying toxins to cleaning out clogged arteries . . . but this capability (granting full Immunity to Disease, often in combination with Longevity) will usually require biomods or nanosymbiotes, and hence is covered in later chapters.

The exception are bioroids, whose radical design may more easily provide this capability.

Immune System Modifications

Trait	Cost	Page	TL
HT+1	10	B15	10
Resistant to Disease (+3)	3	B80	9
Resistant to Disease (+8)	5	B80	9
Resistant to Sickness (+3)	5	B80	10
Resistant to Sickness (+8)	7	B80	10*
Immunity to Disease	10	B80	10†

* Species modification.

† Species modification; bioroids only.



LIFESPAN AND SELF-REPAIR MODIFICATIONS

A person's overall health may be increased by a spectrum of genetic changes, such as eliminating genetic defects and hereditary tendencies toward degenerative illness.

The search for longevity is likely to be a major preoccupation of eugeneering. "Dying of old age" seems to result from numerous factors, each of which must be dealt with separately: arterial clogging, the buildup of free radicals, weakening bones, cancers, diseases, accumulated genetic copying errors, and even the depredations of brain-destroying prions. Any genemod that treats even a few of these factors may increase lifespan.

For example, one major cause of aging might be the damage caused by free radicals, the toxic byproducts of the body's metabolic activity. Genetic engineering aimed at countering this may increase the production of the body's natural antioxidants such as superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPX). This alone could be enough to increase a human lifespan by 10 to 50%.

Another aging theory suggests that some cells seem to accumulate copying errors after a certain number of replications (the Hayflick limit). If that's the case, a "revised Hayflick limit" genetic sequence, designed to produce more robust cells, might be needed in order to grant Extended Lifespan or, ultimately, Unaging.

Regeneration is trickier. Gene sequences copied from lizards (which can often regenerate tails or other extremities) may give humans a similar ability. True immortality may require radical alterations to cell structure, or a colony of symbiotic bio-nanomachines that patrol the body (see p. 166).

Immune system modifications (p. 49) and liver and kidney modifications (p. 46) are closely related to lifespan and self-repair modifications – someone who is immune to toxins and disease is likely to live longer, for example, so these advantages often combine with self-repair and longevity modifications to provide Resistant to Metabolic Hazards. This is especially likely for anyone who also has Unaging.

Slave races may have Self-Destruct modifications to the endocrine system or built in "suicide clocks" in cells that cause rapid degeneration when they reach their aging threshold, to ensure demand for new product via planned obsolescence. A shortened lifespan might be popular for non-sterile slave races, if it allows rapid maturation.

Lifespan and Self-Repair Modifications

<i>Trait</i>	<i>Cost</i>	<i>Page</i>	<i>TL</i>
Extended Lifespan 1-2	2/level	B53	10*
Extended Lifespan 3	6	B53	11*
Extended Lifespan 4	8	B53	12*
HT+1	10	B15	9
HT+2	20	B15	10
HT+3	30	B15	11*
HT+4	40	B15	12*
Longevity	2	B66	9
Radiation Tolerance 2	5	B79	9*
Radiation Tolerance 5	10	B79	10*
Radiation Tolerance 10	15	B79	10/11**
Radiation Tolerance 20	20	B79	11/12**
Rapid Healing	5	B79	9
Regeneration (Slow)	10	B80	10/11†*
Regeneration (Regular)	25	B80	11/12†*
Regrowth	40	B80	10*
Resistant to			
Metabolic Hazards (+3)	10	B80	10/12**
Resistant to			
Metabolic Hazards (+8)	15	B80	11/12**
Self-Destruct	-10	B153	9*
Short Lifespan	-10/level	B154	10*
Unaging	15	B95	11*
Very Rapid Healing	15	B79	10

* Species modification.

† The modifiers Heals Radiation (+40%) and Radiation Only (-60%) are also available; the "Only" version reduces the TL to TL10 for Slow or TL11 for Regular.

MORPHOLOGICAL CHANGES

No terrestrial vertebrate strays from the fundamental skeletal pattern of a cranium, four limbs, and a tail. In some animals, certain of these features are enhanced and others are atrophied – sometimes to invisibility. For example, dolphins replace their legs with flippers and a huge tail, snakes have no limbs, while humans have only a vestigial tail bone, but differentiate their limbs into arms and legs. Nevertheless, the basic pattern remains.

Genetic engineering can alter humans within these limits between TL9 and TL10, changing the function of limbs (or deleting them), adding a tail or altering body posture. However, deviating from vertebrate morphology to give humans more than four functional limbs, or other exotic changes, requires TL11+.

Modified Limbs

First time I saw the new foreman, I was a little skeptical: a work shack's cramped enough without two extra elbows. That lasted until I saw what Lyra could do in zero-G – we got the new solar panels up in record time. A few days later, Lyra invited me to her apartment, in the station hub where it's always weightless. That night, she showed me another reason to appreciate four hands.

– Copernicus Jones, *Posthumans I've Known*

Digitigrade Posture: A human's legs can be redesigned to resemble a quadruped's hind legs. Someone with this modification walks on his toes and the ball of his foot, or a hoof. This is usually a cosmetic modification, for custom-designed satyrs or other beast-people. While less practical for bipeds than for quadrupeds, careful modification of joints can make this posture just as comfortable. This is a feature. 0 points.

Prehensile Toes: These are toes that have been lengthened to serve as fingers and equipped with opposable thumbs. While a person with prehensile toes is using his feet as arms, he can't walk or run; he can still sit, float (in space or liquid) or fly, of course. This ability consists of Extra Arms (Two arms; Foot Manipulators, -30%; Short, -50%) [4]. 4 points.

Legs to Flippers: Altering hands to provide webbed fingers and feet into seal or frog-like flippers grants the No Legs (Semi-Aquatic) trait (p. B145) and can also justify buying a half-level of Enhanced Move (Water) (p. B52). A true "mer-human" human may undergo radical engineering so that the embryo never forms legs, instead developing a dolphin-like lower body and tail, and probably webbed fingers. This gives the No Legs (Aquatic) trait (p. B145) and can justify either Enhanced Move (Water) 1/2 or 1 (p. B52).

Legs to Arms: Only popular in microgravity, this is a radical change suitable for gene-engineered spacers. It replaces both legs with a second pair of arms. This is Extra Arms (Foot Manipulators, -30%) [14] plus Crippled Legs (Accessibility, Not in zero-G, -10%) [-9]. Basic Move must be reduced by half as described in the Crippled Legs disadvantage; this will give extra points back. 5 points.

Extra Arms: Adding one, two, or four extra functional arms (attached between the shoulders and the hips) is

much harder than simply transforming legs into arms. Not only are extensive skeletal and muscular modifications required, but blood flow will need to be increased to handle these busy additions, which means a larger heart and more efficient lungs. The nervous system must also be reworked and the brain modified in order to control them. These modifications give two or four Extra Arms (p. B53).

Modified Limbs

Trait	Cost	Page	TL
Digitigrade Posture	0	51	9*
Enhanced Move (Water)	20/level	B52	10†
Extra Arms (4 arms)	20	B53	11
Extra Arms (6 arms)	40	B53	12
Legs to Arms	5	51	9*
No Legs (Aquatic)	0/-5/-10	B145	9*
No Legs (Semi-Aquatic)	0	B145	9*
Prehensile Toes	4	51	9*
Striker	5-8	B88	11

* Species modification.

† Enhanced Move (Water) requires either No Legs (Aquatic) (maximum 1 level) or No Legs (Semi-Aquatic) (maximum 1/2 level).

Gengineered Tails

Humans have a vestigial tailbone; species modification engineering could use genes from other mammals to give humans a tail. This might be done for cosmetic reasons, or the tail may be usable as a weapon or a functional extra arm.

Ordinary Tail (TL9): A normal animal tail, with various styles available (cat, wolf, pony, rabbit, rat, etc). Clothing should be designed with tail flaps! 0 points.

Prehensile Tail (TL10): A tail capable of grasping, like a monkey's. This requires modifications to the brain and nervous system as well. It may be a popular biomod feature for spacers, where an additional grasping limb is always useful. This is an Extra Arm 1 (Extra-Flexible +50%; No Physical Attack -50%) [10]. 10 points.

Prehensile Trunk (TL11): An elephant-like trunk on the face. Otherwise identical to Prehensile Tail. 10 points.

Scorpion Tail (TL12): A segmented tail with a barbed, poisoned tip. Treat as a Large Piercing Striker (Cannot Parry, -40%; Clumsy, -3 to hit, -60%; Long, +100%) [6] plus Toxic Attack 2d (Cyclic, 1 hour; 5 cycles, resistible, +40%; Follow-Up, Striker, +0; Resistible, HT-3, -15%) [10]. 16 points.

Gengineered Tails

Trait	Cost	Page	TL
Ordinary Tail	0	51	9
Prehensile Tail	10	51	10
Prehensile Trunk	11	51	11
Scorpion Tail	16	51	12

All traits on the *Gengineered Tails* table are species modifications.

Winged Humans

We can synthesize the DNA for feathered or bat-like wings, but you can't just splice wings into a normal genotype and expect it to fly. Thanks to the square-cube law, a set big enough to lift even a child isn't practical. Sure, you can expand the wingspan, but then you end up with wings 50 or 60 feet across. Aside from the inconvenience, you'll run into problems of structural strength and finding the muscles needed to flap them.

As a result, winged bioroids typically have wingspans of about twice their height. While this can be a visually attractive feature, they have no chance on Earth of flying. I use that cliché deliberately: if you can find an extra-terrestrial environment with a lower gravity but normal or higher atmospheric pressure, then you're in luck. Planets like that are rare, but there are artificial habitats. Our Camazotz-series bioroids were grown for the domes on Luna City and Titan, and the big orbitals; in under one-sixth G, they really can fly. I imagine if we ever make a Dyson sphere, they'd be perfect.

– Dr. Sayyid Iqbal, Biotech Euphrates

A flying or gliding human will always have Flight with the Winged and Requires Low Gravity limitation (p. 215). To work out the maximum gravity, in multiples of Earth gravity (G) that the race can fly in, find the average ST of the racial template (e.g., ST 10 for humans, or ST 13 for an upgrade with racial ST+3) and the Basic Lift (p. B17) for that ST. Then determine the average racial body weight as follows: cube the racial ST, multiply by 0.15 lbs., and modify for any build disadvantages (p. B18) included in the template – thus; Skinny is a useful trait for flying humans! Then divide that BL by racial body weight to find maximum gravity in G. This is for flyers; multiply gravity by 1.5 if the race's Flight is limited to Controlled Gliding or by 2 if limited to Gliding.

Example: A variant race of flying humans has racial ST -1 for an average racial ST 9, which also gives a racial average BL 16 lbs. The body weight averages $(9 \text{ cubed}) \times 0.15 = 109 \text{ lbs.}$; however, the race is designed to be Skinny, so this is multiplied by 2/3, giving 73 lbs. $(16 / 73) = 0.22 \text{ G}$ (rounded to 0.2G); they could fly in a domed city on the Moon (0.17 G) but not Earth (1 G) or Mars (0.38 G). Therefore the race must take Flight (Requires Low Gravity, 0.2 G, -40%; Winged -25%) [14].

The limitation assumes a standard-pressure atmosphere (1 atm). In other environments, multiply the gravity the flyer can operate by the atmospheric pressure. Thus, someone who can only fly in up to 0.2 G gravity could fly in 0.3 G gravity if the atmosphere was 1.5 atm., but would be limited to 0.1 G gravity if it was 0.5 atm.

In addition to the difficulties of gravity, there are other problems: the wings themselves. There are two typical approaches to creating wings:

Arms to Wings

Both arms are modified to become a pair of wings. This gives Flight limited as described above, plus some additional limitations or disadvantages.

If the flyer's wings can still be used as arms when not flying, this is a further limitation on the cost of Flight; treat as Temporary Disadvantage (No Fine Manipulators, -30%).

If the wings are usable *only* to fly with, then they give the disadvantage No Fine Manipulators [-30], unless the race has feet or other body parts that can serve as arms.

For a sub-race that has two pairs of arms (see *Modified Limbs*, p. 51), one pair of which can function as arms when not flying, these Extra Arms should have the limitation Temporary Disadvantage (Removes Flight), its value depending on the Flight's cost (after the limitations suggested above).

Angelic Wings

This is the classical fantasy of wings sprouting from the shoulder blades. It's very hard to engineer, for the same reasons as adding an extra set of arms – in addition to the problems of arm-to-wing conversion, it requires redesigning the skeleton and adding new muscles and a modified nervous system. Take Flight with the Winged and Requires Low Gravity modifiers discussed above, and, optionally, either Controlled Gliding or Gliding if the wings are not capable of full powered flight.

Gengineered Wings

Trait	Cost	Page	TL
Arms to Wings	variable	52	10
Angelic Wings	variable	52	11

All traits on the *Gengineered Wings* table require species modification.

Devolutionary Modifications

Some morphological modifications take a backward step down the evolutionary path, causing humans to revert to more bestial forms. These are most likely intended for the creation of toys or slave races, although a very advanced civilization might enjoy creating blank-minded clone bodies this way, then “uploading” their minds into them as a new experience.

Chimerization or gene splicing could create humans with a sphinx-like morphology: a human head atop a quadruped animal body (e.g., a leopard or pony), with hands and feet replaced with walking paws or hooves – the Quadruped meta-trait (p. B263). This can also justify Enhanced Move 1/2 or 1 (Ground) (p. B52) and Hooves (p. B42).

A trickier morphological upgrade would alter chromosomes to blend a human upper body with a bestial lower body. This might require chimerization techniques (p. 38) in conjunction with genetic engineering, and is usually designed to allow faster ground speeds. A centauroid has Extra Legs (Four Legs) [5] (p. B54).

A human head on a snake-like body (such as the “lamia” that Tika Dawnstar created (p. 5) may be possible through radical manipulation of homobox genes. This gives the vermiform meta-trait. A snake-like lower body combined with a humanoid upper body is extremely difficult to engineer, but more practical than a naga-like Vermiform; take No Legs (Slithering). Either justifies taking Constriction Attack (p. B43) and Double-Jointed (p. B56) as well.

All of the above modifications are mutually incompatible.

Devolutionary Modifications

Trait	Cost	Page	TL
Constriction Attack	15	B43	11‡
Double-Jointed	15	B56	11‡
Enhanced Move	20/level	B52	10‡
Extra Legs (Four Legs)	5	B54	11†
No Legs (Slithering)	0	B145	10*
Quadruped	-35	B263	10*
Semi-Upright	-5	B153	9*
Vermiform	-35	B263	10†

* Species modification.

† Radical species modification.

‡ Enhanced Move (Ground) must be justified by taking Semi-Upright (maximum 1/2 level) or Extra Legs or Quadruped (maximum 1 level) as well. Double-Jointed and Constriction Attack may be taken if No Legs (Slithering) or Vermiform is also taken.

MUSCULO-SKELETAL MODIFICATIONS

The BS-2-F Felicia-series combat bioroid is a "special forces" upgrade of our popular AS-2-E, with a wide spectrum of state-of-the-art improvements. In this vidclip, we see a fire team of BS-2-Fs free-jumping from a helicopter 12 meters up and landing on their feet without injury, thanks to their XM-723 feline morphology.

– Biotech Euphrates promo video at WarEx '47 trade show

Meow.

– Felicia-series bioroid, upon landing on enemy soldier

The musculo-skeletal system consists of 206 bones (in adults) and 650 muscles connected to the each other by joints, tendons, and ligaments.

A modest racial bonus to Strength can be achieved with eugenic selection for height and weight, combined with genes that promote the growth of muscle tissue over fat. Species modification provides further improvement.

Bulk changes to body size such as Dwarfism (p. B19) and Gigantism (p. B20) are caused by manipulating growth hormone levels. Eugenic changes can lead to longer fingers, giving High Manual Dexterity (p. B59) or even Long Arms (p. B53) or Long Legs (p. B55). Longer limbs might also result from optimizing humans for low gravity.

Most bones are complex constructs containing hard outer bone tissue, an inner spongy layer (perforated to reduce weight) and, in some bones, a fatty marrow that manufactures new red and white cells for the blood. Species modification may improve the bones or strengthen the skeleton itself. If this is limited to the skeleton, the result will usually be a few extra HP and possibly a racial ST bonus by allowing stronger attachment points for muscles. It's also possible to reverse the process, creating a lighter build (and perhaps even engineering hollow, bird-like bones) to reduce weight – something that might be very important if designing flying humans (p. 52).

The body's muscles represent some 40-45% of its weight. Each is a bundle of thousands of hair-thin myofibers (grouped into bundles) Muscles pull or contract

in response to voluntary or involuntary nerve impulses; sets of muscles work together to move bones or tissue, or tense to hold body parts steady. The face is exceptionally complex, with more than 50 muscles required to produce facial expressions.

A more subtle way to boost strength is modify the structure of both voluntary and involuntary muscle tissue using more or stronger fibers. This increases Lifting ST (p. B65) and Striking ST (p. B88). The musculature can be optimized for crushing, giving Constriction Attack (p. B43). At high TLs, the additions for genes coding for proteins such as resilin (from grasshoppers) might be used to create extra-elastic muscle tissue permitting superhuman capabilities such as Super Jump (p. B89) or Extra-Flexible arms (p. B53).

Joints between bones are composed of cartilage, a softer material lubricated by a slippery fluid (synovial fluid), and attached by strips of tissue – ligaments and tendons – that link them to bones and muscles. Different types of joints exist in nature, such as the very flexible ball-and-socket joint of the hip or the less versatile hinge joint of the knee or elbow. Species modification could provide better-articulated, better-lubricated, or shock-absorbing joints, or stronger connective tissue, giving Brachiator (p. B41), Catfall (p. B41), Double-Jointed (p. B56), or Flexible (p. B56).

Musculo-Skeletal Modifications

Trait	Cost	Page	TL
Brachiator	5	B41	9*
Catfall	10	B41	9*
Constriction Attack	15	B43	10*
Double-Jointed	15	B56	9
Dwarfism (-1 SM)	-15	B19	9
Extra-Flexible	5/10	B53	11*
Flexibility	5	B56	9
Gigantism (+1 SM)	0	B20	9
High Manual Dexterity			
1-3	5/level	B59	9
HP -1 to -3	-2 per -1 HP	B16	9
HP +1 to +3	2 per +1 HP	B16	9*
HP +4 to +6	2 per +1 HP	B16	10*
HP +7 to +10	2 per +1 HP	B16	11*
Lifting ST +1 to +3	3 per +1 ST	B65	9*
Lifting ST +4 to +6	3 per +1 ST	B65	10*
Lifting ST +7 to +10	3 per +1 ST	B65	11*
Long Arms (+1 SM)	10/arm	B53	9*
Long Legs (+1 SM)	10	B55	9*
ST -1 to -5	-10 per -1 ST	B14	9
ST +1 to +2	10 per +1 ST	B14	9
ST +3 to +4	10 per +1 ST	B14	9*
ST +5 to +6	10 per +1 ST	B14	10*
ST +7 to +10	10 per +1 ST	B14	11*
Striking ST +1 to +3	5 per +1 ST	B88	9*
Striking ST +4 to +6	5 per +1 ST	B88	10*
Striking ST +7 to +10	5 per +1 ST	B88	11*
Super Jump 1	10	B89	11*
Super Jump 2	20	B89	12*

* This trait requires species modification.

The combination of bonuses to HP, Lifting ST, and Striking ST may not exceed the maximum allowed ST bonus by more than 50%.

Nonhuman Strength: When engineering a species that starts with an average racial ST other than 10, the maximum alteration is expressed as a percentage increase: +10% per +1 on the table. For example, at TL10, an elephant (ST 45) is not limited to +6 ST; it could be modified for an extra ST +27 (since 60% of ST 45 is 27). This rule also applies to HP and Lifting/Striking ST.



NERVOUS SYSTEM MODIFICATIONS

I knew I was going to join the ranks of the ethically-challenged when the Sultana offered me twenty grand to create a clone of her ex-husband with a engineered low pain threshold.

– Dr. Lucien Locke, Genehackers Inc.

The central nervous system consists of the brain and spinal cord. It sends out nerve impulses to control the body and analyzes sensory information. The peripheral nervous system branches out from the brain and the spinal cord, carrying nerve impulses from the central nervous system to glands and muscles. Finally, the autonomic nervous system regulates involuntary activity, such as the heartbeat and digestion.

Individual nerves are built from billions of specialized nerve cells (neurons) connected to other cells by tree-like branches (dendrites). The arrival of specialized chemicals called neurotransmitters trigger nerve impulses – tiny electrical pulses. These are transmitted across thin nerve fibers (axons). A fatty sheath, myelin, serves to insulate the fibers from electrical activity and improves their transmission rate. Different types of nerve fibers carry signals at different speeds; the fastest nerve signals travel at over 250 mph, permitting a reaction time of 0.2 seconds. Unlike most body cells, which last anywhere from hours to months, nerve cells can live for decades.

Genetic modifications to the nervous system exclusively aimed at improving brain function are covered under *Brain Modifications* (p. 42). This section focuses on modifications to the rest of the central nervous system and autonomic nervous system.

Dexterity and Basic Speed may be improved by redesigning nerve fibers and the spinal cord for faster nerve impulse transmission. Alterations to the nervous system could increase nerve impulse transmission rates and thus reaction speed, perhaps by finding superior protein combinations to build nerve fibers out of, or even through the addition of extra neural pathways; this might also provide Enhanced Time Sense (p. B52). Even so, the limitations of electrochemical reflexes make radical improvement difficult without using cybernetics. More extensive neural modification usually proceeds through quasi-organic enhancements – see the *Biomods* chapter (p. 176). Use of nanotechnology to lay down parallel or replacement electrical nerve pathways may be a more practical – if extremely high-tech – route to super-reflexes than engineering.

The nervous system also controls the sensation of pain. Pain sensitivity is vital. People born without it die early – by accident, or from infection resulting from internal joint and bone damage. (They are unable to tell when a particular posture or sleeping position is over-stressing joints or bones, and so do not receive signals to shift weight or otherwise take corrective measures while sleeping or awake). However, while total insensitivity to pain – the Numb disadvantage (p. B146) – is usually not a desirable characteristic, the ability to selectively block pain is quite useful.

Through genetic modification of the genes responsible for neurotransmitter “signal molecules” or via transplants of engineered nerve tissue to the notochord (the embryonic spine), it may be possible to activate neural gating circuits in the spinal cord to deliberately mitigate incoming pain signals before they are perceived, without destroying the ability to sense pain as a whole. Of course, the opposite could be done to enhance the ability to feel pain . . .

Nervous System Modifications

Trait	Cost	Page	TL
Basic Speed up to +1.00	5 per +0.25	B17	10
Basic Speed up to +2.00	5 per +0.25	B17	11*
Basic Speed up to +3.00	5 per +0.25	B17	12*
Combat Reflexes	15	B43	9
DX+1	20	B15	9
DX+2	40	B15	10*
DX+3	60	B15	11*
DX+4	80	B15	12*
Enhanced Time Sense	45	B52	10†
Extra Attack 1	25	B53	10*
Extra Attack 2	50	B53	11*
Extra Attack 3-4	75/100	B53	12†
High Pain Threshold	10	B59	9
Low Pain Threshold	-10	B142	9
Numb	-20	B146	9*

* These traits always require species modification.

† This trait is a radical species modification.

RESPIRATORY MODIFICATIONS

No need to wait centuries for atmospheric terraforming to be completed! Colonial Genetics has pioneered this new, high-capacity lung system designed to have your children breathing without a respirator and playing outdoors! Mars Development Corporation will offer a 20% rebate on all lung engineering as part of the Ares Pioneer program.

– Colonial Genetics press release

Ship malcons and convicts to Mars, then modify the poor bastards' kids so they can't come back to Earth.

– Professor C. Eric Gideon, *soc.culture.mars*

Unless they buy the nano to turn them back . . .

– Deimos Dog, *soc.culture.mars*

Oxygen is needed to catalyze the body's chemical processes, which break apart the glucose (blood sugar) obtained from food and release its energy to power the body. The respiratory system – the nose and throat, trachea (wind pipe), bronchi (airways in the chest), and the lungs themselves – take in air and pass oxygen into the blood.

The lining of the lungs may produce detoxifying agents to counter or filter respiratory agents, granting the Filter Lungs advantage. Larger low-pressure lungs (p. 212) could be designed that are specialized for breathing in a thin atmosphere, such as a recently-terraformed Mars, or high-pressure lungs (p. 212) could be constructed that are adapted for denser atmospheres.

Another goal of respiratory modification is improving physical performance. Greater elasticity or stronger muscles can improve breath-holding capacity or gas exchange, increasing endurance by adding Fatigue Points.

The larynx (voice box) contains two ridges called vocal cords; when people speak, the voice box's muscles contract the vocal cords. Air passing through the gap between them

Paranormal Abilities

Exotic advantages such as Growth or Telekinesis or supernatural advantages such as Magery may be engineered if they have a mapped genetic cause. This is superscience (TL[^]): the actual TL required is up to the GM, depending on when the genetic basis for the powers in question was discovered. It should require at least TL9 if the paranormal ability is governed by only a few genes, or TL10+ for a large complex of genes.

makes them vibrate to produce sound. A different kind of performance modification would be to alter and improve the larynx to give someone the Voice advantage, or even a multi-functional larynx capable of Mimicry (perhaps derived from mynah-bird genes). Less complicated modifications could remove the voice box (Mute), or limit it to making animal sounds (Cannot Speak), which might be desirable for some servitor races.

Respiratory Modifications

Trait	Cost	Page	TL
Breath-Holding 1-2	2/level	B41	9
Breath-Holding 3-5	2/level	B41	10*
Cannot Speak	-15	B125	9
Filter Lungs	5	B55	9*
FP +1 to +3	3 per +1 FP	B16	9
FP +4 to +6	3 per +1 FP	B16	10*
FP +7 to +9	3 per +1 FP	B16	11*
FP +10 to +12	3 per +1 FP	B16	12*
High-Pressure Lungs	0	212	9*
Low-Pressure Lungs	0	212	9*
Mimicry	10	B68	9*
Mute	-25	B125	9*
Penetrating Voice	1	B101	9*
Voice	10	B97	9

* Requires species modification.

Respiratory Alternatives

Ever looked at an embryo? It has gills. Gengineering to retain these vestigial traits should be relatively simple, right?

– Aquagrll, *sci.bio.genemod.human*

Wrong. It's true that human embryos have gill-like structures – but these serve a different function than in fish or amphibians, eventually forming the chin, jaw, cheek and outer ear. Babies get their oxygen from the mother, through the placenta. As a result, gengineering a merman is a lot more difficult than Aquagrll implies, especially if we want to breathe both air and water. So far, most dual-environment humans are designed like marine mammals. Navy SEAL bioroids don't use gills. They store oxygen in the myoglobin of the muscles, just like whales do. When drawing oxygen from these sources, their lungs aren't necessary, so they can undergo complete alveolar collapse as water pressure increases, letting them ignore the bends and survive very deep dives.

– DocIqbal, *sci.bio.genemod.human*

Attempts to create humans capable of functioning underwater for long periods of time generally involve three different techniques: oxygen storage and (at higher TLs) actual gills. Each may be accompanied by modifications to the lung structures and cardio-respiratory system to allow survival over a greater-than-normal range of pressure.

All of these are variations of the Doesn't Breathe advantage (p. B49). While not needing to breathe *at all* requires radical nanotechnology (see *Solarskin*, p. 189), limited versions are possible with genetic engineering.

Gills: These fine membranes extract oxygen from water. The problem for water-breathing humans is that ordinary sea water has only 1/30 the oxygen content of air. A warm-blooded human being's metabolism requires far more oxygen than a cold-blooded, small-brained fish, so gills capable of supplying enough oxygen for a human to survive would be very large, located on the ribs rather than on the neck. It's possible that the disadvantage Cold-Blooded (p. B127) would be a necessary but unintended side effect. Fish gills also lack stiffness: without the buoyancy of water, they'll collapse, leading to rapid suffocation. Fishlike gills that totally replace lungs and only allow the recipient to breathe underwater provide Doesn't Breathe (Gills) [0] (p. B49). However, gills may be augmented by modified lung structures, such as the suprabranchial arborescent organ possessed by walking catfish. These provide support for gills when out of the water. Someone with these modifications can survive in both land and water. This is the ability Doesn't Breathe (Gills, -50%) [10].

Oxygen Storage: This provides a reserve of oxygen stored in the body. It's useful in airless or low-pressure environments, including arctic waters where there is too little oxygen for gills to function properly. Oxygen storage uses genetic modifications inspired by the physiology of marine mammals such as seals and whales. Someone with this upgrade has greatly elevated levels of the oxygen-storage protein myoglobin in their liver and skeletal muscles, storing roughly six to eight times as much oxygen as a land mammal. This is combined with a "diving

reflex" (diving bradycardia) that results in a dramatic decrease in heart rate in low-oxygen conditions in conjunction with a redistribution of blood from viscera and skeletal muscles to the vital organs and brain. When using this capability, air is expelled from the lungs (which collapse under pressure, often aided by a flexible rib cage, negating any risk of the bends), and all oxygen is derived from the hemoglobin in the blood and the myoglobin in the muscles. As a result, the user can effectively "hold his breath" for 100 times as long as normal. Replenishing this reserve requires 10 seconds breathing air for each minute operating on stored oxygen. This ability is Doesn't Breathe (Oxygen Storage $\times 100$, -30%) [14]. Higher levels with oxygen storage $\times 200$ (-20%) and $\times 300$ (-10%) are also possible.

Oxygen Absorption: The ability to absorb oxygen directly from the environment (or to have a plant-like metabolism) requires radical genetic engineering technology or great size (such as extensive plant-like root networks or leafy membranes) to support human levels of metabolic activity. For this reason it's most likely as a radical biomod transformation rather than genetic engineering. It might also be a backup respiratory system intended for periods of reduced activity, in conjunction with Doesn't Eat or Drink (p. B50) and a Temporary Disadvantage like Decreased Time Rate (p. B129) or No Legs (Sessile) (p. B145).

Respiratory Alternatives

Trait	Cost	Page	TL
Doesn't Breathe	variable	B49	variable
– Gills	0	B49	11†
– Gills	10	B49	12†
– Oxygen Absorption	15	B49	12†
– Oxygen Storage, $\times 100$	14	B49	9*
– Oxygen Storage, $\times 200$	16	B49	10*
– Oxygen Storage, $\times 300$	18	B49	11*
Pressure Support 1	5	B77	9*
Pressure Support 2	10	B77	11*

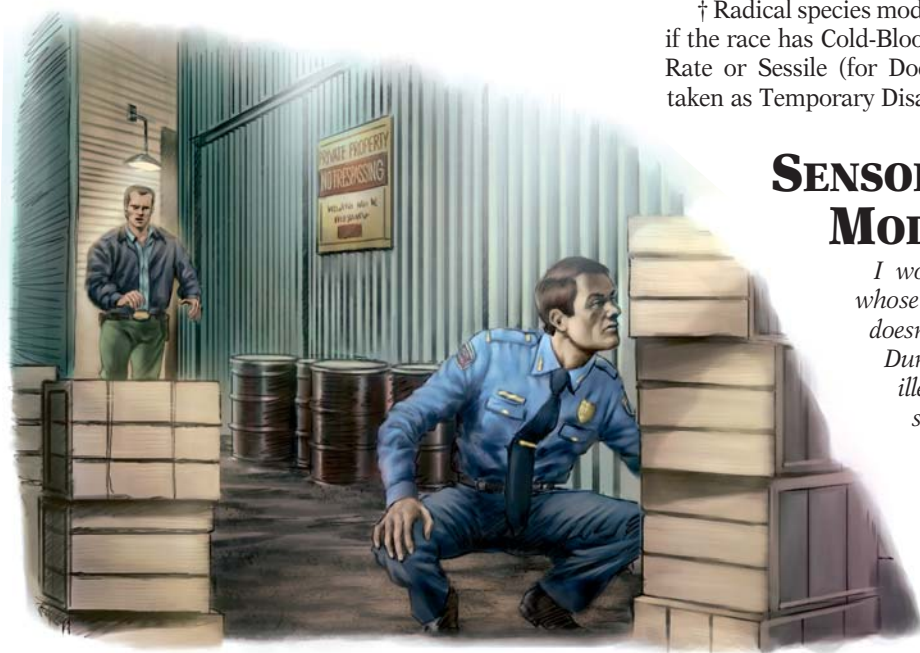
* Species modification.

† Radical species modification. Reduce required TL by 1 if the race has Cold-Blooded (for Gills) or Decreased Time Rate or Sessile (for Doesn't Breathe); the latter may be taken as Temporary Disadvantages.

SENSORY MODIFICATIONS

I work with a Border Patrol bioroid whose sense of smell is cranked up. He doesn't need a chemscanner or dog – Duncan can sniff out drugs, explosives, illegals . . . hey, he can even smell a smuggler's fear. Trouble is, Duncan gets these splitting headaches all the time. Just goes to show, if you want a bloodhound's sense of smell, you need a bloodhound's brain.

– Detective Cody Chase,
Nevada DPS



Engineering the genes governing the development of the rod and cone cells in the eyes, hair cells and membranes in the ears, and the chemical receptor cells in the nose and tongue may enhance basic human senses beyond “perfect” human levels. However, while humans can train themselves over years to develop high “Acute Senses,” inborn bonuses over +5 always require transgenic techniques; e.g., ear muscles that swivel independently to more precisely localize a sound. More exotic animal-inspired genemods are also possible:

Absolute Direction: This can be artificially duplicated by engineering human brain cells to contain the same kind of magnetite particles that certain migratory bird species possess, forming a biological compass. More extreme versions of this could also give Detect (Magnetic Fields).

Absolute Timing: This may be the result of adjustments to the glands that govern the body’s circadian clock.

Discriminatory Smell: This ability, similar to that of a canine or other sensitive-nosed species, could be achieved through enhancement of the chemical receptors in the nose and via modifications to the olfactory lobe.

Detect (Electric Fields): This may be granted by electrically-sensitive organs modeled on those of electric rays or other fish.

Infravision: This may be modeled on viper heat organs – subdermal, heat-sensitive pits found next to the eyes on rattlesnakes and similar species. Unless further genetic modification is done to enhance it, this has lower resolution than infrared goggles.

Night Vision: This could result from a reflective layer of cells that amplify the light reaching the eyes. These “cat’s eyes” could be derived from feline genes.

Perfect Balance: This could follow from an inner-ear balance-organ design patterned on those of cats or squirrels.

Ultrahearing: This could be achieved using ears based on those of canines, bats, or other mammals with high-frequency hearing. Subsonic Hearing is slightly trickier, but might be based on an enlarged middle-ear cavity, like that of the kangaroo mouse.

Parabolic Hearing: This may be achieved using a somewhat asymmetric ear design, similar to that of an owl.

Sonar: This is the only active Scanning Sense that can be bioengineered into humans. Bat voice boxes are the best models for natural air sonar, while underwater sonar may be based on that of marine mammals – probably pinnipeds, such as seals, rather than dolphins. Gengineering will have to both alter the voice box and modify (and probably enlarge) the ears to ultrasonic receivers. The complex gengineering required to allow a human brain to directly process sonar images requires a high TL to manage, especially for long-range sonar.

Vibration Sense: This can be achieved with modifications such as catlike whiskers, which are potent sensory organs for night hunting, capable of detecting air currents flowing around objects. Since this is a completely passive sense that cannot be jammed by most countermeasures, it might be useful for gengineered scouts or warriors. This is best represented as Vibration Sense (Air).

While these upgrades to human senses are exciting and theoretically possible, there are some problems! Evolution has adapted the human brain toward cognition and away

from sensory processing, when compared to the brains of other animals. For example, the olfactory lobe takes up much more of the brain in a dog than in a human. Re-engineering a human with a bloodhound’s sense of smell or a dolphin’s sonar might turn him into a sensory idiot savant unless a very sophisticated redesign of the human brain is performed. Even so, some disadvantageous side effects are likely.

Any sensory species modifications (except those producing Acute Vision, Night Vision, or Perfect Balance) are likely to produce disorientation or sensory overload. This may result in one or more of these disadvantages: Chronic Pain, Confused, Light Sleeper. The brain might be able to develop structures to mitigate such problems, although this may also cause a slight drop in IQ or loss of other senses. For instance, an infrared-adapted human brain may be blind to normal vision (adjust point costs appropriately).

Sensory Modifications

Trait	Cost	Page	TL
Absolute Direction	5	B34	9
Absolute Timing	2	B35	9
Acute Senses (any) 1-3	2/level	B35	9
Acute Senses (any) 4-5	2/level	B35	9*
Detect (Electric Fields)	10†	B48	10*
Detect (Magnetic Fields)	10‡	B48	10*
Discriminatory Hearing	15	B49	10*
Discriminatory Smell	15	B49	10*
– Emotion Sense	+50%	B49	10*
Discriminatory Taste	10	B49	10*
Enhanced Tracking 1	5	B53	10*
Infravision	0/10‡	B60	10*
Night Vision 1-2	1/level	B71	9
Night Vision 3-5	3-5	B71	9*
Parabolic Hearing 1-3	4/level	B72	10*
Perfect Balance	15	B74	9*
Peripheral Vision	15	B74	10
Sensitive Touch	10	B83	10
Sonar	20§	B81	10*
Subsonic Hearing	0/5*	B89	10*
Telescopic Vision 1-2	5/level	B92	10*
Ultrahearing	0/5	B94	9*
Ultravision	0/10	B94	11*
Vibration Sense	10	B96	10*

* Species modification.

† Before TL11 this must be taken as Detect (Electric Fields; Vague, -50%) [5] or Detect (Magnetic Fields; Vague, -50%) [5].

‡ Before TL11 this must be either Infravision (Temporary Disadvantage: Nearsighted, -25%) [8] or as the 0-point version (Infravision *instead* of normal vision). At TL11+, Infravision that can switch freely between IR and normal vision is available.

§ Before TL11, Sonar must be limited with Reduced Range, $\times 1/10$, -50% or Reduced Range, $\times 1/5$, -20%. No special enhancements (p. B82) are available at any TL.

Some features, such as larger-than-usual or oddly-shaped ears, cat-like whiskers, or eyes that grant Night Vision but gleam in dim light, may qualify as Unnatural Features 1+ (p. B22).

Sex Ratios

Most animals we are familiar with produce equal numbers of males and females. A common method in fiction of emphasizing that a species is alien is to alter this ratio. Some thought about *why* real creatures have an equal sex ratio can lead to interesting conclusions about fantasy or science fiction species that don't.

It may seem evolutionarily wasteful to produce as many males as females. After all, one male can fertilize dozens of females – as is the case in harem-keeping species such as sea lions – so why use valuable food resources to produce superfluous males? The answer comes from the interplay of biology and mathematics. Let's assume:

1. A species has two sexes.
2. An individual inherits an equal number of genes from each parent.
3. Those genes form the basis of evolution.

The evolutionary success of a group of genes is measured by one thing only: how many offspring those genes produce. If a population consists of more females than males, then – on average – each female produces fewer children than each male (since the number of children divided by the number of females is less than the same number of children divided by the number of males). So for genes to produce more offspring, it is better for them to be in a male body. Over time, evolutionary pressure will produce more males. The opposite applies if there are more males; either way evolution tends to even out the sex ratio.

For natural species in a hard science setting, assumption 3 is a given. Changing assumption 1 can lead to interesting aliens, but a similar argument proves that a species with any number of sexes must produce each sex in equal numbers.

Some familiar species on Earth *don't* have equal sex ratios: ants and bees. They manage this by breaking assumption 2. Male ants and bees do not have fathers – they get all their genes from their mother. The breeding members of ant and bee colonies are produced in a 3-1 female-male ratio. This also raises the question of sterile worker castes – most ants and bees are actually sterile. Since such drones don't reproduce, they don't enter the above arguments, and can be produced in any numbers.

So naturally evolved species usually either have equal sex ratios, an unusual genetic inheritance mechanism, or sterile castes. But if they were engineered recently (or exist in a fantasy or super-science setting), then all bets are off.



SEXUAL AND REPRODUCTIVE MODIFICATIONS

Jace, it's a hot scoop – the Wimmin's Pantropic Collective are having another try at colonizing Sappho IV, and you should see what they're building into their daughters' germ plasm. Sal got an insect bug into their birthlab. Book both Morgana Selene and one of those Neo-Christian cybervangelists on tonight's show. We'll ambush 'em with the vid and watch the fur fly.

– Noriko Hayakawa, host of *Cyberia Beat*

Adjusting human fertility and sexual potency or pleasure has been an obsession of humanity since prehistoric times. The tools of magic, folk remedies, surgery, and drugs may soon be joined by genetic engineering.

Genetic modification of the testes and ovaries may alter the way children are conceived and the development of sexual characteristics. Some possible modifications are described below. Most are 0-point features, but they will often have a dramatic effect on a person's life or the way that society functions.

Altered Sex Ratio: This modifies the *average* ratio of male to female births. This can be a specific ratio (e.g., five women to every man) or even eliminate births of either sex. These changes may be made to correct a perceived imbalance, or for deliberate attempts at social engineering. However, although an altered sex ratio can be programmed by engineer fiat, it will naturally drift back to equal ratios over evolutionary time, assuming the species is allowed to evolve (see box). *0 points.*

Cross-Species Surrogacy: This allows a female to carry implanted embryos of certain other species to term. This might only work for closely related species, or it might be more general. *1 point.*

Easy Childbirth: Modifications to the structure of the pelvis to help mothers deal with the delivery of (large-headed) human babies have been an ongoing part of human evolution; further ergonomic improvements may be possible via genetic engineering. The ability to shut down many (but not all) pain receptors during delivery may also be welcomed by many women. This advantage gives a +2 to HT rolls to determine the success of any pregnancy. *0 points.*

External Development: Early development in the fetus focuses on the respiratory and gastrointestinal systems. It can be born radically premature; this reduces gestation time (see *Shorter Gestation*, facing page) to as little as halfnormal. After birth it requires immediate transfer of the fetus to an incubator unit or a marsupial pouch (see *Payload* under *Other Transgenic Traits*, p. 45) to complete development. *0 points.*

Light Menses: Alterations to female ovulation and hormone function could ensure post-pubescent women experience greatly reduced monthly discomfort due to PMS and menstruation, as well as the later problems of menopause. This may result in either a very mild period or, if taken in conjunction with Reproductive Control (p. 59), no menstruation at all. *0 points.*

Estrus: This is another approach to avoiding menstruation, altering humans to become fertile for perhaps one month of the year (much like cats or dogs). This is normally worth 0 points, since the advantages and disadvantages cancel out. Males can also have a version of this. Variant humans (male or female) with this feature often have Lecherousness (12; Accessibility, Only in mating season, -80%) [-3] but it is not mandatory.

*I'll never understand what
possessed my mother to put her
faith in God's hands, rather than
her local geneticist.*

– Vincent, *Gattaca*

Reproductive Control: This allows females to control their fertility. This will usually require a day or so to adjust hormonal levels. Combined with the Light Menses modification, this means a woman has a period only if she voluntarily chooses fertility in a particular month. Alternatively, and for the same point cost, a female could be able to absorb an early fetus back into the womb, like a rabbit, with pregnancy being canceled on a successful Will roll. 1 point.

Sexual Orientation: Some credible theories suggest a tendency toward heterosexuality, bisexuality, or homosexuality may be partially or even largely predetermined by genetic inheritance. If so, engineers should be able to select sexual preference before birth, a procedure with potentially explosive social consequences. This could also include an orientation toward partners of another species. 0 points.

Shorter Gestation: Shorter conception-to-birth periods than the human average of 266 days may be possible by modifying human growth factors or altering the chemical environment in the womb. This is convenient for the mother, as well as allowing faster population growth – but careful engineering will be needed to ensure that the fetus develops normally. A reduction to two-thirds the normal gestation period is possible; for alternatives, see *Oviparous* or *External Development*. 0 points.

Extended Fertility: As lifespans increase, genetic engineering may be used to extend the period in which both sexes can produce children. With this feature, fertility is retained until latter in life. 0 points.

Increased Fecundity: This modification means that a woman is more likely to experience multiple births; releasing two eggs every ovulation, for example, could result in twins in as many as one-quarter of all pregnancies. It is a good idea to combine this 0-point feature with the Easy Childbirth feature. 0 points.

Hermaphroditism: Individuals with both male and female primary and/or secondary sexual characteristics

occur naturally in some humans, but usually the mutation is vestigial, and not noticed until puberty. Genetic engineering would allow the reliable creation of functional hermaphrodites. A “utopian” society might try to give everyone this trait to ensure sexual equality (no sexual discrimination if everyone is both sexes). 0 points.

Hermaphromorphs: At TL10+, genetic enhancement might create functional “hermaphromorphs” able to switch sexes or be both at once, which a tolerant culture might find interesting. These often have the limitation “cannot change if pregnant” (-20%).

Oviparous: The fetus is born contained in a soft-shelled egg. This requires a larger birth weight, as food for the infant needs to be contained in the egg with it, but requires a less developed fetus. The gestation time may be cut down to as little as 1/3 normal (see *Shorter Gestation*, above). The egg must be kept warm until hatching (which takes the remainder of the normal gestation period), through constant care or in an incubator.

Parthenogenesis: In females, this may be possible through very high-tech engineering of the human ovum and reproductive organs. A woman's egg cells would carry a complete chromosome map, and could be diverted to her womb, then brought to term. Pregnancy would be triggered by voluntary hormonal changes learned through biofeedback, or by taking a pill (\$1-10). The fetus would effectively be her clone. Parthenogenesis is a superior strategy for rapidly increasing a race's numbers, and might be deemed viable for an all-female sub-race. It means the race won't change, but if they have the capability to engineer themselves, then natural evolution is probably no longer something to worry about. Parthenogenesis is a 0-point feature if the race only reproduces through parthenogenesis, or a Perk if it can also use sexual reproduction. 0/1 points.

Exotic Genitalia: This may include “improved” shape or texture, extra organs in the same or new places, or sensitive erectile tissue added to other areas, such as lips or fingertips. Such modifications may be limited to specialized pleasure models in some societies; in others, they may be standard equipment for everyone. If the modification is designed to simply enhance or modify the user's own experience, this is a 0-point feature. If it enhances his ability as a lover, this will grant a racial bonus to Erotic Art skill.

Modified Genetic Inheritance: This alters the operation of the sex chromosomes so males and females inherit different fractions of their genes from each parent. This could result in schemes such as those used by ants and bees (see *Sex Ratios*, p. 58), or might be used to produce genetically viable individuals with normally rare sex chromosome mutations. This could be done to produce a parahuman species with an altered sex ratio that will survive long-term evolution, but has little effect in the short term. 0 points.

Variant Sexual Schemes: This could give humanity additional sexes, including sterile “drones.” Schemes involving three or more reproductive sexes will require other biological changes (and social adjustments!), but a drone sex would be relatively easy and potentially useful (and would be Neutered or Sexless, p. B165). 0 or -1 point.



Sexual and Reproductive Modifications

Trait	Cost	Page	TL
Altered Sex Ratio	0	59	9*
Cross-Species Surrogacy	1	58	10*
Easy Childbirth	0	58	10*
Estrus	0	59	9*
Exotic Genitalia	0†	59	9*
Extended Fertility	0	59	9
External Development	0	59	10*
Hermaphromorph	5	B59	10*
Increased Fecundity	0	59	9
Light Menses	0	58	9
Modified Genetic Inheritance	0	59	10*
Neutered or Sexless	-1	B165	10
Oviparous	0	59	10*
Parthenogenesis	0 or 1	59	10*
Reproductive Control	1	59	9*
Sexual Orientation	0	59	9
Sterile	0	B165	9
Shorter Gestation	1	59	10*
Variant Sexual Schemes	0	59	10*

* Species modification.

† May justify a racial skill modifier giving +1 to +3 to Erotic Art (p. B192) at a cost of 2 points per +1 skill.

TRANSFORMATIONS

Today, Kosmozavot Tenno Tanjo's engineers announced success on their Void Dancer project. They've added a vacuum-adaptive skin, special muscle sphincters that seal guts and lungs, and nictitating membranes for the eyes. The Void Dancer parahumans are supposed to survive in space without protective gear for an hour or more. According to KTT, the productivity and cost savings from being able to avoid suit-up/suit-down time, safety checks and suit training alone will pay for the program.

— Chance Mackintosh, *Posthuman Consumer Review*

Extreme modifications may be possible at TL12, perhaps using synthetic DNA sequences and techniques

such as neogenesis (p. 27). Human bodies might be adapted to live in space, transformed into plant-human hybrids, or turned into living buildings. The possible transformations (and the modifiers applicable to them) at TL12 are nearly infinite; the list below simply gives some typical traits that become feasible.

Transformations

Trait	Cost	Page	TL
Doesn't Eat or Drink	10	B50	12
DR 5-15	5 per +1 DR	B46	12
– Flexible	-20%	B47	12
– Partial	Variable	B47	12
– Tough Skin	-40%	B47	12
Elastic Skin	20	B51	12
Extra Arms (5+ arms)	10/Arm	B53	12
– any modifiers	variable	B53	12
Extra Head	15/head	B54	12
Extra Legs (5+ legs)	Variable	B54	12
Extra Mouth	5/mouth	B55	11
Hyperspectral Vision	25	B60	12
Injury Tolerance			
– No Brain	5	B61	12
– No Head	7	B61	12
– Unliving	20	B61	12
– No Neck	5	B61	11
Morph	Variable	B84	12*
No Fine Manipulators	-30 or -50	B145	10
No Legs (Sessile)	-50	B145	11
Sealed	15	B82	12
Temperature Tolerance 11+	1/level	B93	12
Universal Digestion	5	B95	12
Unkillable 1	50	B95	12
Vacuum Support	5	B96	12†

* Must have Mass Conservation (-50%); often has Retains Shape (-20%).

† Vacuum Support should normally be taken in conjunction with Sealed (15 points, p. B82).

All of these modifications are radical species modifications.

Radical metabolic changes of this sort are perhaps more realistically achievable through exotic nanotech than with “genetic engineering,” although it is possible that they might “breed true” (at least in the sense of passing on self-replicating nanomachines that would transform any offspring in the same fashion). For examples of this technology, see *Sample Metamorphosis Transformations* (p. 188) in Chapter 7.

UNINTENDED DISADVANTAGES

Most engineered sub-races should have some disadvantages. This has the dual benefit of reducing their racial point cost and making them more realistic. These usually result from a specific desirable trait being linked to an unwanted gene sequence (see *Linked Traits*, p. 62), with the disadvantage being overlooked, or tolerated in this particular design, because it was too much trouble to engineer it away.

Racial attribute or secondary characteristic penalties (especially to HT), below-average Appearance levels, the Sterile feature, and the physical disadvantages Restricted Diet, Susceptible to Disease, and Unusual Biochemistry may be the most common defects produced when designers get too ambitious. A disastrously flawed experiment may require Maintenance (constant care from a specialist) to stay alive!

Unusual Biochemistry is almost certain to occur when attempting complex transgenic gene-splices, chimeras and cell fusions. Other modifications may be side effects of trying for a specific advantage or mixing human and nonhuman genes. For instance, reduced ST or HP (representing light, hollow bones like a bird's) might be an unplanned side effect of designing a winged human.

Genes borrowed from other species may also alter appearance, either as a consequence of borrowing a particular design element (e.g., catlike eyes for Night Vision) or a conscious esthetic choice. For example, in addition to borrowing a dog's sensitive nose, designers may add other canine features, such as a canine muzzle, teeth, and even fur. Realistically, this sort of modification won't be an accidental side-effect – designers would have to be trying for a deliberate “anthropomorphic animal” look, perhaps to deliberately differentiate their creations from humans. Such changes qualify as Unnatural Features, with careful engineering producing an appealing blend of traits rather than a grotesque hybrid.

Sensory upgrades will often result in reductions in other areas, either as a side effect of transgenic engineering or because the brain can often only process so much information at a time. Thus, a variant canine-human transgenic engineered for Discriminatory Smell may suffer Colorblindness or an IQ penalty.

Increasing intelligence or adding neurological modifications will often have unintended and subtle psychological consequences, reflected by various disadvantages. The

result may even be an “idiot savant” with a prodigious mental ability in one area, such as considerable intuition or a photographic memory, but reduced overall intelligence or creativity. Transgenics with extensive animal DNA might occasionally revert to more primitive behavior patterns (Stress Atavism), or have other traits from animal heritage, such as Cannot Speak, Bestial, Dull, Extra Sleep, or Hidebound.

The grosser physical disadvantages like Blindness, Hemophilia, or One Arm are unlikely in a variant race, as defects this obvious will usually be detected in the womb and either corrected via genetic surgery or terminated.

Social Disease can simulate a race that has unusually energetic engineered bacteria (or symbiotic nanomachines), often as a result of an enhanced immune system or regeneration; intimate interaction with the race may cause a rash, or other problems! This should be taken with the Accessibility limitation Other Variant Races Only (-80%).

Bioroid Modifications

Bioroids – variant races created using biogenesis (p. 26) – often incorporate modifications that would be difficult to achieve with normal parahumans.

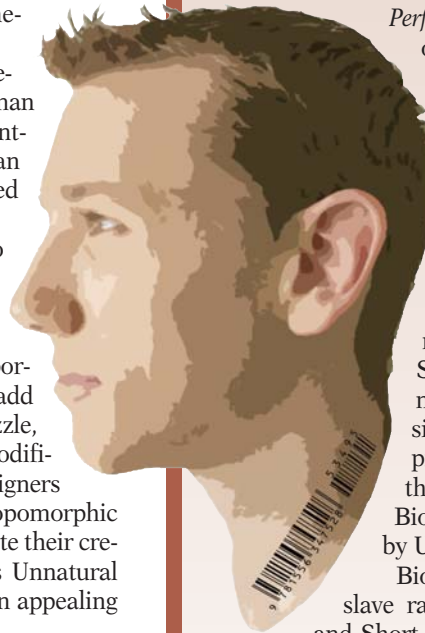
All bioroids have the meta-trait Bioroid [-5] (p. 214). In addition, the following traits are common in some designs:

Perflubron Blood (TL10): The bioroid has an artificial blood substitute – see *Perflubron Blood*, p. 131 – in place of natural blood. This gives +1 FP [3] and Immunity to Bends [5] (p. B81). The bioroid's blood will also have a milky white color.

Self-Replicating (TL11): The bioroid is capable of sexual reproduction (or other reproduction, with appropriate traits). It has the meta-trait Bioroid (Not Sterile) [-5]. As a default, it can mate with a bioroid of opposite sex and the same model, producing offspring who have the same template save that Bioroid (Not Sterile) is replaced by Unusual Biochemistry [-5].

Bioroids created as products or slave races often have Self-Destruct and Short Lifespan, but there is no reason they have to – they could just as easily be built for longevity.

The rules in *Life's Price Tag* (p. 65) apply to bioroids, except that the cost is for a mature bioroid, and the cost is always at least \$50,000 (i.e., being a bioroid itself will count as a species modification).



Common Unintended Traits

Trait	Cost	Page
Absent-Mindedness	-15	B122
Appearance	Variable	B21
Bad Back	-15 or -25	B123
Bad Grip	-5/level	B123
Bad Sight	-25	B123
Bad Smell	-10	B124
Bad Temper	-10*	B124
Berserk	-10*	B124
Bestial	-10 or -15	B124
Bowlegged	-1	B165
Cannot Learn	-30	B125
Cannot Speak	-15	B125
Chronic Pain	Variable	B126
Confused	-10*	B129
Distinctive Features	-1	B165
Distractible	-1	B164
Disturbing Voice	-10	B132
Dreamer	-1	B164
DX -1 to -5	-20 per -1	B15
Epilepsy	-30	B136
Extra Sleep	-2/level	B136
Fat	-3	B19
Hard of Hearing	-10	B138
HP	-2/-1HP	B16
Hunchback	-10	B139
HT -1 to -5	-10 per -1	B15
Indecisive	-10*	B140
IQ -1 to -5	-20 to -100	B15
Imaginative	-1	B164
Jealousy	-10	B140
Light Sleeper	-5	B142
Low Pain Threshold	-10	B142
Maintenance	Variable	B143
Mute	-25	B125
Nervous Stomach	-1	B165
Overweight	-1	B19
Secret Disadvantage (Mental Instability)	variable	43
Selfish	-5*	B153
Short Attention Span	-10*	B153
Short Lifespan	-10/level	B154
Skinny	-5	B18
Sleepy	Variable	B154
Slow Healing	-5/level	B155
Social Disease	-5	B155
Sterile	0	B165
Stress Atavism	Variable*	B156
Stuttering	-10	B157
ST -1 to -5	-10 per -1	B14
Susceptible to Disease	-4/-1 HT	B158
Unusual Biochemistry	-5	B160
Very Fat	-5	B19

* You must select a self-control number; the cost is given for a self-control number of 12.

The above list is not exclusive: just about any other mundane physical or mental disadvantage is plausible,

with the exception of self-imposed advantages such as Vow, and many exotic disadvantages may also be applicable at the GM's discretion.

SIZE MODIFICATION

Fourth Officer Ratzelle is just over two feet tall, has short brown fur, and lives in the vacc-suit locker. Her coverall is always covered in grease, her voice is an irritating chitter, and when she's not working, she's stuffing her face with junk food. But who's complaining? Hiring her was the first smart move I pulled since we spaced the S-3 unit. Now our hyperdrive works all the time, the nanotoaster's no longer a menace, and she even squirmed up the Milliken Tube to hose the scorpion wasps out of number-two engine. Every ship should have a Tek-Rat.

– Captain Zeke Morrigan

Modification of genes governing human growth factor can create pint-sized parahumans who, as adults, are the size of young children, smaller than ordinary genetic dwarves. On the other side of the coin, genetic giants are also possible.

Note: Consumption of consumables (water, air, food, etc.) is normally proportionate to Size Modifier (SM), as described below. Starvation effects (p. B426) accrue whenever a creature misses 1/3 of its daily food requirements – a meal, for a human. These naturally exceed those of a human for creatures of SM +1 or more, and are smaller for those with SM -1 or less. Neither is grounds for Increased Consumption (p. B139) or Reduced Consumption (p. B80), which are for beings that require more or less food than their SM would indicate.

Linked Traits

Sometimes, the genes that combine to produce a specific desirable trait are mingled with those of other traits. GMs can rule that this is the way it works for specific advantages, requiring them to be combined with disadvantages, distinctive features or even other advantages. This has considerable basis in reality, and is very common in science fiction – what if a particular gene sequence known to produce an advantage such as Intuition was linked to a disadvantage like a hereditary propensity for Delusions?

Sex-linked traits are also possible – in the case of a variant race, this means that males and females will have slightly different racial templates.

Miniature Humans

Creating miniature people has some obvious advantages: they'd take up less space (especially useful for military or space vehicle crews) and require less life support. However, there are some serious physiological obstacles to producing doll-sized humans.

First, we define “humanity” in terms of intelligence. The human brain's thinking capacity depends on having a

minimum size and mass. You can shrink the body but not the head, as in a human dwarf, but there is a limit to how big a head can be supported on a shrunken neck and spinal column without causing problems. Alternatively, if the size of the head is reduced proportionately to the rest of the body, intellectual capacity will decline. Fortunately, intelligence appears to be a function of brain area rather than mass or volume, so reducing brain mass does not result in a direct, linear drop in IQ.

Second, a scaled-down human loses heat more rapidly, due to his larger body area in relation to his mass. This means he will need to eat rapidly in proportion to a normal-sized human just to keep his body temperature up. (This is why small mammals like mice are almost always either eating or sleeping.) Even so, overall food consumption will be notably lower (as it eats smaller meals). It might be a good idea to add Fur (to preserve heat) or a longer sleep cycle to any miniature human. Miniatures will eat many small meals, and get hungry if they miss them.

Third, while a smaller size is handy in terms of reduced life support requirements, it is also inconvenient for many other activities, from reaching things on a shelf to finding clothes that fit. It also correlates with reduced Strength.

Miniature Attributes Table

Scale	ST	IQ	SM	Cost	Weight	TL
1/2	-5	-1	-2	-70	1/8	9
1/3	-7	-2	-3	-110	1/27	10
1/4	-8	-2	-4	-120	1/64	10
1/5	-8	-3	-4	-140	1/125	11
1/6	-9	-4	-5	-170	1/216	12

Scale: The reduction in overall proportions, including the body's height, breadth and thickness.

ST, IQ: Suggested racial attribute modifiers for that scale. These limits can be exceeded by modifying the muscles, skeleton or brain using gengineering. However, the maximum increase allowed at each TL should be multiplied by scale. For instance, TL10 Musculo-Skeletal Modifications allow up to +6 ST; in a 1/3-scale human, this would be reduced to a mere +2 bonus, which mean a 2' tall superman would be limited to a ST modifier of -5.

SM: The miniature's Size Modifier.

Cost: The combined point cost of the racial ST and IQ penalties.

Weight: Multiply the miniature's weight by the number shown. Also multiply the weight of any given meal by this amount, e.g., a meal for a 1/2 scale creature has 1/8 normal weight. However, the total number of meals per day (three for normal humans) is multiplied by the *inverse* of scale, e.g., six meals a day at 1/2 scale, nine meals a day at 1/3 scale, etc. Thus, a scale 1/2 creature eats six meals of 1/8th normal weight per day. Thus, the total weight of consumption is the square of scale.

TL: The minimum TL required. "Miniaturization" counts as a single feature of that TL for gengineering purposes; any change below 1/2 scale is species modification; any change below 1/4 scale is also a radical modification.



Giant Humans

The difficulty with engineering giant humans comes from more fundamental physics than the concerns that govern miniatures. As a creature grows, its mass increases as the cube of its linear size – a person twice as tall as a similarly proportioned companion will weigh eight times as much. But the strength of bones and muscles depends on their cross-sectional area, which increases as the square of the linear size – our double-height giant will be only four times as strong.

Large animals can overcome this difficulty in two ways: by being heavily built with more thickly proportioned limbs to support the additional weight, or by being thin and spindly so the weight increase is less. The latter approach is likely to lead to taller giants, but thick-set ones will weigh more (compare the height and weight of giraffes and elephants). Thick-set giants will be relatively slow and ungainly movers, while spindly ones will be fragile.

Increased size also means greater food and life support requirements. On the other hand, large beings are able to retain body heat better, so usually have some degree of Temperature Tolerance to cold. Because of this, metabolism does not need to be as fast as in smaller creatures and meals can be eaten less frequently. However, the sheer volume of food that needs to be ingested might be so much that a single meal might take hours to consume!

Finally, giant humans may have to deal with the inconveniences of living in an environment designed for smaller people. They won't fit into normal-sized furniture or vehicles, will stand out in a crowd, and will have trouble finding equipment suited to their size. Even if suitable equipment is available, it will be expensive.

Giant Attributes Table

Scale	ST	SM	Cost	Weight	TL
1.5	+5	+1	45/25	×3.4	9
2	+10	+2	80/40	×8	10
3	+20	+3	140/60	×27	11
5	+40	+4	240/80	×125	11
7	+60	+5	300/120	×343	12
10	+90	+6	360/180	×1,000	12

Scale: The increase in overall proportions, including the body's height, breadth and thickness. Scale 2 or more is a species modification; scale 3 or more is also radical. Realistic giants should also have either a native gravity of (1/Scale) G, or Extra Legs (4 or more), Quadruped, No Legs (any version), or Vermiform.

ST: Suggested racial attribute modifiers for that scale. These limits can be exceeded by modifying the muscles, skeleton or brain using gengineering. The maximum increase allowed at each TL should be multiplied by scale, as with miniatures. Thus, TL10 Musculo-Skeletal Modifications could give a scale 3 giant +18 ST rather than +6 ST.

SM: The giant's Size Modifier.

Cost: The combined point cost of the racial ST bonuses, as modified by SM (-10% per +1 SM); the cost after the slash is also modified for No Fine Manipulators (-40%) for use if creating a giant that lacks manipulators, such as a Quadruped or Vermiform.

Weight: Multiply the giant's weight by the number shown. This is also the weight of a given meal. Divide the number of meals that must be eaten daily (three for normal humans) by scale, e.g., two meals a day at 1.5 scale, etc.

TL: The minimum TL required. Becoming a giant counts as a single feature of that TL for gengineering purposes; any change over 1.5 scale is species modification; any change over 2 scale is also a radical modification.

OTHER FEATURES

Besides specific modifications or defects, a race may also have a variety of secondary, 0-point features. Several such features appear under Gengineered Advantages and Disadvantages.

Sex Selection

"Of course a boy! We must have a male child, so he can marry and inherit the family business."

"You want a boy, she wants a boy . . . If every parent is going to have boys, who are they going to marry?"

At TL8 it is possible to specify a baby's sex during any in vitro fertilization (or genetic engineering) procedure. This may have profound effects on society. For example, if parents favor boys over girls (as in many Earth cultures), the result could be a demographic disaster within a generation, especially if population controls restrict families to one child each. Sex selection costs \$500 if it's the only modification ordered; it's free with more extensive gengineering.

Taboo Traits

Some genetic constructs undergo selection to screen out or mitigate undesirable traits; therefore, certain advantages or disadvantages may be forbidden to individual characters built with such racial templates. A forbidden advantage or disadvantage is called a taboo trait (p. B452). It costs no character points to assign a taboo trait to a racial template.

For instance, a character can normally have Berserk as a personal disadvantage, even if it isn't in his genetic template. However, if Berserk is a taboo trait for his template, then it cannot be taken. Taboo traits that cover a general class of disadvantages do not prevent specific disadvantages within that class from being part of the racial template. The prohibition is also lifted for disadvantages that are acquired after birth (e.g., due to a proteus virus or brainwashing).

One way to add a taboo trait to a template is through genefixing.

Genefixing

"Unlike a lot of cults, the Neo-Gnostics don't have a taboo against genefixing. Or maybe they just considered it the lesser of two evils when they hired me to ensure none of their babies would ever be born with a lecherous gene in his or her body."

– Dr. Lucien Locke, Genehackers Inc.

The practice of "genefixing" consists of testing germ plasm for genetic defects, such as hereditary diseases, and then fixing them through gengineering at conception. This is the easiest type of trait selection for society to accept – making sure that genes for good physical or mental health are coded into children, while defects are fixed.

At mid to late TL8, this is limited to major genetic defects, where genetic errors result in an excess or deficiency of certain proteins or hormones, producing problems like Dwarfism or Hemophilia.

At TL9+, the definition of "defect" can be extended, ensuring that minor flaws like lantern jaw, knock knees, snaggle teeth, excessive acne and so on are not in a genotype.

It should be possible to suppress or edit gene sequences connected with a tendency toward certain mental states, such as rage, lecherousness or poor self-control. It's not possible to genefix specific mental disorders, such as an individual obsession or phobia, but manipulation of genes governing behavior-modifying neurotransmitters (such as serotonin) can deliberately create "stable personality" genotypes that are less likely to suffer from some forms of mental illness. This is the reverse of the technique used to create the "genetic booby traps," described under *Behavioral Modifications* (p. 43).

While genetic behavioral modification of this sort may be controversial, eliminating aggressive or unstable mental traits may seem more benign. However, it can have an interesting effect on a culture over the long term. A non-aggressive culture might be in trouble the next time it runs into an external enemy, and who knows how many famous artists, prophets, messiahs, and political leaders might have gained their inspiration from mild mental disorders?

Some possible genefixed taboo traits are:

Taboo Trait: Genetic Defects (TL8): Prohibits taking attributes more than 2 below the average for an adult with that genetic template. Also prohibits the disadvantages Bad Sight, Colorblindness, Dwarfism, Dyslexia, Gigantism, Hemophilia, Innumerate, Night Blindness, No Sense of Smell/Taste, Non-Iconographic, and Short Attention Span, or any other disadvantages normally explained as resulting from hereditary defects, e.g., an inherited Neurological Disorder or Susceptible to Disease disadvantage.

Taboo Trait: Unattractiveness (TL9): Prohibits an Appearance of Unattractive or worse, as well as Bad Smell, Bowlegged, Fat, Overweight, Very Fat, and Very Unfit.

Taboo Trait: Aggressiveness (TL9): Manipulation of genes governing certain hormone-producing glands may create a non-aggressive genotype which prohibits Bad Temper, Berserk, Bully and Stubbornness.

Taboo Trait: Mental Instability (TL9): Prohibits Chronic Depression, Delusions, Flashbacks, Guilt Complex, Kleptomania, Low Self-Image, Lunacy, Manic-Depressive, Megalomania, Obsession, On the Edge, Paranoia, Phantom Voices, Pyromania, and any Compulsive Behavior or Phobia worth -10 points or more.

Individual disadvantages which could be taboo traits are Lecherousness (TL9), Shyness (TL9), and Laziness (TL10). It's impossible to engineer against (or for) more complex disorders, such as specific Obsessions or Phobias.

RACIAL POINT COST

This is the point cost required to play someone with a particular variant human template. It is the sum of the costs of all attribute and secondary characteristic modifiers, advantages and disadvantages. If necessary, the GM can balance designs by adding unintended disadvantages. The GM should try to keep the point costs of races intended for use by PCs below the average point total of the campaign, and usually no more than half that cost. Thus, in a game with 200-point characters, races costing more than 200 points should be avoided, and most should cost 100 points or less. On the other hand, in some high-powered game settings, "super races" with very high point totals are perfectly in genre.

These are simply play-balance guidelines, not a hard-and-fast rules; GMs can ignore them or modify them as they see fit. See p. B454 for additional guidelines on racial costs.

LIFE'S PRICE TAG

If you purchase a set of genetic modifications for your children, what is the *dollar* cost? And how much is that run-away genetic artifact worth?

This depends on how complex the nucleotide sequences used in the genotype were, and whether the buyer is ordering a custom-designed genotype or a tried-and-true one.

Beyond the Probable

Many advantages or disadvantages aren't covered in this chapter. These are the ones that human genetic engineering would find very difficult or impossible to reproduce. This may be because they represent social relationships (like Status and other social traits), education (like Languages or Trained by a Master), are very abstract (like Luck), or just because they would be too hard to duplicate genetically without cybernetic implants, psi abilities, "mutant super powers" or ultra-tech "super-science" . . . the province of **GURPS Powers**.

GMs may nevertheless allow them to be genetically engineered if discovered in nature. For example, engineering the ability to teleport or breathe fire is seemingly impossible – but what if a person or alien capable of it were discovered? Engineers may try to hire or capture that individual or creature and study it. Perhaps the genes that code for this ability can be spliced into humans or other animals!

Capturing exotics for genetic hybridization may be a goal of unscrupulous engineers (human or alien) in superscience settings.

Established Variant Races

Once one example of a variant race has been created, that same genetic sequence can be used to modify other human reproductive cells. Since the complex research and development has already been done, it may be possible to simply go to a biotech company and purchase a "genetic program" or "genetic upgrade sequence" for one's unborn children or, if it's legal, have one grown or cloned to order. Depending on the law, a bioengineered person may be considered a child (with whatever legal rights children have) or a form of property . . . or the genetic engineering itself may be illegal!

Assuming it's legal, a suggested price tag for an embryo is \$25,000 if only eugenic modifications were made, \$50,000 if any species modifications were performed including purely cosmetic species modifications (engineering someone with slit-pupil eyes, cat ears, and a tail is still expensive, even if it's worth zero character points). Increase the cost to \$100,000 if any radical species modifications were made. If the racial point cost is positive, increase the dollar cost by \$1,000 per point. If the racial point cost is negative, use only the base cost quoted above. For nonhuman races that start out with racial bonuses, ignore those that are "native" to the race before engineering when calculating the price tag.

Note that this cost reflects the utility of the genetic modification, rather than the difficulty required to design it! The GM may increase the cost for any process that involves radical modifications even if they cost no points: doubling cost is reasonable.

This buys a viable embryo, which can then be implanted in a surrogate mother of the same or similar species (e.g., a human could bring a parahuman to term), raised in a growth tank or other artificial womb, or cloned; see *Reproductive Technology* (p. 19).

Example: Mei and Yukio were both created from cells donated by their parents, using the Pandora-series genetic upgrade (p. 69). This variant template costs 61 points.

Since one of their advantages was a radical species modification, their parents paid \$100,000 + \$66,000 = \$166,000 apiece for the privilege of mentally-enhanced but slightly-fragile offspring. In Mei's case, her mother had the embryo implanted and carried it to term herself; Yukio was grown in a forced-growth tank. Aside from that, Mei is of average height with black hair, while Yukio is a tall redhead. They could have any mundane advantage or disadvantage not prohibited by the Pandora's taboo against genetic defects.

GENGINEERED HUMAN RACIAL TEMPLATES

This section contains sample racial templates for variant humans. Most can be used either for parahuman species with viable germ lines, or for bioroids incapable of reproducing. They can also be used for humanoid species in fantasy worlds, with or without any scientific justification. They can be easily modified by adding or subtracting traits from the earlier lists and adjusting their costs accordingly.

GENETIC UPGRADES

A lot of Orion upgrades find jobs in athletics, emergency services, police work, or the military, but certainly the best-known Orion upgrade is dynamic karate master-turned-megastar Chuck Abrams, whose unchallenged reign as king of the action sensies has had much to do with this genotype's popularity with creche groups and parents.

Upgrades are individuals who have undergone eugenic engineering at conception, with the goal of removing undesirable genetic traits and adding desirable ones. The answer to the question "desirable to whom?" is not always the individual himself or his parents, so some of these "upgrades" are not necessarily an advantage.

Upgraded humans are still capable of interbreeding with baselines, so do not form distinct parahuman species. Bioroids may also be built using these templates, but they will not be capable of reproduction. Some of these upgrade templates can also be stacked with parahuman templates to produce upgraded members of a parahuman species.

Alpha (TL9)

39 points

Careful eugenic improvements ensure an attractive, athletic, healthy individual. Medscanning may reveal minor "mutations" compared to the human norm, such as being born without an appendix. This is a simple *Homo superior* genotype that TL9+ parents – or societies – might select for their children.

Attribute Modifiers: DX+1 [20]; HT +1 [10].

Advantages: Attractive [4]; Longevity [2]; Resistant to Disease (+3) [3].

Features: Taboo Traits (Genetic Defects, Mental Instability).

Availability: \$64,000. LC4.

Sub-Races

Omega (+28 points): An enhanced version of the Alpha, designed to be both beautiful and intelligent; increase appearance to Handsome [12] and add IQ+1 [20]. \$92,000. LC3.

Heavy Worlder (TL9)

46 points

A heavy worlder's weight is 25% over the human norm, but height is 1' less than indicated for ST. Someone with this modification is wider, which can give problems in narrow passages or doors designed for normal humans (a DX roll to squeeze through).

This is a variant human designed for life in a 1.5 to 2 G environment. He has more muscle to get around, strong bones to avoid breaking them in falls, and a resilient circulatory system to prevent early death due to heart failure. However, the "heavy-worlder" is usually unattractive by human standards, with a barrel chest and a compact, blocky body.

Attribute Modifiers: ST+3 [30], HT +1 [10].

Advantages: Improved G-Tolerance (0.5 G) [10].

Disadvantages: Unattractive [-4].

Availability: \$71,000. LC4.

Ishtar (TL9)

20 points

The Ishtar genetic upgrade is intended to cater to the desires of parents and creche-groups who want a child optimized for professions such as vid star, dancer, pop singer, model and so on. Designers selected a light, "elfin" build and a facial bone structure that computer-simulations indicated would produce distinctive but highly attractive looks. An extra feature was an augmented liver. They also deliberately modified the neurochemistry with

sequences believed to enhance ego and competitiveness. Some believe they went a bit too far . . .

Attribute Modifiers: ST-1 [-10]; DX+1 [20]; HT +1 [10].
Advantages: Appearance (Beautiful/Handsome) [12]; Resistant to Disease (+3) [3].
Perks: Alcohol Tolerance [1].
Disadvantages: Jealousy [-10] or Selfish (12) [-10]; Overconfidence (12) [-5].
Quirks: Imaginative [-1].
Features: Taboo Traits (Genetic Defects, Unattractiveness).
Availability: \$45,000. LC4.

Sub-Races

Siduri: A second-generation Ishtar. Add Longevity [2] and Proud [-1]; eliminate Jealousy or Selfish \$48,000. LC3.

*Almost all aspects of life are
engineered at the molecular level.
– Francis Crick*

Light Worlder (TL9)

10 points

Human metabolisms may be genetically adapted for life on planets with gravity significantly lower than Earth's. Generic "light worlder" engineering results in a willowy build, often with long limbs and spidery fingers.

Attribute Modifiers: ST-2 [-20].
Advantages: Long Arms [20]; Long Legs [10].
Features: Home gravity is 0.2 to 0.7 G. Increase height by up to 2' over the norm for the lowered ST, but weight is 15% to 25% lower than normal. They can sometimes squeeze into places that normal people can't fit, but this is balanced by their extra height (needing to duck under doors and so on).
Availability: \$35,000. LC4.

Orion (TL9)

70 points

These genetic upgrades were eugeneered with slight metabolic and glandular modifications designed to burn away excess fat, enhance physical performance, and optimize their crisis response. They are good "super-soldier" candidates, but might be created by anyone who wants a highly athletic variant race.

Attribute Modifiers: ST+1 [10]; DX+1 [20]; HT+1 [10].
Advantages: Appearance (Attractive) [4]; Combat Reflexes [15]; Fearlessness 1 [2]; Fit [5]; High Pain Threshold [10].
Disadvantages: Overconfidence (12) [-5].
Quirks: Attentive [-1].
Features: Taboo Traits (Genetic Defects, Mental Instability).
Availability: \$95,000. LC4.

Helot (TL10)

12 points

This non-aggressive genotype is the result of deliberate engineering to produce a "tractable" variant race. Helot parahumans have been eugeneered to weed out genetic defects and vulnerability to disease, and are fully as intelligent as ordinary humans. However, subtle neurological and glandular modifications have bred rebellious, impulsive and aggressive genes out of the genome – and they are very good at following orders. An unintended defect was some reduction in natural curiosity.

Sometimes called "Social Man," the Helot genetic template's supporters claim that the upgrade makes human beings more suitable for a crowded urban civilization, reducing aggressive and selfish impulses without curtailing overall intelligence. Detractors point out that these traits are exactly what a would-be ruling elite would desire, making the human population more docile and tractable.

Totalitarian governments have used the Helot genotype in an attempt to prevent popular uprisings. Elsewhere Helots are few, since the genotype is unpopular among parents who have a choice of genetic template for their children.

Attribute Modifiers: HT +1 [10].
Advantages: Resistant to Disease (+8) [5].
Quirks: Broad-Minded [-1]; Humble [-1]; Staid [-1].
Features: Taboo Traits (Aggressiveness, Genetic Defects, Mental Instability, Unattractiveness).
Availability: \$37,000. LC3.

Sub-Races

The Helot II is a higher-TL upgrade that incorporates species modification.

Helot II (-4 points): A more elaborate parahuman version of the Helot genotype, this involves a complete restoration of the vestigial human vomeronasal organ, allowing the variant form to be strongly influenced by pheromones. This makes them susceptible to the use of dominance and sexual pheromones as a tool of political control. Add Susceptible to Pheromones 4 [-4]. \$58,000. LC2.

Helot Bioroid (-19 points): A TL10 bioroid version, which "neatly" shuts down and dies after reaching old age. Add Bioroid [-5] and Self-Destruct [-10] to either the Helot or Helot II. TL10; \$50,000. LC2.

HOMO SUPERIOR PARAHUMANS

One obvious reason to create parahuman species is to give the variant greater general capability, making it "human, only more so." These are like genetic upgrades, but pushed beyond the point where the upgrade is still capable of interbreeding with baselines. Often a redesign of the human genotype is motivated by ideology; the engineers are driven by a desire to change "human nature" itself. Such variant forms can be quite distinctive.

These aren't usually bioroids, but at TL10+ they could be built using this technology, either as servants or just as an alternative to reproductive. If so, add Bioroid [-5].

Brownie (TL9)

15 points

One of the earliest attempts to engineer humans for increased health and longevity was the Brownie variant. Rather than tinker with the inner workings of cell biochemistry, the Brownie's designers chose to improve gross human physiology.

Brownies are short and stocky, with heavy layers of muscle and fat padding torso, upper arms and upper legs. Their spines are curved, giving them a naturally forward-leaning posture. Their knee joints have been re-engineered to bend in both directions, giving them a slow, awkward-looking gait. Their voices sound muffled and nasal, the result of tracheal reconfiguration.

Strange as it may seem, all these modifications tend to make the Brownie tough and durable. Brownies are resistant to disease, falls and other accidents, and the slow progress of time. They *age* just as quickly as unmodified humans do, but their bodies don't wear out as rapidly. Although the first cohorts of the subspecies are not yet old enough to demonstrate their durability, most estimates indicate that the average Brownie can expect to live well over a century with minimal medical intervention (and therefore very low medical costs).

Brownies are surprisingly well adapted for life in space – the template's modifications to skeletal structure have made Brownies nearly immune to bone-mass loss in zero-G. Although the merits of the design are rarely questioned, the Brownie template is unpopular due to its odd and unfashionable appearance.

Attribute Modifiers: ST-1 [-10]; HT+2 [20].

Secondary Characteristic Modifiers: Basic Move-1 [-5].

Advantages: Acute Vision +1 [2]; Acute Hearing +2 [4]; Catfall [10]; Resistant to Disease (+8) [5]; Longevity [2].

Perks: No Degeneration in Zero-G [1].

Disadvantages: Disturbing Voice [-10]; Unattractive [-4].

Features: Taboo Traits (Genetic Defects, Mental Instability). Brownies are about 3 inches shorter than average for their ST, but they also average 15 pounds heavier than an unmodified human of their height.

Availability: \$65,000. LC3.

Diana (TL9)

47 points

For the most part the Diana genotype is a typical *Homo superior* type, similar to the Alpha (p. 66). However, Dianic parahumans cannot become pregnant unless they wish to, and they *cannot* bear male children. Male fetuses are spontaneously aborted by an autoimmune reaction by the time they reach the hundred-cell stage. Meanwhile, the brain and hormonal mechanisms responsible for gender identity have been subtly modified, giving them a strong predisposition toward homosexuality. Not all Diana upgrades are lesbians, but most of them are at least bisexual, and fully heterosexual examples are rare.

Attribute Modifiers: IQ+1 [20]; HT+1 [10].

Advantages: Appearance (Attractive) [4]; Fit [5]; Resistant to Disease (+8) [5]; Longevity [2].

Perks: Reproductive Control [1].

Features: Altered Sex Ratio (Female-only births); No Appendix; Sexual Orientation (Lesbian); Taboo Trait (Genetic Defects).

Availability: \$92,000. LC3.

Sub-Races

Artemis (+69 points): A combat model of the Diana, optimized for crisis response and sensory awareness. Add ST+1 [10], DX+1 [20]; Perception +1 [5]; Combat Reflexes [15], Explosive Strength [24]; Overconfidence (12) [-5]. \$161,000. LC2.

Genetic Mixing

Genetic upgrades are capable of breeding with baseline humans, and each other. What happens when they do so?

Since the changes designed into an upgrade are genetically based, there is a chance they will be passed on to any offspring. There is also a chance that the offspring *won't* inherit some or all of the modified features of its parents. It all depends on the Mendelian inheritance (p. 6) of the genes that express each trait (attribute adjustment, advantage, disadvantage, or feature).

A trait is more likely to be inherited if both parents have it, but this is not guaranteed. On the other hand, it's possible for the designers to deliberately make a trait dominant, so that it *will* appear in first-generation offspring. Second generation offspring of mixed parentage may not be so lucky, as they could inherit non-carrying alleles from both parents.

There are three ways to handle trait inheritance in the game:

Realistic: GMs with an understanding of genetic inheritance may want to assign traits to dominant or recessive genes and work out the probabilities – this is beyond the scope of this book.

GM fiat: The details are complex enough that the GM can simply feel free to rule that any particular trait will or won't appear in any given child.

Random: For each trait that exists in the breeding population, roll 3d. If both parents possess that trait, a child will inherit it on a 15 or less. If one parent possesses it, the child will inherit it on a 10 or less. If neither parent possesses it, the child will inherit it on a 5 or less. These numbers are 2 lower for rare traits. Roll separately for each trait (unless some are linked traits; see p. 62) for each child.

For a "technological fix," see the Alternate Gamete Production (p. 184) biomod.

Athena (+7 points): A TL10 design, capable of parthenogenic reproduction. Other modifications extend life span and enhance creativity. Add Early Maturation 1 [0], Extended Lifespan [2], Parthenogenesis [0], and Versatile [5]. \$110,000. LC3.

Avatar (TL10)

42 points

Like the Diana, the Avatar design is motivated by concern over gender roles. Rather than try to redefine what it meant to be masculine or feminine, this design reinforces typical gender stereotypes. As such, it is an exercise in sexual *dimorphism*, in which the physical and psychological differences between males and females of the subspecies are exaggerated. Male Avatars are strong, robust, stoic in the face of pain, and somewhat egoistic. Female Avatars are dextrous, soft-voiced, and demure. Both sexes are engineered for great physical attractiveness, and have extreme secondary sexual characteristics which make their masculinity or femininity almost fiercely obvious.

Male Avatars tend to gravitate toward high-risk occupations such as the military, while female Avatars (especially those who overcome their natural Shyness) are often successful as diplomats, negotiators or entertainers.

Attribute Modifiers: HT+2 [20].

Advantages: Appearance (Handsome) [12]; Resistant to Disease (+8) [5].

Skills: Racial Skill Bonus (Sex Appeal +3) [6].

Quirks: Distinctive Features [-1].

Features: Taboo Traits (Genetic Defects, Mental Instability). Females also have Taboo Trait (Aggressiveness). Both sexes have exaggerated sexual characteristics: Males are blatantly muscular with abundant body and facial hair, while females are very curvaceous and have soft, delicate facial features.

Availability: \$116,000, LC3.

Sub-Races

Select *one* of these lenses:

Female Avatar (+24 points): DX+1 [20]; Voice [10]; Responsive [-1]; Shyness (Mild) [-5].

Male Avatar (+24 points): ST+2 [20]; High Pain Threshold [10]; Overconfidence (12) [-5]; Proud [-1].

Gilgamesh (TL10)

65 points

Gilgamesh parahumans are a *Homo superior* design intended for high intelligence and lengthened lifespan. The Gilgamesh looks human, but features extensive eugenic and species modifications, including redesigned heart, arteries, spleen and gastrointestinal tract, plus alterations to the cell structure itself to reduce cumulative copying errors.

Attribute Modifiers: DX+1 [20]; IQ+1 [20]; HT+1 [10].

Advantages: Appearance (Attractive) [4]; Extended Lifespan 1 [2]; Longevity [2]; Resistant to Disease (+8) [5].

Perks: Reproductive Control [1]; Sanitized Metabolism [1].

Features: Early Maturation 1; No Appendix; Taboo Traits (Genetic Defects, Mental Instability).

Availability: \$115,000. LC3.

Sub-Races

Ladon: A TL11 variant with exotic modifications made to sleep-regulating structures in the brain. Delete HT+1 and Taboo Trait (Mental Instability); add Doesn't Sleep. \$125,000. LC3.

Guardian (TL10)

185 points

The Guardians (the name comes from Plato's *Republic*) are engineered for two major improvements. The first is natural durability. Guardians are slightly faster and more robust than unmodified humans, with cardiovascular modifications to make them fit and tough. The second is *mastery* of other human beings. Their mental balance is designed for personal pride and a willingness to command others. Physically attractive, with pleasant voices, they are engaging from a distance or over a telecom channel. In person, they are *magnetic*, the result of glands releasing dominance and sexual pheromones. These glands do not become functional until after puberty, but they are under the Guardian's conscious control. They work well as a master race for the Helot II (p. 67).

Attribute Modifiers: DX+2 [40]; IQ+2 [40]; HT+2 [20].

Advantages: Appearance (Attractive) [4]; Dominance Pheromones [15]; Combat Reflexes [15]; Resistant to Disease (+8) [5]; Extended Lifespan 1 [2]; Fit [5]; Hard to Kill +2 [4]; Longevity [2]; Sex Pheromones [28]; Voice [10].

Disadvantages: Overconfidence (12) [-5].

Features: Early Maturation 1; Taboo Traits (Genetic Defects, Mental Instability, Unattractiveness).

Availability: \$185,000. LC2.

Sub-Races

Guardian Warrior (+42 points): Designed for combat with a boosted crisis response. Add Burst Reflexes [18] and Explosive Strength [24]. \$227,000. LC2.

Pandora (TL10)

66 points

Instead of just engineering a smarter human, the goal of the Pandora's designers was to create a faster-thinking one. The resulting Pandora genetic upgrades look identical to normal humans, but their brains have been neurologically modified to improve information flow between neurons, permitting faster thought.

Unfortunately, the interface with the speech centers of the brain was not as smooth as intended: they don't actually stutter, but they do find it hard to slow their words down when talking to normal people, so the effect is about the same. The Pandoras were also not as robust as hoped.

Despite their flaws, the Pandoras are popular general-purpose *Homo superior* genetic upgrades, likely to find jobs in many different fields, especially where complex snap decisions are required, such as surgery, piloting or even battle management.

Attribute Modifiers: IQ+2 [40]; HT-1 [-10].

Advantages: Enhanced Time Sense [45].

Disadvantages: Stuttering (Accessibility, no penalty if talking to someone else with Enhanced Time Sense, -10%) [-9].

Features: Taboo Traits (Genetic Defects).

Availability: \$166,000. LC3.

Sub-Races

Prometheus (+19 points): Upgraded Pandora model; delete -1 HT and Stuttering. \$185,000. LC3.

Tiresia (TL10)

47 points

These parahumans are designed to transcend the limits of gender itself. Tiresian parahumans are functional sequential hermaphrodites, able to switch between male and female sex roles. They can both bear and sire children, although they cannot switch sex when pregnant. They have also been modified for enhanced intelligence and physical attractiveness, although they tend to possess a somewhat androgynous beauty.

Attribute Modifiers: IQ+1 [20]; HT+1 [10].

Advantages: Appearance (Handsome, Androgynous) [12]; Hermaphromorph (Accessibility, not while pregnant, -20%) [4].

Perks: Reproductive Control [1].

Features: Light Menses; No Appendix; Taboo Traits (Genetic Defects, Mental Instability).

Availability: \$97,000. LC3.

Herakles (TL11)

192 points

Pushing the limits of genetic technology, the Herakles represents one of the most elaborate *Homo superior* designs available. The muscles, skeleton, and nervous system have all been engineered for maximum performance. The immune system, spleen, liver, and overall biochemistry have been broadly modified to allow near-immunity to infectious disease and cancers and strong resistance to poisons. Several changes to cell structure allow dramatic extension of lifespan. Finally, modifications to the brain allow a Herakles to get by with very little sleep.

Attribute Modifiers: ST+3 [30]; DX+4 [80]; IQ+2 [40]; HT+4 [40].

Advantages: Appearance (Attractive) [4]; Extended Lifespan 1 [2]; Longevity [2]; Rapid Healing [5]; Less Sleep 4 [8]; Resistant to Disease (+8) [5]; Resistant to Poison (+3) [5]; Sanitized Metabolism [1].

Perks: Reproductive Control [1].

Disadvantages: Bad Temper (12) [-10]; Increased Consumption 1 [-10]; Overconfidence (12) [-5]; Unusual Biochemistry [-5].

Quirks: Proud [-1].

Features: Early Maturation 1; No Appendix; Taboo Traits (Genetic Defects, Mental Instability).

Availability: \$242,000. LC3.

Sub-Races

Atlas (+42 points). Radical glandular manipulation results in a truly impressive giant-size version standing nine feet tall! He is a 1.5× scale human (p. 63) with 3.4 times normal weight. Increase to ST+8 (SM +1, -10%) [72]; add +1 SM. \$284,000. LC3.

PANTROPIC PARAHUMANS

"How'd I get away? Well, Galba's assassin had the drop on me. I set my drinking bulb down on the table behind me and raised my hands. He watched them carefully. He forgot I was a Spacer. He wasn't watching my toes."

– Captain Zeke Morrigan, free trader Antares

One approach to using the vast regions of a planet that provide a less than ideal environments for humans is to adapt people to be able to live comfortably there. Parahumans also represent a way to adapt humanity to the challenges of living off a planet. These templates represent variants designed for particular climatic and ecological regions.

Drylander (TL9)

19 points

Drylanders are designed to live comfortably in arid regions, tending wilderness preserves or assisting in desert-reclamation projects, or colonizing desert planets. They appear nearly human from a distance, but have a number of transgenic features that become apparent up close. The type's metabolism has been altered to conserve water and deal with wind-blown dust. The large, catlike eyes have been radically modified, giving them keen night vision and protecting them with a nictitating membrane. As a result, Drylanders can function quite well in the cool desert night, and many of them prefer a nocturnal existence.

Advantages: Filter Lungs [5]; Nictitating Membrane 1 [1]; Night Vision 3 [3]; Reduced Consumption (Water Only, -50%) 1 [1]; Resistant to Poison (+3) [5]; Temperature Tolerance 5 (Comfort zone between 35°F and 140°F) [5].

Disadvantages: Unnatural Feature [-1].

Availability: \$69,000. LC3.

Sub-Races

Martian Drylander (-5 points): Built to survive on a partly-terraformed Mars or other world with thinner-than-usual atmosphere. Add Low-Pressure Lungs [0]. Same availability.

Selkie (TL9)

57 points

A sea-adapted parahuman race. Although modified for a semi-aquatic lifestyle, they must still breathe air. They store oxygen in the myoglobin of their muscles, much like cetacean animals. They have smooth gray, mottled, or black skin and webbed fingers and toes.

Secondary Characteristic Modifiers: +3 FP [9].

Advantages: Amphibious [10]; Combat Reflexes [15]; Doesn't Breathe (Oxygen Storage, 100 times, -30%) [14]; Nictitating Membrane 1 [1]; Pressure Support 1 [5]; Resistant to Disease (+3) [3]; Temperature Tolerance (Cold) 1 [1]

Disadvantages: Unnatural Features 1 [-1].

Availability: \$107,000. LC3.

Sub-Races

Selkie Bioroid (-35 points): Usually used as amphibious commandos or underwater workers. Add Bioroid [-5], Self-Destruct [-10], Short Lifespan 2 [-20]. \$72,000. LC2.

Selkie Chimera (-10 points): A human-seal hybrid in truth, sometimes with a face similar to an anthropomorphic otter or seal. Add Sharp Teeth [1] and Chimera [-10], and upgrade to Unnatural Features 2 [-2]. \$82,000. LC3.

Spacer (TL9)

5 points

Individuals living in micro- or zero gravity tend to be tall and thin – some “spacers” may be unattractive, while others have an elfin beauty. However, while their build is usually lighter than people raised in gravity, a “calcium hack” genetic modification to the parathyroid gland prevents bone mass from reaching dangerously low levels, and their cells are better able to repair radiation damage. A more obvious upgrade is prehensile toes that let the legs be used as an extra set of limbs in zero gravity.

Attribute Modifiers: ST-2 [-20]; DX+1 [20].

Advantages: Prehensile Toes [4]; Radiation Tolerance 2 [5].

Perks: No Degeneration in Zero-G [1].

Disadvantages: Skinny [-5].

Features: Home gravity of 0 G; increase height by up to 3 feet over the norm for the lowered ST, but weight is 50% of normal. Many spacers have 3D Spatial Sense and have Free Fall skill from growing up in zero G, but this is not part of the *genetic* template.

Availability: \$55,000. LC3.

Sub-Races

Bioroid Spacer (-5 points): A manufactured zero-G worker race. Add Bioroid [-5]. \$50,000. LC3.

Camazotz (TL10)

41 points

Camazotz parahumans have a sizable percentage of bat genes spliced into their genome. Their arms double as wings, although they can't be used as arms when they're

flying. They possess large, pointed, bat-like ears, fangs, and soft fur, as well as a modified voice box with natural sonar abilities. Aside from serving as a night-vision aid, this has security (peering inside packages) and medical (performing sonograms) uses.

This is the racial template used to create Tizbeth and her siblings (see p. 36). They were designed as explorers and rangers for an exotic world (a rare planet with low gravity but thick, breathable atmosphere), where their flight and sonar (to see through thick fogs) were invaluable. However, a bat parahuman could be grown as an unusual toy or courtesan, or be intended for work in a microgravity habitat like a hollow asteroid or domed lunar city.

Attribute Modifiers: ST-2 [-20]; DX+1 [20].

Advantages: 3D Spatial Sense [10]; Acute Hearing +2 [4]; Acute Taste and Smell +1 [2]; Flight (Requires Low Gravity, 0.3G, -35%; Temporary Disadvantage, No Fine Manipulators, -30%); Winged, -25% [8]; Sharp Claws [5]; Sharp Teeth [1]; Sonar (Air; Reduced Range $\times 1/5$, -20%) [16]; Ultrahearing [5].

Perks: Fur [1].

Disadvantages: Skinny [-5]; Unnatural Features 1 [-1]; Unusual Biochemistry [-5].

Availability: \$91,000. LC3.

Sub-Races

Camazotz Bioroid (-5 points): Add Bioroid [-5]. \$86,000. LC3.

Camazotz Chimera (-20 points): Add Chimera [-10] and Short Lifespan 1 [-10]. \$71,000. LC3.

Triton (TL11)

36 points

Although Selkies go partway there, true aquatic freedom only comes with the ability to breathe water. Engineering a parahuman with functional gills is the easy part – the difficulties lie in preventing heat loss caused by the blood-rich gill membranes being in contact with the water, and in avoiding dehydration by osmosis from the cells. This requires significant changes to the human biochemistry, slowing down the metabolism to reduce body temperature and adjusting tissue salinity. Tritons can be designed for any particular water salinity, but individuals cannot safely migrate between fresh and salt water. Physically, Tritons are similar to Selkies, but with large gill structures on their chests.



Advantages: Amphibious [10]; Doesn't Breathe (Gills, -50%) [10]; Enhanced Move 1 (Water Speed 10) [20]; Nictitating Membrane 1 [1];

Pressure Support 1 [5]; Resistant to Disease (+3) [5]; Temperature Tolerance 2 [2].

Disadvantages: Cold-Blooded (50 degrees) [-5]; Unusual Biochemistry [-5]; Weakness (Immersion in water of “wrong” salinity, 1d per 30 minutes) [-5]; Unnatural Features 2 [-2].

Availability: \$136,000. LC3.

Sub-Races

Triton Bioroid (-20 points): A less expensive worker version, perhaps designed by an aquatic biocorp. Add Bioroid [-5], Self-Destruct [-10], and Short Lifespan 1 [-10]; delete Unusual Biochemistry (which is already included in Bioroid). \$116,000. LC3.

Void Dancer (TL11)

31 points

Designed as zero-G construction workers, space crew and belt miners, the slender Void Dancers have been extensively adapted to the space environment. Radical dermal and internal modifications adapt them to survive pressure changes and hard vacuum, and they can function without air by storing an hour's worth of oxygen in a modified liver. Brain and inner ear modifications modify the Void Dancers for life without verticals, while cardiovascular and glandular tinkering optimize the metabolism for low or no gravity (and incidentally extend lifespan). Dexterous prehensile toes give them a useful pair of additional arms in zero-G.

Unfortunately, the gengineers' goals outstripped their capabilities, leading to genetic defects that left this particular model with less resistance to bacteria. In sterile space habitats, among other Void Dancers or sanitized parahumans like the Gilgamesh, this isn't a problem – but it restricts their ability to interact with normal humans.

Attribute Modifiers: ST-3 [-30].

Advantages: 3D Spatial Sense [10]; DR 1 [5]; Doesn't Breathe (Oxygen Storage, ×100, -30%) [14]; Extra Arms 2 (Foot Manipulators, -30%; Short, -50%) [4]; Longevity [2]; Sealed [15]; Radiation Tolerance 5 [10]; Regeneration (Slow; Radiation Only, -60%) [4]; Temperature Tolerance 10 [10]; Vacuum Support [5].

Perks: No Degeneration in Zero-G [1].

Disadvantages: G-Intolerance (0.1 G increment) [-10]; Skinny [-5]; Susceptible to Disease 1 [-4]; Unnatural Features 1 [-1].

Quirks: Sanitized Metabolism [1].

Features: Home gravity is 0G.

Availability: \$131,000. LC3.

Sub-Races

Dark Angel Bioroid (+65 points): A robust “combat bioroid” version, built to survive high accelerations or to visit planetary environments. Upgrade to ST-1 [-10] and DX+1 [20], delete G-Intolerance and Susceptible to Disease, and add Combat Reflexes [15], Resistant to Acceleration (+3) [1], and Bioroid [-5]. \$196,000. LC3.

SPECIALISTS AND SLAVES

Adapting a parahuman or bioroid for a specific profession is an obvious path to a more “efficient” society. In addition to changing physical features, a genemod's personality can be adjusted to suit the job by making sure he enjoys the work – or is too docile to complain about it.

Chronos (TL10)

59 points

Designed as soldiers for unsupported, long-range patrol and counterinsurgency operations, these parahumans are lean and muscular, with canine muzzles and sharp teeth, but with large mouse-like ears and eyes. Their bodies are covered with short grey fur. They are transgenic hybrids with human, canine, rodent, and shark genes. They possess modified stomachs so they can live off the land, and bone marrow and adrenal gland upgrades to improve emergency response and health. They are optimized for tracking and spotting the enemy. They can rapidly respond to ambushes by shifting into biological overdrive. If they're a rare bioroid or supersoldier upgrade, they might be deployed in small teams to range ahead of human troops and conduct special operations.

A race of Chronos parahumans could be intended as slave soldiers or hostile-world colonists; a world where all the natives had these modifications could be frightening!

Attribute Modifiers: ST+2 [20]; DX+1 [20]; IQ-1 [-20]; HT+1 [10].

Secondary Characteristic Modifiers: Basic Speed +1.00 (Costs Fatigue, 2 FP, -10%) [18]; FP+3 [9]; Perception +2 [10].

Advantages: Acute Hearing +2 [4]; Combat Reflexes [15]; Discriminatory Smell [15]; Fangs [2]; High Pain Threshold [10]; Single-Minded [5]; Reduced Consumption 2 (Cast-Iron Stomach, -50%) [2]; Very Rapid Healing [15].

Perks: Fur [1].

Disadvantages: Bloodlust (12) [-10]; Disturbing Voice [-10]; Low Empathy [-20]; Unnatural Features 2 [-2].

Availability: \$144,000. LC2.

Sub-Races

Chronos Chimera (-15 points): Add Chimera [-10] and Short Lifespan 1 [-5]. \$129,000. LC1.

Chronos Bioroid (-35 points): Add Bioroid [-5], Self-Destruct [-10], and Short Lifespan 2 [-20]. \$109,000. LC1.

Eros (TL10)

45 points

A high-end pleasure bioroid with an inhumanly perfect body, plus brain, glandular, joint, physical, and bacteriological modifications to ensure it is always eager, playful, healthy, and disease-free. Grown as a professional courtesan or a rich person's living toy, the Eros can also be the basis for a devastating “Mata Hari” spy.

Attribute Modifiers: ST-1 [-10]; HT+1 [10].

Secondary Characteristic Modifiers: FP +1 [3].

Advantages: Appearance (Very Handsome) [16]; Double-Jointed [15]; Resistant to Disease (+8) [5]; Sex Pheromones [28]; Voice [10].

Perks: Alcohol Tolerance [1]; Deep Sleeper [1]; Sanitized Metabolism [1].

Disadvantages: Bioroid [-5]; Chummy [-5]; Impulsiveness (12) [-10]; Lecherousness (12) [-15].

Quirks: Attentive [-1]; Distinctive Feature (Exaggerated sexual characteristics) [-1].

Racial Skill Modifiers: +1 to Erotic Art [2].

Features: Exotic Genitalia; Sterile; Taboo Traits (Genetic Defects).

Availability: \$95,000. LC3.

Sub-Races

Versions of the Eros exist to cater to various tastes, some exotic. Three examples:

Fugu (+17 points): Its saliva and bodily fluids secrete a pleasure drug. Add Ecstasy Glands (p. 49) [17].

Furry (+5 points): This bioroid has big eyes, soft fur, large cat, bunny, or fox ears, and a tail, but lacks such dangerous animalistic features as sharp teeth or claws. Add Acute Hearing 1 [2], Fur [1], Night Vision 1 [1], and Unnatural Features 1 [-1]. \$98,000. LC3.

Gothic (+13 points): A “vampire poser” model. Its metabolism is designed to release endorphins after drinking any quantity of blood except its own. It also has retractable fangs, and can enter a deathlike trance. Change its appearance to Appearance (Handsome, Androgynous) [12] with Distinctive Feature (Pale skin and red eyes) [-1]. Add Less Sleep 4 [4], Metabolism Control 2 [10], Night Vision 2 [2], Sharp Teeth (Switchable, +10%) [2]; Minor Addiction (Blood) [-1]. \$112,000. LC3.



Februus (TL10)

64 points

The Februus is designed to function in environments heavily contaminated by hazardous materials. They might be designed as hazmat workers, colonists for polluted regions, or to inherit the earth after a global holocaust.

They possess modified lungs that filter out toxins, and are almost immune to poisons, although corrosives and certain bioactive chemicals can still damage them. Their cells are designed to be resistant to mutation, and to rapidly repair themselves. They can enter hazardous areas with minimal protective equipment, sensing directly what toxins are present in the area.

The Februus are not conventionally attractive; they have hairless, bright orange or lemon-yellow leathery skin, with thick muscles around the mouth and nose.

Attribute Modifiers: HT+2 [20].

Secondary Characteristic Modifiers: Lifting ST +2 [6]

Advantages: Discriminatory Smell [15]; Discriminatory Taste [10]; DR 2 (Flexible, -20%) [8]; Filter Lungs [5]; Nictitating Membrane 1 [1]; Regeneration (Slow, Radiation Only, -60%) [4]; Resistant to Ingested Poison (+8) [5].

Disadvantages: Appearance (Unattractive) [-4]; Selfless (12) [-5]; Unnatural Features 1 [-1].

Availability: \$94,000. LC3.

Sub-Races

Februus Bioroid (-35 points): A bioroid hazmat worker. Add Bioroid [-5], Self-Destruct [-10], Short Lifespan 2 [-20] \$59,000. LC2.

Felicia (TL10)

151 points

This expensive design resembles a lithe, anthropomorphic cat. It is built for superhuman grace, speed and reflexes, and also possesses upgraded sensory abilities. Felicias are usually employed at jobs that might demand a quick burst of activity rather than strength and staying power. They are also physically attractive, making them in vogue as athletics or aerobics instructors, dancers, personal pilots, chauffeurs, bodyguards, or even bodyguard/courtesans. Military and police forces may also employ the Felicia as aerospace pilots or hostage-rescue troopers.

There's an unintended glitch in the Felicia: after triggering an emergency-overdrive response, glandular imbalances sometimes result in mood swings and heightened appetites. This Aftermath (p. 215) effect occurs after the emergency ends, and lasts for as long as the overdrive was in use (but at least 10 minutes).

Attribute Modifiers: ST-1 [-10]; DX+3 [60]; HT+1 [10].

Secondary Characteristic Modifiers: Basic Speed +2.00 (Aftermath, Gluttony and Lecherousness, -10%; Costs Fatigue, 3 FP, -15%) [30].

Advantages: Acute Hearing +2 [4]; Acute Taste and Smell +2 [4]; Appearance (Attractive) [4]; Catfall [10]; Combat Reflexes [15]; Flexibility [5]; Night Vision 3 [3]; Perfect Balance [15]; Resistant to Disease (+3) [3]; Sharp Claws [5]; Sharp Teeth [1].

Perks: Fur [1].

Disadvantages: Extra Sleep 1 [-2]; Overconfidence (12) [-5]; Unnatural Features 2 [-2].

Features: Estrus; Tail.

Availability: \$201,000. LC3.

Sub-Races

Felicia Bioroid (-35 points): A bioroid soldier. Add Bioroid [-5], Self-Destruct [-10], Short Lifespan 2 [-20]; delete Estrus. \$167,000. LC2.

Felicia Chimera (-15 points): Add Chimera [-10] and Short Lifespan 1 [-5]. \$187,000. LC2.

Lepus (TL10)

9 points

The Lepus models are “rabbitoid” human-rabbit gene-splices designed for fast reproduction and survival on colonial worlds. ST-1, Color Blindness, and Unusual Biochemistry were unintended defects. The Lepus matures one-third more rapidly than humans (puberty around 8-9 years, fully mature at age 12) but does not age any more rapidly.

Attribute Modifiers: ST-1 [-10]; HT+1 [10].

Advantages: Acute Hearing +3 [6]; Acute Taste and Smell +2 [4]; Resistant to Disease (+3) [3]; Peripheral Vision [15].

Perks: Fur [1].

Disadvantages: Colorblindness [-10]; Lecherousness (9) (Accessibility, Only in mating season, -80%) [-4]; Unnatural Features 1 [-1]; Unusual Biochemistry [-5].

Features: Early Maturation 1; Estrus; Increased Fecundity
Availability: \$59,000. LC3.

Sub-Races

Lepus Chimera (-10 points): A sterile human-rabbit gene splice. Add Chimera [-10]; remove Increased Fecundity. \$50,000.

Lepus Bioroid (-5 points): Add Bioroid [-5]; remove Increased Fecundity. \$50,000.

Ranger (TL10)

69 points

This parahuman type depends on several extreme modifications of the basic human sensorium. The primary intent was to produce a genotype that emphasized sensory acuity, with a secondary goal of survival in almost any wilderness environment, alone and with a minimum of technical support. A magnetic-field sense was borrowed from migratory birds, and several sequences for acute hearing and smell were also added. The digestive system and metabolism were upgraded to allow the consumption of almost anything organic. The genotype’s unusual senses are not perfectly integrated into the brain, leading to irritability and chronic insomnia. Meanwhile, subtle tinkering aiming for a self-reliant attitude may have been too successful. Ranger parahumans often find employment as survey scouts, scientists, light infantry soldiers, or guides. As a race, they might be created to colonize hostile worlds.

Attribute Modifiers: ST+1 [10]; DX+1 [20]; HT +1 [10].

Advantages: Absolute Direction [5]; Acute Hearing +2 [4]; Acute Taste and Smell +3 [6]; Discriminatory Smell [15]; Reduced Consumption 4 (Cast-Iron Stomach, -50%) [4]; Resistant to Disease (+8) [5]; Resistant to Poison (+3) [5].

Disadvantages: Bad Temper (15) [-5]; Light Sleeper [-5]; Overconfidence (12) [-5].

Features: No Appendix; Taboo Traits (Genetic Defects, Mental Instability).

Availability: \$119,000. LC3.

Sub-Races

Ranger Bioroid (-25 points): A cheaper mass-produced biogenesis version. Add Bioroid [-5], Self-Destruct [-10] and Short Lifespan 1 [-10] to either version. \$94,000. LC2.

Ranger Chimera (-15 points): Add Chimera [-10] and Short-Lifespan 1 [-5]. \$104,000. LC2.

Fenris (0 points): This has lupine facial features, large ears, fur, and a short bushy tail. Add Fur [1], Sharp Teeth [1] and Unnatural Features 2 [-2]; same availability, and can be combined with the bioroid or chimera versions.

Spartan (TL10)

46 points

The Spartan parahuman has hormone-boosted muscles, a reinforced skeleton, reduced pain response, and sharpened reflexes for emergency situations. They’re usually used as genetic soldiers, specially-bred cops, or colonists on harsh worlds . . . and some Spartans are strong enough to use some crew-served heavy weapons as if they were rifles.

Attribute Modifiers: ST+3 [30].

Secondary Characteristic Modifiers: Lifting ST +2 [6].

Advantages: Combat Reflexes [15]; High Pain Threshold [10].

Availability: \$96,000. LC3.

Sub-Races

Spartan Bioroid (-25 points): A cheap “mass produced” bioroid soldier. Add the Bioroid [-5] plus Self-Destruct [-10] and Short Lifespan [-10]. \$51,000. LC2.

Tek-Rat (TL10)

-42 points

Using a mix of human, raccoon, hamster, and possum genes, the Tek-Rat is about 2’ tall, with a rodent-like face, prehensile tail, and marsupial pouch it uses for young or tools. It has undergone TL10 eugenic modification for a higher IQ and ST to counteract its small size, and its cardiovascular system is also somewhat more efficient (giving an extra hit point).

Attribute Modifiers: ST-6 [-60]; DX+1 [20]; IQ-1 [-20].

Secondary Characteristic Modifiers: HP +1 [2]; SM-2.

Advantages: 3D Spatial Sense [10]; Acute Hearing +1 [2]; Acute Taste and Smell +1 [2]; Extra Arm (Extra-Flexible, +50%; No Physical Attack, -50%) [10]; Payload 2 [2]; Sharp Teeth [1]; Unnatural Features 2 [-2].

Perks: Fur [1].

Disadvantages: Increased Consumption 1 [-10].

Availability: \$50,000. LC3.

Sub-Races

Tek-Rat Bioroid (-15 points): A commercially-manufactured bioroid worker version. Add Bioroid [-5] and Self-Destruct [-10]. \$36,000. LC3.

Tek-Rat Chimera (-15 points): Add Chimera [-15]. \$36,000. LC3.

CHAPTER THREE

MAN'S BEST FRIENDS

Guys, you won't believe this! You know we tried to scope GenPacifica's Deepstralia III, got chased off by the security? Well, second time's the charm: We got Tegan's sonofish to distract their war-dops, then went to max on the aquasleds. The Pacifica vent mine's as big as rumored, but get ready: Their construction workers ain't seal bioroids – they're genemod octopuses! I'm not raptured, gridfriends; these are definitely engineered bioroids, they were working with their tentacles. And their heads – brrr. Like, an octo with a face, you know? Check out my site for the movie! Better hurry, though. My sysop says she's getting some threatening email from GenPacifica.

– Aquagrml,
alt.ocean.development.korporate.otaku

We raise crops and livestock for food, chemicals, drugs, and materials. Researchers will always attempt to make the organisms we use healthier and more efficient in the ways they produce things. We can also engineer plants and animals for completely new uses.

PROCESSED BIOPRODUCTS

Many of the materials we use are biological in origin. By modifying the organisms that make them, we can produce materials more efficiently, in greater quantities, or with improved properties. Designers can even come up with new materials and the creatures or plants to make them.

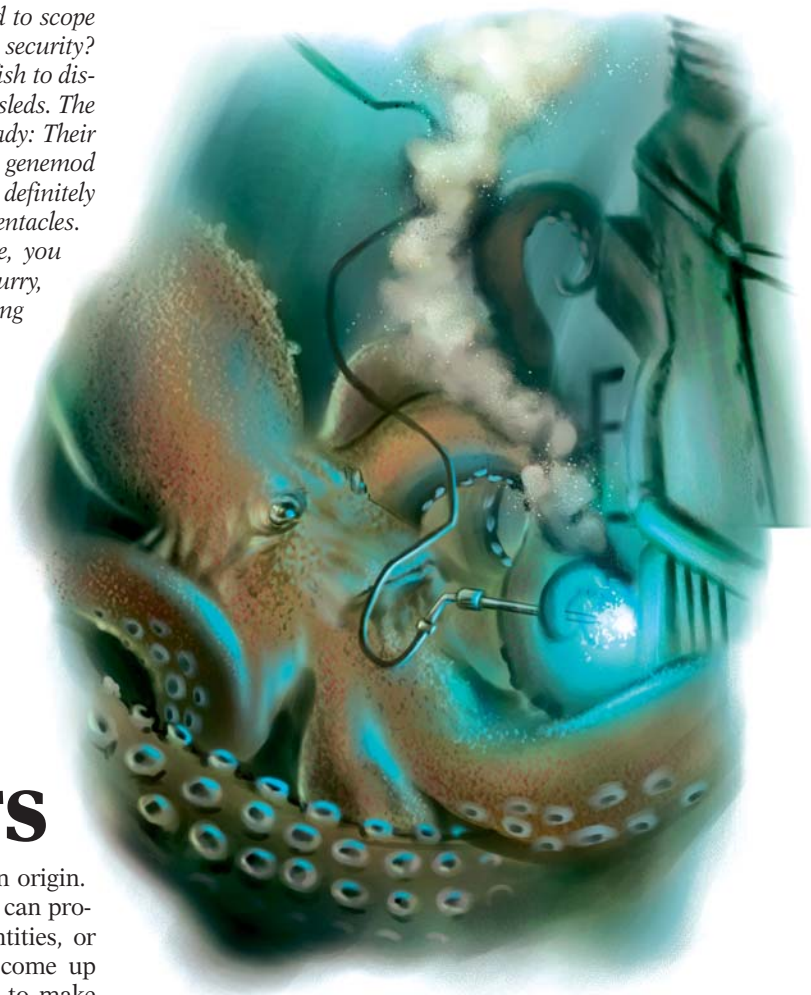
Fibers and Wood

Natural fibers include wood as well as cotton, flax, and hemp from plants, and silks and wools from various animals. These are used for clothing, shelter, ropes, sails, paper, and many other things. Fibers with high tensile strength can be used to weave fabrics capable of stopping bullets or other weapons; linen was used for shields and padded armor in the Middle Ages. Wood has always been versatile, but it will become even more so when engineered to

be faster-growing, stronger, and lighter. Building materials may even be grown to shape; see *Residential Trees* (p. 80).

Oils and Waxes

Some plants and animals produce useful oils and waxes, from vegetable oils to lanolin and beeswax. With some genetic tweaking, these organic compounds can be made useful as fuels, biodegradable lubricants and detergents, cosmetics, and water repellents.



Polymers

Not traditionally associated with biological materials, polymers can nevertheless be produced from proteins, forming horny materials like keratin and chitin. Engineers may design proteins that polymerize into plastics with desirable properties, then put genes to produce them into various plants and animals. An advantage of protein-plastics is that they are biodegradable, allowing easy recycling rather than polluting the environment.

Ceramics

Bone, silica, and calcium carbonate are some of the ceramic materials produced by organisms. Others could be crystallized out of raw chemicals by biological processes. Engineered organisms could be designed to grow everything from ultra-pure crystals for use in precision electronics up to bulk construction material. They could also be used to synthesize artificial gemstones, both crystalline such as diamond and amorphous such as opal. Other ceramics with properties based on precise microscopic structure, such as light refraction, could also be grown organically.

BIOLOGICAL CONTROL

Humans have been fighting pest species since prehistoric times. We pull up weeds in our gardens, spray insecticides on our crops, lay traps for mice, and scrape floating plants off our waterways. These labor-intensive and sometimes unsafe methods are never effective for long.

Biological control uses organisms to do the work of fighting pests for us. (Another method of controlling pests is to modify the pests themselves; see *Genetically Defective Vermin*, p. 87.)

The cost of species used for biological control is highly variable. They may be released en masse by government programs, or purchased by individual farmers or residents. A box of common insect agents such as ladybugs or lacewings costs \$20-\$100. Each contains a few thousand eggs or a few hundred adults, suitable for treating up to an acre of land. Engineered species would cost more.

CONTROL USING EXTANT SPECIES

The ancient Egyptians practiced biological control when they realized that keeping cats could hold mouse populations down. Some early Asian farmers encouraged ants to live amongst their crops, to protect them from other insects. Modern biological control began in 1762 when colonists successfully transported a species to a foreign location specifically to reduce vermin: mynah birds to control locusts on Mauritius. Scientists of 19th-century Europe controlled several crop-eating insects using parasitic wasps and predatory mites, and developed the principle of transferring native predators to control pests introduced into new areas. This technique has since been used many times to control both plant and animal pests, using agents as varied as insects, internal parasites like nematode worms, and fungi.

Using existing species as biological controls is attractive for a number of reasons. It is relatively cheap, as the animals breed themselves in the wild and spread to cover nearby infested areas. It also avoids the use of chemicals, which avoids any problems of toxicity in the environment or final product, and makes the products more attractive to consumers.

Discovering a suitable biological control agent takes more than just finding a naturally occurring predator on

the pest organism. If released into a new ecosystem, such a creature could wreak havoc on the local native species as well – or instead of! – the desired target. Several attempts over the years have backfired in exactly this way: mongooses introduced to Hawaii to control rats have exterminated many bird species. Ideally, a control species will not prey on any species other than its intended target, and die off as the pest is brought under control. Nowadays, exhaustive testing is undertaken before releasing a control species to ensure this. The problem is, most candidates don't measure up.

ENGINEERED CONTROL SPECIES

Engineering is an obvious way to produce species more satisfactory as biological control agents. Usually the trait needing modification will be the tendency to attack species other than the one to be controlled. This might be achievable with purely behavioral modifications, but a more reliable approach is to engineer a reliance on the target species or an aversion to other potential targets. The first method relies on finding some protein or nutrient supplied only by the target organism, and engineering the control species to die without it. The second method is more difficult as it requires finding substances in all other possible targets and engineering them to be poisonous or distasteful to the control organism.

CONTROL USING MICROORGANISMS

All of the principles discussed above can also be applied to biological control using microbes. There are additional considerations, however. The naturally occurring disease myxomatosis was used to control rabbits in Australia, until the remaining rabbits spread myxomatosis-resistant genes throughout the population. The next stage was to be a controlled release of rabbit calicivirus, but the virus escaped a highly secure experimental quarantine area on an offshore island in 1995 and spread to every state on the mainland within a few months, before anyone knew if the virus could affect native mammals.

This example demonstrates the hazards of using a disease for biological control. Any pests that survive the first wave of infection are likely to pass on resistant genes to later generations, reducing the long-term efficacy of the control. And dealing with an infectious organism requires stringent safety precautions, with any breach having serious consequences.

The potential dangers of using natural pathogens can be reduced by engineering diseases to target only the desired species. These would be similar to target-seeking pathogens (p. 115), but homing in on the genome of an entire species rather than subsets of it.

ENVIRONMENTAL CONTROL

Organisms can also be used to control non-biological aspects of the environment. An example is the planting of

trees to stabilize loose soil against landslides, or to prevent soil erosion along riverbanks. Plants can also be used to slow water flow, encouraging sedimentation and the production of solid land in wetland areas and tidal river deltas. Some species can even adjust the local climate: dark algae spread over ice increases solar energy absorption and can melt otherwise permanent snow cover; engineering the albedo of tree foliage could make large areas of land warmer or cooler. These techniques would be an important part of terraforming a hostile landscape, after microorganisms have produced an atmosphere suitable for them – see *Terraforming* (p. 109).

Although most examples of controlling the environment in this way use plants, certain animals are also suitable. Coral can be encouraged or engineered to grow into breakwaters to protect coastlines from erosion.

PLANT TECHNOLOGY

Humans have been growing plants ever since Neolithic people noticed plants grew from seeds and decided to try growing food near their settlement. Apart from a few genuine innovations such as crop rotation and fertilizers, agriculture up to TL7 has used the same basic technologies, albeit writ larger as mechanization has made the tilling of fields easier. The future will be very different.

PROPAGATION

The growth of new plants from old is the most important necessary step of agriculture. Several methods are used.

Seeds

Most plants reproduce sexually, either by dispersing pollen (typical of flowering plants) or self-fertilizing (most grains). This forms seeds, which later develop into embryonic plants. Since seeds are small and more or less durable, they can easily be transported by humans and planted where required. For non-self-fertilized seeds, the gamble of mixing genes means that the next generation of plants may not inherit desired characteristics of the parent plants. This can be overcome if the grower can be sure that male and female gametes come from plants with the same genome – either the same plant or a pair of clones.

Even without engineering the seeds, treating them in various ways can produce useful products:

Coated Seeds (TL1): Seeds can be coated in material as low-tech as clay (to prevent birds eating them) to tailored herbicides (TL7) designed to kill competing weeds without harming the seed. Temperature-activated polymer coatings (TL8) allow farmers to plant seeds before the growing season begins, ensuring the seeds are protected from cold and then germinate as soon as the weather is suitable, rather than allowing the weather to control sowing date. Farmers may coat their own seeds or buy precoated seed from a supplier. Precoated seeds cost 10-50% more than uncoated.

Polyculture Seed Mix (TL7): For much of agricultural history, crop plants have been grown in monoculture – mass plantings of one species. This depletes soil fertility and makes them susceptible to pests and diseases that attack the species, like that which caused the Irish potato famine. Natural plant communities are polycultural, with many species commingled, resulting in better defense against pests and natural renewal of soil nutrients. Blending a viable mixture of useful crop plants and supporting species requires extensive research, but the resulting mix produces a sustainable long-term crop that needs little to no pesticide or fertilizer. Currently this is only practical for gardens that can be tended by hand because of the difficulties of automatically harvesting multiple species, but research may develop mixes suitable for large-scale commercial agriculture. Such seed mixes reduce agricultural labor and expense, and would be invaluable to colonies if tailored to local conditions.

Cloning

Plants can also reproduce asexually by growing and separating into a new organism – the equivalent of cloning. Horticulturists do this artificially by taking *cuttings*: slicing off a branch or shoot and planting it so that it grows new roots. A related technique is *layering*: wrapping material around a growing branch to encourage it to develop roots, and cutting it off for replanting once the roots have formed. Finally, plants can be cloned by *root separation*: dividing the root mass and letting each section grow into a new plant.

These techniques require no technology beyond a knife, so plants are easy to clone compared to animals. An advantage over using seeds is that cloned plants will have the same genetic growth patterns and resistances to disease as the parent. A risk of making thousands of identical copies, though, is the reduction of overall genetic diversity, which can make a species more vulnerable to pests or diseases that do manage to attack it.

Grafting

This is a technique in which a cutting, or *scion*, is attached to a different plant, known as the *rootstock*. The two bond together and the rootstock provides water and nutrients for the attached scion. The advantages of grafting come from the combination of desirable properties of the rootstock, such as size or hardiness, with those of the scion, such as high quality fruit or flower production. Without gengineering, only closely related species can be grafted together successfully, but this can provide such things as a tree that grows both lemons and oranges.

HYDROPONICS

This is the growing of plants without soil, by suspending their root systems in a liquid solution of nutrients. Physical support for the plants can be provided either by a loosely packed inert medium – such as sand, spun ceramics, or natural fiber matting – or by a solid plate with holes through which the roots can grow. The nutrient solution is circulated past the roots or sprayed onto them in a mist,

with the required chemicals being replaced as the plants take them in. The solution must be aerated too, since roots need air as well as water. All plants can be grown in this way, though some are more successful than others.

Hydroponics provides a controlled environment for growing plants, without worries about soil-borne pathogens or weeds. In a sealed space, airborne pests can be eliminated, but fungal, algal, and waterborne pests can be a problem. If a hydroponics expert (Farming/TL7+ at 12+) is available, the plants can be grown closer together than in soil, meaning greater productivity in a given area. And because the flow of water is controlled without soil runoff, hydroponics requires only 5% of the water of conventional irrigation. All these factors are crucial for enclosed environments such as spacecraft or colonies on hostile worlds, as well as more prosaic uses such as providing cheap “natural” food.

Cost: One gallon of concentrated hydroponic nutrient solution costs \$20. Diluted with 500 gallons of water this grows enough crops to produce 50 person-days of food.

ENGINEERED PLANTS

The full potential of plants as useful resources becomes available when gengineers apply their techniques to them.

BIOTECH FOODSTUFFS

Besides traditional crops, biotech can produce many cheap alternatives:

Algae (TL7) are easily cultured in natural or artificial ponds or lakes, and require only very simple chemicals, as they get most of their energy from sunlight. Genemod algae could produce yields several times greater than wheat at very low costs, and could be easily harvested and flavored.

Mycoprotein (TL7) is a high-protein, high-fiber “synthetic food” manufactured by the ton from mold cultures. Much cheaper than meat, but just as nutritious, mycoprotein can be grown using simple starches, or even nutrients derived from the waste products of pulp and paper, cheese-making, and other industries. Raw mycoprotein is safe to eat but utterly bland. It can be modified to look and taste like a variety of foodstuffs, such as meat or fish.

High production start-up costs and consumer resistance in favor of “real food” have limited algae’s and mycoprotein’s acceptance as human staples, but both are in use as animal feed and food additives. If future overpopulation makes raising cereals, fish, or animals too expensive, they may take over, forming a staple diet to feed the hungry masses. Mycoprotein may also be a good choice for spacecraft “food vats.”

One problem with these foods is that they do not contain the full range of dietary nutrients required to maintain health. If they are eaten without other food such as fruit and vegetables, consumers will develop vitamin or mineral deficiency diseases like scurvy or beriberi. This can be overcome

with vitamin supplements (p. 157) or hydroponic vegetables (above).

CROP MODIFICATIONS

Drought-resistant rice is all well and good, but the real money is in making our customers not just want our product, but need it. Sure, we’ve been upping the nicotine levels in tobacco as far as we can through selective breeding, but let’s see just how far we can push our product’s addictiveness. And if the feds start breathing down our necks, we’ll tone it down here and pump it up overseas . . .

– Gibson Wallace, CEO, Quarticum Ltd.

Farmers and scientists have long used eugenic procedures to produce crops with higher yields or faster growth rates. Gengineering will speed up these improvements, but it can also offer more exotic biomods. A number of GM (genetically modified) crop enhancements are listed below. These can be combined; e.g., plant-cloning of especially healthy, climate-adaptive, nitrogen-fixing beefapples.

Disease-Resistant Plants (TL8)

Gengineers have already succeeded at introducing genes into several crop plants to make them tolerant of germs, fungi, and chemicals. At TL8 these are usually disease-specific, aimed at resisting common scourges. A common engineered trait is resistance to herbicide, so that chemicals can be used to kill weeds without affecting the crop. Broad-spectrum disease resistance (TL9+) is possible, allowing crops to be protected against unknown threats or even engineered bioweapons.

Market-Friendly Crops (TL8)

Food plants may be redesigned with the supermarket shelf in mind. Possibilities include longer shelf life (adding genes designed to block ripening enzymes), tougher skin (to reduce bruising and allow mechanical picking), and antioxidants that would keep fruit from going brown when exposed to air. At TL9+, shape may be customized: How about square fruit for easier packing? Designer shapes and flavors would be popular with chefs or showoffs.

Flowers, lawn grass, and household plants may be gengineered with exotic aromas (apricot blossoms), colors (electric-blue roses), or shapes. Some may have bioluminescent genes spliced into them. The market for exotic flowers may be huge!

Symbiotic Plants

If bacteria can live in symbiosis on a human, why not algae, or even vascular plants? Needing sunlight, they would grow on the skin or just beneath it. Algae would be solar powered versions of symbiotic bacteria (p. 120), performing many of the same functions while giving a green, red, or brown cast to the skin. Plants with root systems embedded in living flesh could provide cosmetic effects (grass hair), insulation, or protection (DR 1 to 2), but few other effects.

Nif Plants (TL8)

Cells require nitrogen to build proteins. While animals get nitrogen by eating things, plants extract it from “fixed” nitrogen (ammonia and nitrates) in soil. A major limit on crop yields is infertile soil that lacks nitrogen. Fertilizers add nitrogen to soil, but they are expensive, and many are dependent on oil supplies.

Some microbes that live on the roots of legumes can extract nitrogen from the air and create ammonia, nitrates, or other compounds, thus fertilizing the soil. Farmers have known for centuries that planting legumes helps restore depleted soil. Current research is engineering similar microbes on other species, such as rice or wheat, to fix nitrogen better. By TL9, a universal nitrogen-fixing (“nif”) bacterium capable of symbiosis with *all* plants may be developed, or nif genes could be inserted into crop plants themselves!

Nutricrops (TL8)

Plants may be genetically altered so that their stored proteins (in cereal seeds or fruits) have more of the essential amino acids that humans and domesticated animals require. This would mean that fewer “nutritional additives” would be needed in animal feed, or foods that are packaged for human consumption, reducing agribiz costs. A variant is “fad crops,” designed to appeal to followers of the latest fad diet.

Pest-Resistant Plants (TL8)

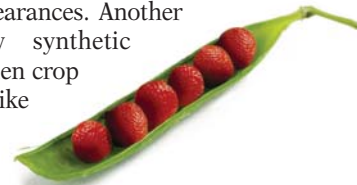
Insects lay waste to billions of dollars worth of crops every year, or force the use of expensive (and sometimes environmentally damaging) chemical pesticides. By splicing in genes from a bacterium or virus that makes a particular insect sick but which has no effect on other species, plants can have built-in insecticides targeted against their natural enemies. This has already been done with some tomato, cotton, and potato plants, making them resistant to particular caterpillar species.

Environment-Tolerant Crops (TL8/9)

Vast tracts of land are presently useless for agriculture due to insufficient water, high salinity, or extreme temperatures. One solution may be to make the deserts and tundras bloom without irrigation or hothouses. Genes regulating osmosis, respiration, and transpiration may be tinkered with, following the examples of harsh-climate species. The result will be crop strains adapted to drought or other harsh conditions. Frost and drought tolerance are already being engineered into crops, and heat tolerance will surely follow. Tolerance of more water (swamp cactus, anyone?) is another possibility. Metabolic modifications could also enable plants to cope with too little or too much sunlight or carbon dioxide. This may be vital if environmental catastrophe looms.

Chimera Plants (TL9)

After crop yields are improved, further transgenic gene splicing and a quest for fad food may lead to exotic, cross-species genemod plants, like bananawheat or even beefapples, with unusual flavors or appearances. Another possibility is totally synthetic species, or terrestrial/alien crop genesplices that taste like nothing on Earth.



Non-GM GM Crops (TL9)

Sometimes it is desirable to have the products of a genetically modified crop not contain the modified genes of the parent plant. Using self-modifying genetic code (p. 14), it is possible to rewrite or excise any artificial changes to the genome when growing cells are destined to become end products: food or seeds. This allows a food crop to be modified for improvements in its growth, while still producing a crop that contains genetic material identical to the unaltered species. Such plants have the advantages of genetically modified crops, while being more acceptable to consumers wary of eating a non-natural product. (Some consumers may still object on principle, though.)

Another use for this technique is to make sure enhanced crops produce seeds that revert to the baseline plant, rather than containing proprietary (and profit-making) genemods. A gengineering company using this tactic can claim that its plants produce viable seeds, while still protecting its revenue stream.

Manna (TL10)

Sophisticated engineering may produce a single food crop that can fulfill all human nutritional needs! This would be a boon for overpopulated worlds, since cultivating one crop is easier than many. Even if it tastes good, eating the same thing will get boring after a while, so designers may build many different flavors into the plant. At TL11+, food crops become less important, as nanotech “protein factories” can synthesize food from basic chemical compounds.

PLANTS AS MATERIALS PRODUCERS

Plants have long been used as sources of raw materials, from fibers like hemp and cotton to wood for construction. Engineering plants can make them even more useful.

Industrial Plants (TL8)

Researchers have already spliced bacteria that produce normally expensive biodegradable plastic into fast-growing plants; with “plasplants,” it should be possible to harvest such environmentally friendly plastics at a small fraction of their usual cost. In a similar vein, oilseed crops (like soy beans and rapeseed) are being engineered to produce oils that can be used to make environmentally friendly lubricants and detergents. At TL9+, there are numerous possibilities. How about two-year-growth trees with easy-peel bark for the wood and paper industry, or long-fiber, seedless cotton with the dye already engineered in?

Pharm Plants (TL8)

Like bacteria, transgenic plants can be engineered to yield medically useful proteins (usually, a certain amount of processing is required). Already, trials are underway with plants designed to produce serum for treating burn victims. At TL9+, plants may produce designer proteins that can be used to manufacture various “wonder drugs.”

PLANT BIOWEAPONS

Plants can be engineered for offensive or defensive purposes. Virulent weeds can be made to choke enemy crops or overgrow installations. These can be combined with damaging capabilities such as poisonous thorns. One of the more frightening types of plant weapons uses pollen or spores designed to be toxic. As these are produced in massive quantities and fill the air, they could render large tracts of land uninhabitable – then spread on the wind to infest new areas.

Bioweapon Detectors (TL8)

Plants can also be used to *fight* bioweapons (and chemical weapons). Engineers can make plants sensitive to various pathogens and chemicals, so that they die or change color when exposed to minute quantities. Such plants can be used for street decoration or in parks – any public space

where an attack might be likely. Since people are used to plants, these would cause less concern than artificial biosensors. Detector plants could also be spread over wide areas relatively inexpensively once developed.

Blood Roses

These TL9 transgenic roses have poison sacs and more – and tougher – thorns than usual. Someone pushing through blood roses will take 1d-2 cutting damage per yard of distance traveled. If any damage penetrates DR, a HT roll is required. Failure means taking 4d toxic damage after a 10 minute delay. The roses retain their poison after being cut (losing one die per day). Someone handling them must make a DX+1 roll to avoid being jabbed. A single, cut blood rose costs \$50; seeds are \$100 each.

RAPID-GROWTH PLANTS

Some plants grow very fast – bamboo can gain three feet per day in ideal conditions. But most are relatively slow, and speeding up their growth is a logical goal of engineering. When plants can be grown really quickly, they can be used for many purposes.

Residential Trees (TL10)

Trees could be engineered to grow a huge, thick trunk, with room for hollow spaces inside it and complex, modified roots capable of carrying water for use by the occupants. Engineered seeds to grow a house-sized tree might cost \$5,000, with the tree being ready within two years. Remodeling and decorating the interior (probably installing “cybernetic” plumbing and heating) would cost an extra \$15,000, but even without this, the tree would be useful as a survival shelter. Real estate to grow the tree on is extra! In a similar vein, “shelter seeds” which yield giant gourds in mere weeks may be available; they would cost \$500 each and grow a DR 1, 50 HP gourd large enough to shelter four people.

World Trees (TL11)

Away from the constraints of gravity, and provided with enough resources, there is no reason a plant could not grow to immense sizes. Sunlight is plentiful in space, but sources of nutrients are few and far between. Freeman Dyson suggested growing gigantic trees on comets, and Larry Niven’s *The Integral Trees* postulated a stable ring of gas and debris in orbit around a star, and the miles-long trees that might grow in it. (A gas torus around a star or planet would slowly leak to space, but might be kept in equilibrium by replenishment from a planet or moon, respectively.) In such an environment, huge trees could be engineered to float through the microgravity gas. They would provide anchor points, habitats, and resources converted from the diffuse atmosphere by solar energy.

Suitable raw materials are more commonly found in an asteroid belt or planetary ring system than a gas torus. Planetary rings are ideal, as the particles range from smoke to boulder sized and are relatively close together. A plant within a ring system could spread tendrils to gather this material to use as chemical resources. The distances between asteroids in a belt are greater, but a single asteroid would provide more material and allow a plant to grow larger.

Even on a planet, gravity does not prevent plants from growing horizontally. Voracious plants may spread over vast areas. Unless stopped by competitors or unsuitable geography, a plant may eventually encircle a world. It could transform the planet into almost anything, and colonizers may seek to herbiform worlds rather than terraform them.

ZOOGENETIC PLANTS (TL12)

Taking self-modifying genetic codes to an extreme, a plant could conceivably grow a structure containing genetic

material that would allow it, once detached, to live an independent existence – as an *animal*. A likely method would be for the plant to grow something like a seed pod, in which it produces cells with animal genomes and provides a suitable environment for them to develop into a viable creature. The seed pod is then an artificial egg or womb for the animal, which can be born when it is ready.

Animals grown in this way could be bioroids or – more difficult but possible given high enough technology – members of a separate species capable of breeding and reproducing by themselves. It would even be possible to grow members of a pre-existing species, either with unique random genomes or clones of a given individual. A human colony on a new world may be able to scatter some seed and use nothing but the power of sunlight, water, and a few trace chemicals to *grow* new colonists!

An interesting option is for the resulting animals to reproduce by generating seeds that grow into plants, resulting in an organism that alternates between generations from a plant phase to an animal phase – see *Botanogenesis* (p. 88).

ENGINEERED FUNGI

Fungi are not plants, but form a separate kingdom of their own. For the most part they are tiny threads that only become apparent when they release reproductive spores from fruiting bodies, which are known as mushrooms in some species. They break down organic materials into simpler molecules, providing the decomposition part of the ecological cycle. While some fungi digest dead matter, others parasitize living organisms. These properties can be put to use by engineers. The cost of engineered fungi can vary greatly, so no specific costs are given. See *Purchasing Microorganisms* (p. 105) for general guidelines.

Drug Factory Fungi (TL7)

Several species of fungi produce hallucinogenic and other psychoactive compounds, or natural antibiotics like penicillin. Engineering these for improved production and new compounds is an important area of research.

Bioluminescent Fungi (TL8)

Several species of fungi have natural bioluminescence. The genes that produce luminescent chemicals can be spliced into other organisms to make them glow. Alternatively, the fungi can be modified to grow where required, even into symbiotic forms that generate patches of light on the bodies of animals. At TL8 this is unimpressive as the glow is dim, restricting it to commercial applications, but by TL9 it should be bright enough to be popular with customers.

Food Fungi (TL8)

Many consider mushrooms a delicacy, but some species are rare and difficult to cultivate. Cultured black truffles

and matsutake will taste the same but be much cheaper. At the other end of the scale, unicellular yeast-like fungi could be engineered into an easy-to-grow complete food source for starship crews or overpopulated billions in future dystopias. It might be made to taste good, or it might just taste like yeast.

Bioweapon Fungi (TL9)

Fungi secrete enzymes to dissolve organic matter. Some are so powerful they can dissolve plastics, ceramics, and even metal. Engineered fungi can be targeted to attack particular materials, in order to recycle waste products that do not decay naturally, or as an offensive weapon against enemy materiel. Mechanical and electronic devices don't operate too well when a fungus is dissolving the components from the inside. The fungal spores can be spread in the same ways as anti-materiel bacteria (p. 188).

Simple molds can also be bad enough to make property worthless. Boosting a mold's ability to survive drier climates and resist removal attempts will make it a viable long-term weapon against buildings and vehicles.

Parasitic Fungi (TL9)

Another offensive use of fungi is to enhance parasitic traits and use them as biological weapons. Fungi are perfect for attacking and digesting living plants, but can also cause problems for animals, creating annoying, disfiguring, or fatal infections. Spores of a herbicidal fungus released on an enemy's crops is more efficient than chemical spraying, as the parasite will reproduce by itself and spread to infect other areas – although the user must be sure to have crops resistant to his own fungus.

Fungal Infonets (TL10)

Transgenic sequences can grow neural tissue within fungal threads, allowing them to act as conduits for electrochemical signals. This means fungi can build “wires” and “circuits” on and within any medium in which they can grow – which is just about anywhere. By planting such a fungus, one can grow circuitry in places where building it by more intrusive means would be too difficult or too noticeable. Special nodes in the fungus allow connections to be made to conventional electrical circuitry, or other organisms that can send and interpret signals through the fungal net.

Fungal Surveillance Net (TL11)

With their ability to grow on anything and their tendency to be ignored or overlooked by people, fungal infonets make ideal infiltration organisms. Further gengineered enhancements can add organs sensitive to light, sound, and chemical stimuli, turning them into organic surveillance systems that can be installed simply by spreading spores.

Smart Fungi (TL11)

By concentrating neural tissue into distributed processing nodes, a fungal infonet can be modified to allow a more coordinated reaction of the entire organism to local stimuli. Although a far cry from true intelligence, this gives the fungus rudimentary problem-solving capability and allows it to seek particular targets to grow into and digest. When combined with acidic or parasitic properties, this produces an insidious biological weapon.

Intelligent Fungi (TL12)

Further enhancements give fungi neural processing centers and problem solving capabilities similar to sponge computers (p. 29). Although sponge computers are likely to be more generally useful, fungal versions may find use in applications where other fungal properties are desirable. They can grow almost anywhere there is sufficient moisture and organic material, and can be combined with a surveillance role, for example.

GENGINEERED INSECTS

An insect can be altered and conditioned to transform it into a useful tool, or even a form of organic robot. All references to “insects” below can be taken to also refer to other small arthropods, like spiders.

HELPFUL INSECTS

Although insects can be vectors of disease for humans and livestock, they are also useful and form an important part of an ecosystem. Reducing the numbers of pest insects can have undesirable side effects on populations of other organisms, and shows diminishing returns as the population drops. Instead, the insects could be gengineered to be incapable of transmitting diseases. A dominant gene that kills malaria parasites so that a mosquito cannot transfer them to a new host would spread rapidly throughout the population, particularly if combined with genes that make the modified insects more successful reproducers, or that change the genetic inheritance ratios of their gametes.

Enhanced Silks (TL9)

Natural insects already produce organic materials with mechanical properties exceeding those of many manufactured materials. Silk from spiders, caterpillars, and other insects can be spun into useful and beautiful fabrics. The insects can be gengineered to make silk in greater quantities or with enhanced strength, so that it can be used for industrial purposes.

An example of enhanced silk is *arachnofiber*. This material is used for off-the-shelf TL9 ballistic suits and gloves (p. B284), possessing 1.5× the DR of TL8 ballistic materials. Arachnofiber ropes are stronger than nanofiber ropes of the same thickness (see **GURPS Ultra-Tech**), but more expensive:

3/16” diameter rope: Supports 1,500 pounds. 10 yards of rope: \$10, 0.25 lbs.

3/8” diameter rope: Supports 6,000 pounds. 10 yards of rope: \$40, 1 lb.

3/4” diameter rope: Supports 24,000 pounds. 10 yards of rope: \$160, 4 lbs.

This is the safe working load. Strength doubles each TL after introduction. Theoretical breaking strain is five times as great; if exceeding safe load, roll vs. the rope’s HT 12 at -1 per multiple of working load whenever it is stressed to see if it snaps.

INSECT BIOWEAPONS (TL9)

Insect bioweapons are usually stored as vials of eggs and released into still water; in a few hours, days or weeks, they will hatch into tens of thousands of insects.

An area might be seeded with biting insects, such as horseflies or blackflies. Multiple bites cause irritation (-1 on DX and IQ until treated) and prevent anyone from getting any sleep (resulting in fatigue). A sealed suit or the Sealed advantage protects against this.

Other insect bioweapons might be given more subtle targets. While sending genemod moths with a programmed desire to eat the enemy’s uniforms is probably more an exercise in whimsy than anything else, a plague of unseasonal pests that eat crops or get into stored grain is no laughing matter, especially if they’ve been altered to resist the usual pesticides.

For greater lethality, insect pests could be infected to carry genemod plagues dangerous to humans or other animals. Often, bloodsucking, winged insects are chosen, such as mosquitoes (which can already carry several diseases). In game terms, anyone traveling through an area infested

with plague-carrying insects is treated as being in a disease-ridden area (see *Contagion*, p. B443); roll at -2 if they lack appropriate repellent, insect-resistant clothing or force fields.

Genetic modification can be used to make an insect bioweapon much more useful. The insects could be designed so that they will not attack if they detect certain chemical cues – which are often odors below the human olfactory threshold. That way, you can protect your own people with a specialized form of repellent.

For even greater precision, insect weapons could be programmed to home in on a specific chemical cue and only attack targets that give it off. This is easy if the enemy are another species, but if (for instance) the enemy uses a particular food, lubricant, or laundry detergent and none of the local civilians or your own people do, then you can engineer your insects to go after them and leave everyone else alone. For the enemy to discover what was happening, they would have to first trace any plague to the insects, dissect an insect to understand what molecules it is reacting to, then correlate this with the odors of all their equipment and supplies. Even with chemical sensors and computer analysis, this could take weeks. A more trial-and-error approach would be to leave out certain supplies to see if the insects are attracted to them in the absence of humans.

Another modification that could make insect weapons nastier is to redesign them to be resistant to certain common types of insect repellent, or to have pan-specific poison resistance. A pesticide that kills any insect can be engineered, but this may fatally damage the ecosystem (killing beneficial insects or plants) and have toxic short- or long-term effects on human health as well.

The best ways to deal with genemod insects may be swarms of engineered defensive insects, target-seeking viruses, tiny microbots, or nano-machines.

Insect Agents (TL9)

An insect agent is an insect or arachnid altered by cybernetic implants (and sometimes gengineering) to make it an effective covert-operations device. Insect agents are useful for spying, sabotage and assassination.

The insect's genes are tinkered with to make it vastly more intelligent within a limited sphere. While it is IQ 1, it can perform a specific, preprogrammed mission as if it were IQ 6. The engineering includes a biological clock, allowing the insect to perform actions (such as returning to its owner) at specific times. Further modifications permit it to receive and transmit signals, usually via tiny infrared "pits" or modified pheromones; organic radio (range one mile) is possible at TL10. An insect agent does not have cybernetic implants – in fact, that is its main advantage: as a totally organic construct, it doesn't show up on sensors that detect power sources or metal.

Insect agents are controlled by insect directors (see below), which provide a limited ability to communicate with them. They can be given very simple orders, provided

these are unambiguous and within the capabilities of a trained, IQ 6 animal. However, the insect can't be programmed with more than one mission at a time. In general, an insect can be programmed to travel to a landmark or search for a target object it is capable of recognizing. If it finds a target, the insect can then follow it, mark it with pheromones, bite it, deposit a payload upon it or, if the target is tiny enough for the insect to carry, retrieve it.

A major limitation of insect agents is their limited ability to recognize things. In general, an insect will recognize its owner and can be programmed to recognize up to two other things during a mission; for instance, a target building it is to fly to and a person or object it is to find within that building. An insect director can transmit images of specific way stations and targets to the insect along with mission instructions.

Insect agents have an extremely limited ability to communicate with their owners. They can basically give yes-or-no answers to very simple, mission-related questions such as, "Did you complete your mission?" If in contact with the insect director, they can also upload limited sensory perceptions related to their mission, such as sensory "snapshots" of the seconds before, during and after the objective is reached, along with a general impression of the route taken to the target. These can be experienced directly by anyone accessing the insect director software via neural interface, and will be extremely disorienting – with strange insect-eye views and olfactory cues – but perhaps useful (make an IQ-4 roll to get blurred sensory impressions from it; robots add +4). Alternatively, the computer software can try to overlay it on a map and thus find out where the insect has been.

Insect Director (TL9)

This is a small peripheral, usually attached to a portable computer or built into a robot or suit. The user can key in or speak simple commands, which are translated into infrared, audio, or chemical signals that can be understood by the gene-altered sensory and nervous systems of an insect agent. The director can also receive chemical, audio, or infrared reports from the agent, and translate for the operator. The communicator has a range of only one yard, and works best if the insect is actually sitting on it.

Programming an insect agent with a mission takes five minutes. The GM can make a secret Computer Operation or Electronics Operation (Surveillance) skill roll to see if this was done properly, with penalties if the instructions seem confusing. Failure means the insect does not do quite what the user intended. Critical failure means the program causes the insect to do something totally different than what the user wanted, or to behave in a self-destructive fashion, resulting in its loss or capture.

To work, an insect director must be plugged into a computer running an "insect translation" program (Complexity 4, \$4,000). A separate program is required for each brand of insect agent. The director itself is \$2,000, 0.2 lbs. (computer not included).



SAMPLE INSECT AGENTS

These are just some of the possibilities for gengineered insects.

Smart Mosquito (TL10)

Among the most common insects to be modified are female (bloodsucking) mosquitoes. A mosquito's ability to fly, its small size, its excellent sense of smell, and, most of all, its ability to be modified to deliver chemicals into the blood make it a highly useful organic platform for covert operations.

A smart mosquito has the usual mental and physical modifications common to insect agents. It also has a pheromone gland that allows it to mark objects with a distinctive scent so that it can find them later. It will always mark its owner.

The insect can fly at about 2 mph (Move 1). It has an effective Tracking skill 10, which can be used to find objects or people it has been programmed to recognize. It can be programmed to scent-mark an object it has found. Provided that target is not behind a sealed barrier or more than a mile or so distant, this gives the mosquito +3 on any Tracking rolls to find it later on.

The mosquito can be programmed to perform one of several tasks if it finds its target:

Payload: The mosquito cannot carry anything heavier than a few grains of sand, but sometimes that can be enough! Useful payloads include pinhead-sized listening devices and messages that are coded as microdots (\$1 each). These can also be deposited somewhere – or on someone – and scent-marked for later retrieval.

Sampler: The mosquito can draw blood from a subject and retain it without consuming it for up to six hours. This can provide a blood sample for analysis.

Target Marking: Mark the object with a pheromone marker. This can be combined with any other task.

Vector Attack: The insect can carry and transmit a dose of a germ-warfare agent or proteus virus (designed not to affect the mosquito). It may also carry a drug or poison, but

as it can only carry a small dose, HT rolls to resist are at +4. Delivery is by biting. This won't penetrate armor, but many people won't even notice a mosquito bite (make a Perception roll at -2 to do so).

A target being stalked by a smart mosquito should get a Hearing roll to notice it. A mosquito-sized insect has SM-16, but any hit will kill it.

A smart mosquito costs \$8,000; it can be carried in a matchbox-sized carrying case. They live only two months. Drugs that extend the mosquito's life span by one month per dose cost \$100 per dose. They are effective on a roll of 15 or less; roll each month. Mosquitoes can also be bought as dried eggs, which remain viable for 20 years and hatch after a day in water. Smart mosquitoes are LC3.

Smart Bug (TL10)

A smart ant or small spider uses the same rules as a smart mosquito, except that it is limited to moving on the ground at Move 1, cannot act as a blood sampler, has Tracking-7, and can carry a little more (gives only +2 to resist any drug or poison). While it can't fly, it can walk up walls, and is silent so it's hard to notice; a Per-4 roll is required to spot an ant or spider sneaking up on you. On the other hand, it's easy to kill – just step on it.

Smart ants or spiders are slightly easier to construct than mosquitoes, and cost \$5,000. They can be equipped with two additional biological modifications:

Hardened Mandibles (TL10): These bioceramic jaws allow the bug to perform sabotage, chewing tiny holes in ducts, slicing wires, or biting for 1 point of damage per minute. A swarm of at least 100 is needed to do 1 HP of injury per second and will be dispersed after losing 6 HP; see p. B461. Add \$1,000.

Vacuum Adaptation (TL11): The insect's body has been surgically adapted to survive for a short time (up to an hour) in space, or other high- or low-pressure environments. Add \$10,000.

GENGINEERED ANIMALS

Larger animals – such as fish, dogs, or cows – can be bio-engineered, often by adding genes from other species. Just like humans, animals can be modified with germline gengineering or a biomod operation. The former has the potential to create a race of modified animals (if a breeding pair is modified). The latter only modifies a single individual, but can usually be performed at an earlier TL.

So why would someone want to gengineer animals? Some possible objectives are described below.

Companions and Working Beasts

Pet owners already enjoy exotic breeds. If laws don't get in the way, we may see dogs with pink fur or strange

hybrids like a cat-rabbit. Even if they are illegal, there may still be a black market for radically altered pets. While society may frown on giving rabbit ears and a semi-intelligent brain to a cat, genemods designed to enhance the intelligence of working beasts like sheep dogs, police dogs, or horses may be acceptable. At high TLs or in cyberpunk worlds, customized "super pets" could be created by finding a freelance genehacker and having him make a pet to order.

Some societies may even permit the design of "guard-beasts" or "warbeasts" with enhanced combat abilities, derived from deadly animals. These might also be used in ecological warfare. Most such beasts are LC2-3; those that can breed rapidly might be LC1.

Hardy and Pantropic Animals (TL8/9)

Just like plants, animals can be engineered for improved disease-resistance or to survive changing climates (perhaps brought on by eco-disasters). More exotically, they might be made to smell or taste bad to pests or predators, designed to survive on other planets by splicing in genes so that they can digest alien plants or animals, or modified to survive in unusually harsh climates. For example, “Mars Goats” designed for a partially terraformed red planet may possess hyper-evolved lungs, internal water storage capacity, and thick fur.

High-Yield Farm Animals (TL8/9)

By modifying genes that control growth hormone or fat production, animals can be designed with leaner meat, improved milk, egg, or wool production, and other commercially desirable genemods. Splicing in genes from related species (e.g., putting cow genes in pigs) may also produce larger – or different-tasting! – species. An advantage over post-natal growth hormone treatments is that the animal’s descendants will inherit these traits, reducing long-term costs.

One oft-suggested modification would be to give the super-efficient ruminant digestive system found in cows and goats (which uses symbiotic bacteria and a modified intestine to aid digestion) to animals such as pigs. This would allow them to forage, which would reduce the cost of feeding them.

Pharm Animals (TL8/9)

Animals can be turned into living pharmaceutical factories by adding genes that code for commercially useful proteins, or splicing in genes from humans, other animals, bacteria, or plants. The advantage of using animals rather than bacteria is twofold. First, more kinds of proteins can be created, since animals have more than one cell to work with. Second, animals do not require the fermentation vats and downstream processing that bacteria need.

Domestic milk animals like goats or cows can be modified so that their milk contains “natural” additives. For instance, transgenic cows have been grown with genes for lactoferrin, a compound used in human baby formula; this minimizes the need for further processing and reduces production expenses. Pigs have already been grown with human hemoglobin in their blood so they can be bled for human blood substitute. Other animals are being designed to produce vaccines.

More exotic pharm animals are possible, including ones whose organs can be harvested for use by humans, or whose secretions and bodily fluids (such as milk, blood, or urine) or products (eggs or meat) contain chemicals or even wonder drugs. A good example are the transgenic “spider goats” with orb spider genes; they look like normal goats, but their mammary glands can produce valuable spider silk proteins in commercial quantities.

A pharm animal could be a highly complex “bio-reactor” if its own genetics were modified and its gut also played host to a variety of engineered bacteria. While the engineering required is high-tech, it would produce drugs

Levels of Sapience

GURPS classifies a sapient being as IQ 6+. Animals with enhanced intelligence can be classed as either non-sapient, low-sapient, or fully sapient:

A *non-sapient* animal still has IQ 5 or less, even if its intelligence has been boosted over its species average, or it has other mental improvements (e.g., the removal of the Hidebound trait). Non-sapient animals are generally considered property, although they may be protected by laws against animal cruelty.

A *low-sapient* animal has an average IQ 6-8, but, unlike a human child, will also suffer from some or all of the racial mental traits that commonly limit animals; see the Domestic Animal and Wild Animal meta-traits, p. B263. It is intellectually halfway between smarter animals and adult humans. Low-sapient animals are rarely considered “people” but may have some legal rights. Some societies might not care how such creatures are treated – corporations could breed near-sapient workers or war-beasts, individuals could go to genehackers to buy upgraded pets, and so on. A more compassionate culture might enforce laws regarding their creation, treatment, and ownership, with licensing requirements for individuals permitted to work with them. For example, low-sapient dogs might be used by police, scouts, or rangers, but be restricted to trained officers who know to treat them as partners rather than pets.

A *fully sapient* animal is mentally equivalent or superior to a human. This means IQ 8+ and few or none of the negative mental traits common to animals (those in the Wild Animal and Domestic Animal meta-traits), or, if they possess these, a way to mitigate them (such as an animal that can’t speak having the ability to write). A sapient animal may be a full citizen, a slave, or somewhere in between (e.g., ward of the state, second-class citizen). Either way, it’s intelligent enough to *resent* being treated as less than human . . .

These classifications are game mechanical. Societies may have specific intelligence tests, legal codes, or other rules that define the status of animals.

and chemicals in a very low-tech fashion, making pharm animals very suitable for developing nations or colony worlds.

Besides their obvious commercial and medical uses, pharm animals could also manufacture recreational drugs, poisons, or even explosives. By modifying a venomous creature into a pharm animal, it might be possible to dispense drugs in combat as well as manufacture them.

Reproductive Modifications (TL8)

Animals may be gengineered for improved fecundity (giving birth to larger litters, for example), an altered sex ratio (usually, more females than males is desirable), etc. Use the TLs given under *Sexual and Reproductive Modifications* (p. 60). Reduce the TL required by 1 when dealing with common lab or farm animals – work on animal reproductive gengineering is well on its way, and will precede similar work on humans.

Near-Sapient and Low Sapient Animals (TL9)

Bioengineers can use a process that has come to be known as *uplift* to turn non-sapient animal stock into sapient intelligent species (see p. 85). This is most effective with near-sapient species (IQ 5) or those which have other promising traits, e.g., manipulatory ability. Another common uplift procedure is the enhancement of low-sapient species that already have IQ 6+ but which nevertheless lack manipulatory ability, cannot speak, or suffer various other mental handicaps (typified by the Wild Animal or Domestic Animal meta-traits, p. B263).

Slow-and-sure uplift procedures aimed at producing stable races might take centuries to evolve a species toward sapience. Quicker but riskier procedures may achieve success (but often with various defects) in only a generation or so. Possible motives for creating a near-sapient or sapient animal include:

Ethical Duty: Some societies or individuals may feel that it is their duty to uplift near-sapient animals.

Scientific Curiosity: The project is an experiment. A single evolved creature may be created, or the experiment may proceed to see what kind of society a race of enhanced animals would produce, either in isolation or in partnership with man. If contact with aliens is expected, we might learn a lot by making our own aliens.

Subject Race: The goal may be to produce smarter domestic animals, either for a specific purpose (e.g., as companions or soldiers) or as a servitor underclass.

Uplift can also be achieved in a non-germline way by performing surgery. Brain tissue grafts (p. 179) can enhance intelligence, and other biomods can alter the physical capabilities of animals. This method is suitable for TL5+4 steampunk inspired by *The Island of Dr. Moreau*.

CREATING BIOMODIFIED ANIMALS

These rules are guidelines for creating genetically altered animals in conjunction with the rules on *Racial Templates* (p. B450) and *Animals and Monsters* (p. B455).

First, determine the statistics of the baseline animal. Statistics for common animals are found on pp. B455-460. If it's important enough to be a character, create a racial template using the rules on p. B450. Racial templates can be derived from abbreviated animal statistics using the guidelines on p. B456. Statistics and templates for many other real and fictional animals are in *GURPS Bestiary*.

The GM may wish to research other traits for a particular animal (since only the major ones are given) but it is just as valid to assume that many traits will be *lost* as a side effect of genetically upgrading (in exchange for improved intelligence, etc.)

Modifying Animals

Once the racial template or set of abbreviated statistics has been determined, use the rules for human gengineering and biomods to make any modifications. The key difference is that animals may already have certain attribute modifiers, advantages, or disadvantages without the need for gengineering.

Gengineers may also want to remove some disadvantages native to animals. Some suggested modifications are described below. These may also have side effects (unintended disadvantages). As side effects aren't deliberate modifications, they don't affect the difficulty or dollar cost of the modification process, but they do reduce the race's point cost.

Some special considerations that apply to gengineering animals:

Animal Intelligence

Modifications to the brain's size or structure can improve racial IQ. These include enlargement of the frontal lobes, modifying the language and creative centers, and other changes intended to improve reasoning ability and abstract thought. Use the rules for enhancing human intelligence; that is, germline gengineering can add up to +2 IQ at TL10, etc. For biomods, see *Brain Tissue Graft* (p. 179) and *Neurovirus* (p. 186).

The Wild Animal or Domestic Animal meta-trait can be removed by engineering out one or more of its traits – usually either Cannot Speak or Taboo Trait (Fixed IQ) are the first to go.

A side effect of increasing IQ is to reduce an animal's sensory bonuses, as more of the brain is devoted to reasoning and language processing. For every +1 increase in IQ, it would be realistic to reduce either Perception or all Acute Senses by one level, or, possibly, to remove a Discriminatory sense such as Discriminatory Smell.

Altering IQ or other racial mental disadvantages or mentality meta-traits often gives the Stress Atavism disadvantage.

Modified Manipulators

Animals such as chimpanzees, elephants, octopuses, and raccoons may already have arms: grasping paws, trunks, tentacles, or crude hands with Bad Grip 1-3. Reducing Bad Grip by one level (eliminating Bad Grip 1 entirely) is possible at TL9, by two levels (eliminating Bad Grip 2) at TL10, or by three levels (eliminating Bad Grip 3) at TL11+.

Modifying flippers, legs, bird talons, or wings to give them crude grasping paws or claws while still retaining original function and posture is possible at TL9 for animals that already have paws or talons, or at TL10 for trickier uplifts (such as hoofed animals). This will generally replace No Fine Manipulators with Bad Grip 3.

If the animal normally moves on all fours, these modifications will lower its mobility.

If the animal has the Horizontal disadvantage, or a meta-trait that includes it such as Quadruped, its effective Move on the ground should be halved. Either remove a level of Enhanced Move (Ground), if any, or apply an equivalent reduction to its Basic Move. If the animal is semi-upright, the reduction should be less: usually -1 or -2 to Basic Move.

These modifications can also be created with transplant surgery. Cost is $\$20,000 \times (\text{TL}-8)$, where “TL” is not the current TL but rather the minimum TL required. The procedure takes six weeks and is LC4. Metamorphosis nanovirus (p. 187) can also improve manipulatory ability.

Creating New Species

Bioengineers can design and create new species of animals using chimerization at TL8+ or biogenesis at TL10+. Chimeras should have the Chimera meta-trait, while biogenetic animals will have the Bioroid meta-trait; see p. 214. Without restricting oneself to an existing animal body plan, the possibilities are limitless. One branch of this technological path leads to biogadgets (p. 95).

Enhanced Voice Box

It's possible to modify the animal's voice box to make it capable of human speech. This can be added to any mouse-sized or larger animal. At TL9, gengineering can upgrade the Cannot Speak disadvantage to Disturbing Voice (modifying the cost of the Wild or Domestic Animal meta-trait if the animal has it). This represents an animal that can speak, but has trouble doing so. At TL10, Cannot Speak can be completely removed. A talking animal that lacks sapience (IQ 5-) can pick up or be taught individual words or phrases by rote, like a parrot, especially if it has (or was engineered with) Mimicry.

An enhanced voice box can also be created using surgery. The cost is $\$10,000 \times (\text{TL}-8)$ where “TL” is not the current TL but rather the minimum TL required. Time is two weeks to change Cannot Talk to Disturbing Voice, or six weeks to for human-level speech. Metamorphosis nanovirus (p. 187) can also enhance a voice box.

Modified Posture

A species with legs can be modified from a Horizontal posture like a horse or dog to Semi-Upright like an ape or bear, or from Semi-Upright to an upright bipedal posture like a human. This requires modifications to the legs and spine, usually as a result of deliberate chimerization or a transgenic splice between two species, and goes hand-in-hand with other blended traits.

A change of Horizontal (or a meta-trait that includes it, such as Quadruped) to Semi-Upright, or of Semi-Upright to upright bipedal stance is TL9. Changing Horizontal to upright is TL10. Removing the Invertebrate trait is TL11. These modifications generally result in the loss of any Enhanced Move (Ground) and Extra Legs traits, but may replace No Fine Manipulators with Bad Grip.

An alternative (and somewhat cinematic) uplift for horizontal posture is to radically alter their body to create a centauroid form, which means they have Extra Legs but lack Horizontal or No Fine Manipulators. This requires TL11 for the addition of two extra limbs (as described for humans, p. 51).

These modifications can also be created using surgery. The cost is $\$50,000 \times (\text{TL}-8)$, where “TL” is not the current TL but rather the minimum TL required. This takes eight weeks. Metamorphosis nanovirus (p. 187) can also make these changes.

ANIMAL MODIFICATIONS

These are some possible animal modifications that are not necessarily reflected in terms of advantages and disadvantages on a racial template.

Genetically Defective Vermin (TL8)

A form of biological control (p. 76), this is another method of reducing or eliminating pest species. Instead of relying on another species to target the pest as prey, the vermin themselves can be genetically engineered. This is the next step beyond releasing sterilized individuals to reduce the breeding population (which has been done using radiation to sterilize mosquitoes). The problem with that is that the next generation obviously doesn't descend from sterile adults and inherit sterility. By modifying the genes, gengineers can produce a dominant allele that spreads throughout the population over a few generations, and that provides a trigger that will kill all carriers of the gene. The trigger could be exposure to an otherwise harmless chemical – in effect engineering the species to be susceptible to a safe “pesticide” – or a genetic clock that self-triggers after a given number of generations.

A related method is to engineer the pests to stop them from engaging in the behavior that makes them pests. For example, boll weevils might be modified to lay their eggs on plants other than cotton, which could turn them from agricultural pests into relatively harmless insects.

Hormone-Reliant Species (TL8)

Any gengineered animal can have genes added to make them unable to produce some vital protein or hormone for themselves. These will then need to be supplied through diet or injections to keep the animal healthy. There are several reasons for wanting to do this.

If an animal is potentially dangerous or could adversely affect the local environment if it escaped, having a control like this on its ability to survive without human care could save environmental disaster, dollars, and even lives. A rare or otherwise desirable animal with this trait would be rendered pointless to steal, as any thief would have to have a supply of an expensive or unknown chemical to keep his prize alive. And finally, commercially supplied animals such as gengineered livestock could be given this modification simply to force consumers to buy expensive hormone supplies from the manufacturer.

Statistics: This gives the animal Dependency (Commercial hormone, Common; Daily) [-30], Dependency (Commercial hormone, Common; Weekly) [-20], or Dependency (Commercial hormone, Common; Monthly) [-10].

Hypoallergenic Pets (TL8)

The allergic reactions some people have to common pets is caused by specific proteins secreted by the animal's skin glands. The production of these proteins can be switched off, resulting in a pet that doesn't stimulate an allergic reaction. This adds \$2,000 to the normal cost of the animal.

Pharm Animals (TL8/9)

At TL8, a pharm animal can be designed to produce blood products or exotic proteins that can be easily synthesized into drugs or vitamins, for only 10-20% of the cost of producing the drug in the normal laboratory fashion. Milk proteins might even be engineered to produce a biological explosive, causing (TL-4)d damage per lb.

At TL9 (or the drug's TL+1, whichever is higher) a pharm animal may be able to produce ready-to-use compounds, drugs, or even foodstuffs – for example, milk with health-enhancing or narcotic effects. If the animal can produce multiple different compounds, add +1 to the highest TL for two drugs or +2 for three or more.

Normally, pharm animal products cannot be delivered actively – the animal must be bled, milked, or whatever, taking several minutes. Animals produce one dose (or 0.1 lbs. of explosive) every four hours, storing a maximum of HP/2 doses until milked.

On the other hand, ready-to-use compounds such as poisons or narcotics might be able to be delivered by biting, spraying, scratching, or secretion. These can be built as Afflictions or Innate Attacks. A ready-to-use explosive can result in the animal being a biological bomb, set off when killed violently or by chemical or implanted electronic triggers.

At the GM's option, it may be impossible to produce some compounds using pharm animals, regardless of the TL.

Statistics: A pharm animal modification is a feature or perk, unless it lets the creature deliver effective drugs quickly and directly to someone else, in which case it's Affliction, Healing, Toxic Attack, etc. as appropriate. It's possible that pharm animal modifications will have severe side effects on an animal's metabolism, giving it various disadvantages (or even exotic advantages). Pharm animals cost more than normal members of their species by 200 times the usual cost of a dose of the drug or product. This is increased to 1,000 times the cost if the compound is ready to use without additional processing, or reduced to 100 times cost if the animal must be killed to retrieve the product.

Glowing Animals (TL9)

An early application of engineering is to graft bioluminescence genes from bacteria into various animals. This

is relatively simple and has already been used to create glowing fish and mice, but the luminance is low. By TL9, the glow can be bright enough to make this genemod attractive to some pet buyers; beyond simple novelty there is some value in having a cat that you can't trip over at night or a dog that is easily visible on a dark street. Road safety activists have also suggested that spreading this modification through wild populations of animals such as deer would reduce animal-related accidents. While true, ethical questions would be raised if the species depends on hiding to avoid predators. A glowing animal costs \$2,000 more than normal.

Giant Animals (TL10)

Increasing the size of animals can turn them into useful beasts of burden (or war), and increases the efficiency of turning feed into meat. In many cases it is the *rate* of growth that is crucial, but if a rapid rate can be sustained for a longer time that naturally leads to larger adult livestock. Realistically, giant animals run into the same problems of scale as giant humans. Use the same rules as given on p. 63.

Miniature Animals (TL10)

On the other hand, reducing the size of an animal species could be desirable for several reasons. Smaller animals require less food and water (and less air in a life support situation). They are easier to control and move around, and in the case of large animals, less likely to injure people. Miniature versions of popular animals like elephants could also make interesting pets. To scale an animal down, use the same rules as for creating miniature human templates (p. 62).

Botanogenesis (TL12)

The reverse of zoogenetic plants (p. 81), this is a modification that causes mobile animals to have a sessile plant-like generation. This costs at least \$100,000, and creates a normal animal with the feature that it reproduces by releasing plant seeds.

SAMPLE GENGINEERED ANIMALS

These Earth animals have been biomodified in ways that make them more useful to people. Animals may be purchased from a biotech company as embryos, as young or as adults. If a breeding pair (or herd) is acquired, they can be bred normally, provided they aren't sterile. Sterile versions of otherwise-fertile biomodified animals can usually be purchased at half cost or less.

A list of the major changes (in game terms) that each animal has undergone has been appended to the description, so that GMs can alter the templates to create other versions of the same species.

Cost

Domestic genetically modified animals usually cost up to 10 times as much as a baseline animal, depending on the degree of modification.

For sapient animals created with character templates, the same formula as genetically engineered humans (see *Life's Price Tag*, p. 65) can be used: \$25,000 for eugenic modifications or \$50,000 for species modifications, plus an additional \$1,000 per character point the template costs if it is worth more than 0 points.

For non-sapient animals, modify the cost depending on the average racial IQ.

Racial IQ	Dollar Cost
IQ 1	×1/100
IQ 2	×1/10
IQ 3	×1/5
IQ 4-5	×1/2
IQ 6+	×1

The cost of genetically modified animals only applies if purchasing a new animal; if fertile, non-sterile animals are available, anyone might try breeding genemod species for themselves. If genemod animals are common, they might even displace original species and be found running wild. In some settings, *baseline* animals might only exist in zoos or as archived genomes in life banks, and cost \$25,000-\$50,000 for an "original"!

Doolittle Dolphin (TL10)

56 points

Navy's been using conditioned dolphins since the 20th century – and the program's been continuing, though under pretty deep cover, mostly out of PR concerns. Some corporate security outfits are also using them. Recon, mine detection, counter-diver missions and counter-terrorist security at oil rigs and such. This is the new generation. The D-model was packed full of cyberwear implants, but they were too easy to detect. This model's all gene-wear.

– Captain (ret.) Dana Martello, Marine Force Recon

Last year, Blue Shadow ecowarriors, with some inside help, raided the dolphin training farm at Pearl and liberated a couple of Doolittles before the Navy's conditioning process could be completed. Friend of mine in the Movement says one of the dops has joined up with the Shadow boys, but he isn't too stable.

– Aquagrll, alt.ocean.development.korporate.otaku

Attribute Modifiers: ST+4 (No Fine Manipulators, -40%; Size -10%) [20]; DX+3 [60]; IQ-2 [-40]; HT+1 [10].

Secondary Characteristic Modifiers: SM +1; Per+2 [10]; Will+2 [10].

Advantages: Acute Hearing +4 [8]; Doesn't Breathe (Oxygen Storage 100×, -30%) [14]; Enhanced Move 1 (Water) [20]; Enhanced Tracking 1 [5]; Injury Tolerance (No Neck) [5]; Nictitating Membrane 1 [1]; Peripheral Vision [15]; Pressure Support 2 [10]; Sonar (Reduced Range 1/5, -20%) [16]; Temperature Tolerance 1 [1]; Ultrasonic Speech [10].

Disadvantages: Cannot Speak (Mitigated by computer interpreter, -60%) [-6]; Distractible [-1]; Hidebound [-5]; Innumerate [-5]; No Legs (Aquatic) [0]; No Manipulators [-50]; No Sense of Smell or Taste (Can taste, -50%) [-2]; Short Lifespan 2 [-20]; Social Stigma (Valuable Property) [-10]; Stress Atavism (12; Severe) [-20].

Features: Most have Broken literacy.

Availability: \$106,000. LC4

People have long admired dolphins for their seeming intelligence, so they are a natural candidate for uplifting experiments, but their aquatic nature presents some unique problems. The Doolittle dolphin represents a first generation uplifted germline, in which the result is not yet ideal – the gross structural changes to the dolphin's brain produce near-human intelligence at the expense of instinct. Doolittles lack many basic behaviors of baseline dolphins and require assistance to live natural lives (they are incapable of the "half-sleep" of dolphins, for example, and cannot rest fully submerged or they will drown in their sleep). They do not interact well with baseline dolphins, but their brains are capable of processing human-style conceptual strings and forming meaningful sentences with them. With a translator that can interpret the ultrasonic part of their speech they can communicate easily with humans.

Doolittles are of course suited to working in water, but also adapt well to microgravity environments in space, as there is no danger of their lungs being crushed by their body weight. They require special "moistsuits" to prevent their skin drying out though.

Although not included in the template, substantial minorities of Doolittles experience severe personality disorders shortly after reaching maturity. The most common symptoms are combinations of Bestial, Bully, Manic-Depressive, Low Empathy, Paranoia, and Slave Mentality. These often manifest after an episode of stress.

Delphis: A refinement of the Doolittle dolphin germline, the Delphis (from Greek, plural Delphi) has further enhanced intelligence and fewer psychological limitations. Delphi can suffer the same personality disorders as Doolittles, but this is rare. To the Doolittle template: increase IQ to -1, decrease Perception to +1, remove Hidebound, Innumerate, and change Stress Atavism to (15, Mild) [-5]. 96 points (\$137,000).

Jagrilla Hound (TL10)

82 points

I'd heard the government was using cloned warbeasts against the insurgents, but I'd never seen one until the general brought his bodyguard to the cease-fire talks. It was like a 7-foot-tall gorilla, but with a jaguar's pelt, a canine muzzle and long, pointed ears. The eyes were the worst: glittering with intelligence not quite human. It wore combat webbing and cradled an M-22 assault cannon in its clawed hands. As I approached them, the warbeast sniffed the air and growled something to its master. I was afraid it could smell my fear.

– "War in the Andes," by Captain Dana Martello, *Stars and Stripes*, Oct. '53

Attribute Modifiers: ST+4 (SM +1, -10%) [36]; DX+2 [40]; IQ-2 [-40]; HT+2 [20].

Secondary Characteristic Modifiers: SM+1; Per+2 [10]; Will +2 [10]; Basic Move +2 [10].

Advantages: Acute Hearing +2 [4]; Claws (Sharp Claws) [5]; Combat Reflexes [15]; Discriminatory Smell (Emotion Sense, +50%) [23]; Fearlessness +3 [6]; High Pain Threshold [10]; Night Vision 3 [3]; Singled-Minded [5]; Super Jump 1 [10]; Teeth (Sharp Teeth) [1].

Perks: Fur [1].

Disadvantages: Appearance (Monstrous) [-20]; Bad Grip 1 [-5]; Bloodlust (12) [-10]; Disturbing Voice [-10]; Hidebound [-5]; Innumerate [-5]; Semi-Upright [-5]; Sense of Duty (Individual) [-2]; Short Lifespan 2 [-10]; Stress Atavism (12, Mild) [-10]; Unusual Biochemistry [-5].

Features: Sterile; most have Broken literacy.

Availability: \$132,000. LC2.

This is a cross-species fusion of gorilla and jaguar, modified for enhanced IQ, a near-human voice box, and canine genes that give it a dog's Discriminatory Smell. Unintended defects are Monstrous, Sterile, Stress Atavism and Unusual Biochemistry.

K-10 (TL10)

-43 points

Attribute Modifiers: ST-1 [-10]; DX+1 [20]; IQ-4 [-80]; HT+2 [20].

Secondary Characteristic Modifiers: Per+6 [30]; Will+4 [20]; Basic Move +5 [25].

Advantages: Claws (Blunt Claws) [3]; Discriminatory Smell (Emotion Sense, +50%) [23]; Extra Legs (Four legs) [5]; Teeth (Sharp Teeth) [1]; Ultrahearing [5].

Perks: Fur [1].

Disadvantages: Chummy [-5]; Colorblindness [-10]; Hidebound [-5]; Innumerate [-5]; Quadruped [-35]; Sense of Duty (Individual) [-2]; Short Lifespan 2 [-20]; Sleepy (1/2 of the time) [-8]; Stress Atavism (15) (Mild) [-5]; Stuttering [-10].

Quirks: Responsive [-1].

Features: Most have Broken literacy.

Availability: \$50,000. LC4.

These are semi-sapient, domesticated canines. They resemble large dogs or wolves, but their skulls are somewhat larger, with a higher cranium. Their voice boxes are modified to allow them to speak, although words have a strong, growling "canine accent."

Likely owners include rich people, police, customs agents, hunters, security agencies, farmers, and exploration teams. A K-10 would also make a good seeing-eye dog, but the technology base needed to create them can probably cure most forms of blindness. The armed forces might find neo-dogs useful for military police or rangers, often with added cybernetic or biomod enhancements.

The K-10 is produced by TL10 engineering of canine stock. Significant modifications are increased IQ, and an enhanced voice box that reduces Cannot Speak (from the Domestic Animal meta-trait) to Stuttering. The only unintended defect was Stress Atavism. All the other advantages and disadvantages are native to canines.

Larger or smaller K-10 breeds are also possible, although further engineering may lead to more disadvantages as well. A trained "attack dog" might have Bad Temper or even Bloodlust.

Monkey Plus (TL10)

-51 points

Attribute Modifiers: ST-6 [-60]; DX+3 [60]; IQ-3 [-60]; HT+3 [30].

Secondary Characteristic Modifiers: SM -4; Per+3 [15]; Will+3 [15]; Basic Speed +0.50 [10].

Advantages: Acute Hearing 2 [4]; Brachiator [5]; Extra Arm (No physical attack, -50%; Short, -50%) [2].

Perks: Fur [1].

Disadvantages: Chummy [-5]; Innumerate [-5]; Semi-Upright [-5]; Short Arms [-10]; Short Lifespan 2 [-20]; Sleepy (1/2 of the time) [-8]; Social Stigma (Valuable Property) [-10]; Stuttering [-10].

Features: Temperature comfort zone 55°-120°F.

Availability: \$50,000. LC4.

Monkeys are engaging animals and would be popular pets if they were more tractable and easier to look after. This template represents various attempts to uplift small species such as capuchins or spider monkeys into suitable household companions. They make high-maintenance pets, requiring almost constant attention and social interaction; if they get bored they can be destructive. A crude but workable voicebox gives the Monkey Plus the ability to speak.

Neo-Coon (TL10)

-92 points

Missing: Two raccoons, aged 3 and 4 E-years. Gray fur, distinctive black mask marking over eyes, rings on tail. \$10,000 reward for information leading to recapture. Please contact Macrotech@Fed.Net.Com.

"Let's see if I understand this. Two of our Doolittle Virus-enhanced Neo-Coons faked a stomach ache, lured you into the cage, took your tangler and glommed you to the wall. Now they're loose. Where would they go?"

"I don't know, sir. These ones were being trained by the Bureau for covert ops, but we hadn't completed indoctrination – there were some problems in training. Anyway, after they jumped me, they used the computer to send out e-mail, then wiped the system."

"Used the computer? How? We didn't modify their hands! They're supposed to look like ordinary raccoons!"

"Even normal 'coons have good grasping paws, sir. That was the whole point of using them. Our Neo-Coons can't talk, but they can type and use tools if they're sitting on their haunches. I just wish I knew who they were trying to get in touch with . . ."

Attribute Modifiers: ST-5 [-50]; DX+2 [40]; IQ-3 [-60]; HT+1 [10].

Secondary Characteristic Modifiers: SM -3; Per+4 [20]; Will+3 [15].

Advantages: Claws (Sharp Claws) [5]; DR 1 [5]; Night Vision 1 [1]; Super Climbing 1 [3]; Teeth (Sharp Teeth) [1].

Perks: Fur [1].

Disadvantages: Bad Grip -3 [-15]; Cannot Speak [-15]; Curious (12) [-5]; Horizontal [-10]; Short Lifespan 2 [-20]; Sleepy (1/2 of the time) [-8]; Social Stigma (Valuable Property) [-10].

Availability: \$50,000. LC4.

These were modified for increased IQ +2 and to remove Wild Animal meta-trait (except Cannot Speak). All other advantages and disadvantages are native to raccoons.

Neo-Horse (TL10)

9 points

This is an uplifted saddle horse. It isn't sapient by any means, and can't talk, but it's as bright as a chimp and can do anything a "movie" horse can do, and then some. It also has a spleen engineered to produce enhanced, disease-fighting leukocytes.

Attribute Modifiers: ST+11 (No Fine Manipulators, -40%; SM +1, -10%) [55]; IQ-5 [-100]; HT+1 [10].

Secondary Characteristic Modifiers: SM+1 (3 hex); Per+7 [35]; Will+6 [30]; Basic Move+1 [5].

Advantages: Enhanced Move 1 (Ground Speed 12) [20]; Hooves [3]; Less Sleep 5 [10]; Peripheral Vision [15]; Resistant to Disease (+3) [3].

Disadvantages: Domestic Animal [-30]; Quadruped [-35]; Short Lifespan 1 [-10]; Weak Bite [-2].

Availability: \$34,000. LC4.

These were modified for +2 IQ, +1 DX, and an augmented spleen. All other advantages and disadvantages are native to horses.

Wonder-Horse: This variant is more robust, can survive on just about any vegetable matter, and doesn't need shoes, making it ideal for colony worlds or anachronistic cavalries. Increase Basic Move to +3 [15], add Damage Resistance 4 (Feet only, -40%) [12], Reduced Consumption 1 [2], and Universal Digestion [5]. 43 points (\$78,000).

Octosap (TL10)

38 points

Octopuses are among the most intelligent non-mammalian aquatic creatures. I'm surprised that no one has attempted uplift before. I suspect these were surgically augmented, rather than truly engineered, and I doubt they're much more intelligent than a dog. Still, a dog with tentacles? Interesting thought.

– DocIqbal, alt.ocean.development.korporate.otaku

Attribute Modifiers: ST-4 [-40]; DX+3 [60]; IQ-4 [-80]; HT+2 [20].

Secondary Characteristic Modifiers: Per+3 [15]; Will+2 [10].

Advantages: Chameleon 2 [10]; Constriction Attack [15]; Damage Resistance 1 [5]; Doesn't Breathe (Gills) [0]; Extra Arms (6; Extra-Flexible, +50%) [90]; No Neck [5]; Obscure 4 (Smell; Ink; Drifting, +20%; Limited Use, 4 per day, -20%; Link, Obscure Vision, +10%; Only in Water or Zero-G, -30%; Persistent, +40%) [10]; Obscure 10 (Vision; Ink; Drifting, +20%; Limited Use, 4 per day,

-20%; Link, Obscure Smell, +10%; Only in Water or Zero-G, -30%; Persistent, +40%) [24]; Peripheral Vision [15]; Sharp Beak [1].

Disadvantages: Bad Grip 1 [-5]; Bad Sight [-25]; Cold-Blooded [-5]; Fearfulness 1 [-2]; Hidebound [-5]; Incurious (12) [-5]; Innumerate [-5]; Invertebrate [-20]; Mute (Mitigated by computer interpreter, -60%) [-10]; No Legs (Aquatic) [0]; Short Lifespan 2 [-20]; Social Stigma (Valuable Property) [-10]; Stress Atavism (Mild; 12) [-10].

Availability: \$88,000. LC4.

The only change made to an ordinary octopus was to raise IQ. The only unintended disadvantage was Stress Atavism. All other advantages and disadvantages are native to octopuses.

Astropus: The *Octopus astra* (commonly called the astropus, or "vac sucker") is a TL11 upgraded model of the octosap designed for further increased intelligence and the ability to breathe air as well as water. In microgravity they can propel themselves through atmosphere by sucking in and expelling air. Increase to IQ-2 [-40], add Air Move -10 (Air speed 2) [-20], Amphibious [10], Doesn't Breathe (Gills, -50%) [10], and Flight (Costs Fatigue 1 FP, -5%; Requires Low Gravity 0G, -50%) [18]; delete No Legs (Aquatic) [0]. 96 points (\$146,000).

Space Cat (TL10)

-32 points

Order: One Felis domesticus, female siamese, with following genemods: augmented intestinal fauna, boosted brain, internal gravity web, jacked-up immune system.

"I had them grow Tarot for me after those parasite bunnies got into the fiber optics on our last run. With Tarot on the prowl, no xeno-rodent's going to run wild on my ship."

– Captain Zeke Morrigan, free trader Antares

Attribute Modifiers: ST-6 [-60]; DX+4 [80]; IQ-4 [-80].

Secondary Characteristic Modifiers: SM -3; Per+6 [30]; Will+5 [25]; Basic Move+4 [20].

Advantages: Catfall [10]; Claws (Sharp Claws) [5]; Combat Reflexes [15]; Improved G-Tolerance (1G) [15]; Night Vision 5 [5]; Reduced Consumption 1 (Cast Iron Stomach, -50%) [1]; Resistant to Disease (+8) [5]; Silence 1 [5]; Teeth (Sharp Teeth) [1]; Ultrahearing [5]; Vibration Sense (Air) [10].

Perks: Fur [1].

Disadvantages: Curious (15) [-2]; Domestic Animal [-30]; Quadruped [-35]; Short Lifespan 3 [-30]; Sleepy (2/3 of the time) [-16]; Stress Atavism (12; Mild) [-10].

Quirks: Proud [-1]; Responsive [-1].

Availability: \$50,000. LC4.

The changes made to an ordinary cat were to raise its IQ and add Reduced Consumption (Cast-Iron Stomach), Resistant to Disease and Improved G-Tolerance. The only unintended disadvantage was Stress Atavism. All other advantages and disadvantages are native to cats, although the Vibration Sense has been augmented somewhat compared to a cat's normal ability to sense vibrations with its whiskers.

Ganesh (TL10)

51 points

Attribute Modifiers: ST+35 (No Fine Manipulators, -40%; Size, -30%) [105]; DX+2 [40]; IQ-2 [-40]; HT+2 [20].

Secondary Characteristic Modifiers: SM +3; Per+2 [10]; Basic Speed -3.00 [-60].

Advantages: Acute Hearing +1 [2]; Damage Resistance 4 (Tough Skin, -40%) [12]; Enhanced Move 1 [20]; Extra Arm (Extra-Flexible +50%; Long +1 SM, +100%; Weak, 1/4 ST, -50%) [20]; Less Sleep 4 [8]; Peripheral Vision [15]; Subsonic Speech [10].

Perks: Penetrating Voice [1].

Disadvantages: Cannot Speak [-15]; Chummy [-5]; Increased Consumption 1 [-10]; Innumerate [-5]; No Depth Perception [-10]; Quadruped [-35]; Slow Eater [-10]; Social Stigma (Valuable property) [-10]; Stress Atavism (12; Mild) [-10].

Quirks: Dull [-1]; Staid [-1].

Taboo Traits: Cannot Jump.

Availability: \$101,000. LC4.

Ganeshes are uplifted Asian elephants. They are very intelligent, hardworking, patient, and affectionate toward their handlers. Effective beasts of burden, they can assist intelligently with forestry, land reclamation, or construction jobs. Note that the cost of the template is for a zygote engineered from scratch – naturally bred ganeshes are *much* less expensive.

Genetic engineering has reduced the size of the male ganesh's tusks until they are no longer effective as strikers (female ganeshes have no tusks at all). Other modifications raise the ganesh's trunk ST slightly, raise its IQ by 2 points, and removed the Wild Animal meta-trait (replacing it with less severe mental and social disadvantages). Side effects include Stress Atavism, some reduction in sensory acuity, reduced robustness, and reduced walking speed. All other advantages and disadvantages are those of wild elephants.

Cinematic Uplifts

The uplifted animal templates presented here tread a middle road between conservative and optimistic, and suit realistic settings. In more cinematic settings – or just at higher TLs – uplifts may equals (or exceed) of humans in terms of intelligence. To create a template for such a cinematic uplift, remove any IQ penalties and mental disadvantages as desired, adjusting the point total appropriately. If the template has a positive Perception modifier, adjust it downward by as many points as the IQ was adjusted upward.

Neo-Gorilla (TL10)

76 points

Discrimination at the construction site? Well – there were a few banana and Tarzan jokes when I started. Yes, ma'am, but we're used to them. Nothing nasty. No one wants to get their arms ripped off, see. Uh, that was a joke, ma'am. Of

course I wouldn't do anything like that. I got along with the napes – I mean you humans – just fine. Uh, naked apes, ma'am. You humans. Bad habit I picked up, I admit. Yes, I won't use it again, ma'am.

Attribute Modifiers: ST+5 (SM +1, -10%) [45]; DX+2 [40]; IQ-2 [-40]; HT+2 [20].

Secondary Characteristic Modifiers: SM+1; Per+2 [10]; Will+2 [10].

Advantages: Arm ST +3 (SM +1, -10%) [14]; Brachiator [5]; DR 1 [5].

Perks: Fur [1].

Disadvantages: Chummy [-5]; Innumerate [-5]; Short Lifespan 1 [-10]; Sleepy (1/2 of the time) [-8]; Stress Atavism (15; Mild) [-5].

Quirks: Proud [-1].

Availability: \$126,000. LC4.

Modifications make the gorilla's crude hands into human-equivalent ones (buying off Bad Grip 2), improve the voice box to human levels and adjusting the brain (removing Wild Animal and adding +2 to IQ). Side effects were mild Stress Atavism, and, due to the change in posture, a loss of the gorilla's higher-than-human Basic Move.

Neo-Pinniped

3 points

Attribute Modifiers: ST+3 (No Fine Manipulators, -40%; Size -10%) [15]; DX+2 [40]; IQ-2 [-40]; HT+2 [20].

Secondary Characteristic Modifiers: SM +1; Per+2 [10]; Will+2 [10].

Advantages: Acute Taste and Smell +2 [4]; Amphibious [10]; Combat Reflexes [15]; Enhanced Move 1 (Water) [20]; Doesn't Breathe (Oxygen Storage $\times 100$, -30%) [14]; Pressure Support 1 [5]; Teeth (Sharp Teeth) [1]; Vibration Sense (Water) [10].

Perks: Fur [1].

Disadvantages: Chummy [-5]; Colorblindness [-10]; Horizontal [-10]; Increased Life Support [-10]; Innumerate [-5]; No Fine Manipulators [-30]; No Legs (Semi-Aquatic) [0]; Short Arms [-10]; Short Lifespan 2 [-20]; Social Stigma (Valuable Property) [-10]; Stress Atavism (12; Mild) [-10]; Stuttering [-10].

Quirks: Distractible [-1]; Dull [-1].

Features: Early Maturation.

Availability: \$53,000. LC4.

A neo-pinniped is an uplifted sea lion. They are playful and independent creatures, but they can quickly learn to perform complex tasks and have meaningful conversation with humans. When not on duty, neo-pinniped groups are showing signs of developing a complex and alien culture of their own.

Genetic engineering has increased the sea lion's natural IQ by 2 and removed the Wild Animal meta-trait (replacing it with less severe mental and social disadvantages). A working voice box has been added, allowing the neo-pinniped to speak human language (indistinctly and with difficulty). Side effects include a loss of sensory acuity and mild Stress Atavism. All other traits are similar to those of wild sea lions.

Ursamorph (TL11)

31 points

"Bob, what did you do with my Ursamorphs?"

"Research program's finished, Judy. You did your part. Your bears can talk, manipulate things and they're mentally stable. Now we're in the next stage. They're at Fort Drum, with Henderson."

"Fort Drum? That's—"

"Combat training, Judy."

"You're teaching Uther and Terri to shoot guns? Bob, it's wrong! I designed the Ursamorphs to hibernate during the long voyage, then help build the Mars Base. They're space construction workers – astro-engineers!"

"Combat engineers, Judy. Get used to it. Mars Base is being trimmed. The program funding might be cut at any time, and we still haven't got a working space suit for them! But you should see the film from Fort Drum – an Ursa can hip-fire an assault cannon or a Snapdragon missile! Their fur even gives them good thermal camo. The Pentagon liked the Ursas. It's a big defense contract, Judy. Bigger than this Mars stuff."

Attribute Modifiers: ST+4 [40]; DX+1 [20]; IQ-4 [-80]; HT+3 [30].

Secondary Characteristic Modifiers: Per+4 [20]; Will+4 [20]; Basic Move +1 [5].

Advantages: Arm ST +3 [15]; Claws (Blunt Claws) [3]; DR 1 [5]; Metabolism Control 4 (Hibernation, -60%) [8]; Teeth (Sharp Teeth) [1]; Temperature Tolerance 2 [2].

Perks: Fur [1].

Disadvantages: Bad Grip 2 [-10]; Bad Temper (15) [-5]; Innumerate [-5]; Semi-Upright [-5]; Short Lifespan 1 [-10]; Sleepy (1/2 of the time) [-8]; Stress Atavism (15; Mild) [-5]; Stuttering [-10].

Quirks: Staid [-1].

Availability: \$81,000. LC3.

The changes made to an ordinary black bear were to raise IQ, change No Fine Manipulators to Bad Grip, and modify brain and voice box to remove the Wild Animal template (but gaining Stuttering and Staid as disadvantages). The only unintended defect was Stress Atavism. All other advantages and disadvantages are native to bears.

NON-SAPIENT ANIMALS

Animals unlikely to be suitable as possible player characters, allies, or dependents can just be described as animals (see p. B455). Here are two examples:

Pharm Goat (TL8)

ST 9; DX 11; IQ 3; HT 11.

Will 10; Per 12; Speed: 5.5; Dodge 8; Move 6.
SM 0; 100 lbs.

Traits: Chummy; Domestic Animal; Hooves; Pharm Animal (see below); Quadruped; Reduced Consumption 1 (Cast Iron Stomach); Unusual Biochemistry.

Skills: Jumping-12; Survival (Plains)-12.

A nanny goat, modified to produce components that can be used to make a single TL8 compound, such as

infant formula, spider silk, a cancer vaccine, super steroids, an enzyme blocker, or maybe a wonder drug. Modifications were Pharm Animal (Must be milked). Unintended side effects were a reduction in HT and Unusual Biochemistry (compared to an average goat). \$10,000, LC4.

Neo-Vampire Bat (TL9)

ST 1; DX 12; IQ 3; HT 10.

Will 10; Per 12; Speed: 5.5; Dodge 8; Move 5 (ground).
SM -6; 0.1 lb.

Traits: Clinging; Discriminatory Smell; Flight (Winged; Air Move 10); No Fine Manipulators; Sharp Teeth; Sonar; Toxic Attack 2d (Cyclic, 1 day, 4 cycles; Follow-Up, Sharp Teeth; Resistible, HT-4); Wild Animal.

Skills: Brawling-12; Stealth-12; Tracking-12.

An example of an exotic bioweapon that might come out of an underground cyberpunk biolab, this transgenic vampire bat has been engineered with poison sacs and a bloodhound's sense of smell. Capable of identifying and tracking down a specific target by scent and sonar, it is an exotic "black ops" weapon. \$10,000, LC2.



INDUSTRIAL AND RESEARCH ANIMALS

Some animals are modified for purposes other than usefulness as livestock or for enhanced intelligence. These are the industrial animals, who perform work that humans and their machines cannot do as conveniently. Some can even be used for warfare purposes.

Lab Mice (TL8)

These are mice that have been adapted to be genetically closer to humans, for use in lab experiments. Their statistics are identical to normal mice – i.e., inconsequential – but they can catch (and carry) the same diseases that humans can.

Cleaning Eels (TL9)

Exploring pipes to clear blockages is a messy job, and it becomes impossible if the pipe is too small to crawl through. Modified eels can do the job of slithering into a narrow pipe and locating the blockage. If it's organic matter, a cleaning eel can eat through it; otherwise it can be trained to trip a switch that turns on a radio beacon, or releases chemicals or nano to deal with the problem. Eels find applications everywhere from sewers to starship engines.

Construction Coral (TL9)

Corals of the genus *Acropora* grow rapidly, and can be the basis for gengineered versions that lay down limestone fast enough to be used for underwater construction projects. If irrigated with sea water to provide dissolved calcium and organic nutrients, such corals could conceivably accrete layers of limestone at up to half an inch per day. Although the limestone is strong, it is not solid, and contains small chambers and channels that can be colonized by other creatures to form a living structure, or filled with an organic polymer for extra strength. Once a structure has reached the requisite size, a synthetic hormone released into the water switches the coral into a slow-growth mode, in which it adds less than an inch of material per year. Maintenance can be carried out either conventionally or with a supply of various hormones to influence growth rate. Since the coral polyps need to reproduce in order to grow, the real cost is that of the hormones that promote rapid growth.

Self-Shearing Sheep (TL9)

Sheep can be modified to produce easily broken wool fibers at a particular time of year, so that all a farmer needs to do is pull the fleece off when the sheep are ready for “shearing.” The only problem is that the sheep need to be penned at moulting time, so the fleeces aren’t scattered in pieces across fields. Of course, the wool itself could be gengineered for quality, strength, and color.

Munition Mares, Guerrilla Goats, Bomb Bovines (TL9)

A milk-producing animal could be gengineered so that curd formed from its milk can, with minimal preparation, be formed into a stable and potent biochemical explosive. This is an exotic pharm animal; assume the milk or other products have an explosive REF 0.5 (about half as good as TNT). At TL9 they require minor additional processing (a day’s work with common household chemicals); at TL10 they are “ready to use.” LC2.

Bio-Bombs (TL10)

A creature may be gengineered into a “living bomb” that can actually blow itself up! Some creatures can actually have a solid-fuel skeleton and structural tissues. This is best acquired as the Fragile (Explosive) or Fragile (Flammable) disadvantage (p. B137) plus Easy to Kill (p. B134). The explosion is usually designed to take place if the creature dies violently, e.g., ramming into something, getting shot or run over, etc. Bio-bombs can also be fitted with chemical triggers or biochips that will activate hormones that arm the explosive after receiving a coded transmission, coming into contact with a particular target, or similar conditions. Take this as a Trigger limitation on either the Fragile or Easy to Kill disadvantages. LC2.

SYMBIOTIC PARASITES

Parasites provoke feelings of revulsion, but some could be turned to good use as companions performing important

jobs. Before they can be made useful, however, many parasites need to be engineered to be harmless to the host, avoiding disease symptoms or annoying side effects such as itching. An important part of this will be rendering them sterile, so they cannot multiply in the host’s body, or spread to other people who may not desire them. They should also take minimal nutrients from their host, and not produce any harmful or irritating wastes.

The best place for a beneficial symbiotic parasite is where most natural internal parasites live: the lower digestive tract. There, a creature can absorb nutrients from semidigested food rather than directly from the host’s tissues, and waste products can be eliminated without being absorbed by the body. Being internal, it is also protected, and can’t be accidentally removed or cause awkward social problems. Suitable starting organisms would be various parasitic worms.

What good could such a creature do? A drug factory (see *Pharm Animals*, p. 88) could produce useful or needed compounds; these can either be absorbed by the host’s digestive tract or the parasite might inject them into a handy blood vessel. These could be a “wet biotech” approach to the idea of encapsulated cell implants (p. 120). A digestive symbiont could also provide some protection against ingested poisons; by absorbing and metabolizing them into harmless wastes, it could grant its host Resistant to Poison. Finally, a symbiont might attack any unwanted parasites that find their way into the host. All of these functions can even be combined into one highly engineered organism, at TL9.

Internal symbionts could also exist in other parts of the body, but there they would need to tap the host’s bloodstream or tissues for nutrition. This may be acceptable if the symbiont is doing an important job. One with an electrical organ could monitor heart function and provide the same benefits as a mechanical pacemaker. Others might substitute for damaged sense organs or augment intact ones with additional abilities. Finally, a symbiont may be designed to interact with the host’s brain, providing enhanced capabilities.

External symbionts can also do similar jobs. They can interact with things outside the body, and might keep the skin clean or detect toxic gases. Some symbionts may be partially embedded in the host, with external and internal structures. An externally visible symbiont may provoke a negative reaction from someone who sees it. On the other hand, in some societies having an expensive braincrab on the back of your skull might be a status symbol.

Statistics: In general, a symbiotic parasite could provide many of the same benefits as various biomods or implants, at the same TL or one TL higher. The GM should rule on what modifications are available as engineered symbionts; in some game worlds such modifications might *only* be available as symbionts. The same statistics will apply and the symbiont will cost a similar amount to the normal operation. A symbiont might be installed simply by swallowing a pill containing an egg; it will take a time to grow equal to twice the corresponding modification’s surgery recovery time.

Parasite Weapons

Parasites can also be used for sinister purposes. Many don't even have to be modified. Fleas and ticks carry disease and cause misery to millions of people – they can simply be spread amongst enemies. If they carry designer germs (p. 116), so much the better.

Engineered parasites can be even more nasty. Internal worms might burrow through the host's body, seeking particular organs to infest and attack. This can result in anything from inefficient kidneys causing a slow illness to heart failure. More cinematically, parasites can attack specific cognitive regions of the brain, rendering the host pliable and susceptible to suggestion, amnesiac, or insane.

Attacks by parasite weapons make dramatic story opportunities, particularly when at first nobody believes

the victims. Convincing a skeptical doctor that you need a brain-eating worm removed is difficult, but then it has to be followed up by the surgery!

*You see, their young enter
through the ears and wrap
themselves around the cerebral
cortex.*

*– Khan, Star Trek II:
The Wrath of Khan*

BIOGADGETS

A biogadget is a living plant or animal that has been gengineered into functioning as a device or tool. Biogadgets may also be designed and created from whole cloth by biogenesis (p. 26). This type of technology is most common in cultures that possess advanced biotech, but lack advanced metallurgical and high-energy technologies (or the opportunity to develop them; e.g., a culture living underwater, inside a gas giant atmosphere, or on a metal-poor planet).

Biotechnology may also represent a deliberate choice for environmental or even aesthetic reasons). To foreign cultures, biogadgets may seem very alien, but they could perhaps be profitably traded. The creation of biogadgets generally requires TL10+ biotechnology.

The primary advantages of most biogadgets are self-maintenance and self-repair. They heal at the same rate as living organisms if damaged but not destroyed. They also require minimal maintenance if healthy. However, the GM could always rule that they can get sick or contract diseases.

EMULATING EXISTING TECHNOLOGY

Many technological items listed in *GURPS* books could potentially be biogadgets. Mostly, it's just a matter of changing their description – a strength-enhancing exoskeleton could be formed of living bones and muscle, a respirator might be a living creature that you breathe through, and a bug detector could resemble a snail with big antennae that hisses when it senses electromagnetic emissions. Biogadgets might communicate not via cables or radio, but by pheromonal signals.

At TL10, biogadgets will not be able to duplicate items with more than DR 15; most will be DR 0, like human skin. They also won't use energetic radiation emissions (like a beam weapon, force sword, or laser communicator) or have the structural strength of metals or ceramics. At TL11, bioceramics can constitute rock-hard parts suitable for cutting edges or combustion engines, but they will still be more brittle than metals.

Care and Feeding of Biogadgets

Depending on the specifics of design and function, biogadgets may require minimal care or careful pampering to keep them healthy and functioning. If possible, they will be designed to be robust, free of harmful parasites and diseases, and long-lived. When first introduced, these ideals are unlikely to be met, and gadgets will need to be protected from physical damage, temperature extremes, and other environmental hazards. Eventually this will be no more onerous than keeping sand and water off your MP3 player.

In general, the equipment damage and maintenance rules on pp. B483-485 can be used to cover the care of biogadgets. Most biogadgets do not have any form of Injury Tolerance, but they do have the advantage that they will heal themselves from anything other than permanent crippling injury. Supplied with

enough nutrients, biogadgets heal at the same rate as humans (see p. B424). They can also be "repaired" using the rules for surgery and medical care (p. B424) *instead* of the rules for repairing artifacts (p. B484). The required skill is Physiology (Biogadgets), combined with Physician or Surgery.

All biogadgets need some source of energy, whether it be body heat or food. Ambulatory gadgets might find their own food, but some will need to be fed. This could be as simple as table scraps, or a special diet that has to be bought from a supplier. This can be the case if the gadget is a biogenetic organism with a biochemistry incompatible with human food, or if the manufacturer has included a dependency on some exotic hormone to ensure a revenue stream.

CREATING NEW GADGETS

A biogadget doesn't use batteries or power cells for energy; instead, pick an option below. Sensible combinations are also allowed. Apply all cost multipliers to the cost of the regular, unliving version of that gadget. Options include:

Bioconverter: The default is that the gadget ingests food and water. This will normally be anything a human could eat – table scraps will suffice. Gadgets might conceivably attach to a separate bioconverter organism designed to consume food and produce chemically stored energy for it. Cost×1.

Body-Powered: This is available for gadgets that are worn next to the skin (or implanted), such as suits or goggles. The gadget is powered by the user's body heat, lives off bodily secretions, etc. It will cease working when not in contact with the user. Cost×2.

Nutrient Bath: The gadget absorbs nutrients through its skin. It will operate for half as long as an energy cell-operated gadget would, but then needs to be placed in a nutrient solution to recharge (takes at least eight hours). A nutrient solution pack can be emptied into any suitable container big enough for the gadget. A nutrient pack costs 10% of the cost of an energy cell and stays fresh for a month. Cost×2. *Fixed:* The gadget requires nutrients constantly and dies if removed from the bath; cost×0.5 instead.

Rooting: The device will operate for just as long as a power cell-operated gadget would, but then needs to be placed in moist, fertile soil for at least eight hours. It will uncoil roots and suck necessary nutrients into its body in order to recharge. Cost×3. *Fixed:* The gadget needs soil constantly and dies if uprooted; cost×1.5 instead.

Solar-Powered: The gadget's skin can convert light to electricity. It works constantly in sunlight or strong artificial light. In darkness, it can work for 1% of the duration listed for a normal gadget of the same type before running out of power. Cost×2.

SAMPLE BIOGADGETS

Some of these biogadgets are highly modified animals, while others are artificial organisms created using biogenesis (p. 26).

Biofilter Canteen (TL9)

A relatively simple biogadget, this uses a living directional osmotic film (p. 111) to purify water of anything short of toxic waste. It holds a quart of water, and filters it clean in 30 minutes. The canteen needs to be exposed to sunlight a few times a week, but the filter never needs replacing. \$380, 1 lb. empty, 3 lbs. full. LC4.

Fleshbed (TL10)

This is a biogenetic mass of flesh, tailored for spinal support and comfort. It's alive, warm, and you'll never want to leave. \$7,500, 60 lbs. LC4.

Garbage Disposal (TL10)

This lives under the kitchen sink, digesting all organic scraps and excreting partially treated waste into the sewer. It might be biogenetic, or based on a small omnivore. \$1,000, 8 lbs. LC4.

Skullcat (TL10)

This solar-powered living hat keeps the head warm. Its aphrodisiac purrs add +1 to Sex Appeal used on people who like cats, but drives others nuts. \$500, 1 lb. LC4.

Smart Rug or Bathmat (TL10)

This slowly tugs itself across the floor, slurping up dirt, puddles, soap, hair, etc. ST 4, DX 2, IQ 1, HT 12; Move 1. \$500, 4 lbs. LC4.

Squidpack (TL10)

This resembles a squat squid with four arms. It wraps its tentacles around the user's body and forces water out of its natural hydrojet for propulsion. The wearer's body tension guides the squid, but it takes practice to steer accurately (treat as a familiarity of Swimming; Aquatic and Amphibious users instinctively know how to use it). The pack provides Move 5 in water. It needs to be fed daily, but is happy with table scraps and vitamin supplements. \$300, 10 lbs. LC4.

BIOVEHICLES

Larger and more complex than most biogadgets, biological vehicles are different enough to merit discussion by themselves. Engineering an organism large enough to serve as a vehicle presents some unique problems. Biovehicles small enough to carry a handful of people on land are not beyond reason – horses and elephants perform that job well enough. But larger vehicles capable of traveling great distances need interior living spaces for long occupancy; this adds to overall size and means the vehicle needs significantly more structural strength to support its own bulk. For this reason, biovehicles capable of carrying internal passengers typically exist in the same environments as our largest mechanical vehicles: either in media that provide buoyancy such as water or air, or in the weightlessness of space.

Other traits will depend on the type of biovehicle and its intended mission. The most common types in science fiction are spacecraft, submarines, and airships.

DESIGNING BIOVEHICLES

As a living organism, a biovehicle is best designed by generating a racial template.

Attributes

Biovehicles are larger than man-sized, which means high Strength. The ST of a biovehicle depends on its size and mass. ST 3-6 per yard of longest dimension is a good rule of thumb.

DX, IQ and HT are usually in the 7-15 range. The exceptions are non-sentient vessels, like space trees, which often have DX 0 and IQ 0. It's suggested that attributes other than ST not exceed TL+2. Larger vehicles tend to have a lower DX but higher IQ.

Size Modifier and Weight

Size Modifier (SM) can be calculated from the specified dimensions and shape of the vehicle (see p. B19). A biovehicle's weight averages $(ST \times 0.5)$ cubed pounds.

Example: A 30-yard long bioship with ST 150 (a racial attribute modifier of ST+140) would have SM+7. It would weigh about 420,000 lbs. (210 tons).

Payload

The most important trait for biovehicles is Payload (p. B74), split between occupants and cargo. For significant usable space, 100 or more levels of Payload may be required. Biovehicles intended for long-term accommodation, such as bioships, will devote some of their payload to cabins.

Some bioships have building or even city-sized spaces inside them. A biovehicle's internal area will be about 1-4 hexes of floor or corridor space for every ton (2,000 lbs.) of internal Payload weight it can carry. Most ships have sphincters in their body that serve as airlocks, opening up to provide access to their interior.

Some interiors may be furnished capsules implanted into the ship, their interior little different from any other spacecraft. Others may be disturbing places, with warm, fleshy walls, pulsing internal organs, writhing cilia, and strong smells – after all, the occupants are inside an enormous creature!

Controls

A biovehicle may respond to commands like a trained animal, or have some form of implanted physical or biotronic system to allow its master to operate it. If it's sapient, commanding it is like giving orders to a subordinate.

If its crew can control its functions, give it the Compartmentalized Mind (Controls) advantage. If the vehicle *requires* a human at the controls to do anything, it should have IQ 0. Otherwise, crew members can give the ship orders and make decisions (e.g., Leadership, Strategy and Tactics skill) perform damage control (e.g., First Aid, Surgery and Veterinary skill), and man and maintain cybernetic implants, such as weapon turrets. Control of the latter can be handled via Compartmentalized Mind (Dedicated Controls).

Limbs

Many biovehicles have no arms or legs: take No Manipulators (p. B145) and No Legs (p. B145), or an appropriate morphology meta-trait (p. B263) like Ground Vehicle or Quadruped. Those that do have arms may have lots of insect-like arms, tentacles, or weapon mounts: take Extra

Arms (p. B53) often enhanced with Extra-Flexible or Long, or limited with Weapon Mount.

Mobility

Enhanced Move (p. B52) is important for any high-speed vehicle. Biovehicles will have mobility traits appropriate to the environment they operate in, such as Flight (p. B56) and higher or lower Move (p. B17) traits in different environments.

Weaponry

Many bioships are unarmed, or have cybernetic weapons (see below) or psi powers. Some have natural weapons such as Claws (p. B42), Strikers (p. B88), or Teeth (p. B91). Biovehicles could also be capable of generating some form of biological weapon, often an electrical discharge, web, or corrosive digestive acid (which can also represent hungry symbiotic bacteria, enzymes, or nanomachines). Represent these through Affliction (p. B35), Binding (p. B40), or Innate Attack (p. B61).

Defenses

Biovehicles are usually thin-skinned compared to ultra-tech vehicles, but tough compared to normal organisms, with DR (p. B46) in the DR 5 to 200 range; tougher ships in superscience settings often have some sort of biological force field. Other common defenses include Chameleon skin (p. B41) and life support advantages such as Sealed (p. B82), depending on the environment they are bred to operate in. Many other advantages, such as Hard to Kill (p. B58) or Injury Tolerance (p. B60) may be appropriate depending on the original species and genetic engineering performed.

Internal Advantages

Special advantages can also be bought that apply to the *inside* of the biovehicle so that it can interact with its occupants and cargo!

A biovehicle is assumed to have no senses (except pain) or manipulatory ability inside itself. However, it can buy advantages to manipulate internal cargo or passengers, perform repairs on cybernetic implants and the like:

- Internal Arms or Strikers (1/5 the usual cost of an Extra Arm or Striker)
- Internal Hearing [4]
- Internal Sight [10]
- Internal Speech [5]
- Internal Taste and Smell [1]

Enhancements to internal senses (e.g., Internal Discriminatory Smell), new internal senses (e.g., Internal Radar), and internal weapons (e.g., Internal Toxic Attack) are also available at 1/5 the usual cost. The reduced cost is not a limitation – these are different advantages, and actual limitations and enhancements can be applied on top of internal advantage point costs. For example, to create “horror” bioships with the bad habit of accidentally digesting passengers (or intruders), buy Internal Extra Mouth

(p. B55) or Corrosion Attack (p. B61) at 1/5 cost, then apply the Uncontrollable (-30%) limitation.

All of these costs assume the internal advantage is usable anywhere within the bioship. If it can only reach certain areas, this is a -50% limitation.

Appearance

A biovehicle might be no more frightening than any large, alien animal, or even be attractive or cute . . . but grotesque constructs with Appearance (Monstrous) (p. B21) are common. A biovehicle's *insides* may be quite different: Biovehicles may take Internal Appearance or even Internal Bad Smell at one-fifth the normal cost.

Transformation

In cinematic campaigns, especially those inspired by Japanese anime and manga, a biovehicle may possess the ability to transform into a much smaller "mundane" form. This is very convenient, since it allows a huge space battleship to hang around with other PCs. Buy this as Alternate Form (p. B83)). The best fictional example of such a vessel is Ryo-Ohki, from the Japanese anime series *Tenchi Muyo* and its sequels.

Status

Biovehicles may or may not be sapient; many have Slave Mentality (p. B154) or mentality meta-traits such as Automaton, Domestic Animal, or Wild Animal (p. B263). They are often considered property or subhuman: Social Stigma (Monster, Subjugated, or Valuable Property) (p. B155) are likely.

SPACECRAFT (BIOSHIPS)

Bridge, this is Falcon Two. I have a visual on the alien ship, and – you're not going to believe this, captain, but it's shaped like a giant eel, only covered in spines! Sort of an organic-looking hull, but with metallic blisters that look like turrets embedded in it. The vessel is now turning toward me – is that a mouth? My God, these things are alive!

– Lt. Majid Asad, U.S. Space Navy

The biological spacecraft may be the most exotic example of biogadget technology in science fiction. A bioship is truly alive, as opposed to ships that use only a few living, organic parts (such as a cyborg brain) or whose organic components are dead, such as wooden or plastic spacecraft.

Living ships are the result of taking a large alien life form (or less often, a big terrestrial creature), then using bioengineering to adapt it to serve as a space vessel. Often, they have been engineered to make them even larger, by modifying their genes to increase growth hormone production.

The advantage of engineering organisms as spaceships, rather than as water, ground, or air vehicles, is that it is easier to grow things to huge sizes in zero gravity. They may also be created by a race living on a metal-poor world, or to take advantage of existing qualities of the animal, such as psionic powers.

While a living ship's body is, by definition, primarily biological, it may also be a cyborg, possessing inorganic systems that are grafted onto it. The TL required to create living ships depends on how much modification is needed to transform the original organism into a vessel; usually, the degree of genetic manipulation required is TL11+ and often requires superscience.

A suitable organism should be large (at least several tons in weight) and tough enough to hold pressure or atmosphere. It may or may not be intelligent. Ideally, it should also possess an organic space-propulsion system, but this may be too much to hope for in a "hard-SF" setting.

It's possible to have a humanoid bioship, but that's rather unlikely. More often, bioships resemble planetoids, streamlined whales, eels, spined sea-beasts, spider-crabs, or even trees. Ship organisms in science fiction usually tend to fall into one of these categories:

Atmosphere Dwellers are alien life forms that resemble giant balloons or blimps (sometimes with tentacles). They might be found on any world with a dense atmosphere, including gas giants. Since they can already hold an internal atmosphere, they have some of the traits needed in a spaceship.

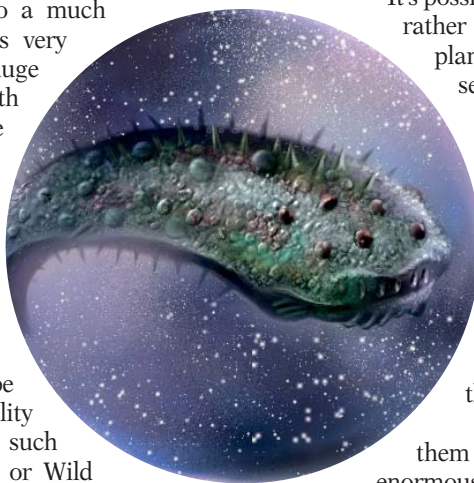
Giant Trees are bioengineered to adapt them into spaceships, and may be grown to enormous sizes in zero-G, inside greenhouse habitats or amid the life-giving gases of comets.

Marine Dwellers are huge, deep-sea animals like whales or – on a simpler level – coral reefs. The ability of underwater beasts to grow to great sizes and adapt to extremes of pressure makes them well-suited for use as bioships. While the actual use of Earth cetaceans might be impossible (or unethical), alien worlds might possess suitable whale-sized or larger beasts, perhaps possessing additional useful traits like tough shells, tentacles or even bioelectric organs.

Vacuum Dwellers are natural spacefaring creatures, sometimes even possessing their own form of organic stardrive. Some spacefaring life may be too fragile or diffuse to make a good ship (living solar sails, plasmas, or gas clouds without extensive changes). Other types might require only minimal modification.

Biomechanoids may have started out as any of the above, but have been turned into living machines. Protein-based components are used to create pseudo-alive controls, space drives, computers and other systems. In some types, the ship's body plays host to smaller, specialized organisms – a communicator-creature, a drive-creature and so on – all fused into one entity.

Propulsion systems for bioships may be mundane abilities, such as expelling internal gases for thrust or deploying a living solar sail. High-speed propulsion might



be achieved through biomechanical or cybernetic space-drive implants – or even psi powers, such as a form of psychokinesis or teleportation that can move the ship, perhaps at faster-than-light speeds.

A bioship is normally somewhat cheaper than an equivalent spaceship, reflecting the fact that bioships can be bred or cloned. It can usually heal itself and requires little or no fuel or maintenance. However, it is generally more delicate (with less DR and fewer hit points) than inorganic vessels of similar size. Flesh is easier to damage than machinery.

To survive in space, a bioship should have Doesn't Breathe (p. B49), No Degeneration in Zero-G (p. 211), Radiation Tolerance (p. B79), Sealed (p. B82), Temperature Tolerance 50 (p. B93), and Vacuum Support (p. B96). Reduced Consumption (p. B80) helps during long voyages.

Space travel requires Flight (with space flight enhancements) (p. B56) and often Enhanced Move (Space) (p. B52). Superscience designs often have Warp (p. B97). 3D Spatial Sense (p. B34) is likely for any entity that evolved or was designed for spatial navigation.

Resistant to Acceleration (p. B81) is useful for craft capable of extreme maneuvers.

To detect and communicate in space Enhanced Tracking (p. B53), Infravision (p. B60), Protected Vision (p. B78), Scanning Sense (Radar) (p. B81), Telecommunication (p. B91) and Telescopic Vision (p. B92) are all useful.

Bioships often have No Legs (Aerial) (p. B145) and sometimes No Fine Manipulators or No Manipulators (p. B145). Those that do have manipulators often have Extra Arms.

Some bioships are wispy constructs – such as living light sails or magnetic sails – that cannot survive significant gravity fields. These have much lower ST than their SM indicates, Injury Tolerance (Diffuse) (p. B60), and Weakness (Gravity) (p. B161).

Sample Bioship: Voidshark (TL11⁺)

1,564 points

Attribute Modifiers: ST +90 (No Fine Manipulators, -40%; SM +10, -80%); [180]; DX+1 [20]; IQ-3 [-60]; HT+3 [30].

Secondary Characteristic Modifiers: Per+3 [15]; Will+4 [20].

Advantages: 3D Spatial Sense [10]; Chameleon 4 (Extended, Radar and Infrared, +40%) [28]; Combat Reflexes [15]; Compartmentalized Mind 1 (Controls) [25]; Corrosion Attack 30d (Costs Fatigue, 2 FP, -10%; Takes Recharge, 5 seconds, -10%) [240]; DR 100 (Can't Wear Armor, -40%) [300]; Doesn't Breathe [20]; Enhanced Move 17 (Space) [340]; Enhanced Tracking 2 [10]; Extra Arms (Eight arms; Weapon Mount, -80%) [16]; Flight (Space Flight, +50%) [60]; Hyperspectral Vision (Extended Low-Band, +30%) [33]; Internal Corrosion Attack 5d [10]; Internal Hearing [4]; Internal Taste/Smell [1]; Internal Speech [5]; Payload 100 [100]; Peripheral Vision [15]; Pressure Support 1 [5]; Protected Vision [5]; Radiation Tolerance 10 [15]; Reduced Consumption 3 [6]; Resistant to Acceleration (+8) [10];

Sealed [15]; Special Rapport [5]; Spines (Long Spines) [3]; Teeth (Sharp Teeth) [1]; Temperature Tolerance 50 [50]; Vacuum Support [5]; Warp (Blind, +50%; Hyperjump, 1 light-year/day, -25%; Naked, -30%; Reliable +3, +15%) [110].

Perks: Accessory (Airlock), No Degeneration in Zero-G [2].

Disadvantages: Bad Temper (12) [-10]; Electrical [-20]; Internal Appearance (Hideous) [-3]; Overconfidence (12) [-5]; Sense of Duty (Individual) [-2]; Vermiform [-35]; Wild Animal [-30].

Features: Sterile.

Availability: \$1.4 million. LC3.

The Voidshark was once a water creature similar in mentality to a whale, but resembling a giant electric eel, with a tough, spiky hide, a mouth full of sharp teeth, and corrosive digestive venom similar to battery acid. Centuries of genetic engineering transformed it into a biomechanical construct.

A typical adult Voidshark is 100' long, 10' wide, and 10' high, and masses 125,000 lbs. Its skin has been toughened to resist vacuum, and internal pockets have been added to provide room for occupants and cargo. Its electrical abilities and digestive enzymes have been enhanced to provide power to internal mechanisms as well as serving as weapons. A family of superscience symbiotic biomechanoid organisms – a communicator beast, life support beast, reactionless drive beast, etc. – have been implanted into its body to give it extra capabilities.

All these modifications have left the Voidshark sterile – and bad-tempered. It is controlled by internal mechanisms and a pilot who provides strategic direction and can take over control of some functions. For best results, Voidsharks must be raised from birth by a particular pilot (usually a child), who they are fiercely loyal to. The Voidsharks share a pseudo-empathic bond with their pilots.

The interior of the Voidshark is not pleasant; it is filled with pulsing organs, dripping ichor, and odd smells. It has an airlock, several corridors and internal compartments (25 hexes worth). Assuming average ST and Basic Lift, its Payload 100 gives it 20,000 lbs. of internal capacity, split into six cabins (12,000 lbs.) and 8,000 lbs. of cargo space.

Voidsharks can fight at close range by spitting corrosive nano-augmented digestive enzymes. For longer range combat their weapon mounts are equipped with missiles or other weaponry (which must be purchased as equipment; this is not included in their template). This is usually operated by the crew member rather than the Voidshark.

AIRSHIPS (BIOBLIMPS)

These remain buoyant due to hot air or hydrogen in internal sacs. They may be propelled by gas vents, wings, or cybernetic implant propellers or jets, or they may simply drift in the wind. Some models have manipulatory ability – for instance, alien gas-secreting glands might be combined with cetacean or squid/octopus morphology and neural structures to develop tentacles for picking up cargo or mooring. Trunk-like tentacles could even siphon water for ballast, or to drink.

Due to the size of the gas bag, bioblimps will have a very large volume relative to their weight. This means they usually have only ST 1-2 per yard of diameter, sometimes less. Calculate their weight from their ST as usual (ST/2 cubed).

They have Flight (Lighter Than Air) (p. B56) and sometimes a level or two of Enhanced Move (Air) (p. B52). Common disadvantages are Fragile (Flammable) (p. B137), Invertebrate (p. B140), and No Legs (Aerial) (p. B145). Some bioblimps have Slow Eater (p. B155).

WATER VEHICLES (BIOSUBS)

These are engineered water creatures, usually propelled by flippers, a fluke or tail, or a squid-like jet. These are the most plausible type of biovehicle.

Biosubs should always have Doesn't Breathe, often with the Gills limitation (p. B49). They will need either Amphibious (p. B40), No Legs (Aquatic or Semi-Aquatic) (p. B145), or the Ichthyoid meta-trait (p. B263), usually with Enhanced Move (Water) (p. B52).

They will have Pressure Support (p. B77) for deep dives. To keep the payload from getting wet, they may have Sealed (p. B82). Other useful advantages include Chameleon (p. B41), Nictitating Membrane (p. B71), Peripheral Vision (p. B74), Reduced Consumption (p. B80), Sonar (p. B81), Speak Underwater (p. B87), and Vibration Sense (Water) (p. B96). Naval biosubs often possess tentacles in the form of Extra Arms or Strikers and electrical Innate Attack (Burning or Fatigue) (p. B61). They can sometimes hide themselves using ink jets; this is Obscure (Accessibility, Only in Water, -30%) (p. B72). Small, fast drones can be used as torpedoes.

*Natural species are the library
from which genetic engineers can
work.*

– Thomas E. Lovejoy

OTHER CONSIDERATIONS

The range of possible traits for biovehicles is nearly infinite, especially since they are often engineered from alien organisms or created by biogenesis. Anything possible for an alien race, animal, or cyborg is possible in a biovehicle.

Drones

Biovehicles occasionally contain organic drones – perhaps natural parasites that have been engineered into symbiotic life forms, or specialized “children” created by the vehicle itself. These often help keep the ship’s insides clean and perform repair duties, and may also enable the ship to interact with human crew. Combat-capable drones could serve as a “macroscopic” immune system to repel boarders.

A biovehicle may also carry much smaller drone bioships as shuttles, fighters, or even kamikaze missiles.

Drones may be acquired as Allies (p. B36). They are characters with their own racial templates.

Drones may or may not be sapient, but even highly intelligent drones often lack initiative. Common traits include Automaton (p. B263), Domestic Animal (p. B263) traits, Sense of Duty (p. B153) to their vehicle, and Slave Mentality (p. B154).

Some drones are physically rooted to part of the vehicle – depending on their degree of initiative these could just be bought as additional advantages plus Compartmentalized Mind to control them, or as separate Allies with No Legs (Sessile) (p. B145).

Drones are often caste-species optimized for specific jobs, with inborn Talents or racial skills. Mental disadvantages will also reflect this: drone warriors often have Bloodlust (p. B125), workers have Workaholic (p. B162), etc.

Sapient biovehicles can sometimes take over, communicate with, or interrogate their drones using advantages such as Mind Control (p. B68), Mindlink (p. B70), Mind Probe (p. B69), Possession (p. B75), Puppet (p. B78), Special Rapport (p. B88), and Telecommunication (p. B91). This need not represent any paranormal powers – depending on the biovehicle’s nature, it might instead require physical contact between the biovehicle and the drone, a cloud of pheromones or other chemicals, or radio control.

Good fictional examples of bioship drones appear in George R. R. Martin’s *Wild Cards: Aces High*, Walter Jon Williams’ *Angel Station*, and Bruce Sterling’s *Crystal Express*.

Cybernetics and Implants

Various weapons and gadgets could be cybernetically implanted into a biovehicle – see Cybernetics (p. B46) and Accessory (p. B100). This is a good way to give a vessel technology capabilities that transcend those plausible for biological systems. It may be a lot easier to implant a cybernetic radio, a radar, or laser into a biovehicle than figure out a way to bioengineer one!

Cyborgization could cause health problems if the implants are not entirely biocompatible (resulting in slow tissue rejection or infections), or leak radiation or toxic chemicals. This may lead to disadvantages like Chronic Pain (p. B126), Dependency (p. B130) on anti-rejection drugs, Slow Healing (p. B155), or Terminally Ill (p. B158).

Tech Level

Biovehicles are usually at least TL11, but might be available at a considerably lower TL if an alien organism that is especially easy to adapt into a vehicle can be utilized. If so, the engineering required varies widely, especially since exotic advantages (e.g., DR and Flight) may be innate to the species – this is why no TLs are assigned to them.

If GMs want to use the engineering rules to “game out” the design of a bioship, use the general guidelines for engineering animals – that is, come up with the original species template, then apply modifications to it. Assume that any bioship advantage/disadvantage not native to the species and not mentioned elsewhere requires TL12.

Purchase Price

Bioships may be priceless, but if they can be easily cloned or bred, a good way to estimate purchase price is to

multiply final point cost by \$1,000 (and add the price of any cybernetics). If bioships are much harder to produce (perhaps they must be captured wild and surgically modified), multiply the cost by a factor of 10 or more.

BIOBUILDINGS

Buildings can be grown using bio-nanotech. At TL10, the result is an empty, unfurnished building with an exotic organic shape and texture, perhaps suggestive of coral, chitin, a seashell or a beehive. At TL11+, the building can be alive, with self-healing (perhaps even edible!) walls, mutable rooms that can change color, scent, or texture on demand, and floors that extrude living furniture. It could even be chemically persuaded to resume its growth when more stories are needed. (This cuts both ways, though: a growing or live building might be vulnerable to biochemical attack.) A bio-nanotech “seed” costs about one-tenth what the resulting building would cost to build conventionally. Growth takes (seed cost/1,000) hours.

A near-sapient or sapient “living building” should be created like a biovehicle (p. 96), but without movement abilities; use the No Legs (Sessile) disadvantage (p. B145). Being sessile, a biobuilding may have almost any amount of occupiable internal space without needing the Payload advantage. If it has arms, they are usually only internal ones. Many living structures have a more rectangular, squat construction than biovehicles.

Sapient Building (TL12)

83 points

Yes, children, that cross-shaped building is our very own Dr. Raymond Garcia. His parents were Neo-Christian Hyper-Evolutionists, which is why he is a sapient biomass. Dr. Garcia is very clever, with six basic patents in his field just this year. Of course, we shouldn't be surprised, because his brain has a surface area the size of our swimming pool. Now, when we visit, we'll have to change and spray first, because Dr. Garcia doesn't want us tracking our germs inside his body.

– Carmen Ortega, schoolteacher

Attribute Modifiers: ST 0 [-100]; DX 9 [-20]; IQ +3 [60]; HT+1 [10].

Secondary Characteristic Modifiers: HP +100 (SM +6, -60%) [80]; SM+6.

Advantages: 360-degree Vision [25]; Doesn't Breathe (Oxygen Absorption, -25%) [15]; DR 10 (Can't Wear Armor, -40%) [30]; Extra Mouth 4 [20]; Hyperspectral Vision (Extended Low-Band, +30%) [33]; Injury Tolerance (No Head, No Neck) [10]; Internal Extra Mouth 3 [3]; Internal Hearing [4]; Internal Discriminatory Smell [3]; Internal Taste/Smell [1]; Internal Speech [5]; Unaging [15]; Universal Digestion [5].

Perks: Accessory (Airlock) [1].

Disadvantages: Increased Life Support (Massive) [-10]; No Manipulators [-50]; No Legs (Sessile) [-50]; Unusual Biochemistry [-5]; Weak Bite [-2].

Features: Weighs about 62 tons.

Availability: \$1 million. LC4.

Here's a sample “living building.” In Dr. Garcia's case, the goal was to produce a “new evolutionary stage” for humanity. He is a cross-shaped living building about 10 yards across. His interior is divided into several rooms, some containing major organs.

Gaia: Planet-Sized Organisms

If we can build a living building or vehicle, why stop there? How about a living planet?

This may seem incredible, but it has some precedents in James Lovelock's *Gaia Hypothesis*: that all the living matter on Earth functions effectively as a single large organism, making changes to the inorganic structure of the planet as well, in order to preserve its own existence. This is more a matter of descriptive interpretation than anything else. While the Earth is a complex system that consumes sunlight, reproduction – one of the hallmarks of life – has not occurred to our knowledge. This may change if we begin colonizing other worlds!

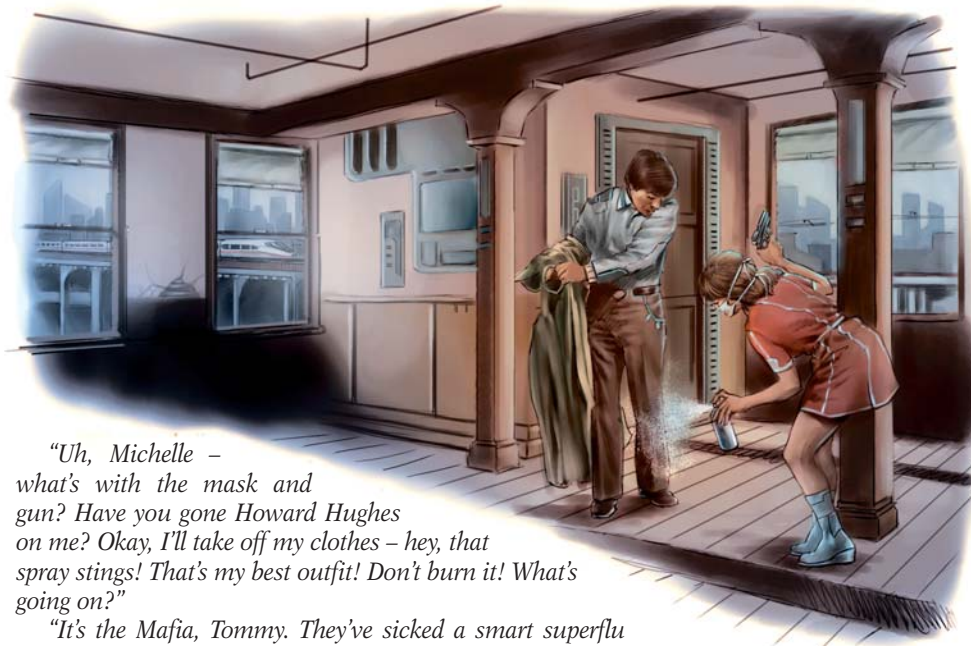
Building a planet-sized organism runs into the problem that its gross structure would be dictated by gravity. It would be very nearly spherical, and its innermost parts would be under intense pressure. A more promising approach would be to use a terrestrial planet as a core and create a living shell around it. This is not even really cheating – take away the non-living material of our skeleton and see how well we survive!

A single planetary organism would get energy in the form of sunlight, take in whatever atmosphere is around it, and digest the rock beneath it. It might be able to reproduce, if it could somehow reach another planet. But perhaps that's not a requirement for whoever designed it. Such a being might even conceivably evolve naturally.

One possible application of a living planet would be terraforming – converting a dead world into something that other species can live on. Building a civilization on a living creature that maintains the atmosphere in a nice condition is preferable to eking out an existence in a domed city on a hostile rockball.

CHAPTER FOUR

MICROORGANISMS



"Uh, Michelle – what's with the mask and gun? Have you gone Howard Hughes on me? Okay, I'll take off my clothes – hey, that spray stings! That's my best outfit! Don't burn it! What's going on?"

"It's the Mafia, Tommy. They've sicked a smart superflu virus on me, tailored to my genetic code. They don't know where I'm hiding, but it doesn't make a difference. Anyone in town could be a carrier – you, the dog, the landlady – it's not important, 'cause it won't do a thing to them. It has my name on it."

Microbes range from simple bacteria to more complex algae and fungi (such as yeasts and molds). They are living chemical factories, taking in specific raw materials and converting them into the proteins their metabolisms require.

The advantage of engineering microbes is that their simplicity and short generation length enable projects to proceed on a scale of months rather than years. Once microbial products have been developed, industrial biotech processes enable them to be cultured in giant fermentation vats that can hold thousands of gallons. With the right nutrients, such a biomass can grow very quickly, increasing its total mass eightfold every hour!

TYPES OF MICROORGANISMS

The terms *microorganism* and *microbe* are interchangeable, and in common use refer to living organisms too small to be seen with the naked eye. A more useful definition is a unicellular organism. Despite a few colonial species being microscopic and some single-celled protozoa being just large enough to be visible, this definition provides a coherent group of organisms, which come in several different types. At the grossest level they can be classified into *eukaryotes*, *bacteria*, and *archaea* – see the box *The Domains of Life*.

Protozoa

Protozoa are single-celled eukaryotes that exhibit some characteristics we consider animal-like, such as movement and ingestion of food. Most cannot produce their own food through processes such as photosynthesis. They come in several varieties, usually classified by means of locomotion: flagellates which move with a whip-like tail, ciliates with a coat of beating hairs, amoeboids with their extending pseudopods, and non-motile parasitic forms. Protozoa are

common in fresh and salt water, as well as soil, playing an important role in the recycling of nutrients. Parasitic protozoa cause malaria, cryptosporidiosis, and other important diseases.

As engineering subjects, protozoa offer relatively little raw material, since they ingest food rather than producing it and do not actively decompose matter. Parasitic types may be the best bet, for germ warfare applications.

Algae

Microscopic algae are the plant-like equivalents of protozoa – single-celled eukaryotes capable of producing carbohydrates from water and carbon dioxide with chlorophyll. Some algae grow into large multicellular organisms, most notably seaweeds, but the unicellular varieties are overwhelmingly more varied and abundant. They form the largest biomass in the seas – the phytoplankton – which produces most of the oxygen we breathe and forms the basis of vast food chains.

The Domains of Life

Life on Earth can be divided into three main categories of organism based on fundamental properties. Whereas previous generations classified living things into plants and animals, we now know that these organisms, as well as fungi such as yeast, are more closely related to each other than either is to a bacterium. Fungi, plants, and animals are all *eukaryotes*, organisms that possess a clearly defined nucleus, as well as organelles and DNA introns. *Bacteria* form the second main division; they are distinguished by a lack of any nucleus, organelles, and introns. The third major division of life only became known in 1977, when Carl Woese showed that certain organisms without nuclei had different DNA transcription and translation processes than bacteria. This group, known as the *archaea*, have cell chemistry and flagella structures unlike those of bacteria and eukaryotes.

Organelles

One of the major differences between the domains of life is that eukaryotes possess miniature, organ-like parts called “organelles.”

Organelles are located outside the cell’s nucleus, and perform specialized tasks, much like our body’s organs. For example, the mitochondria are bundles of rod-like organelles where vital, energy-releasing chemical reactions take place. These energy factories consume oxygen to break down sugars and acids, then capture the resulting energy for the cell’s use. Other types of organelles include plastids (organelles where photosynthesis takes place in plants) and undulipodia (whip-like bodies found in the tails of sperm).

Organelles resemble tiny bacteria – in fact, they possess minute amounts of their own DNA and RNA. In effect, they have their own tiny genomes. A growing body of recent evidence suggests that in the distant

past, organelles were originally free bacteria, but were engulfed by other bacteria and incorporated into them as symbionts. Our genetic code seems to show that it was this evolutionary leap that transformed simpler organisms into the more complex eukaryotic species, enabling them to evolve into plants and animals.

Organelles – specifically, the mitochondria – have helped scientists study the way species have evolved. When an organism reproduces sexually, the sperm and egg unite to combine the mother’s and father’s genetic information.

However, the sperm only carries a nucleus – it doesn’t transmit any of the father’s mitochondria, which are outside the nucleus. This means that mitochondrial DNA is passed on only through the mother. By measuring the rates of genetic mutation over generations – which, in the simple genome of mitochondria, are remarkably regular – it is possible to get estimates as to how old a particular species is, and at what point it diverged from other, related species.

In 1987, a team of scientists used this “mitochondrial clock” to develop the “Eve” theory. Study of different human populations allowed them to calculate an average mutation rate for human mitochondria, and they used that to conclude that the ancestor of all surviving mitochondrial DNA types existed around 200,000 years ago (in Africa, based on fossil evidence). This doesn’t imply there was only one human female – only that, of several thousand early humans, only one particular African genetic line has survived.

The “Eve” theory is controversial, and there are questions about the accuracy of the statistics used in the calculations. Nevertheless, as our knowledge of genetics improves, this kind of genetic analysis may prove to be a valuable tool in measuring the way species evolve.

Algae offer the twin benefits of producing food and oxygen, so they can be useful for biotechnologies requiring these resources, from feeding an overcrowded world to preparing a breathable atmosphere on a new one.

Fungi

Fungi are eukaryotic organisms unlike animals or plants. They grow in forms resembling plants, but are incapable of manufacturing food; instead, they secrete enzymes that break down organic materials, which they then absorb. They thus play the role of decomposers in an ecology, or sometimes parasites. Many fungi form visible threads and reproductive bodies (mushrooms), but other important ones such as yeast are unicellular.

Microscopic fungi are good candidates for use as chemical processors, with their ability to break down complex molecules. They can also be used for biological warfare.

Bacteria

A *bacterium* is a single-celled microscopic organism, of which there are countless different species. Bacteria are the simplest forms of life, capable of rapid reproduction by dividing to form more bacteria.

Bacteria are generally smaller than eukaryotic organisms. Many species are capable of becoming dormant if environmental conditions are unfavorable, forming an impervious skin and turning into spores, which are capable of reviving when conditions improve. They can survive this way for hundreds – maybe thousands – of years. It is in this spore form that some disease organisms (e.g. anthrax spores) are be transmitted.

Bacteria are the darlings of microorganism biotech. Their DNA is easily modified, so they can be made to produce a vast range of organic compounds. They reproduce rapidly under the right conditions, and they are small enough to be used anywhere. The fact that they are the most common agents of infection also makes them ideal for applications such as biological control and warfare.

Archaea

Archaea resemble bacteria, and until recently were thought to be an ancient branch of the bacteria genetic tree. Detailed study of their genomes reveals that two-thirds of the genes are unlike any other living creature, suggesting they diverged from the bacteria evolutionary lineage at least three billion years ago.

Many archaea exist in extreme environments, where people had long thought life was impossible. These include the high-temperature water near deep sea thermal vents. Other species survive in freezing temperatures, or in highly saline, acidic, or alkaline water that would kill any other organism. Some species have metabolisms that produce methane, hydrogen sulfide, or other gases; these occur both in extreme environments and within the digestive tracts of mammals.

These strange organisms are likely to become important raw materials for biotechnology, as they have a wide range of properties and abilities to withstand any environmental extreme we can imagine. Archaea will be important for terraforming applications, to convert hostile atmospheres to ones more benign to other forms of life. No archaea are known to cause disease in any animals; biowarfare applications will likely revolve around using them to produce toxic gases, and not just as poisons – hydrogen sulfide in an oil well can ruin its production.

Viruses

A *virus* is much smaller – too small to be seen under the average optical microscope – and consists of a clump of genetic material (DNA or RNA) sheathed in protein. By some definitions, it's not alive at all. Viruses grow only in living cells, whereas certain strains of bacteria can survive almost anywhere. A virus lacks the molecular machinery to reproduce itself, such as the ribosomes that cells possess. Instead, a virus seeks out living cells, slips into them, and hijacks the cells' machinery into working for it.

A *retrovirus* is a virus whose genetic material consists of RNA. This type of virus can be modified into a tool useful in engineering. For instance, genetic engineers can create modified "transfer" viruses that can carry new genes (or gene regulators) into cells in order to alter them.

Retroviruses use an enzyme called reverse transcriptase to transcribe the RNA code into a DNA code, which the virus then inserts into the genome of its host. The human immunodeficiency virus (HIV) is an example of a naturally occurring retrovirus.

A *nanovirus* (p. 12) isn't a real virus – it's a bio-nanotech construct that sometimes behaves like a virus. It might have a virus in its ancestry, but its relationship is about as close as that of a wooden ship to a tree. Note that the term "nanovirus" is a popular SF neologism. In real biology, the term is used for a genus of plant-infecting virus.

Prions

Prions are infectious proteins that can be copied by cells in the right biochemical environment, much like viruses, but without any DNA at all. First hypothesized in 1982, prions demonstrated that self-replicating biological information could be transmitted using a different mechanism. Nobody classifies prions as alive, though. They are simply proteins, with the same amino acid sequences as normal and useful proteins in organisms, but twisted into a different geometrical shape. If a prion enters a cell, it can induce those normal proteins to convert into the pathological prion shape.

Many prions are harmless, but some aggregate into polymer-like structures that form fibrous plaques within brain tissue. These plaques interfere with neurons and produce a sponge-like pathology of the brain, resulting in disabling and ultimately fatal disorders like Creutzfeldt-Jacob disease, kuru, and mad cow disease. Prions are not destroyed by cooking or even medical autoclaving, and they can infect people who eat infected food or whose tissues come into contact with infected material (such as during brain surgery).

While much remains to be learned about prions, it is possible that they could be designed to have specific effects. Prions in some yeasts appear to confer improved resistance to invasion by unrelated strains, so engineered prions may have some use in improving disease resistance, but the most obvious use is to produce an insidious plague weapon.

INDUSTRIAL AND COMMERCIAL MICROBES

For thousands of years, people have used yeasts, fungi, and bacteria to manufacture products such as beer, bread, and cheese. From the mid-19th century (TL5), researchers applied scientific techniques to the study of microbes to find natural strains that performed new tasks or did old ones better. This produced microbes usable in improved food and beverage products, industrial chemicals, and medicine (e.g. *Antibiotics*, p. 150).

Early 21st-century (TL8) advances in biotechnology largely relied upon engineering specialized microbes,

using the techniques of gene cloning and "protein farming" (see *Gene Cloning*, p. 12). With genetic engineering, organisms can produce or extract a wider range of products, ranging from drugs and fuel to industrial chemicals.

For microbes to thrive, they need nutrients (such as sugars) for growth, as well as a carefully regulated pH (acid) balance. Some also require a narrow temperature range, and temperature in a vat can change as the amount of biomass increases. TL8+ fermentation vats have sophisticated temperature – and acidity-regulating equipment. As the

optimum combination of temperature, acidity, and nutrients varies from species to species, and the details can greatly affect yields, experimenting to find the correct vat environment is an important part of industrial biotech research.

Not all “working bacteria” are involved in fermentation or protein farming. There are bacterial species which are naturally capable of metabolizing metals or chemical waste, are resistant to heat (even living in ocean vents), or are anaerobic (don’t require oxygen). These have a multitude of applications, as described below.

ENERGY AND FUEL PRODUCTION

All living things require energy, so are capable of harnessing it in some way or another. Organisms then use it to drive chemical reactions to produce compounds with stored potential energy. If done in bulk, this produces a resource that technology can exploit.

Methanol and Ethanol (TL6)

Yeasts acting on organic waste matter can convert it into methanol and ethanol. These alcohols are liquid and so a more convenient form for vehicular fuel than methane (below). Alcohol contains half the energy of gasoline per gallon; this reduces the range of the vehicle on a full tank, but doesn’t adversely affect the power generated by the engine (many racing cars today use methanol fuel).

Methane and Hydrogen (TL8)

Some bacteria or archaea can produce methane gas. These can provide renewable energy and a source of industrial chemicals. Natural bacteria capable of performing these activities are in limited use today. At TL9+, engineered bacteria capable of much higher performance will be introduced.

Methanogenic microbes consume organic waste. A bioreactor would be a vat into which vegetable and animal wastes could be fed, to be converted into methane by the bacteria. As a byproduct, the remaining waste after processing will have been converted into a rich fertilizer. This sort of recycling would be valuable for isolated colonies of people. On a larger scale, landfills full of urban waste can be capped with an impervious membrane to capture the methane, which is then piped to a central collection facility for distribution to buildings as a replacement for natural gas. This is already being done in some places, and should become more common in the future.

Hydrogen is another gaseous fuel that can be produced by bacteria. Only a few species naturally do so, and produce only small quantities, but at TL9 these should be available for mass production. Interestingly, hydrogen-producing bacteria can use as raw materials the waste products of fermentation to produce fuel alcohol (see above).

Photosynthetic Applications (TL8)

Plants have the best known biological energy producing mechanism: photosynthesis. The process is carried out by

Purchasing Microorganisms

Many of the microbes described in this chapter are not listed with a purchase price. This is because the price can vary widely depending on the circumstances of production and distribution.

Intrinsically, microbes are cheap to make, as they reproduce by themselves with nothing more than a suitable environment and nutrient supply. The physical production costs will be from \$10 to \$100 per dose or small useful amount. And once a sample is acquired, someone wanting more can simply grow them himself with the right equipment.

The market price of microbes will be set to account for R&D costs, patent lawyers, commercial production monopolies, any legal risks, and whatever the market will bear. The GM should set prices taking these factors – and game balance – into account.

Natural bacterial or viral cultures (for existing germs) might be available on the black or open market. The open-market price for sale to legitimate science labs is in the \$100 to \$1,000 range. Only a few doses of any disease culture will be sold, since after the sale, it is relatively easy for anyone with a genetics lab to culture the disease extremely cheaply. For this reason, engineered microorganisms with commercial or military value will often have sticker prices up to a thousand times higher, in order that some profit can be realized.

Lethal bioagents are usually LC0, and black-market prices may be a hundred times higher per dose. If a production line is set up, prices may drop to about \$10/dose. A pathogen whose purpose is relatively benign (e.g., one intended to get rid of a certain breed of dangerous animal or to kill off insect pests) may be LC3 and available on the open market.

Any system for delivering drugs (hypos, needler rounds, etc.) can carry biological weapons. A HT-4 roll is required to avoid contagion if injected or shot. Depending on the disease vector, bioweapons may also be delivered by insects (see p. 82) or other animal carriers. Bacterial spores or virus particles can be loaded into a chemical round such as a gas grenade or bomb and detonated to create a plague-ridden area, or put into ventilation systems, sprinkled on artifacts in tombs, and so on. To fill a typical 40-mm grenade warhead, 10 doses are required.

organelles called chloroplasts inside plant cells, which take in water, carbon dioxide, and energy in the form of sunlight, to produce oxygen and carbohydrates. The chemical bonds of the carbohydrates store energy, which the plant can later use to grow. Humans have been using this energy for millennia, in the form of burning wood.

One application of photosynthesis currently being tested is to embed unicellular algae into polymer beads, and spread them out on a pond surface. They are continuously circulated through a machine that harvests the accumulated carbohydrates and releases them back on to the pond.

TL9+ biotech will also allow a more direct use, with harnessed chloroplasts embedded in mechanisms that can oxidize carbohydrates to release the energy (see *Cellular Batteries*, p. 109). This would be a self-renewing power source or provide supplemental energy for biogadgets (p. 95).

*Why trouble to make
compounds yourself when a bug
will do it for you?*

– J.B.S. Haldane

Photozyme Solar Film (TL9)

The next step beyond photosynthesis is using biological molecules to generate electricity directly. Certain enzymes react to light by becoming electrically polarized, separating positive and negative charges to opposite ends. Embedded into cells in a lipid membrane or biofilm (p. 111), these *photozymes* produce a usable electrical potential across the film. This technology allows growing a biological solar cell on any surface exposed to light, though it is not as efficient as manufactured solar panels.

Statistics: Photozyme solar film costs \$100 for a living cell culture adequate to cover one square foot. It grows at a rate of a linear foot per week (see *Biofilm Growth*, p. 110). It can also heal damage at the same rate. Photozyme film requires twice the area to collect the same amount of power as solar panels of the same TL.

MINING AND REFINING

Bacteria exist whose proteins can bind to and concentrate traces of metals from mine shafts, industrial wastes or sea water. The biomass can then be collected and refined. More complex (TL9+) versions of these bacteria can excrete the minerals themselves, reducing the cost of downstream processing.

Ore Extraction (TL8)

The bacterium *Thiobacillus ferrooxidans* is the best known of several species that thrive in sulfur-rich acidic environments and can leach sulfur out of metallic ores to produce refined metal. The bacteria break down the ore, releasing metal ions into an acidic solution, which can be collected and easily processed into pure metal. This process is suitable for refining gold, copper, nickel, zinc, and some

other industrial metals. It is cheaper than conventional smelting, and can be done in situ, resulting in less landscape disruption than mining, but poses the risk of groundwater contamination with the acidic product. At TL8, economic factors favor smelting, but as the process is improved and pollution control becomes easier, bioleaching will become a mature technology.

Refining Sea Water (TL9)

Sea water contains many useful chemicals, albeit in low concentrations. Bacteria are ideal for absorbing and concentrating particular elements. By engineering them with protein coats that catch particular ions, they can be made into tiny selective sponges and storage cells. After being allowed to float in the sea for some time they would be harvested and processed to extract the chemicals. Encapsulating the bacteria in semi-permeable polymer beads would make them easy to circulate and collect.

CORROSION CONTROL

Corrosion of materials exposed to the elements is one of the major concerns of industrial engineers. Besides using a biofilm (p. 111) as a barrier to corrosive substances, bacteria can be employed to fight corrosion in more active ways. At appropriate tech levels, the following mechanisms may be standard parts of equipment maintenance, particularly for vehicles.

Prevention (TL9)

Metal corrosion is caused by interactions between adjacent materials of different electrochemical activity. Bacteria can circumvent this by adjusting the chemistry of a metal surface with enzymes. Long-term protection requires hardy bacteria that can survive on a metal surface, but the advantage over a biofilm barrier is that they can spread quickly to attend to scratches or other damage site that are normally sites of rapid corrosion.

In many cases, corrosion is enhanced by the presence of sulfate-producing bacteria that generate an acidic environment. Preventive bacteria would seek and destroy these harmful microbes, further reducing the risk of corrosion.

Reversal (TL10)

Specially designed bacteria can also be applied to already corroded metal to undo the chemical processes of that corrosion. This involves reducing the metal oxides and other compounds to release the non-metallic elements and rebuilding the metal's crystal structure. This works well for early stages of corrosion, but cannot restore heavily pitted or disintegrating metal.

POLLUTION CONTROL

Bacteria can be designed to break down plastics that have been properly treated, while those that metabolize hydrocarbon molecules can mop up oil spills. Often, bacteria of this sort don't even have to be genetically engineered.

Instead, biotechnicians look for sites that have been contaminated for years by (for example) an oil spill, and then isolate the microorganisms that are thriving there. These may also be designed as weapons – see *Anti-Material Bacteria* (p. 118).

Greenhouse Reversal (TL9)

The major contributor to greenhouse warming on Earth is atmospheric carbon dioxide. To reverse a potentially catastrophic increase in carbon dioxide levels, engineers may boost the carbon-absorbing abilities of microscopic algae. Oceanic phytoplankton already account for the bulk of the world's carbon dioxide converted to organic matter, so improving their productivity and increasing their geographic range would have a significant impact.

DOMESTIC BACTERIA

Microorganisms have been used for domestic purposes for millennia, from the yeasts that make our bread rise and beer brew, to the microbes that recycle our wastes.

Composting (TL1)

Bacteria naturally break down organic waste and release the basic chemicals and nutrients that other organisms need to grow. Humans can aid the process simply by throwing their wastes into a pile, which they have been doing for millennia, but deliberate efforts probably began in the Bronze Age.

Septic System (TL6)

Septic systems are sewage and organic waste treatment systems that do not rely on sewers to take waste to a centralized treatment plant. Invented in 1860, a septic system consists of a large tank in which sewage separates into liquid and a solid sludge that sinks to the bottom. Anaerobic bacteria decompose the sludge, while the liquid drains into a leach field via pipes buried over a large area. Natural decay in the soil purifies the water, which returns to the ecosystem. The decomposed sludge must be drained eventually, and can be dried and used as a fertilizer on plants not destined for human consumption (it retains microbes that can cause diseases in humans).

Septic systems were used in early TL6 cities – in an effort to control increasing outbreaks of cholera – before centralized sewage treatment facilities were built, and remain useful for remote settlements. They would be a good choice for sewage disposal in high-tech colonies, including on newly terraformed planets.

Statistics: Price ranges from \$2,000 for a system large enough for a household, to \$10,000 or more for a communal system servicing a village. Larger settlements will need more systems.

Composting Toilet (TL7)

These differ from septic systems in that they use an external power source to provide ideal conditions for rapid

decomposition of sewage by bacteria. They are more compact but more expensive than septic systems. Another advantage is that they heat the waste to a temperature that kills microbes dangerous to humans, so the resulting sludge can be used to fertilize crops. Composting toilets are ideal for enclosed systems such as on board spacecraft or colonies on a hostile world.

Statistics: A single composting toilet costs \$2,000 and requires electrical power.

TARGETED MICROBES

In many cases it is desirable to engineer bacteria for specific targets, either by giving them properties that are useful when delivered to targets selected by other means, or by making them seek out desired targets.

Surveillance Infection (TL9)

The idea behind this is to mark people who come into contact with specific items or places, for the purposes of deterring or tracing trespassers and thieves. The concept is similar to money containers spraying potential thieves with an indelible dye, so that they can easily be identified. For much more subtle and permanent marking, items can be coated in engineered microbial parasites or their spores. These can either have no noticeable effect on the victim, simply living within his body, or might produce chemical markers that make him detectable from a distance by biosensors (see *Communicators* under *Symbiotic Bacteria*, p. 121). Either way, a blood test will detect the organisms and mark the suspect as having had contact with the protected item. If the thief suspects such an infection, he may be able to use drugs or targeted nano to remove it.

At TL10, an even more subtle and permanent tracer uses retroviruses to insert a genetic marker sequence into the thief's DNA. At its simplest, this does nothing but provide positive identification with a DNA test. More insidiously, it could do anything achievable with genetic surgery (p. 14). Since such genetic surgery is not done under controlled conditions, the victim gets a HT roll to resist the modifications.

Infections that do nothing have standard microbe costs (*Purchasing Microorganisms*, p. 105). Those that perform genetic surgery have *at least* the additional cost of the procedure performed.

Targeted Fluorogenia (TL9)

Given a DNA sample from a crime suspect, a lab can customize these bacteria to recognize and bond to cells containing the same DNA, and no other cells. It takes 48 hours to engineer the microbes and culture enough for use. Forensic investigators can then take a solution of the bacteria and spray it over a crime scene. If the bacteria find the target DNA, they fluoresce, making them easy to see. The labeled cells can then be collected for further analysis. \$1,500. LC3.

MICROBIAL CONSTRUCTION

With their ability to secrete various chemicals, microbes can be used to build various materials and structures with properties difficult to achieve by other manufacturing methods.

Surface Coatings (TL8)

Besides bulk material, microbes and protein matrixes can be used to grow thin coating layers on substrates of other material.

Stain repellent coatings form a barrier against dirt and grime. They can be constructed with ion profiles that make paints and adhesives refuse to stick to them, as well as repelling everyday stains. Applications range from non-stick cookware and graffiti-resistant walls to sensors that resist weather and sabotage.

Scratch and corrosion resistant coatings are usually a thin layer of ceramic in a polymer matrix, laid down on various substrate materials. Hard crystal coatings on softer substrates resist abrasion, and can be used to produce lightweight polymer windows that stay as clear as glass or flexible plastic materials that maintain a glossy, scratch-free appearance. Similar coatings can also protect metals from corrosion and polymers from chemical attack – allowing items such as fuel tanks to be made from light plastics.

Filtering coatings are designed to block specific parts of the electromagnetic spectrum. This is useful for sunglasses, scientific instruments, radiation shielding, and antilaser armor.

Economic Impact of Biological Manufacturing

Microbial manufacturing has the potential to change society as much as anything wrought by the Industrial Revolution. Suddenly making a lot of previously expensive things simple to manufacture will have economic implications, and can lead to the usual sort of social disruptions: unemployment, economic depression, and social unrest. At the same time, society as a whole will become more affluent. This leads naturally to a dislocation between the wealthy and the poor, creating a society ripe for political revolutions. This process is a good justification for GMs wishing to develop a dystopian or socially stratified future.

On the other hand, microbial manufacturing can simply be seen as the natural progression of ever more efficient industrial methods, leading to nothing more than the expected gradual price drop of manufactured goods. Under this assumption, the future is bright, and everyone down to third-world farmers can afford the latest bacterially-grown personal computing and telecommunication devices.

Gems (TL9)

By producing crystals in precise alignment with a protein matrix, microbes can be used to grow gem-quality stones. Easily available “bugstones” are indistinguishable from naturally formed gems and can be grown for a fraction of the price. Besides the obvious uses for inexpensive jewelry, gemlike crystals also have industrial uses ranging from diamond-cutting gear to laser equipment, all of which will benefit from cheap, high-quality gems. They cost \$10 per karat, but can be traded to buyers unaware of the technology for the market value of natural gems.

Precision Equipment (TL9)

The higher the technology level of a society, the smaller and more precisely machined components must be to fit into ever more complex devices. Microbial construction is perfectly suited to making precision components, at a cheaper cost than using machinery to create them. Typically, components are grown by bacterial cultures in organic molds which can be removed by solvents. This is more precise than die-casting or injection molding as the parts are grown at room temperature, avoiding thermal expansion problems.

At TL9+, the GM can assume that most small parts are manufactured in this way, as part of the natural progression to relatively cheaper goods.

Supermaterials (TL9)

Several high-tech materials require precision construction on a molecular level – construction that can be achieved by microorganisms. The microbes can either produce short fibers in a vat, which are then harvested and processed into bulk material, or they can be engineered to excrete a protein polymer matrix as a supporting structure and then build the material directly in place. This method can be used to grow supermaterial structures in situ.

BIOELECTRONICS

High-tech electronic components have structures of similar scale to microorganisms. Given the vast range of properties of microbes and their ability to convert between electrical and chemical signals, it makes sense to incorporate them into electronics.

All of these developments can be treated in two ways:

- They form part of the natural progression of electronic technology, and will be integrated into equipment that follows the normal **GURPS** TL progressions. In this case, no special rules are needed, and ultra-tech equipment can simply be assumed to use these developments where appropriate.

- Alternatively, these technologies can be breakthroughs leading to vastly superior equipment. In this case, they will likely see application first in military gear before filtering through to the public. The new high-spec gear will be more reliable, faster, and cost half as much to manufacture as the standard varieties – but consumer prices may be more expensive because of licensing and regulation!



Living Chips (TL8)

These are electronic chips containing living cells as an integral part of their circuitry. One application is the detection of hostile chemical substances. A cell is sensitive to toxins in its environment and will quickly react if exposed to certain chemicals. These are broadly similar in application to biomimetic biosensors (p. 28), except that by using living cells the sensor can self-repair if damaged.

At TL9+, the cells in a living chip could implement DNA computers (p. 28), allowing some processes of the embedding electronic computer to be performed by the rapid parallel processing capabilities of DNA. This greatly speeds up tasks requiring repeated number-crunching, such as scientific data processing and cryptography.

Cellular Batteries (TL9)

Tiny nanomachines might use bacteria or cell cultures to store energy and release it on demand. Cells store energy in a molecule called adenosine triphosphate (ATP), which releases it in a variety of reactions. Cells can use this energy to separate ions, forming an electrical field that can drive a current in an external circuit. The energy production can be sensitive to environmental factors such as temperature or chemical cues, producing reactive behavior in the circuitry. Solar-powered devices may also use photosynthetic cellular batteries instead of electrical solar panels or photozyme solar film (p. 106), providing power generation and storage in one integrated technology.

Bioswitching Electronics (TL9)

Antibodies are extremely sensitive detectors of particular chemicals. Their reactions to exposure can be used to switch electronic circuits. The antibody receptors are contained in cells that connect to a circuit. Receptors for any specific chemical can be designed and engineered into the cells, tailoring the bioelectronics to any specialized application.

SUCROCHEMICALS

Up to TL8, industry makes heavy use of petrochemicals – products derived from fossil fuels, such as gasoline, asphalt, and many plastics and synthetic fibers like nylon. These are all made up of hydrocarbon organic molecules, which are the end product of millions of years of compression and heat acting on decaying organisms. In contrast, sucrochemicals are products based on carbohydrates, which are polymerlike molecules made of sugars, produced directly by living things. With a reliance on fossil fuels likely to be phased out around TL9 because of increasing

expenses and environmental concerns, sucrochemicals will be developed to fill the gaps.

Biological material can already be processed into fuels (see *Energy and Fuel Production*, p. 105); the remaining challenge is to adapt carbohydrates to replace the diverse array of petrochemical polymers. People have been using one sucrochemical polymer since TL1: cellulose. It is the major component of cotton fibers, and has been used in the processed forms of celluloid and rayon since the late 19th century (TL6).

The most likely method of producing enough sucrochemicals to replace petroleum-based plastics will be to engineer microbes to produce them. This will also allow the design and production of new carbohydrate polymers with desired properties. By TL9, there should be enough new materials to make us wonder why we ever needed petroleum.

TERRAFORMING

Colonizing a new planet is one of the greatest challenges for a technological civilization. One approach is the pantropic concept of engineering humanity to suit the local conditions (see Chapter 2). But if the world is too hostile or the goal is to make it comfortable to baseline humans, planetary engineering is required.

Engineered algae and bacteria will play a major role in any such program. Once water and methane have been added – if necessary – by hitting the planet with ice asteroids or comets, most of the work is done by living organisms. The required organisms can all be engineered by TL9 – finding a suitable world and getting there are more likely to be the limiting technological factors!

Changing the Atmosphere

The first step in terraforming a hostile world is to change the atmospheric pressure and composition. With no free oxygen and potentially extreme temperatures, anaerobic archaea would be the best bet for an initial planetwide seeding. Their main job depends on what sort of world is being terraformed.

For a Marslike world, cold with little atmosphere, the microbes would need to act on and below the surface to release nitrogen and carbon dioxide locked into the rocks. As the atmospheric pressure increases, greenhouse warming would heat the planet, allowing biological processes to speed up. If the microbes are dark in color, the reduction in albedo would also contribute to planetary warming. If even more warming is required, specialized microbes producing strong greenhouse gas halocarbons (such as CFCs) could be added.

With the opposite problem – a high-pressure runaway greenhouse world like Venus – the microbes will need to remove gas rather than produce it. They can do this by converting it into solid compounds such as carbonates and oxides. It may be easier to design the microbes to float in the atmosphere rather than try to survive at ground level; they can simply drift down with their sequestered load of solids when they die. As the atmospheric pressure drops, greenhouse warming will also drop, cooling the planet somewhat (although in the case of Venus, additional measures would be needed to reduce incoming solar radiation if the goal is to make it comfortable for baseline humans).

For example, in a Mars terraforming project, they would be released a decade or so after ice asteroid or comet strikes had provided water, but before organisms are added to the ecosystem. Hardy anaerobic bacteria would perform the critical task of releasing nitrogen locked beneath the plan-

etary surface. Within decades, they could be followed up by engineered lichen and fungi. In several generations (50-250 years), the soil might be fertile enough that simple oxygen-producing plants can be introduced.

Producing Oxygen and Soil

After a few decades, the world would have a more hospitable climate, but the wrong mix of atmospheric gases. This is relatively straightforward to address, with photosynthetic algae working to process carbon dioxide into biomass and oxygen, but would take a long time. Engineered lichen and fungi can be added as soon as they are capable of surviving on the surface, to add additional biomass and provide additional organic material that will build a fertile soil. Eventually, the soil will be able to support macroscopic plants and engineered animals.

ZOOGLOEAL ORGANISMS

Some microorganisms form large colonies or collective bodies that behave in ways similar to a single macroscopic organism.

Slime molds are protozoa that usually exist as average-looking amoeboid forms, but occasionally aggregate into

large masses for the purposes of migration and reproduction. Individuals of some species coalesce together to form a single huge cell with thousands of nuclei; this giant amoeba is called a *plasmodium* (not to be confused with *Plasmodium*, the genus of protozoan that causes malaria). These plasmodia resemble mucousy blobs of slime, and are known to cover areas up to two square yards in size! Other species collect into slug-like forms that maintain individual cell walls, but move together as a single colonial creature. After the plasmodium has moved to a suitable area, it sprouts stalks and releases reproductive spores. Experimenters have shown that slime molds are capable of navigating the shortest distances through mazes, which may lead to future applications for this sort of cellular “intelligence.”

Zoogloal organisms are bacteria that form similar large masses, but by excreting polymeric macromolecules (proteins, nucleic acids, lipids, polysaccharides) to form a gel matrix around their cells. This bonds them to neighboring bacteria, as well as any other microbes or inert material in the vicinity, producing large masses of organic sludge. The polymer film around each bacterium protects it from predators and traps any biocidal chemicals or heavy metals so that the bacterium can safely eat any organic wastes in its environment. This makes zoogloal organisms difficult to kill by chemical means; even most antibiotics are ineffective.

Sludges (TL7)

Zoogloal sludges are important in industrial waste water and sewage treatment processes, as they multiply successfully in heavily contaminated water, bonding particles and chemical ions in their gel matrix. The viscous mass of bacteria settles out and leaves relatively pure water behind. This is a standard sewage processing technique at TL7+.

Biofilm Growth

An advantage biofilms have over inorganic coatings is that they can grow. The rate of growth varies according to what nutrients are available and the current size of the film. Under ideal conditions, a film grows outward at a constant linear rate, meaning its area grows faster as it gets larger. Assume a film can grow one linear foot per growth period (defined to be a day, week, or whatever for each particular film). The table summarizes the rate at which the area covered grows:

Growth Periods	Area	Growth Periods	Area
0	1	20	1,300
1	8	30	2,900
2	21	40	5,200
3	40	50	8,000
4	65	60	11,500
5	97	70	15,600
10	350	80	20,400
15	760	90	25,800

Area is in square feet. For films larger than 25,000 sf, assume they grow 500 sf per growth period.

Example: A film has a growth period of a week. It is initially spread over 40 sf. A week later, it covers 65 sf. After a year, it will cover a little over 8,000 sf.

BIOFILMS

Zoogloal bacteria can also stick to surfaces in relatively thin layers, producing what is known as a biofilm – an example is the slimy layer on your teeth when you haven't brushed them for a while. Like sludges, these also have application in water purification, but their thin surface-coating nature makes them suitable for other purposes.

Biobarriers (TL8)

Since biofilms absorb many chemicals, they can form protective layers between sensitive areas and potential contaminants. This has many applications:

Environmental Protection: Biobarriers can keep soil or groundwater from being compromised by industrial activity such as mining. They are also an ideal form for using pollution control and removal bacteria (p. 106).

Evaporation Prevention: Water reservoirs lose significant amounts of water to evaporation, particularly in hot and dry climates where water supplies are precious. A biofilm floating on the surface can cut down evaporation dramatically.

Food Processing: Cleanliness is vital to keep harmful bacteria away from food during manufacture and transport. Biobarriers can keep food pure and fresh, but may require removal before consumption. Advanced types may be edible and unnoticeable, except that the smell of the food doesn't penetrate. Additional costs will be negligible unless the patent holder is particularly greedy.

Insect Deterrent: Mosquito larvae live in water and breathe through snorkels. A biofilm can prevent them reaching the air they need, in a more environmentally friendly way than the old method of using a petrochemical slick. A biofilm on structures or worn as a second skin can also present a repellent surface for verminous or biting insects.

Medicine: Biobarriers can protect healing wounds from infection, and may be one effective method of approaching synthetic skin for trauma victims. They may also form protective skins for work in contaminated environments.

Biofilms worn as protective skins can be smeared on like sunscreen or sprayed on for more even coverage. They are imperceptible once applied.

For the first half of geological time our ancestors were bacteria.

– Richard Dawkins

Photosynthetic Film (TL8)

A straightforward application of biofilm technology is to use cells with chloroplasts to generate carbohydrate fuel, or electrically active cells to generate electric current. See *Photosynthetic Applications*, p. 105, and *Photzyme Solar Film*, p. 106.

Giant Blobs!

Not all unicellular creatures in fiction are microscopic – some are decidedly macroscopic! While the oozes and jellies of classic fantasy role-playing may be magically created or otherwise defy the laws of biology, the giant blobs of science fiction might be achievable with suitably advanced biotechnology.

One obvious source for a possible giant blob is a slime mold plasmodium (p. 110). Realistically, plasmodia don't have the structural strength to hold themselves taller than a thin smear of slime on the ground, but if you're going for giant blobs you'll have to bend some rules somewhere. A pseudoscientific justification for a tall blob with Basic Move greater than 0 could be hydraulic organelles anchored to a semisolid protein matrix, either naturally evolved, the result of atomic radiation, or a product of deliberate engineering.

Superscience technology could simply enlarge an existing microbe, embedding it in a field that allows it to act as though the laws of physics were still working on a microscopic object.

The most realistic giant blobs would actually be multicellular creatures with internal musculature attached to a rearrangeable framework.

Directional Osmotic Films (TL9)

Biofilms can be asymmetric, with different properties on each side. This can be useful if one side can absorb particular molecules and pass them through to be expelled from the other side. Whereas an inert semipermeable membrane will allow osmosis of soluble chemicals in whichever direction is supported by a chemical gradient, an active biofilm can drive against osmotic pressure by using cellular energy. This has several applications:

Water Purification: Unlike reverse osmosis which requires an external energy source to supply the pressure to force water through the membrane, a biofilm purifier powers itself as the bacteria in the film either absorb nutrients from the impure water or generate energy through photosynthesis. A useful application is biofilter canteens (p. 96).

Corrosion Prevention: A directional biofilm can actively repel corrosive ions from any surface, while allowing through any other chemicals that might be necessary for proper operation of whatever is being protected.

Synthetic Skin: Suitably engineered osmotic film makes an ideal synthetic skin material that can be applied to seal wounds and promote healing. At TL9, different types exist for maintaining proper hydration levels in air, fresh water, and salt water. At TL10+ a single smart film can adapt automatically to any environmental conditions, and also excrete suitable antibiotics. This is the basis for TL9+ bandaging material such as bandage spray and plasti-skin (p. 124).

GERM WARFARE

Not all microbes are busy little workers. Pathogenic microorganisms, such as bacteria and viruses, have a long history as weapons. Even before people had an inkling of the germ theory of disease, medieval siege engines lobbed disease-ridden carcasses into fortified cities. Some evidence suggests Europeans deliberately used smallpox-ridden blankets to infect Native American tribes in the 18th century. In the 1930s and 40s, Japan experimented with the use of plague in its conflict with China.

Ecological Warfare

Biowarfare need not be restricted to causing primary damage against human targets. As much as we ignore it in modern society, humans are dependent on plants, animals, and microorganisms. Attacking *those* is the basis of ecological warfare: disrupting the web of life in occupied territory and bringing about the enemy's defeat through the collapse of vital resource supplies.

There are countless possible approaches. Livestock can be targeted with bacterial or fungal diseases, or their feed contaminated with prions. Biological control methods (p. 76) can be used against crops, employing anything from fungal infections to ravenous beetles. The seeds of weeds can be scattered far and wide. The attackers can also disrupt wild ecosystems by releasing predators or fungi that rot vast forests. And this is all without engineering the agents of attack; designing new ways to kill plants and animals will make ecowarfare even more horrible. When strange plagues start to kill your food sources and you have no idea how to counteract them, or if they'll be dangerous to humans, all the nukes in the world won't help you sleep at night.

If anything, a highly biotechnological society may be more at risk from ecological warfare than a low-biotech one, as such a society is more reliant on various organisms. Industrial bacteria, engineered monoculture plant strains, and biogadgets would all make tempting targets.

Modern science has made it possible to prepare stockpiles of germ cultures, and to arm spray tanks, bombs, and missile warheads with disease-carrying bacterial spores. However, science has also alerted us to the dangers of these weapons. No weapon is more uncontrollable than a plague, capable of crossing borders with impunity to scythe down friend and foe alike. While limited numbers of people can be given preventive treatments in advance (perhaps even

secretly, disguised as a routine flu vaccine), germs also have a distressing tendency to mutate.

Society bans weapons when they are simultaneously difficult to control, imprecise in their effects, and capable of exciting moral outrage. Germ warfare falls into all three categories, so international efforts to outlaw microbiological weapons have been relatively successful. While stocks of bioweapons existed at the height of the Cold War, most nations at least claim to have destroyed their germ warfare arsenals today – although some are suspected of having secret bioweapons programs. Some germ cultures – notably smallpox – have been preserved so that they can be studied for disease prevention and treatment.

There is also concern regarding the risk of bioweapons being used as a “poor man’s nuke” by desperate “outlaw regimes,” although in practice, most such nations seem to have preferred to pursue nuclear or chemical weapons programs. Current fears of biological weapons are centered on their use by terrorists such as the Aum Shinrikyo cult – which released nerve gas in Tokyo’s subways in 1995 and which was also developing biological weapons – and the perpetrators of the 2001 anthrax mail attacks in the United States.

Although there have been no large-scale biological attacks so far, progress in genetic engineering threatens to make improved microbiological weapons that are even more deadly (and perhaps even more controllable) than nature’s plagues. Recent controversial medical research experiments involving genetically improved flu viruses (to study how these mutate) highlight the potential capabilities of such technology in the wrong hands.

Fortunately, the mechanics of epidemics make it difficult to kill off an entire species with a single disease. A germ that is “too successful” and kills off all exposed targets leaves behind no reservoir of disease organisms to infect isolated victims who escaped the initial outbreak. A disease that is less lethal will leave a population of survivors immune to it, lessening the disease’s future impact. Deliberate or accidental germ warfare might kill off most – even 95% – of a particular species, but probably won’t wipe it out entirely. Even so, the effects can be devastating. The greatest 20th-century natural pandemic, the super flu of 1918, killed over 20 million people in three months, and that was without widespread air travel to rapidly propagate the disease.

BIOLOGICAL AGENTS

The most popular biological weapons are pathogenic bacteria and viruses. Some types of bacteria can also be used to manufacture poisons, just as they can make useful proteins. An effective germ-warfare agent should be lethal, or at least incapacitating, and easily spread. If you can only catch the disease from sexual contact, for example, it is less dangerous than one that will contaminate an area and whose spores can be inhaled.

Bacteria are easier to spread than viruses because they can survive as spores and contaminate an area for long periods; however, viruses are harder to treat, being immune to antibiotics. Biotoxins are not contagious, but

can be used to contaminate food or water supplies – terrorists, for instance, might dump botulinum toxin into a city water plant.

Since germs are difficult to control as a weapon, it can be a good idea to choose a pathogen that can be treated, as this gives you time to secretly prepare for the disease, while your target may be caught by surprise.

The following biological agents are presented using the *Disease* rules (pp. B442-B444).

Anthrax

This disease is caused by the bacterium *Bacillus anthracis*. It is most common in agricultural regions, usually caught by humans from infected livestock or eating infected meat; death occurs in 20-60% of cases. However, weaponized anthrax is delivered in the form of dried powder-like spores, which cause pulmonary anthrax when inhaled by victims, with 80-100% lethality.

Several nations have cultured anthrax spores since WWII, and terrorists used them as a weapon in 2001. They are persistent, contaminating an area for about 40 years before weather breaks them down. However, an infected human cannot infect someone else – although this reduces its lethality, it also makes anthrax more attractive as a military biological weapon, since it is unlikely to spread far beyond the target area. Vaccines exist, and antibiotics are effective against it.

Statistics: Respiratory; HT-4 to resist; 1d+1 days delay; 1d toxic damage (with coughing after loss of 1/3 HP); 24-hour cycle with six cycles. Symptoms initially resemble influenza, but progress to severe breathing difficulties and shock (p. 125). Not contagious.

Botulinum Toxin

This biotoxin is a poison excreted by the bacterium *Clostridium botulinum*. It can be manufactured in fermentation vats, and may be a favorite of terrorists because of its extreme toxicity at low doses. It breaks down rapidly when exposed to air – contaminated areas are safe to enter after 24 hours. Victims who suffer respiratory symptoms need a ventilator to help them breathe for two to eight weeks until they recover. An antitoxin which halves any damage taken is available (\$10). The statistics below are for weaponized botulinum, not normal food poisoning.

Statistics: Digestive or respiratory; HT to resist, success only halves damage; 2d hours delay; 4d toxic damage; one cycle. Symptoms are blurred vision (-4 on Vision rolls), paralysis, and retching (p. B429) after the loss of 2/3 HP and choking (p. B428) after the loss of all HP. Not contagious. \$200 per dose.

Bubonic Plague

The “Black Death,” caused by the bacterium *Yersinia pestis*, devastated Europe in the Middle Ages. Bubonic plague is spread by rat-borne fleas and affects the lymph nodes; this most common form of the plague is fatal in 55% of cases if untreated. Bubonic plague may progress to septicemic plague, or infect the lungs and become pneumonic

plague, which can spread via respiratory droplets. Untreated, septicemic and pneumonic plague are fatal.

Understanding of the disease’s vector, improved sanitary conditions, and antibiotics have reduced the threat of the plague, but not eliminated it. Small outbreaks periodically reoccur, even in developed nations; 1,000-2,000 people get it each year, with 10-20 cases in the United States. Plague cultures exist in research labs around the world, making it relatively easy to acquire. Bubonic plague has been used as a biological weapon in the past.

Symptoms are shivering, headache, fatigue, and high fever. Left untreated, pain spreads to the back and limbs and the victim becomes sleepless, apathetic, or delirious. The most characteristic sign is buboes, swollen lymph nodes producing painful purple welts, especially in the armpits and groin. If someone does not know that the plague is in the region, a successful Diagnosis+2 roll will reveal what is happening on first sight of a buboed victim. Vaccines have existed since TL6, and antibiotics are effective against it.

Statistics (bubonic plague): Blood (insect borne); HT-2 to resist (critical failure results in pneumonic plague); 1d+1 day delay; 1d-2 toxic damage; six-hour cycle with 12 cycles. Symptoms produce severe pain (p. B428) and Unnatural Features 1 (buboes) after the loss of 1/3 HP. Mildly contagious (highly contagious if the flea-borne vector is not understood and precautions taken).

Statistics (pneumonic plague): Respiratory; HT-6 to resist; 1d/2+1 day delay; 1d toxic damage; 12-hour cycle with 12 cycles. Symptoms produce moderate pain and coughing (p. B428) after the loss of 1/3 HP, and choking (p. B428) after the loss of all HP. Highly contagious.

Ebola

A viral hemorrhagic fever, Ebola is an extremely lethal retrovirus that appears to have originated in Africa, spreading to humans from chimpanzees. The first confirmed outbreak of the most deadly strain, Ebola Zaire, was in 1976.

Ebola spreads from direct contact with blood or other secretions and infected needles, rather than through inhalation of viral particles. There is no chance of contagion if all contact with victims is avoided – in effect, it’s a blood agent.

Victims develop fever, chills, headaches, muscle aches, and loss of appetite. As the disease progresses, vomiting, bloody diarrhea, abdominal pain, sore throat, and chest pain results. The blood fails to clot and patients “bleed out” from all orifices, injections, and into the stomach and internal organs. Mortality rate is 60% (Ebola Sudan) to 90% (Ebola Zaire); most patients die within three days of developing symptoms. There is no vaccine, and antibiotics are ineffective.

Statistics: Blood; HT-3 to HT-5 to resist; 3d+1 day delay; 1d toxic damage; 12-hour cycle with seven cycles. Symptoms are frightening: moderate pain (p. B428) after loss of 1/3 HP, nauseated and severe pain (p. B428) after loss of 1/2 HP, and Hemophilia after loss of 2/3 HP; death comes with convulsions, which can splatter blood around the immediate area. Highly contagious; HT rolls are at -5 if in physical contact with a victim’s blood or bodily fluids.

Influenza

Influenza is a respiratory viral infection. Symptoms of flu include fever, headache, extreme tiredness, dry cough, sore throat, runny or stuffy nose, and muscle aches. There are numerous influenza strains, which mutate rapidly. Flu is spread easily by contact with infected individuals, and is most dangerous to the elderly and those already weakened by other privations or diseases. Vaccines are available, but antibiotics are ineffective. Statistics for a mild flu are on p. B443.

Some strains of flu can be especially deadly, such as the 1918 influenza A pandemic. Other deadly pandemics occurred in 1957 and 1968. There are fears that Asian avian influenza ("bird flu") may mutate from its current mildly contagious form to highly contagious, resulting in a similar disaster. Deaths from flu are usually due to respiratory complications such as pneumonia. The statistics below are for such a "killer flu," the fatigue loss and its effects simulating progression to pneumonia.

Statistics: Respiratory; HT-4 to resist; two-day delay; 1 point of toxic damage and 1d/2 fatigue; 12-hour cycle with 12 cycles. Symptoms include coughing (p. B428) and drowsiness (p. B428) after loss of 1/3 HP. Highly contagious.

Cleanup

If an area becomes contaminated with a biological agent, hazmat specialists will be called on to clean up the mess. Depending on the incident, decontamination can take months or even years, as initial obvious agents are cleaned up, followed by a lengthy hunt for contaminants lurking in inaccessible locations such as cracks in buildings or pavement.

Hazardous Materials skill (p. B199) includes the knowledge of cleaning up biologically contaminated areas. Labs (p. 16) may be equipped with ultraviolet lamps that can kill germs. Ordinary disinfectants and detergents may work in some cases. Ordinary household bleach (sodium hypochlorite) is one of the best decontamination agents and is used in most laboratories, although its caustic properties are not environmentally friendly.

Although peroxides and other oxidizing agents can destroy disease cells and spores, they can take hours to work. For more rapid decontamination, nontoxic catalysts composed of iron and chemical structures known as tetra-amido macrocyclic ligands are being developed specifically for biohazard clean-up. For example, spores such as anthrax could be killed in half an hour by spraying a solution of sodium carbonate, bicarbonate, and small amounts of these iron-ligand catalysts followed by the oxidizing agent tertiary butyl hydroperoxide.

The top-of-the-line method would be various types of nanomachines programmed to destroy a particular germ and nothing else. And if all else fails, fire (or nuclear weapons) can be used . . .

Rabbit Fever (Tularemia)

Believed to have been used in some germ-warfare programs, rabbit fever is caused by the *Francisella tularensis* bacterium. It resembles a mild form of bubonic plague, but is one of the most infectious organisms known (and is known for causing occasional lab mishaps). Humans can catch it by eating infected rabbits or other animals, by tick or flea bites, by an accident while preparing an animal carcass, or by drinking water contaminated by a dead animal.

The bacterium can easily be cultured so that contact with aerosol spores causes infection. A large warhead could spread it over a city-sized area. The Japanese worked on weaponized tularemia during World War II; during the Cold War the United States, Soviet Union, and possibly other nations developed stocks of the aerosolized bacterium. A terrorist attack using tularemia could kill over half a large city's population.

Tularemia causes swollen purplish lymph nodes (and might be mistaken for bubonic plague without a successful Diagnosis roll). Rabbit fever caught in the wild is rarely fatal to a healthy adult, but the inhaled form of the bacterium is more dangerous, causing additional symptoms including fever, sore throat, abdominal pain, diarrhea, and vomiting.

Statistics: Digestive or respiratory; HT-2 to resist (HT-5 to avoid initial infection); 1d/2 + 2 days delay; 1d-2 toxic damage; 12-hour cycle with four cycles, or 12 cycles if inhaled. Symptoms include moderate pain (p. B428) after loss of 1/3 HP and retching (p. B429) after loss of 1/2 HP. Not contagious from human to human.

ENHANCED GERMS

This is the biowarfare nightmare scenario – the use of genetic engineering to produce an "improved" pathogen. Some possibilities:

Treatment-Resistant Germs (TL8): The simplest kind of engineered germ warfare is to modify a virus or bacteria so that it does not respond to known vaccinations. While a new vaccine may be developed against it, it could be too late by the time it is ready.

Increased Infectivity (TL8): Designing a more infectious strain. A -1 or -2 on the HT roll to resist is possible at TL8, a -3 or -4 at TL9+. Other modifications may also be possible.

Species-Jumping (TL8): While some lethal germs harm multiple species, many diseases that are very lethal against certain animals have no effect on humans, and vice versa. In nature, this can change through mutation, allowing a virus or bacteria to "jump the species barrier." This might also be done artificially, so that a disease known to be a very efficient killer of monkeys, sheep, or Alpha Centaureans (for example) could be altered into one that kills humans. Modifying terrestrial diseases to affect aliens (or vice versa) requires at least TL9; having live subjects to experiment on is usually necessary.

Tailored Lethality (TL9): Designing a more (or less) lethal strain, modifying the number of cycles, damage and modifiers to resist it, or secondary symptoms. At TL9



doubling effectiveness (halving the interval but doubling number of cycles) may be possible. At TL10+, more drastic modifications can take place (e.g., increasing the lethality of influenza to that of bubonic plague).

Vector Modifications (TL9): Some of the most lethal diseases (like AIDS or rabies) spread only through contact with bodily fluids. This means that they can be contained by taking the proper precautions. However, engineering might be used to alter a particular agent so that it can be airborne – e.g., redesigning Ebola so it can be spread by coughing, or carried by mosquitoes, fleas, and the like. Of course, this might not always be desirable, since it makes it much harder to control. This will modify the circumstances under which a contagion roll is required.

Nanoviruses (TL10): Bio-nanotech can produce wholly artificial infectious toxic agents. These biological nanomachines allow entirely new modes of cell destruction as they disrupt vital chemical reactions or physically interfere in other metabolic processes. As such, antibiotics and Resistance to Disease have no effect against them. Protection can only come from guardians (p. 165) or Resistance to Nanomachines or Metabolic Hazards. Design nanoviruses using the same rules as inventing other infectious agents, but double the development and production costs.

TARGET-SEEKING PATHOGENS

I didn't mean it! It was a mistake! How was I supposed to know the sequence I picked to target that Michelle woman was also found in the capo's wife and daughters?

– Doc Hobo, street splicer

This genetic modification is one of the more exotic potential spin-offs of engineering and genome mapping.

With this know-how, a microorganism (most likely a virus or nanovirus) might be modified so that it will only attack individuals who possess certain genetic markers. What is possible varies by TL:

- At TL9, a virus can be modified so that it affects a fairly clear-cut set of genetic traits; e.g., blond hair, men only, women only. People possessing recessive genes may be vulnerable to target-seeking viruses without exhibiting those traits.
- At TL10, a virus can be modified to attack individuals with more complex combinations of genetic traits – for example, those that make up a particular racial group, or even traits known to be common to a particular family.
- At TL11, even more discretion is possible. A virus might be targeted specifically at an individual – it would affect him, or his clone or twin, but no one else.
- At TL12, target-seeking viruses can be a lot smarter, using biological nanomachines rather than simple engineered viruses; if the genome information is correct, they are reasonably foolproof.

It is absolutely vital to have accurate information on the genetics of the intended target group before the virus is created! The would-be viral warrior should exercise great care in specifying what traits the virus will target. For instance, suppose a white-supremacist terrorist group wants a virus that will target non-whites. Unfortunately for genetic Nazis, in all but the most isolated countries, there have been centuries of racial mixing. As a result, the virus will probably either kill a lot of the group's own members, or spare many of the people they want to affect, depending on how selective its designers made it. This is even true of "simple" targets like hair color, since very few phenotypes are governed by a single gene – a competently designed virus intended to kill blonds will do that, but will also kill some non-blonds and leave some blonds alive.

Sample New Bacterium – Oedipus-5 (TL9)

This terrifying bacteriological weapon attacks the nervous system and strips away neural sheathing. It also has a special affinity for attacking eye tissue. Oedipus-5 does not always kill, but survivors are often left uncoordinated and blind, posing additional problems for treatment.

The disease is spread by contact with infected individuals or the germ in the environment. Symptoms develop in 24 hours, and consist of blurred vision and dizziness; the eyes turn into weeping sores filled with pus, and the body shakes constantly. Antibiotics have their normal effect. Neural and vision damage may be fixed by TL9+ fetal tissue and eye transplants, but the process requires major surgery, costing at least \$2,000 per point of disadvantage that is to be repaired.

Statistics: Contact; HT-4 to resist; 24-hour delay; 1 point of toxic damage; one-hour cycle with 12 cycles. Symptoms include -1 DX after loss of 1/3 HP; an additional -1 DX, Bad Sight (Nearsighted), and Total Klutz after loss of 1/2 HP; and a third -1 DX, Blindness, and Confused (6) after loss of 2/3 HP. Highly contagious.

DESIGNER PLAGUES

Even more frightening than tinkering with existing germs is the prospect of an entirely new “designer plague.” This can be produced by modifying an existing (even harmless) bacteria or virus, perhaps combining genetic material from multiple different organisms into one.

New germs should be designed using the guidelines on pp. B442-444 or by modifying the diseases described in this chapter. The best way to “personalize” new diseases is to select afflictions, features, or disadvantages that occur as symptoms in addition to HP loss, usually after 1/3, 1/2, or 2/3 HT has been lost to that disease. Appropriate disadvantages include Blindness, Sterility, or even Bad Smell (from rotting flesh). More exotic diseases might even cause mental disadvantages by attacking brain tissue. GMs should not go overboard with symptoms, however: toxic damage is assumed to include pain, fever, chills, fatigue, etc., so it isn’t necessary to spell out every problem. Focus on the most interesting or frightening possibilities.

GERM DELIVERY

Once you have a biological warfare agent, you need to find a way to deliver it to your target, preferably without infecting yourself and your allies! If the infection is designed to target only your enemies, this is much easier, since it poses no risk to anyone else. There are many

possible scenarios for deploying germ warfare or bioterrorism agents, and just as many for detecting it, figuring out what is happening, and stopping it before it’s too late. Many of these have been explored in fiction and would make tense and exciting game plots.

Area Contamination

The simplest method of infecting a population is to release the germs over a wide area. This is only suitable for agents that can survive outside the body and infect people by contact or inhalation. Spraying the germs from an aircraft is effective, although likely to result in the craft being shot down or captured. Shooting it down may still spread the contagion just as well as if the craft gets away, posing a dilemma for any potential defenders if they are aware of its mission. A missile warhead is a less risky delivery system, but is harder to come by than a modified crop duster.

A more subtle approach is to use field agents to carry samples of the plague into the target area and release them as a coordinated attack. In its crudest form this is a suicide mission, but a moderate application of technology could program the germ containers for a time-delayed release. The agents might also be vaccinated, or not subject to a genetically targeted contagion. Air conditioning systems in modern buildings are an ideal target for such activity, as they have centralized plants that distribute air to large numbers of people. An organism that produces a contact biotoxin could be engineered (TL9) to grow as a biofilm (p. 111) when smeared on to doorknobs or other surfaces, contaminating wide areas.

Attackers can also spread bioweapons through distribution channels such as mail or courier services. This approach exploits an existing infrastructure to disperse the infection. It requires little hardware or expense, but can quickly be shut down once the attack is discovered.

Food or Water Contamination

Spraying crops or reservoirs is easier than spraying a populated area, but an infiltration mission to release the contagion in farmland or a city’s water supply is even less likely to be detected. Although it is relatively straightforward to spread the germs in this way, it is less effective for actually infecting anyone. Developed cities have drinking water treatment specifically designed to kill or filter out any infectious organisms, and crops are processed and purified before reaching consumers. Bypassing these defenses may be possible with small enough and hardy enough organisms, such as bacterial or fungal spores, or prions.

Another way of contaminating food or water is to do it at the processing plant. This allows the infiltrator to add the germs after any purification treatments, making them more likely to reach consumers. The difficulties here are gaining access to secure facilities and finding the right place within them to release the contagion, where it will be effective, and not noticed until it is too late.

Finally, food sources can be infected in the distribution chain between plant and consumer. Real incidents of people contaminating food on supermarket shelves (with poison rather than germs) have led to tamper-proof or

tamper-evident packaging which makes this difficult in some cases, but a hypodermic syringe can still work wonders with many products. The problem with this method is that it is labor-intensive and results in relatively few affected products, making the contamination easy to contain once it is identified.

“Typhoid Mary”

This method uses a carrier – a person infected with the disease organisms, but who has not (yet) succumbed to its symptoms. The carrier may be immune, or within a long incubation period for the disease before it manifests symptoms. A healthy-looking person can normally travel freely, and thus may carry the infection to other countries, continents, or planets. Once there, the carrier infects other people with whom he comes into contact. These victims develop symptoms, ideally after an infectious incubation period in which they infect a second generation of victims, and so on. As the disease spreads throughout the population, an immune carrier may remain unidentified as he has never developed the disease himself, though he may be tracked down through conventional and forensic detective work. If the carrier has succumbed, he might be identified earlier. By that stage, however, it is too late.

An immune carrier could easily be a plant, while a non-immune one must either be an unwitting stooge unaware of his fate or on a suicide mission. Infecting a willing carrier is trivial; getting the germs safely onto a dupe is another matter. It would be easy to plant engineered microbes on someone, by brushing past him or surreptitiously squirting him with an atomizer; the tough part is avoiding infecting yourself or anyone else, or contaminating the entire area. Thus some care and subtlety are called for.

Insect Vectors

If your bioweapon needs to get through the skin to be effective, simply contaminating a region won't work – you need to use something to get the organism into the body. Several types of insects and arachnids already have the habit of biting people and injecting them with disease organisms: ticks carry bacteria that cause Lyme disease, spiders harbor bacteria that produce necrosis of the flesh, and mosquitoes host the malaria protozoan and various viral diseases. There are also biting flies, ants, and other insects in various parts of the world.

The best natural bioweapon carriers would be mosquito species, as they are the most widespread and common biting insects encountered by people, and will raise few suspicions until it is too late. All you need is a small breeding facility able to release mosquitoes that carry the weapon in the target area. Each mosquito can infect multiple people, and once a few are infected the local mosquito population will begin transmitting the disease too. For more control or greater reliability, engineered insects could be used instead – see *Insect Bioweapons* (p. 82).

ANTI-GERM WARFARE

Once the prospect of using infectious agents as weapons becomes likely, people will begin inventing ways to defend against them. Many of the same procedures that work against natural infections will be effective, such as vaccination, antibiotics, and antiviral drugs. For pre-existing diseases, these things may already exist; the main problems will be ones of supply and distribution. Attackers will know this and factor it into their estimates of how effective a contagion will be. They may choose a disease for which no treatment is yet known, or for which effective treatment is too expensive for widespread use.

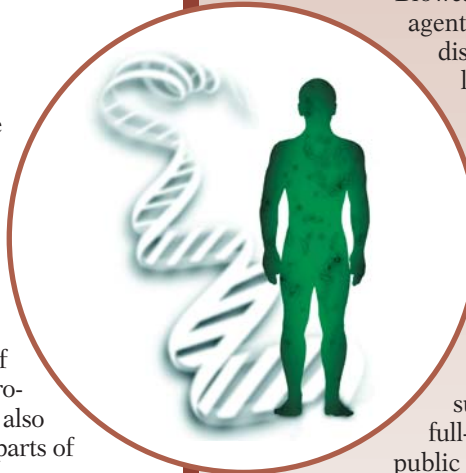
An engineered plague is another matter, as the contagion is completely new and precious research time will be needed to identify the pathogen before trying to come up with ways of fighting it. The most effective biowarfare agents will reduce the defenders to the basic methods of isolation, containment, and quarantine, which leads to ethical and social dilemmas for leaders, as well as adventuring opportunities for those caught in the chaos.

Combating germs spread by insect vectors can be approached in a different method: by controlling or eliminating the insects before they can infect people. Besides insecticides and repellents, biological control methods could be used – see *Biological Control* (p. 76).

Germ Warfare and Terrorism

Bioweapons make terrifying agents for sowing fear and discord – terrorism at its most literal. In 2001, terrorists in the United States mailed anthrax spores to media agencies and senators, causing the infections of 22 people and the deaths of five. The wake of panic following these attacks saw thousands of people seeking prophylactic antibiotics, while supplies quickly ran out. In a full-blown bioterrorism attack, public panic is likely to cause chaos, overwhelming emergency responses and spreading the contagion as desperate people evade or break through containment measures.

This reaction makes biological weapons an attractive choice for those seeking to maximize discord and make political statements. Many bioweapons are expensive to develop and distribute, but a few are simple enough and available enough to cause antiterrorism forces to fear the worst.



ANTI-MATERIAL BACTERIA

Halfway between killer germs and exotic industrial bacteria, these are microorganisms designed to attack nonliving things rather than animals or plants. Some types that are already under development (making them TL8) include:

Explosive-Eating Bacteria: Usually targeted at a specific chemical explosive; e.g., TNT, RDX, Plastex-B, etc. These will knock out explosive warheads and chemical propellants.

Petroleum-Eating Bacteria: Based on bacteria used to clean up oil spills, these are designed to eat hydrocarbon-based lubricants and fuels such as gasoline, diesel and jet fuel.

Rubber-Eating Bacteria: These could destroy tires, fuel lines, valves, boots, etc., disabling vulnerable equipment.

Other Types: At TL9+, more exotic types of bacteria (or nanomachines that work like bacteria) may become available that can rapidly degrade plastics, various biotech materials and even silicon chips. However, bacteria won't have much chance against metal, stone or most advanced composites and ceramics. Other types of microbes may also be used.

If equipment or supplies that are vulnerable to a particular anti-material bacteria are in an area that is contaminated, or come into contact with infected material, check for infection. Use the Contagion rules (p. B443) as guidelines to see if the bacteria infect particular material. Ignore modifiers for eating flesh, but "intimate contact" would be direct physical contact with contaminated material – e.g., topping off an uninfected fuel tank with contaminated gasoline, or spraying the bacteria directly into a mechanism. If the HT of the material (or its container) is unknown, use HT 10 for machines, 12 for solid objects.

Anti-material bacteria work slowly. Generally, infected material will show initial signs of rot or contamination after 24 hours and become useless (eaten away, turned to goo, etc.) within 48 hours. During this time, the bacteria can infect other material it contacts. A roll against Hazardous Materials skill (with appropriate equipment) can detect contamination early enough to treat it (using disinfectant bleaches, etc.). A fully airtight container or seal will protect against anti-material bacteria. In the case of sealed vehicles or bases, GMs can require occasional rolls vs. Hazardous Materials skill, with a failure or indicating that some sort of mistake was made (e.g., a seal left open), which will allow a chance of contamination. Of course, saboteurs can always open up machinery and spray the bacteria into it!

In general, anti-material bacteria are devastating against unprepared targets (especially at TL7 or less) but will be of limited use against targets equipped with countermeasures, such as ultra-tech military forces. See also *Cleanup* (p. 114).

Anti-Nano Bacteria (TL10)

One of the primary applications of nanomachines is to seek and destroy cells of various types. Turning this around, it is possible to engineer microbes to seek and destroy nanobots. This is a trickier task for the developers, as they need to equip the bacteria with the ability to detect nanomachines – which can come in a wide variety of physical shapes – and the ability to damage them.

At TL11 it becomes possible to engineer bacteria to *reprogram* nanobots. Reprogramming bacteria would cost at least as much as the purchase price of the reprogrammed nanobots, but the advantage is that the original nanobot controller may be unaware of the reprogramming, and might even be fed false information.



MEDICAL APPLICATIONS

Microorganisms have many applications for improving and sustaining the health of people, and in preventing or curing illnesses.

FIGHTING DISEASE

What science produces, it can also cure – sometimes. In addition to chemical treatments, bioengineering has produced several methods of dealing with disease.

Vaccines (TL5/6)

A vaccine is a suspension of material designed to produce antigens when introduced into the body, thus provoking the subject's immune system into producing defenses ready to fight off a real disease, should it appear. Some vaccines contain dead or weakened viral particles or bacteria, while others have DNA fragments or pathogenic toxins.

Crude attempts at exposing healthy individuals to smallpox scabs originated in China and India (TL5) and spread to Europe in the 18th century. In the late 18th century, Edward Jenner inoculated humans against smallpox by using the less virulent cowpox, and by 1800 vaccination was common in Europe. Louis Pasteur perfected the first modern “active” vaccine using weakened forms of the rabies virus by 1885 (TL6). Vaccines for a wide range of diseases followed quickly.

Today vaccines are relatively cheap (prices average \$20/shot, but can be as little as pennies per shot). Programs of mass vaccination have virtually wiped out several diseases, including smallpox. They have also spread a few diseases, when inoculations were performed with unsterilized needles. At higher tech levels, other diseases we consider common may be eradicated through mass vaccination programs. If a historically crippling disease such as smallpox is reintroduced to a world in which vaccination against it is no longer considered necessary, the consequences could be disastrous. This could happen if samples kept for scientific study are released – accidentally or deliberately; they would make tempting biological weapons. Or diseases could be reintroduced from other planets or timelines . . .

With few exceptions (notably rabies and smallpox), vaccinations are only effective on someone who has not yet caught the disease. They offer either boosted resistance or complete protection, but many wear off after a few years. As viruses constantly mutate, new vaccines need to be created – use the *New Inventions* rules on p. B473, using Pharmacy or Bioengineering (Vaccines)/TL6+ depending on the approach.

Making a vaccine is tricky: If it's too weak, it won't provide immunity, while if it isn't weakened enough, it may infect the patient! New solutions at TL8 include:

- Recombinant vector vaccines, made by splicing genes for a virus' outer protein coat (which is what the immune

system recognizes) into bacteria. Proteins harvested from the cloned bacteria are used to make a vaccine.

- DNA vaccines, which use lab-built DNA fragments directly injected into the body. These are designed to stimulate the production of antibodies to fight specific diseases. With no real virus particles, these methods are both strong and safe.

Statistics: A vaccine gives someone Resistant to Disease (+8) or Immunity to Disease limited to one particular strain of pathogen. This can wear off after six months (influenza, cholera) to 10 years (tetanus). The diseases protected against are unlikely to be encountered, making this resistance so limited that it is not worth any character points. Immunity to a *commonly encountered* disease would make a good perk. Ultra-tech vaccinations that protect against *all* diseases provide full Resistant to Disease.

Phage Therapy (TL7)

This is an alternative to antibiotics in the fight against infectious bacteria. Rather than chemical compounds, phage therapy uses *bacteriophages* (viruses that attack bacteria) to attack and kill the infection. This has the advantages of not killing beneficial bacteria or producing allergic reactions, as the phages only attack the target bacterium species. It also requires only small doses of the phages, as they reproduce naturally by themselves, and phages are harder than antibiotics, having shelf lives of years. Finally, the target bacteria evolve resistance to phages much more slowly than they can evolve into antibiotic-resistant strains.

Starting in the late 1930s, Soviet scientists researched phage therapy with great success, as they were isolated from western antibiotics production technologies. The techniques remained virtually unknown elsewhere for political reasons until the collapse of the Soviet Union, and are still obscure today because most of the research remains untranslated from Russian. But interest is increasing, as this is one of few avenues open for winning the battle against increasingly antibiotic-resistant infections.

*Bacteria never die, they just
phage away.*

– Mark Müller

Phage therapy provides the same bonuses to fight bacterial infections as antibiotics. Phages are normally highly species-specific; broad-spectrum varieties targeted at several pathogens only become available at TL9. These can be used to impregnate bandages for infection control.

PROTEIN FACTORIES

Physicians and bioengineers often need large quantities of particular proteins to treat medical conditions or for research and development. An example is the hormone insulin, used to regulate blood sugar levels in diabetics. These can be harvested from pharm animals (p. 85), or produced by bacteria. Bacteria have the advantage that they can be grown easily in a vat and processed in bulk.

E. coli (TL7)

Escherichia coli is a species of bacterium found in the intestinal tracts of mammals and birds. It has a simple genetic structure and is amenable to carrying plasmid (p. 12) DNA inserted into it. The *E. coli* cell will then express the DNA sequence and produce the proteins that it codes for. In this way, the bacteria can be “farmed” to produce useful quantities of any specific protein as required. *E. coli* were first used to produce human insulin in 1978.

ENCAPSULATED CELL IMPLANTS (TL8)

One problem with having bacteria produce therapeutic drugs, proteins, or hormones is that they can't simply be introduced into a patient's body to make the drugs there, because the body's immune system will recognize them as foreign and attack them. Producing the pharmaceutical in batches and supplying it to patients to inject works, but the drug is delivered periodically rather than continuously, and doses can be forgotten. Encapsulated cell implants overcome these difficulties by encasing the bacteria in a biologically inert semipermeable membrane. This allows nutrients from the body to enter and the therapeutic molecules to leave.

The membrane can be a polymer which controls the chemical flow by pore size, or a biofilm (p. 111) tailored to allow the penetration of specifically selected molecules. The cells within the implant, besides being engineered to produce the required pharmaceutical, are also modified so that they can survive for long periods in the resulting environment. The implant also contains an internal structural matrix for strength – it may be designed to facilitate diffusion of various chemicals in and out of the implant. The resulting implants can be very small, about the size of a grain of rice.

Some applications include:

Artificial Glands: Diabetics can obviously benefit from implantable insulin factories, designed to replace the failing pancreas function. The implants must react to hormonal levels in the body, so that they release insulin at the correct rate for auto-regulation. Generalizing from insulin factories, implants can take over the role of any regulatory hormone producing gland. Other possibilities: growth hormone for children lacking sufficient production, estrogen for post-menopausal women, sex hormones for sex-reassignment patients, and serotonin for sufferers of seasonal affective disorder. See

Genetic Surgery (p. 181) for therapeutic glands and the *Sleepless* biomod (p. 180) for a lifestyle option.

Cosmetic Implants:

Color-changing microbes can provide fashionable or useful appearance shifts; see the *Altered Appearance* biomod (p. 169).

In Vivo Drug Testing: Testing experimental drugs on humans can be dangerous, and animal testing can only go so far. Cell encapsulation allows cloned human cells to be implanted en masse into animals; the animals can then be treated with a drug over an extended time and the implant extracted and examined for any long term effects on human tissues.

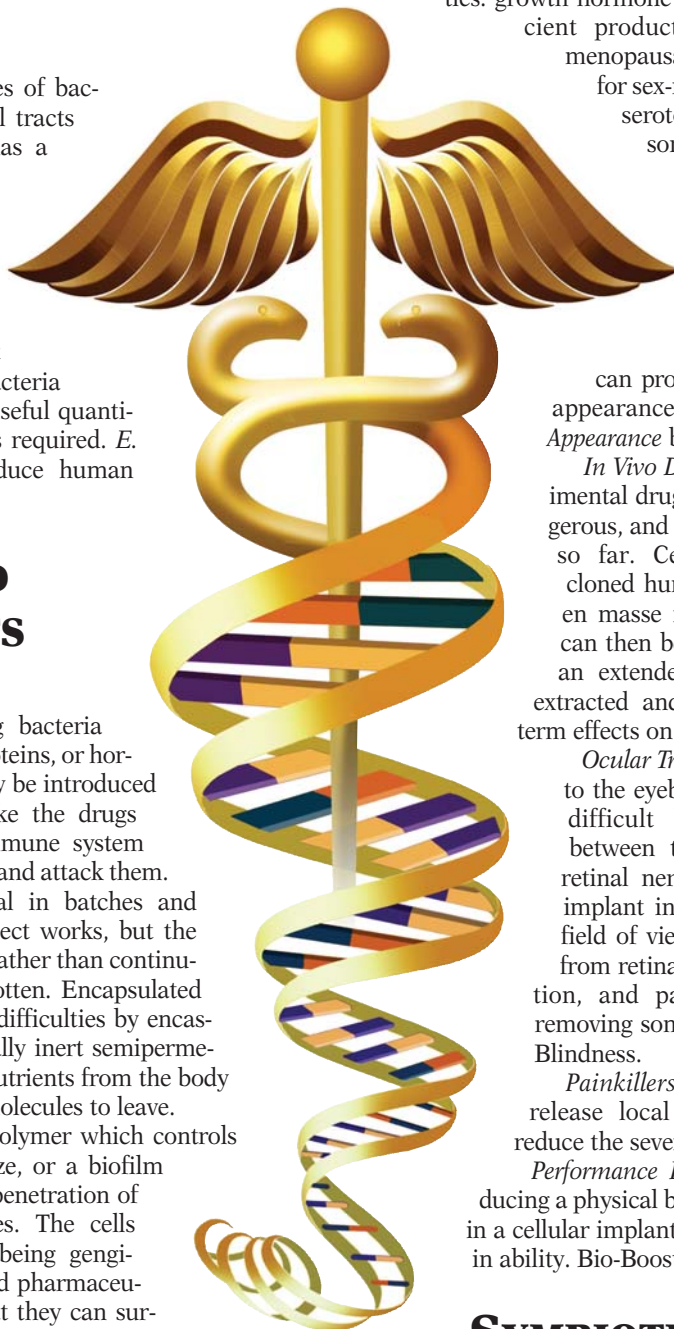
Ocular Treatments: Delivering drugs to the eyeball and retina is normally difficult because of the barrier between the bloodstream and the retinal nerve complex. Inserting an implant into the eyeball (out of the field of view) can treat eyesight loss from retinal degeneration, inflammation, and pathological angiogenesis, removing some forms of Bad Sight and Blindness.

Painkillers: Implants that slowly release local analgesics can cure or reduce the severity of Chronic Pain.

Performance Enhancers: Any drug producing a physical benefit can be encapsulated in a cellular implant, leading to improvements in ability. Bio-Booster (p. 174) is an example.

SYMBIOTIC BACTERIA

Bacteria can also perform useful functions in parts of the body where they will not come under attack by the immune system. Around 1,000 different species have lived in symbiosis with humans ever since we evolved, in



the mouth, intestines, and on the skin. In fact, the bacteria on a human body outnumber the human cells by 10 to one. We don't notice them because they are so much smaller than our own cells.

Modifying these bacteria leads to several useful new species. Nanosymbionts can do the same jobs, but not until at least a TL later in most technology paths, and at a higher cost. Bacteria also repair themselves and reproduce – tricks that add further to the expense of nano.

Communicators: Bacteria are essentially machines for analyzing their chemical environment and producing proteins. Skin bacteria could react to subtle changes in the body chemistry of their host by releasing specific molecules into the air, forming a scent. Perhaps undetectable by humans, this scent could be detected by tuned biosensors (or perhaps even animals). Together, this produces a subtle method of communicating information on the host's activity state and hormone levels. Applications include remote diagnostic monitoring, pheromone production keyed to arousal level, and a scent-based communication system.

Deodorizers: Offensive body odor is caused by naturally existing bacteria that metabolize sweat. Engineered bacteria with no detectable smell could outcompete or destroy these, resulting in permanent and complete deodorizing, granting Sanitized Metabolism. Variants could produce subtle (or not so subtle) perfume scents.

Enhanced Digestive Bacteria: With microbes that can digest nearly anything, it's only a matter of time before someone creates transgenic species capable of living in the human gut. Adapting existing bacteria from termite guts would allow humans to digest cellulose, gaining additional nutrition from plant matter. A more radical idea is to enable digestion of materials like polymers; the only real limit is what people can manage to swallow without poisoning themselves. More usefully, microbes could be engineered to convert food with a different biochemical basis into nutrients usable by humans. This would be valuable for colonists on an alien planet full of life, but based on a different chirality or genetic macromolecule complex – see *Alternative Biochemistry*, p. 35. Pets and livestock could be similarly equipped to deal with their new food supply.

Infection Sentries: Capable of detecting potential infectious organisms before they enter the body, sentry bacteria would carry loads of viral “ammunition” to attack and destroy any identified hostile microbes or spores. This could ward off anything from athlete's foot to tetanus, providing Resistant to Disease at some level.

Oral Hygiene: Bacteria in the mouth cause bad breath and tooth decay. By replacing them with engineered varieties, one could be assured of sweet breath and no cavities.

Tracers: Using any of the methods of infecting a germ warfare carrier (p. 112), someone could easily plant engineered microbes on another person – microbes that will stay on the target forever after, and may transfer to anyone who comes into contact with him. This provides a method of tracing the target, and his contacts and movement through a society. The signal can be picked up with biosensors tuned to detect a molecular scent, as with *Communicators* (above).

If the designer is only interested in the target, the bacteria can be engineered to produce their tracing scent while in the immediate environment of the target's specific biochemistry. This requires a sample of the target's skin cells and sweat.

DNA Eraser (TL10)

This is a specially designed retrovirus that spreads to and infects every cell, but otherwise remains dormant in the user's body. It acts only when a cell undergoes apoptosis and dies. When that occurs, the virus quickly destroys the DNA within the cell. This is useful for people who do not want to be traced by genetic fingerprinting (p. 9), as it means any cell samples they leave behind cannot be used to identify them.

The virus must be injected and takes a week to spread to all the living cells in the body. Pre-existing hair and nails will retain the original DNA, but new growth will not from then on. \$20,000. LC2.

Chimeric Retrovirus (TL11)

Yeah, I dropped the cash for a custom DNA edit job on my shed cells. I figured in this business, a guy needs all the protection he can get, right? Better to go for the real deal than a cheap knockoff. It worked fine for a while, until the cops found some skin flakes at a break and enter in some town I never even heard of halfway across the country. They ran a match and got a partial on a hair I left in the CEO's office at Macrogen – yeah, that was my hit. Anyway, turns out the lab monkeys did a comparison, backtracked the common edits, and fingered this petty crim and me. The first guy I took out after I got the virus should have been the slimeball doc who made it for me and then decided to make a quick buck by selling cheap copies . . .

This is a more advanced version of DNA eraser. Instead of simply destroying the DNA in dying cells, it *edits* the DNA, changing it so that it no longer matches the DNA of the user. The virus is customized for each individual, so that the resulting DNA is not an obviously edited fake. The advantage over DNA eraser is that shed cells look normal, and do not raise suspicions against people who have procured eraser.

Black market versions are likely to be simple copies of a virus ordered by someone else, which means they produce the same telltale edits. If a genetic analyst gets hold of DNA from two different people edited by the same virus, he can determine the common edits and reconstruct the unedited DNA of each person on a successful Bioengineering (Genetic Engineering) roll. Each additional sample edited by the same virus from a different person adds +1 to the roll.

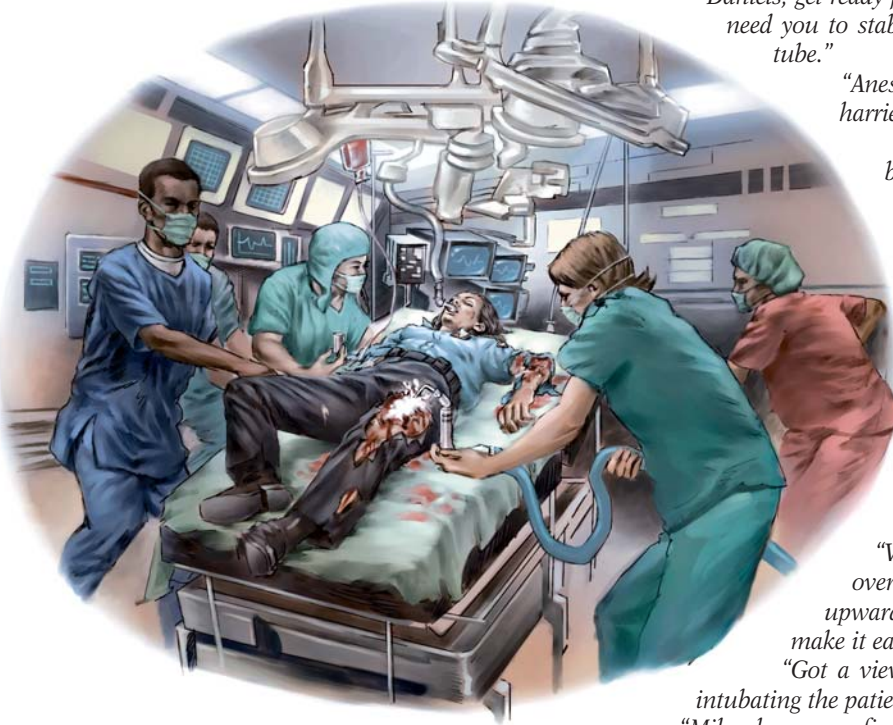
At TL12, the retrovirus can be customized so that it edits the user's DNA into an exact copy of the DNA of *another person*. This requires a DNA sample of the target person and two weeks to prepare and culture the virus.

Availability: *TL11 version:* \$100,000. LC1. *TL12 version:* \$250,000. LC0.

CHAPTER FIVE

MEDICAL

TECHNOLOGY



It was 1:20 AM. Mike had been in theater for most of the last 15 hours, and was looking forward to a nap. His pager buzzed insistently.

"Trauma call. Female police officer high speed MVA limb and closed head injuries GCS 10 ETA 5 minutes," read the text message.

Mike took the lift to the Emergency Room.

"It was a roll-over during a high-speed chase." That was Nurse Daniels. She always knew. "Officer Stacey Polanski." She frowned. "Her partner was DOA."

Polanski was barely conscious and looked ashen. Blood oozed from her mangled left arm and leg.

"Pressure and stats are dropping," Nurse Velacroix warned.

"Where's anesthesia?" Mike asked.

"On his way, doctor," Daniels said.

"Damn. We have to intubate, now."

"I've got a RIC in the right arm," Sung, the new resident, reported. He had a cool head, the best of the crop.

"Good. Get some volume in and stop the bleeding," Mike ordered.

"I'm on it."

"Daniels, get ready for a rapid sequence. Velacroix, we'll need you to stabilize the patient's C-spine when we tube."

"Anesthesia's here." It was Reich, looking harried. "Car chase, huh?"

Mike nodded, his expression hidden by the surgical mask.

"Drugs or airway?" Reich asked.

"Airway. Let's go. Velacroix,

hold the neck. Daniels, you're on

cricoid." Mike had no more time

for thought, only trained reflex.

Reich induced anesthesia.

"Drugs are going in. Cricoid on, now!"

Mike began to ease the laryngoscope into position. "Can't get a view. Suction!"

Reich glanced at the monitors.

"Vitals are stable. You want me to take

over?" he asked. "Daniels, try a bit of

upwards pressure on the larynx. Might make it easier for Mike."

"Got a view. Thanks. Tube!" Mike said, deftly intubating the patient's trachea.

"Mike, have you finished your primary survey?" Reich asked Mike as Daniels tied the airway tube in place. "I'll call theatre and let them know we're coming up in a few minutes."

"Systolic is 80, pulse 107," said Daniels.

"Sung, you happy with that bleeding?" Sung nodded as he grimly pressed on Polanski's mangled arm. "Okay Daniels, 500 cc of warm Ringer's lactate, stat."

"Yes, doctor," Daniels responded.

Mike finished examining Polanski. "Let's go. She's going to lose that arm." Under his breath, Mike murmured, "Hopefully we can save the rest."

The most basic use of biotechnology is to take care of the sick and injured. This chapter presents extra details and expanded rules for many medical situations. All of the rules in this chapter are *optional*, and the GM may choose to use some or all of them as desired.

Along with procedures, various items of equipment used to perform them are described. The equipment quality modifier (p. 15) and biotech equipment cost (p. 15) rules apply to them. Where appropriate, the real-world year of invention is given immediately before the equipment's cost.

FIRST AID

First aid is care given to an injured person in order to stop immediately life-threatening conditions and stabilize the patient so he doesn't get any worse. Once stabilized, the long-term effects of shock can be treated. First aid deals with surface wounds as well as obvious internal issues such as lack of breathing. Internal injuries are often not detectable by a first aid provider, and the best treatment for them is to keep the victim still and comfortable until expert medical care arrives.

First aid is given at the scene of the injury, either by bystanders or by professionally trained paramedics. At high tech levels, first aid may be robotic.

Basic rules for first aid are on p. B424. This section presents expanded rules for specific first aid situations.

STABILIZATION

The first order of business is to check if the patient is breathing and has blood circulation. If not, the patient needs to be resuscitated; basic rules for this are on p. B425. Details for specific parts of the resuscitation and stabilization processes are given below.

First Aid/TL?

Many first aid techniques can be learned and used with minimal equipment. Game Masters may choose to treat First Aid as a cultural skill, rather than a technological skill. Depending on the game world, effective first aid could be known and used by Bronze Age cultures, or it may be a relatively unknown skill in ultra-tech futures. In such cases, drop the /TL designation.

Airway

If the patient's airway is blocked, this is choking (p. B428), which causes suffocation (p. B436). Commonly, the airway is blocked by the relaxation of muscles caused by unconsciousness; lifting the chin remedies this. A foreign object lodged in the throat can sometimes be cleared by slapping the victim on the back or, more effectively, by firmly pressing the diaphragm from below (first advocated by Heimlich in 1973). If nothing helps, the patient will need a tracheotomy to bypass the blockage and allow breathing. Even if the airway is clear, paramedics at TL6+ often insert a tube into an unconscious trauma victim's windpipe to ensure it stays open, preventing further airway complications.

A First Aid roll can remove a foreign object blocking the airway, and can be repeated every two seconds. This roll is

at -2 before TL7. Performing a tracheotomy requires a Physician/TL5+ roll – or a First Aid/TL5+ roll at -4. A critical failure results in 1d-4 cutting damage to the neck. See Trach Kit (p. 124) and Intubation Kit (p. 124).

Optional rule: Treat any crushing injury over HP/2 to the neck hit location as a crippling injury which crushes the windpipe, causing choking.

Breathing

Once the airway is established, the patient must receive oxygen to avoid brain damage and eventual death. If the patient is not breathing on his own, his oxygen supply can be sustained artificially by inflating the lungs with air.

The easiest short-term method is mouth-to-mouth resuscitation, which was developed as a resuscitation technique in the 1950s. Prior to this, the best method in use was to lay the patient down and periodically compress the torso. This was about as effective as the 15th-century practice of rolling drowning victims over a barrel, or 16th-century attempts to use bellows – i.e., not very.

Mouth-to-mouth breathing can sustain a patient indefinitely, but the first aid provider loses 1 FP for every 10 minutes of breathing; each point of loss may be negated by a successful Breath Control roll. A bag mask (p. 124) or mechanical ventilator (p. 136) provide breathing assistance without requiring mouth-to-mouth breathing. The *Resuscitation* rules (p. B425) imply that restoring breathing requires Physician/TL7+ or First Aid/TL7+ (with a roll against First Aid at a -4 penalty). If a lower TL technique is attempted, as described above, treat this as an "Improvised Equipment with a -5 (quality) penalty to skill.

Circulation

Heart failure is far more serious than the cessation of breathing. Until the invention of cardiopulmonary resuscitation (CPR) in the 1950s there was no known method of sustaining or reviving a victim whose heart had stopped or gone into a rhythm that prevents blood flow. CPR alone may restart the heart, but often this requires defibrillation (first demonstrated in 1947) to restore a normal pulse. Recovery rates are not as rosy as depicted on television dramas. If a defibrillator is available, victims of cardiac arrest revive in only 30% of cases; without it, recovery is even less likely. Giving CPR properly requires a First Aid/TL7+ roll and costs the first aider 1 FP per 5 minutes if done manually.

The chance of successful resuscitation depends on the patient's health. He makes a HT-2 roll each minute, at an additional penalty of:

- -1 for every minute elapsed since arrest if CPR and defibrillation are being used;
- -2 per minute if defibrillation is used without CPR;
- -4 per minute for CPR without defibrillation.



On a success, circulation returns; on a critical success, the patient regains consciousness. Failure means that circulation is still absent; CPR can continue and defibrillation can be tried again. Critical failure equals death. Unlike restoring breathing, restarting the heart *cannot* be done at all at tech levels below TL7, unless the rescuer is somehow familiar with CPR techniques. Travelers from TL7+ may teach CPR to natives of lower TLs.

Bleeding and Bandages

Once the victim's oxygen supply is established with breathing and circulation, the first aid provider must stop any bleeding. At most TLs this involves some form of bandaging, whether it be with strips of cloth or a spray-on synthetic skin.

High-tech equipment can reduce the time taken to bandage a patient; see the entries for specific items below, under *First Aid Equipment*.

Rules for bandaging are on p. B424. Bandaging is only effective if the wound is bleeding. This will not normally be the case for crushing damage or blunt trauma (p. B379). In those cases the GM may rule that bandaging is useless, although this does not reduce the HP restored by treating shock.

First Aid Equipment

The following equipment is available for emergency treatment. All these items are LC4.

Crash Kit (var.)

A complete kit for treating *serious* injuries. Includes sterile bandages, sutures, and drugs appropriate for the TL. At TL6+, includes IV drip, needle, and plasma. +2 (quality) to First Aid skill, providing the level of treatment (see p. B424) appropriate for its TL. It can be used for Surgery but is improvised gear giving a -5 (quality) modifier. \$200, 10 lbs. LC4.

First Aid Kit (var.)

A complete kit for treating wounds, with bandages, ointments, etc. Gives a +1 (quality) bonus to First Aid skill, providing the degree of treatment appropriate to its TL (p. B424). \$50, 2 lbs.

Trach Kit (TL5)

A large-bore needle that is inserted in the windpipe to allow breathing. At later tech levels this kit includes a tube for fitting a bag mask or oxygen supply. A tracheotomy can be performed with improvised equipment, at -5 to skill as per p. B345. \$150, 0.5 lb.

Bag Mask (TL6)

A rubber or plastic mask with an attached bulb or bag. The rescuer pumps the bag by hand while holding the mask in place, delivering a steady flow of air to the victim. \$15, 1 lb.

Intubation Kit (TL6)

This consists of a selection of laryngoscopes, tubing, and other equipment necessary to place a breathing tube into the windpipe of a patient. \$200, 2 lbs.

Defibrillator (TL7)

Metal plates connected to a power supply, designed to give brief electric shocks to a patient undergoing cardiac arrest, which may "reset" the heart into a normal rhythm. Can also be used as a weapon, causing 4d of nonlocalized lethal electrical damage (see p. B432). 1947. \$8,000, 40 lbs.

Phage-Impregnated Bandages (TL7)

Wound dressings in a sterile package, impregnated with naturally occurring bacteriophages; counts as antibiotics for infection control – see *Phage Therapy* (p. 119). By TL9 these are broad-spectrum versions designed to kill most infectious bacteria; grants an extra +3 to HT rolls over antibiotics. The phages remain active for two years. \$10, negligible weight.

Chitosan Hemostatic Bandages (TL8)

These are impregnated with chitosan – a freeze-dried protein derived from insect chitin. It reacts with blood to promote clotting, significantly reducing bleeding. When used for bandaging a bleeding wound (p. B424), it gives a +1 (quality) bonus to First Aid skill and reduces bandaging time to 30 seconds. 2004. \$20, negligible weight.

Bandage Spray (TL9)

This is an advanced liquid spray-on, breathable, analgesic, and antiseptic bandage that seals and disinfects most minor wounds. It comes in flesh-tone or transparent versions; the former changes hue to match the user's skin (and will hide tattoos or distinguishing marks for 24 hours), the latter is preferred by medics, so they can keep an eye on the injury. It gives +2 (quality) bonus to First Aid for bandaging purposes and reduces bandaging time to 10 seconds at TL9. At higher TLs, anti-coagulants, wound-cleaning biofilms, or cell-repair nanomachines further reduce this time: 5 seconds at TL10, 3 seconds at TL11, 2 seconds at TL12. A small can (one application) is \$15, 0.1 lb. A large can (10 applications) is \$150, 1 lb.

Plasti-Skin Bandage (TL9)

This is an antiseptic and analgesic patch containing elastic nanofibers that serve as a pressure bandage or a tourniquet. Plasti-skin comes in visible colors for use by medics, as well as versions that blend into the user's skin, making it hard to notice. It falls off after the flesh beneath it heals sufficiently. If used to cover tattoos, scars, and marks, or for disguise, it lasts 24 hours. It reduces the time required for bandaging to 20 seconds. TL10 plasti-skin is an active biofilm that excretes antibiotics. A field dressing pack (four applications) is \$2, 0.1 lbs.

Smart Diagnostic Bandage (TL9)

A plasti-skin bandage that is also a small dedicated printed computer. It has diagnostic sensors which monitor the patient's pulse, temperature, and blood pressure, and provide Diagnosis-10 at the computer's TL (restricted to surface conditions in the area of the bandage). The bandage itself is a display screen and (at TL10+) a speaker. The device is \$40, 0.02 lbs. and runs on solar power (storing enough energy to function during hours of darkness). With software, the cost is \$90.

SHOCK

The body's normal reaction to severe injury or psychological trauma is to go into *shock* (this is a medical term, not the same as the **GURPS** condition known as "shock," p. B419). This is a state in which oxygen supply cannot meet tissue demand. It can be caused by blood loss, heart irregularities, infection, allergic reactions, or stress. Many of the results of the Fright Check Table can be interpreted as various severities of shock. Symptoms of shock include

weakness, anxiety, pallor, weak pulse, and low blood pressure. Anyone trained in first aid will expect shock if he knows the patient has suffered some trauma, and can attempt appropriate action.

If someone is not expecting a person to be in shock, roll vs. Diagnosis+4 or First Aid+4 to recognize the symptoms. To treat shock, use the rules on p. B424. The changes in time taken to attend to shock and the effectiveness of the treatment at different tech levels reflect the increase in medical knowledge and availability of better equipment.

DIAGNOSIS

Once a patient is out of immediate danger, the next step in medical care is determining what the patient is suffering from. In many cases, this is the first stage of medical attention, as when a patient with an illness or minor injury seeks a doctor. The diagnosis process can involve interviewing

the patient (if conscious) to learn what symptoms he has noticed, external examination of the body, measuring vital signs, testing samples, technological imaging techniques, or exploratory surgery.

Medical Treatment

This chart describes the sequence of events when a patient seeks modern medical treatment (TL6+). Most of

these tasks are routine and do not require a skill roll (see p. B345); make only the skill rolls noted below.

1. The patient sees a general practitioner, who performs a *Basic Examination* (p. 126) and makes a Diagnosis roll. If the problem is not obvious, the doctor orders *Laboratory Tests* (p. 127) and/or *Medical Imaging* (p. 127).

2. If tests are required, a lab technician or radiologist uses Chemistry/TL6 or Electronics Operation (Medical)/TL7+ to process the results.

3. The doctor uses the results to make a new Diagnosis roll at a bonus (p. 127). Depending on the diagnosis, go to step 4a or 4b.

4a. The doctor uses Physician skill to prescribe medication or other appropriate treatments (bed rest, bone setting, physical therapy, etc.).

4b. If the doctor recognizes the problem is out of his field, he refers the patient to a specialist.

5a. The pharmacist dispenses any needed medication. If the medicine is not prepackaged, he makes a Pharmacy skill roll.

5b. The specialist confirms the GP's diagnosis. An additional Diagnosis roll is only required if the GP was stumped or wrong. The treatment may be simple (see 4a) or require surgery.

6b. If surgery is required, the surgeon operates, rolling on Surgery skill.

6a. If the patient is not self-medicating, a nurse administers the medicine, using Physician to make sure the dosage is within safe limits.

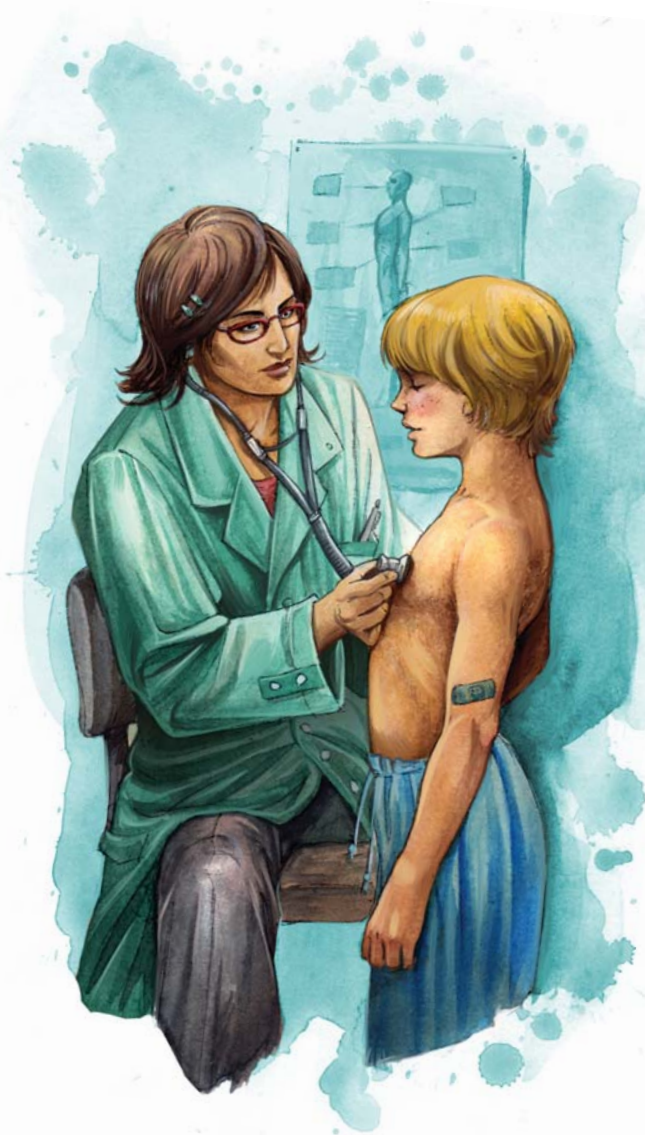
7b. After surgery and throughout *Recovery* (p. 139), the medical staff uses Diagnosis to make sure the patient is stable and healing as expected.

VITAL SIGNS

The most basic inspection of a patient can determine several important conditions. The patient's level of consciousness is readily apparent to anyone, barring unusual states such as drug-induced or magical paralysis.

A roll against First Aid or Diagnosis at +6 will determine if an unconscious patient is breathing and has a pulse. If this roll is made by 6 or more, the examiner notices any unusual conditions of these – shallow breathing, thready pulse, etc. If the patient isn't breathing or has no pulse, immediate resuscitation is called for; see *First Aid* (p. 123).

For a conscious patient, his level of lucidity is important. Delirium or the inability to respond sensibly to stimuli can be caused by a number of conditions such as infection, lack of food or water, heatstroke, poisoning, drug overdose, or addictive drug withdrawal. A patient reduced to 0 FP or less by such conditions should be treated as hallucinating (p. B429), though he may not actually be seeing visions.



Basic Examination

A medical examination of a lucid patient begins with the physician asking the patient what symptoms he feels. This can be pain or discomfort in the affected part of the body, or a general feeling such as feverishness.

Depending on the answers, the physician will then perform various external examinations, targeting areas of concern. This could be as simple as looking down the throat to see an infection, followed by prescribing antibiotics to cure it. Other procedures include:

- Various simple diagnostics, such as taking the patient's pulse, checking reflexes, using a finger-to-nose test to check coordination and equilibrium, etc. *Blood pressure* can be measured at TL6. Unusual results on these tests indicate a variety of possible conditions.

- Taking the patient's *temperature* with either a traditional mercury or alcohol thermometer (late TL5), or an electronic device (TL8). Elevated body temperature is a fever, often indicating infection or internal injuries. Low temperature can be caused by shock or exposure to cold.

- The sounds of the *chest cavity* can indicate many different problems, from unusual heart rates to constricted breathing in the lungs. The physician can use a stethoscope (TL5) to hear these. He may also tap the chest with his fingers or a small rubber hammer to listen to the quality of the echoes (TL5).

- An *electrocardiogram* (ECG, or sometimes EKG from the German spelling, TL6) is a tracing of the electrical activity of the heart, measured across external electrodes by an electrocardiograph. This reveals much more information than just the pulse rate – a skilled doctor can interpret the precise shape of the electrical wave to diagnose many different cardiac abnormalities, as well as blood clots and abnormal electrolyte levels in the body.

All these diagnostic tests are considered standard at appropriate tech levels, allowing a Diagnosis roll with no equipment penalty. The Diagnosis skill can only reveal knowledge appropriate to the TL of the examining physician! A successful Diagnosis roll *will* always be helpful, however. At low TLs, the explanation the physician gives for an illness may involve evil spirits, but successful diagnosis will lead him to the most appropriate treatment he has available. In untreatable cases, proper diagnosis reveals that nothing can be done, and allows the doctor to prepare the patient's friends and relatives for the inevitable. In many societies, particularly at low tech levels, this is an important and expected part of a doctor's job.

The following equipment is used for basic examination:

Sphygmomanometer (TL6)

An inflatable arm cuff and pressure gauge for measuring blood pressure. Early versions require a stethoscope; by TL8 they are automatic. 1896. \$60, 2 lbs. LC4.

Stethoscope (TL5)

Used to listen to sounds of the heart and lungs. This simple procedure helps diagnose many different problems. 1816. \$15, 0.25 lb. LC4.

Electrocardiograph (TL6)

A device for recording the electrical voltage across the heart, using externally attached electrodes. 1911. \$18,000, 60 lbs. LC4.

Endoscopy (TL7)

This is the examination of internal parts of the body by inserting a probe into a natural opening or small incision. Rigid endoscopes have been used on humans since 1853, but were of limited value. Optical fiber led to the invention of the more useful flexible endoscope in 1957, but this did not become common until after 1960, with the adoption of a cold light source that did not heat up the patient's interior.

Through natural body openings, endoscopy can examine and sample tissue from the gastrointestinal, respiratory, and urinary tracts, and the female reproductive organs. With an incision, endoscopy can be used on the chest and abdominal cavities, and the interiors of arm and leg joints.

Endoscopes can also be equipped with biopsy sample collection tools and operating tools. These allow biopsies of internal organs to be taken with minimal discomfort and the performing of some operations with tiny incisions.

Flexible Endoscope (TL7)

This is two yards long and as thick as a finger. It has bundles of fiber optic cables inside it to allow light to be channeled inside a patient, and an image to be transmitted back to the user. 1957. \$8,000, 2 lbs. LC4.

Diagnostic Camera (TL8)

A tiny camera and light source inside a swallowable capsule. Allows diagnosis of gastrointestinal disorders without endoscopy or surgery. 2004. \$500, negligible weight. LC4.

LABORATORY TESTS

The next step beyond a basic examination is the taking of samples for laboratory analysis. Urine samples can reveal chemical or hormonal imbalances in the body, impaired liver or kidney function, and the presence of many types of drugs. Blood samples provide evidence for blood-related diseases such as anemia, hormonal diseases such as diabetes, and infection by various pathogens. More invasive is a biopsy – the sampling of cells or tissue – which can diagnose tissue abnormalities like cancer. At the GM's discretion, blood or tissue sampling requires a roll against Physician+4 to collect a usable sample without contamination.

A full battery of lab testing performed at a hospital or specialist pathology lab qualifies the diagnosing physician to make a new Diagnosis roll with the "best equipment possible at your TL" giving a + TL/2 quality bonus. This is normally combined with medical imaging techniques (below) if they are appropriate. At TL8+, basic tests performed by a hand-held analyzer provide a +2 (quality) bonus; the full +TL/2 (quality) bonus is only gained if *both* full lab tests and medical imaging are available. If only one is used and the other might provide additional information (GM's call), the bonus is only +3.

Portable Clinical Analyzer (TL 8)

A self-contained biochemical analysis lab in a hand-held unit. This can do a basic blood test for glucose, iron, and other levels without requiring a lab. It provides a +2 (quality) bonus to Diagnosis skill. \$5,000, 3 lbs. LC4.

MEDICAL IMAGING

Wilhelm Röntgen's discovery of X-rays and their ability to penetrate soft tissues in 1895 was a breakthrough in diagnostic science. For the first time, physicians could see the interior workings of the body without opening it up.

More advanced imaging methods are described below.

As described for Laboratory Tests (above), appropriate medical imaging performed at a hospital or radiology lab qualifies the diagnosing physician to make a new Diagnosis roll with +TL/2 (quality) bonus. At TL8+, medical imaging without appropriate lab tests provides only a +3 (quality) bonus.

X-rays (TL6)

Simple X-ray photography (TL6) is limited in what it can reveal, being restricted to pathologies of the skeletal system and a few specific soft tissue diseases such as pneumonia and lung cancer. *Angiography* (TL6) uses X-rays to image blood vessels – normally invisible to X-rays – by injecting them with a contrast solution which absorbs the rays. Angiograms can be recorded either on film, showing constrictions and blockages, or by video cameras, showing the speed of blood and any abnormalities of flow in the circulatory system. Angiography is usually used for coronary or cerebral diagnosis. Related procedures involving enemas can be used to image the lower intestinal tract.

Exploratory Surgery

When non-invasive tests are inconclusive or not available, the only option remaining for diagnosis of an internal pathology is surgery. Physicians prefer to exhaust all non-invasive methods before resorting to exploratory surgery, as it is a drastic step. The surgeon will generally have some idea of the condition in mind before the surgery, and be seeking confirmation, rather than going in blind.

In game terms, exploratory surgery is called for if exhaustive tests have been undertaken and the Diagnosis skill has failed to produce a definitive answer. Use the normal rules for surgery (pp. 135, B223, B424), but a successful Surgery roll allows a new Diagnosis roll, removing the -5 penalty for diagnosing internal injuries.

If the expected pathology is confirmed and immediately treatable, it may be treated during the same operation. This requires another Surgery roll.

X-ray machine (TL6): This is an X-ray source and a place to put a photographic film. At TL6, radiation is not well understood; both the patient and the person operating the machine are exposed to 1d rads per photograph. 1896. \$15,000, 1 ton. LC4.

Portable X-ray Machine (TL7): As above, but smaller and shielded for safety; the patient takes 0.01 to 3 rads from a series of X-rays. If deliberately set to maximum intensity, an X-ray machine could expose a target to 1,000 rads per hour. \$30,000, 500 lbs. LC4.

Computed Tomography (CT) Scanning (TL7)

This uses X-rays to build up a more detailed picture of the interior of a body. The technique, invented in 1972, involves passing a thin “slice” of X-rays through the body and rotating the emitter and detector around it to image the slice from all angles. A computer then uses the data to reconstruct the X-ray absorption at each point in the slice. The resulting image indeed resembles a slice of the body, rather than showing the combined absorption through a solid mass of tissue like a photographic X-ray. Several CT scans of adjacent slices can generate a three-dimensional image of the body’s interior, showing the shapes and positions of soft organs as well as bones.

CT Scanner (TL7): A large machine with a hole in the middle large enough for a person to lie in. The X-ray transmitter and detector circle the patient’s body and transmit data to a computer, which processes it to produce an image. 1972. \$400,000, 2 tons. LC3.

Ultrasound Imaging (TL7)

This uses ultrasonic sound waves to penetrate the body and build up images as the sound is reflected off interior structures. It is most useful for showing muscle, soft tissues, and the interfaces between them. Images are produced in real time, so the physician can rapidly adjust the diagnosis procedure to examine any findings. Ultrasound is also harmless, unlike the radiation exposure of X-ray techniques, making it ideal for fetal examinations. The first medical ultrasound was performed in 1953, using equipment that had been used for industrial materials testing for some years.

Ultrasound (TL7): A hand-held ultrasonic transducer connected to a display screen. 1953. \$60,000, 400 lbs. LC4.

Magnetic Resonance Imaging (MRI) (TL7)

Invented in 1971, this uses powerful electromagnets to stimulate the nuclei of hydrogen atoms into emitting pulses of radio energy. This reveals the locations of water molecules inside the body, which can be mapped into an image. MRI images resemble CT scans, but have the advantage of much greater contrast between soft tissues, making MRI a more suitable technique for brain and spinal cord imaging. MRI also uses no harmful radiation, although the magnetic fields can be dangerous if the patient’s body contains any

metal. Inert metal such as shrapnel may heat up or move through the body tissue, while mechanical or electronic implants could fail. A disadvantage of MRI is that the images it produces are not as high resolution as CT scans.

MRI Scanner (TL7): Similar in appearance to a CT scanner (above), but with powerful electromagnets and radio receivers instead of X-ray equipment. It also contains a dedicated computer control and image processing system. 1971. \$600,000, 3 tons. LC3.

Positron Emission Tomography (PET) (TL7)

First performed in 1973, PET uses radioactive isotopes injected into the body to trace the uptake of the element by various organs. The isotope decays by emitting a positron (the antiparticle of an electron), which immediately annihilates with an electron to produce two gamma rays traveling in opposite directions. When detected, these pinpoint the location of the decaying atom. The radiation dose from a PET scan is similar to a chest CT scan, but the image resolution is even lower than an MRI scan. PET is commonly used for tumor and neural activity diagnosis and monitoring.

PET Scanner (TL7): Another machine similar to a CT scanner – the differences are mainly internal – for producing PET scans. 1973. \$400,000, 2 tons. LC3.

Antiproton Imaging (TL8)

This uses beams of antiprotons to penetrate the body to various depths, where the antiprotons annihilate with normal nuclear particles and emit pions and radiation, allowing their locations to be pinpointed. This provides imaging capability because the distance the antiprotons travel through the tissue before being annihilated depends on their energy (controllable from the imaging apparatus) and the density of tissue through which they travel. This technique exposes the body to considerable radiation, and is normally only used in combination with antiproton treatment for tumors (see p. 132). It was proposed as an imaging method in 1995, but not widely developed because of cost.

Antiproton Imager (TL8): This machine needs access to antiprotons, generated from a nearby cyclotron. 1995. \$1,000,000, plus cost of cyclotron, 2 tons. LC3.

Diagnosis Bed (TL9)

At ultra-tech levels, many of these systems are miniaturized and integrated via sensor fusion. This is an examining table with a full range of biological and medical scanners. These incorporate X-ray (p. 127), CT (above), PET (above), and ultrasound (above) into a single unit; at TL10+ the system also includes MRI (above) but not HyMRI (p. 129). The patient lies on the table and scan results are projected onto an overhead screen. It normally operates off building or vehicle power. It gives +3 to Diagnosis skill, which increases to +TL/2 if combined with diagnostic probes or lab tests. \$25,000, 250 lbs. LC4.

Hypersensitive Magnetic Resonance Imaging (HyMRI) (TL9)

This is an extrapolation of MRI technology, utilizing superconducting magnets and hyperpolarized noble gases which are inhaled or injected. HyMRI also exploits intermolecular quantum effects to give resolutions far better than any previous imaging method. HyMRI equipment can be used to justify ultra-biotech concepts such as complete brain scans suitable for compiling psychological brain maps or ghost personality simulations (see *GURPS Ultra-Tech*).

Hospital HyMRI (TL9): \$250,000, 500 lbs. LC3.

Portable HyMRI (TL10): \$25,000, 50 lbs. LC3.

Nano-Imaging (TL9)

This uses injected diagnostic probes to make a full survey of the body, revealing both structural and chemical make-up. It combines the functions of imaging and lab tests in one procedure.

Diagnostic Probes (TL9): These are tiny robots used to determine what is wrong with a patient. They add +3 to Diagnosis skill; they can also identify nanomachines, such as the proteus virus. They take two hours to circulate through body and diagnose problems, and another hour to retrieve. The patient must be attached to a diagnostic bed, automec, or emergency support unit. \$200/dose. Can be retrieved using an emergency support unit or automec, or will degrade harmlessly in a month. LC4.

Diagnostic Bionet (TL10): As above, but equipped to report back constantly without having to be retrieved; this lets the nano remain within the patient, providing constant updates. Bionet microbots degrade harmlessly within the body in a month. \$1,000/dose. LC4.

MONOCLONAL ANTIBODIES

Antibodies are a vital part of the body's immune system, seeking out and attaching themselves to intruders such as microbes, viruses, or foreign proteins. Each antibody is shaped to match puzzle-fashion with the physical contours of its target molecule (or *antigen*), so that when they accidentally run into one another, they will lock together. This alerts the rest of the immune system (white blood cells, for instance) to attack. There are millions of different kinds of antibodies, each specialized to detect one particular type of unwanted organism. They are manufactured by specialized *B-cells* in the lymph nodes, spleen, and blood.

Monoclonal antibodies (MAbs) are antibodies of exceptional purity and specificity. They were first created experimentally in 1975 (late TL7) by using modified cancers in mice to produce specific antibodies in large quantities. By TL8 their value as diagnostic tools had been recognized. Because MAbs are produced without the millions of other antibodies made by the immune system, they can seek out and target pathogens with pinpoint precision.

MAbs can have fluorescent or radioactive molecules bonded to them after they are created. When mixed in a sample solution they will attach to their target molecules, if present, as normal. The sample can then be filtered to remove any unattached MAbs, and the presence of the tags indicates the sample contains the target molecule. This

ability to find needles in biochemical haystacks makes MAbs useful for a wide variety of industrial and medical processes, such as refining exotic proteins, creating "diagnostic bed" sensor systems, and consumer products.

By 1987 (TL8) MAbs were regularly being produced in rodents for use in medical research. Deliberate cultivation of cancers in mice or other animals, however, has become increasingly controversial on ethical grounds; their production has been banned in some nations (LC2). And despite their usefulness in the lab, rodent MAbs are less than ideal for treating humans, because of immune responses.

Human MAb production is still in its infancy in mid-TL8, due to the difficulty of producing them. It's theoretically possible to produce human MAbs using the same technique as used on mice, but deliberately growing hybrid cancers inside human hosts would only be an option for mad scientists or amoral regimes. With that avenue closed off, current methods instead involve modifying rodent cells via genetic engineering and stabilizing them through repeated cloning cycles, or creating hybrid human and mouse antibodies. Another alternative is the *in vitro* mass production of MAbs through tissue engineering (p. 26) or industrial gene-cloning (p. 12) techniques – essentially, growing the antibodies in vats. Affordable vat-grown MAbs are still in the early stages at TL8, but are likely to become widespread by TL9, and promise to be a rapid but accurate form of laboratory test. At TL9+, wide-spectrum tests using vat-grown MAbs are standard in clinics, diagnostic beds, automecs, and hospitals.

MAbs can also be further engineered as the "guidance systems" of other substances. Treatments such as chemotherapy release toxic chemicals, intended to kill cancers, into the body. Unfortunately, they also poison the body, and selecting a dosage that will kill cancer but not the host is difficult. By bonding drugs to MAbs, far more toxic chemicals can be used in much smaller amounts, because the antibodies deliver the chemical directly to the target cells, while avoiding nearby tissue. Aside from smart-bombing cancers, MAbs can be used as the targeting system for other drugs, guiding various chemicals directly toward specific proteins. Many of the TL9+ drugs described in Chapter 6 use MAbs.

Disposable Test Kit (TL8)

A cigarette-sized plastic vial containing monoclonal antibodies tailored to detect specific biomolecules. The user pricks his finger on the included needle, lets a drop of blood fall in, shakes, and squeezes to break the membrane. If the vial glows a particular color, he tests positive.

No skill is required to use it, but each kit tests for one specific thing. Kits can test for anything from diseases like HIV, various types of influenza, or cancer, to pregnancy, malnutrition, or the use of a specific drug. Kits can also be designed to test non-clinical samples for molecules such as poisons, drugs, or other organic matter. A genetics lab is needed to design new test kits – kits will only be available for testing known diseases, drugs, etc. At TL10+, monoclonal antibodies are supplemented by tailored nanomachines that perform similar tasks with even more precision. Civilian test kits may be available from vending machines. Military kits may test for biochemical weapons. \$5, 0.1 lb. LC4.

NON-INVASIVE PROCEDURES

If a patient can be cured or treated without surgery, that is usually the most desirable course of action. Non-invasive procedures are simpler, less intimidating, and often safer than surgery, and don't require a surgeon! They may also be faster or cheaper, but sometimes require additional time and specialized equipment that adds to expense.

These procedures provide more detail than the *Medical Care* rules (p. B424), where the GM is interested in distinguishing different types of injury and their treatments. Use either those rules or the optional rules presented here, not both.

Medical Supplies (TL6)

Drugs, bandages, syringes, and other disposable supplies sufficient for 20 patient-days of Physician treatment

Blood Types

Human blood can be characterized by the presence or absence of a number of different antigens on the surface of the red cells. Antibodies in the blood serum react against the antigens of incompatible blood types, breaking down the cells. If this occurs as the result of a transfusion, the patient will become anemic, his kidneys will fail, and death will follow. To transfuse blood safely, the *blood types* of the donor and recipient must be identified to ensure compatibility.

The most important typing method is the *ABO system*, in which the blood is typed according to which of two antigens (named A and B) are present: type A blood contains antigen A, B contains antigen B, AB contains both, and O contains neither. A transfusion recipient will suffer an adverse reaction to donor cells that contain antigens *not present in his own blood*. Thus a type A patient can receive blood of types A or O but not B or AB, an AB patient can receive any type, while an O recipient can only receive O blood.

A second typing consideration depends on the presence or absence of the *Rh factor*. An Rh-negative patient cannot safely receive Rh-positive blood; Rh-positive patients can receive either. Both the ABO and Rh conditions need to be satisfied for a safe transfusion.

The proportions of each blood type in a community vary by region and ethnicity. GMs interested in keeping track of characters' blood types are encouraged to do some research. This may be important for games involving unusual forms of vampirism!

ABO blood types were first described in 1909 and the Rh factor in 1940. From TL7 onward, any modern hospital will be able to identify blood types and perform transfusions safely.

(TL6-8), 50 patient-days (TL9-10), 100 patient-days (TL11), or 200 patient-days (TL12). Gives a +1 (quality) bonus to Physician skill. In addition, without this gear, the doctor operates as if at the TL5 level. \$500, 5 lbs. LC4.

BLOOD TRANSFUSION

An average person has two pints of blood per 25 lbs. of body weight. Trauma victims who lose 30% to 40% of their blood will die within two hours due to lack of oxygen reaching vital systems; more than 40% blood loss is fatal within minutes. (In *GURPS* terms, this is covered by the standard HT rolls to survive injury.) The most effective treatment is to rebuild blood volume by transfusion. Transfusion may also be required during surgery to replace blood loss from incisions and hemorrhaging. If blood is in short supply, assume each lost HP treated by surgery requires from half a pint to one pint of blood.

Transfused blood must be compatible with the recipient's blood type, or the transfusion will be fatal. If compatible donor blood is available the risks of transfusion are negligible. This does not necessarily require knowing the types of both donor and recipient – see *Blood Types*. If a transfusion is attempted in ignorance of blood type compatibility, there is a 45% chance that the types will be incompatible (9 or less on 3d); this is an approximation given real-world distributions of blood types.

At high TLs, an artificial blood substitute may be available; see *Perflubron Blood* (p. 131). This avoids any problems of blood type compatibility.

Blood Donation (TL6)

Blood is donated in pint-sized *units*. Donating one unit at a time is safe for people above 100 lbs. in weight, but anyone may feel dizzy from lack of oxygen for a while. The body naturally regenerates blood volume and the donor's supply is back to normal within eight weeks.

A person who donates a unit of blood must make a HT roll. On a failure, the donor feels dizzy and is at -2 to DX and IQ for 20 minutes; critical failure indicates a faint. If a dizzy person tries standing suddenly, make another HT roll, with critical failure indicating fainting. Donating again within eight weeks results in dizziness as above on any roll but a critical success, and is potentially dangerous; treat it as a bleeding wound (p. B420). The lost HP will heal normally, but it will take eight more weeks to replenish the blood. Plasma can be donated every two weeks; use the same rules, reading "two weeks" instead of "eight weeks." Some jurisdictions allow payment for donations; \$20 is typical.

Blood Supplies (TL6)

Whole Blood (TL6). Lasts only a week in the refrigerator at TL6; a little over a month at TL8. Per pint: \$150, 1 lb.

Plasma (TL6). Dehydrated; requires a half-pint of water. Shelf-life is one year. Per pint: \$200, 0.5 lbs.

Perflubron Blood (TL8)

This is an artificial blood substitute made of polymer particles coated with perflubron, suspended in plasma. It transports oxygen and waste gases more efficiently than normal blood. Perflubron blood is a milky white fluid and contains a clotting agent so that it hardens if exposed to air. It can be transfused to restore blood volume of a patient suffering blood loss, with no adverse side effects. Another application is to create bioroids – see *Bioroid Modifications* (p. 61).

Blood Doping (TL8)

This technique is used by athletes to improve their stamina. It involves transfusing additional units of blood into a person who is at normal blood volume. The blood can either come from a donor, or have been donated earlier by the recipient and stored until needed. Doping increases the number of red blood cells in circulation, improving the body's ability to utilize oxygen. Donor blood can be detected as of 2000, but self-donated blood cannot be detected at TL8.

Blood doping gives the user +1 FP and doubles the rate of recovery of lost FP for four weeks after the transfusion. Additional treatments within the same time have no extra benefit, and can cause heart failure (critical failure on a HT roll).

NON-SURGICAL TREATMENTS

These are treatments that can be performed on a patient in a hospital, or in some cases a physician's practice.

*Surgery is always second best.
If you can do something else, it's
better.*

– Dr. John Kirklin

Bone Setting (TL5)

A lasting crippling injury (p. B422) to a limb or extremity caused by crushing or cutting damage is likely to involve a broken bone (GM's option). Setting a broken bone requires only 15 to 30 minutes and a Physician roll – remember to adjust for any relevant equipment modifier. A failure will require resetting the bone; a critical failure means the bone heals in a deformed position, making it permanently crippled. Bones can be set before TL5, but any failure results in permanent crippling, and a critical success is required to avoid cosmetic disfigurement. Setting the bone is painful; the patient will suffer agony (p. B428) unless anesthetized for the procedure. This can replace the rule for repairing lasting crippling injuries (p. B424) for suitable injuries; it's easier to fix (no surgery required), but recovery time does not reduce to weeks on a success.

Burn Treatment (TL5)

Burns are among the most serious of common wounds. Injury caused by burning requires a successful Physician roll and an hour of nursing attention per day (changing dressings, applying ointments, etc.) to qualify for natural recovery. Additional medical care (p. 424) adds to this normally. Burns are prone to infection; roll as described on p. B444 at a -5 penalty to HT. A hospital stay is usually required until the injury has healed.

A burn that has caused a major wound or worse is a serious problem. All Physician rolls to treat the injury are at -1 per 2 HP lost. Such a burn also causes a tremendous loss of fluids, requiring a number of IV units (see *Intravenous Fluids*, below) per day equal to remaining points of burn injury until it heals. Without these, the patient takes 1 point of damage per missing unit of fluid each day.

Poison Treatments (TL5+)

General poison treatment rules are on p. B439. Specific treatments include:

Gastric Lavage (TL5): A stomach pump can remove poisons or swallowed acids from the stomach if used within an hour of ingestion. This grants a +1 to HT rolls to fight off the poison. Gastric lavage takes 20 minutes and requires a roll against the Physician skill.

Activated Charcoal (TL6): These tablets partially absorb organic poisons in the stomach, granting +3 to HT rolls. For treating ingested poison. \$1 per dose, negligible weight. LC4.

Chelating Drugs (TL6): These bind to metallic poisons such as arsenic or mercury, rendering them less harmful. They improve at higher TLs; +TL/2 to HT rolls. \$3 per dose, negligible weight. LC4.

Vaccination (TL5)

See p. 119 for a description of this disease-prevention technique.

Heat Stroke Treatment (TL6)

Someone trained in first aid can treat heat stroke (p. B434) by rapidly cooling the victim (e.g., an ice water bath) and giving lots of electrolytes (usually by IV at TL7+). This takes one hour and requires a roll against First Aid+4. If successful the patient recovers 7 FP and 2 HP (up to the maximum lost by the subject). Further recovery is as normal.

Intravenous Fluids (TL6)

Intravenous (IV) fluids can help stabilize a patient who has lost either blood or water from dehydration. This technique was invented in the 1830s (TL5) to treat cholera patients, but not regularly used until the early 1900s. IV solutions are largely water with a small amount of electrolytes or sugars. An IV drip can also be used to deliver drugs over the course of hours or days. Inserting an IV requires a roll against Physician+2; at the GM's option, critical failure causes a point of injury or results in a chance for infection (p. B444).

IV fluids are required for first aid gear to get a +2 (quality) bonus for being “fine equipment” for treatment of shock; without them the best possible equipment quality modifier is +1. Additionally, each bag of IV fluid counts as drinking a quart of water for hydration purposes (p. B426), and may also count as a meal for FP and HP recovery purposes if a sugar solution is used. Starting an IV fluid drip takes a minute; most IV solutions are delivered over four to six hours.

Intravenous Solutions (TL6)

Saline, for rehydration: \$4/bag, 2 lbs. LC4.

Dextrose, for meal replacement: \$3/bag, 2 lbs. LC4.

For blood plasma, see *Crash Kit* (p. 124).

Infection and Antisepsis

Rules for infection and its treatment are on p. B444. Expanded rules for the effects of antibiotics are on p. 150.

Surgery with properly sterilized equipment and antiseptic technology will not result in infection unless the patient is exposed to an antibiotic-resistant microorganism. This occurs in a few percent of cases during post-operative care; if the GM wishes to determine it randomly, the patient *will* be infected on a 4 or less on 3d. Surgery without a sterile environment counts as “infected matter in the wound” and can result in a non-resistant infection; roll as normal for the surgery *and* as above for post-operative care.

Physiotherapy (TL6)

Many forms of injury, chronic pain, and physical disability can be treated by physical therapy. This may include external manipulation of the musculo-skeletal system, massage, heat and cold treatment, and exercise programs designed to target the condition. Physiotherapy began in the late 19th century, when nurses recognized the value of therapeutic massage in the treatment of some injuries. Massage itself is much older (TL1), but based on trial and error and tradition rather than physiology principles.

Physiotherapy can ease the pain caused by a Bad Back (p. B123) or Chronic Pain (p. B126). A successful Physician (Physiotherapy) roll will “reset” a mild case of Bad Back, or halve the penalties from a more serious case or from Chronic Pain.

Cancer Treatment (TL7)

Cancers and other tumors can be treated by surgical removal, chemotherapy, radiotherapy, or a combination of these. Surgery can be difficult and often leaves malignant cells behind, so the other approaches are often used.

Chemotherapy involves doses of more or less toxic drugs. Radiotherapy uses selective irradiation of parts of the body to destroy malignant cells. Both these methods work best on fast-growing tumors, as they target the cell division process. Unfortunately they also cause significant

side effects, commonly including hair loss, nausea, anemia, and a weakened immune system.

A course of treatment involves daily doses of chemotherapy drugs and/or irradiation for a week or more. After each week of treatment, the patient gets a HT roll to put the tumor into remission (or destroy it on a critical success), at -2 if only one method is used. Radiotherapy subjects the patient to the indicated doses of radiation (which may be reduced by drugs; see p. B436). Radiation damage will accrue, however, and it may be better to stop treatment after a few weeks.

- *External beam radiotherapy* is the most common form at TL7, involving focused beams of high energy X-rays or gamma rays. More invasive TL7 techniques involve the injection or implantation of radioactive isotopes. 3d rads per week of treatment.

- *Proton beam radiotherapy* (TL8) uses beams of accelerated protons fired into the body. These can be targeted more precisely than electromagnetic radiation, since the protons only interact at a depth below the skin that can be controlled by their energy. 2d rads per week of treatment.

- *Antiproton beam radiotherapy* (TL8) fires antiprotons into a tumor, where they annihilate with protons. This deposits a dose of radiation within the tumorous cells, while also providing feedback on the precise location of the dosage via antiproton imaging (p. 128). Thus the radiation can be placed accurately at a specific point within the body. 1d rads per week of treatment.

- *Brachytherapy* (TL8) injects targeted radioactive isotopes into the body, providing pinpoint doses which cause the body negligible overall radiation exposure.

- *Nanotech Laser Therapy* (TL9) uses monoclonal antibodies to bind molecules to targeted cancer cells; an infrared laser then heats the bonded molecule and kills the cells without harming surrounding tissue. This procedure is in development today.

At TL9+, genetic engineering techniques promise to make these therapies redundant; see *Cancer Elimination* (p. 182).

Dialysis (TL7)

This is the artificial filtering of bodily waste chemicals such as urea from the bloodstream – a job normally performed by the kidneys. A patient with renal failure requires dialysis a few times a week to avoid toxic chemical buildup – treat as Dependency (Common, Weekly) [-20]. Dialysis is commonly done by a dedicated machine that either filters blood outside the body before returning it, or that circulates a cleansing fluid through the abdominal cavity. It can also be performed manually by the patient with a system of catheters and prepared bags of fluid. A kidney transplant obviates the need for dialysis.

Treatment by dialysis machine takes three to four hours, three to five times per week. Self-treatment with peritoneal dialysis fluid takes 30 minutes to drain used fluid and load new fluid, daily, and the patient can engage in non-strenuous activity during this time. Dialysis is an expensive ongoing cost, but because the patient would die without it, it is government-subsidized in all but the least caring regimes.

Dialysis Machine (TL7)

An external pump to circulate blood through a filter which removes waste products normally removed by the kidneys. 1943. \$25,000, 300 lbs.

Bags of dialysis fluid for peritoneal self-dialysis: 1962. \$100, 4 lbs. LC4.

Lithotripsy (TL8)

This uses high-intensity ultrasonic sound waves, focused to a point inside the body, to shatter hard, brittle objects such as kidney stones. The stones shatter into pieces small enough to be passed from the body in urine. Lithotripsy can also be used on some gallstones, in combination with oral bile acid tablets to dissolve the particles, but they tend to recur without surgery. Lithotripsy machines could shatter brittle implants such as ceramics, but metal is immune. Electronic components are highly susceptible. Treatment takes one hour.

Lithotripsy Machine (TL8)

A high-intensity ultrasonic transducer for shattering kidney stones inside the body. 1984. \$1,500,000. 500 lbs. LC4.

Cell Regeneration (TL10)

This is a radical non-invasive technique to heal the body on a cellular level using nanomachines. The patient must be placed in an regeneration tank (see below) or chrysalis machine (below). Nanomachines permeate the body, instructing and assisting every viable cell in what repairs to make. Nonviable cells are programmed to apoptose (self-destruct), or are removed and replaced with clones of healthy cells.

A Physician roll is required to supervise the procedure. Success means it works normally; failure takes twice as long as usual. It can heal everything up to permanent crippling injuries at 1 HP per 12 hours, or radiation at 10 rads per day. Missing limbs and organs regrow in six weeks.

Regeneration Tank (TL10): This requires bio-nanomachines and feedstock: a week's supply is \$1,000, 1 lb. \$500,000, 500 lbs. LC3.

Chrysalis Machine: At TL11+, this is used for cell regeneration. See below.

Reattachers (TL10)

These are nanomachines that are injected near the site of a traumatic amputation, and into the severed body part. While the pieces are held apart, the nanobots clamp off severed blood vessels, dampen nerve responses to anesthetize the area, clean up any ragged flesh, and destroy infectious bacteria. They also build scaffolds to hold the severed part when it is reattached. As soon as the parts are put together, the nanobots seek analogous tissues and start stitching them together. Broken bones are bonded with a strong biopolymer glue, and then the tiny machines begin work on the soft tissue. They are smart enough to join arteries to arteries, veins to veins, and nerves to nerves, but will make errors if the part is improperly aligned – make a Physician+2 or First Aid roll to properly align the pieces. On a failure the part will reattach at the wrong angle and

look weird. On a critical failure it will reattach but be effectively crippled.

Reattachers can successfully attach parts that have been severed for up to 12 hours. It takes six hours to attach a digit, 24 hours to attach a limb. They can reattach a head, but the patient is likely to be dead long before the process finishes. \$6,500, negligible weight. LC3.



Chrysalis Machine (TL11)

The ultimate in biomedical technology, a chrysalis machine is a medical device designed for nanotechnological repair and transformation. It is a coffin-sized or larger machine that the user steps into or is placed within. The machine then spins a life-support web around the patient, completely enfolding him. Each cell is surrounded with microscopic biological repair and support machinery, which takes over control from the patient's own DNA. The chrysalis instructs the cells to begin self-repair procedures, and if necessary, takes the patient apart cell by cell and rebuilds him in accordance with its own programming.

A chrysalis can heal almost any wound. Normal HP loss is regenerated at 1 HP per hour. Crippled limbs or organs are restored when lost HP recover. A chrysalis machine can also function as a nanostasis tank (p. 147).

A person who is dead, but who has not suffered serious brain injury, can be restored to life. Roll against Physician, at -2 for every hour the subject has been dead. Success restores the patient to life; failure by 1 or 2 indicates recovery, with personality intact but substantial memory loss (equivalent to Partial Amnesia). Failure by 3+ also restores him to life, but as a blank-minded clone, with no memory or personality. A person who has suffered severe brain damage can still be restored, but only as a blank-minded clone.

Beyond that threshold, if there are some cells left, the chrysalis can clone the original (the body may be totally crushed or burned, but not disintegrated). The chrysalis machine functions exactly like a forced-growth tank (p. 21). The result will be a blank-minded clone (unless uploading technology is also used).

A chrysalis machine can also be used to transform someone, performing safe, fast clinical metamorphosis (see p. 190) in conjunction with a metamorphosis nanovirus.

A chrysalis machine can direct itself using its own dedicated computer's Physician-13 skill (15 at TL12), or be controlled by an operator. \$500,000, 600 lbs. LC3.

Magical, Psionic, and Super Healing

GURPS Bio-Tech focuses on technological means of healing . . . but in some worlds there may be other options.

A range of magical healing spells are found on p. B248, with many others described in the Healing college in **GURPS Magic**.

The Healing (p. B59) advantage can represent many different forms of psionic, super-powered or divinely-inspired faith healing; see also Psychic healing (p. B256). **GURPS Powers** describes numerous other ways to use advantages for curing injuries.



“Do You Have Insurance?”

Medical treatment can be *expensive*. Below TL5, prices are not fixed – patients will have to negotiate a price and pay it somehow, perhaps in goods or live-stock.

For TL5+, rather than give a cost for every treatment, the following guidelines provide an estimate which the GM may then adjust to suit campaign assumptions; or randomly by 10-60% in either direction. First, rate the treatment's complexity as either Simple, Average, Complex, or Amazing, following the examples below. A rough total cost including ambulance, hospital stay, operating theater fees, etc., is then given by:

- *Simple* (GP consultation plus prescription, physiotherapy session, simple X-ray): 10% of the typical monthly pay for the TL (p. B517);
- *Average* (diagnostic scan, radiotherapy, simple surgery e.g. appendectomy, vasectomy): the typical monthly pay;
- *Complex* (routine surgery, simple organ transplant): 10 times the typical monthly pay;
- *Amazing* (open heart or brain surgery, major organ transplant): 100 times the typical monthly pay.

This is the expense of providing the service and equipment, not the final bill presented to the patient! How this cost is covered depends a lot on the country or campaign setting.

Today, medical costs are covered differently around the world. Governments with socialized health care – particularly in Europe – partly or completely pay for necessary treatments (funded by taxes). Travelers from countries with similar programs can also have their costs covered simply by presenting a passport. If the

subsidy is only partial, the patient can be left with an expense of 10-60% of the actual cost. In either case, *elective* (or *illegal*!) surgery is not covered. A drawback of subsidized medicine is that waiting lists for non-urgent treatment can be *long*: six to 12 months or more in some cases. Economies of plenty (TL10+) may be rich enough to provide universal free health care. Totalitarian regimes might also provide health care, but the doctors work for the government, not the patient.

In countries where a free market economy applies to medicine, such as the United States, only limited subsidies exist (e.g. for the poor or elderly) or none at all, and patients have to pay the full cost. This sort of economy tends to drive the base prices up too! Hospitals won't deny emergency care, but can deliver a bill big enough to bankrupt an average patient.

Covering any outstanding cost is the job of medical insurance. In places such as the United States, where this is almost a necessity, insurance is expensive and often negotiated as part of employment packages. At the GM's option, this can be abstracted out and assumed to be deducted from the gross salary before an employed character receives income. Where subsidized health care exists, additional insurance is optional and cheaper – it can be treated as part of the cost of living. In other words, the GM can assume most people have adequate health insurance without worrying about the cost.

The other option is to force characters to actually pay for their insurance or treatments. This requires more bookkeeping, but can lead to the (all too real) scenarios of people needing extra cash just to pay for medical care – which for an adventurer is another potentially interesting challenge.

SURGERY AND LIFE SUPPORT

Sometimes, drugs and non-invasive treatments are not enough to deal with an illness, or a patient suffers an accident causing physical trauma that needs to be repaired. In these cases, the only option is surgery.

ANESTHESIA

Ideally, a patient undergoing surgery should first be rendered immobile and insensitive to pain. Opium, hemp, and alcohol have been used as pain suppressants since pre-historic times (TL0), but these are only marginally effective. Hypnotism and acupuncture have also been used for anesthesia purposes, though people disagree on the efficacy of these methods. In some game worlds they may be as effective as chemical anesthesia (GM's option).

TL4- surgery modifiers assume the above improvised techniques are used, or the surgery is performed with great haste. TL5+ Surgery skill modifiers *assume* effective anesthesia is used: if not, apply a -2 modifier to skill instead of the usual -1 penalty for a missing item. (See *Surgery*, p. B424 and *Surgical Procedures* on p. 136).

General Anesthesia

General anesthesia is intended to leave a patient unconscious, free of pain, and with no memory of the procedure for the duration of the surgery. It is also designed to inhibit bodily reflexes and relax muscles to make the surgery easier to perform.

Effective general anesthetics arrived at late TL5, with the inhaled gases *nitrous oxide* ("laughing gas"), *ether*, and *chloroform* all first used in surgery in the 1840s. All were usable, but have limitations. Nitrous oxide is weak, and is mostly used for dental treatment. Ether is slow but effective (although it's also explosive, limiting its use with devices that might cause a spark). Chloroform can render someone unconscious in minutes (the instant unconsciousness of the chloroform-soaked rag is a cinematic myth!), but overuse can damage the organs. Various delivery systems were used through TL6: a face mask and tubing connected to a gas tank for nitrous oxide, or, for ether or chloroform, a wire basket mask covered with gauze that was placed over the patient's mouth and nose connected to a metal tank. As the anesthetic slowly dripped onto the gauze it evaporated, allowing the patient to inhale the vapor. Often the patient was not entirely unconscious: he remembered the surgery, but experienced no pain as a result.

The next major breakthroughs (TL6) was *sodium thiopental* (also known by the trademark name *sodium pentathol*), discovered in 1936, which induces rapid general anesthesia when injected intravenously. It was widely used to induce anesthesia until the introduction of *propofol* in 1989, and is still used in many countries. Other agents used include ketamine and various opioids.

Total intravenous anesthesia – using only intravenous agents only – was dangerous since the dosage could not be adjusted. This resulted in the development of *balanced anesthesia* in which an intravenous anesthetic (as described above) is used to quickly start the process. Once anesthesia has been induced, it is *maintained* by an anesthetic machine – a combined ventilator with supplies of anesthetic gas.

Modern anesthetic machines (TL7) include diagnostic monitors for breathing, pulse, blood pressure, and blood oxygen level. This allows the level of anesthesia to be carefully adjusted. Many anesthetic gases are used; at TL7-8, the important ones include *halothane* (1956) and *sevoflurane* (1971). Halothane can cause liver damage in humans with prolonged exposure, but is still used in veterinary surgery because it is inexpensive.

Recently, total intravenous anesthesia has made something of a comeback, with the invention of target-controlled infusion (TCI) pumps – computerized delivery-systems. These methods require less machinery than anesthesia machines, making them more affordable and lighter, although they do not, as yet, offer the same degree of control.

General Anesthesia Equipment

Anesthesia equipment is *included* in all TL5+ operating theatres (p. 138) and portable surgeries (p. 138). If acquired separately, its capabilities are shown below.

Gas Anesthesia (TL5). Face mask with ether or chloroform. Roll vs. Physician to use; a failed roll gives -2 to Surgery skill due to under (or over-) anesthetizing the subject. \$50, 2 lbs.

Portable Anesthesia Machine (TL6): Roll vs. Physician+2 to use it; a failed roll gives a -2 to Surgery skill. \$2,000, 40 lbs., plus tank. One tank lasts four hours (\$150, 25 lbs.). LC4.

Hospital Anesthesia Machine (TL7): This is a combined ventilator and vital signs monitor for delivering anesthetic gas in controlled doses during surgery. It provides balanced general anesthesia. Very reliable if used by someone with Physician or Electronics Operation (Medical) skill; no roll required. 1951. \$24,000, 300 lbs. LC4.

Local Anesthesia

Specific parts of the body can be rendered completely numb to pain with topical or injected drugs. Most are artificial drugs related to cocaine; the first was *procaine*, developed in 1905 and used successfully for dentistry. *Lidocaine* largely replaced it after 1948 and is in common use today. Some simple surgical procedures such as vasectomy are performed with local anesthetic. They render the affected parts of the body completely insensitive to pain, and make them Numb (p. B146); this wears off in (20-HT) × 15 minutes (minimum one hour).

Lidocaine or similar local anesthetic: \$20 for a 20-dose tube or vial, 0.1 lbs. LC 4.

Neural Inhibitor (TL10)

A flat disk (two inches in diameter) with adhesive bonding material on one side. It uses technology related to ultratech neural disruptors to cut off nerve impulses when applied to the bare skin of a being with an approximately terrestrial vertebrate nervous system.

Effects depend on where it is placed. If a neural inhibitor were attached to a person's forearm, his hand would be paralyzed, but he would feel no pain from a hand or forearm injury, and surgery could be performed without anesthesia. If one were placed near the neck over the spinal cord, he would be paralyzed from the neck down. Use on the skull induces unconsciousness until removed. They are usually available only to licensed medics, but may be acquired for other than medical purposes, e.g., restraint or torture.

Used as an electronic anesthetic, it adds +1 to First Aid for treating shock, and can also replace anesthesia machines. If the subject is not cooperating, treat this as a HT-6 affliction attack; the victim may roll to resist each second in contact. \$200, 0.1 lb. LC3.

LIFE SUPPORT

Without blood circulation or breathing, a person will die within minutes. The immediate game effects of having no circulation are the same as suffocating (p. B436), as the damage is caused by lack of oxygen to the brain. When the body cannot control these actions itself, life support technology can keep the patient alive.

Mechanical breathing assistance first became possible in 1928 with the invention of the *iron lung*, followed in 1951 by the first flow-controlled *ventilator*. Ventilators can deliver either air or pure oxygen. The latter is useful because lower volumes of gas are needed to deliver the same amount of oxygen to the lungs, and it can partially compensate for reduced blood circulation.

For planned procedures that will interrupt blood circulation, such as open heart surgery, a patient can be connected to a *heart-lung machine*. Invented in 1951, this circulates blood outside the body, oxygenates it, and pumps it back in. It is suitable for surgery, but prolonged use damages brain tissue because of the pressure required to pump the blood around the body. It also causes immune activation in the blood, damaging *all* tissues.

If breathing or circulation fail during surgery, the surgeon will immediately stop operating and attempt to resuscitate those systems – see *First Aid* (p. 123).

Game effects: See *Mortal Wounds* (p. B423) for the effect of life support machinery: the patient rolls to survive each day rather than each half-hour, and may use the higher of his Physician skill or his HT. This assumes the machinery is providing ventilation and, if necessary, blood flow. Such equipment can also maintain the biological functions of someone who is brain dead (unless they're at $-5 \times$ HT or worse), preserving the body intact for later use (harvesting organs, autopsy, brain transplant, etc.). Attaching life support quickly to a mortally injured character requires an Electronics Operation (Medical) roll; each attempt takes at least 10 seconds. Life support can function as a Mitigator

(-60%, see p. B112) for any Terminal Illness disadvantage caused by organ failure or similar problems. It can also perform blood transfusions.

Several types of life support equipment are described below. Weight of electrically powered equipment halves a TL after introduction.

Iron Lung (TL6)

A metal case in which the whole body, except for the head, is encased. Pumps cyclically create negative pressure in the machine, which inflates the patient's lungs artificially. 1928. \$1,000, 1 ton. LC4.

Heart-Lung Machine (TL7)

An external pump and aerator to provide artificial blood oxygenation and circulation in patients with stopped hearts. Provides the benefits of life support (above). 1951. \$15,000, 100 lbs. LC4.

Ventilator (TL7)

A system of compressed air and oxygen, connected to the patient's mouth and nose via pipes. Cyclic pressure inflates the lungs and then allows them to exhale as they relax, several times a minute. Used when a patient has difficulty breathing and during general anesthesia. Provides the benefits of life support (above) in cases where the heart is still working. 1951. \$3,000, 30 lbs. LC4.

Emergency Support Unit (TL9)

This device is a trauma maintenance life support system designed to keep alive a patient who can no longer sustain his own bodily functions. The system also includes diagnostic biosensors (p. 28). An ESU provides a +2 (quality) bonus to Physician skill or HT rolls for life support (above). \$15,000, 120 lbs. LC4.

*Surgery is the red flower that
blooms among the leaves and
thorns that are the rest of
medicine.*

– Dr. Richard Selzer

SURGICAL PROCEDURES

Surgery can be used to cure some illnesses, repair damaged organs and tissues, relieve pain, and rectify impairments.

Surgery has been practiced since ancient times, but was hit and miss until anatomy developed an accurate understanding of how the body was put together. Early surgeons valued speed above all things. A leg amputation might be done in a few minutes, for example.

This changed with the discovery of the anesthetics ether and chloroform and the ability to perform blood transfusions (TL5), which permitted slower but much more careful operations, with proper surgical repair of internal damage; historically, this saw surgery recognized

as a skilled profession, equal with that of the physician. Of equal or greater importance was the realization of the importance of hygiene and the introduction of antiseptics, which vastly increased the survivability of operations.

Modern surgery (TL6-8) builds on these advances to vastly increase the chance of success. Life support (p. 136) can keep patients alive during heart surgery and similar major procedures. Medical imaging (p. 127) vastly reduces the need for risky exploratory surgery. Surgery and its tools become increasingly specialized, and training and operating room techniques are refined; by TL7 surgery can perform previously impossible procedures, such as heart transplants and neurosurgery. A vast range of elective operations are available for everything from weight reduction to sex change.

A major new technology (TL8) is robotic surgery. Present-day surgical robots consist of robotic arms slaved to an imaging and teleoperation system controlled by a human surgeon. In the operating room, the surgeon controls the robot from a console while watching a 3-D image of the surgical field. He manipulates traditional surgical instrument handles and a computer relays his movements to robotic arms on the operating table. Typically a pair of robotic arms will follow the surgeon's movements from a patient side cart, guided by an endoscope arm that provides a view of the patient's insides. The arms operate through small incisions in the patient; as a result, major procedures on the torso and head are less invasive than traditional surgery. While robotic surgery is somewhat slower (at TL8), it decreases the fatigue that doctors experience in long surgeries. See *Surgical Robots* (p. 138) for statistics and game effects.

Advancements in artificial intelligence and robotic arm design may eventually permit the development of surgical robots that can operate completely autonomously. Ultra-tech surgeons may routinely guide swarms of microbots optimized for internal surgical procedures. They could also be used to prevent secondary hemorrhaging and look after any critical systems that might be adversely affected by the operation. Surgical microbots would also allow delicate internal operations that are otherwise impossible or unacceptably risky, such as repairing nerve tissue or removing brain tumors.

Operations

Stabilizing a Mortal Wound: Someone who failed a HT roll to avoid death by only 1-2 is mortally wounded and dying (see p. B423). A surgeon can try to save him. Each attempt takes one hour. The roll is at -2 if the patient is at -3×HP or worse, or -4 if he's at -4×HP or worse. On a success, the mortal wound is stabilized. On a failure, repeated attempts are allowed, at a cumulative -2 per attempt, but patients must check every half-hour to avoid death (see p. B423), or less frequently if on trauma maintenance (see *Life Support*, p. 136).

Repairing Lasting Crippling Injuries: It is possible to fix a lasting crippling injury (see *Duration of Crippling Injuries*, p. B422) through surgery rather than leaving it to heal on its own. This takes 2+ hours. On a success, measure the injury's remaining recovery time in *weeks* rather than

Exploring Inner Space

One radical method of surgery in a superscience setting is to physically shrink the surgeons to the size of cells and inject them into the body of a patient, usually inside a vehicle like a submarine. This idea was explored in the classic film *Fantastic Voyage*, which showed that the interior of a body is a wondrous place filled with plenty of opportunities for adventure. In a campaign with physical shrinking technology and without the medical advances necessary to treat certain conditions, inner surgery may be the best technique available. This is more likely at relatively low tech levels with rubber science, such as an Atomic Horror 1950s setting with a sprinkling of superscience, as medical advances will quickly make it redundant beyond TL8.

The setting needs to brush aside realistic problems such as how cell-sized humans would breathe, retain body heat, and deal with the overwhelming surface tension of liquids, and instead focus on dramatic possibilities. These include navigating the circulatory system, battling white blood cells which recognize shrunken humans as foreign bodies, and dealing with the infection or disease when they find it.

With another order of shrinkage, people could even have adventures inside a *cell*!

A still fantastic – but slightly more realistic – way to adventure in inner space is to have the intrepid surgeons remotely piloting teleoperated surgical microbots. Virtual reality or a direct neural interface could give the illusion of presence in the body. There is no direct risk to the medical team (unless the neural interface is itself dangerous) but there may still be a dramatic race against time to preserve their 'bots and save the patient's life.

months. But on a critical failure, the injury becomes permanent!

Repairing Permanent Crippling Injuries: High-tech surgery may replace lost or destroyed limbs, eyes, etc. One way to do this is through attaching replacement parts – see *Transplants* (p. 141). This is tricky: a minimum -3 to skill (unless noted otherwise). On a failure, the patient needs 1d months to recover before another attempt is possible.

Repairing Medical Conditions: The disadvantages Bad Back, Chronic Pain, Terminally Ill, and Wounded may, at the GM's discretion, be the result of conditions that can be cured through ordinary surgery (without transplants). For example, a person who is Terminally Ill may be curable by a heart-bypass operation. The operation usually takes 4+ hours; success may remove or reduce the severity of the disadvantage; failure has the usual consequences of failed surgery and the patient needs at least 1d weeks to recover before another attempt is possible.

Biomods: Elective surgery to enhance or modify the user is covered in Chapter 7, but uses the rules described below. See Chapter 7 for time required and recovery periods.

If surgery cures a disadvantage, see *Buying Off Disadvantages* (p. B291-292) for guidelines.

Cinematic Surgery

In cinematic games, the nitty-gritty of surgery might be much faster and more effective. Cinematically high levels of the Surgery and Physician skills (or Medicine!, p. 214) allow amazing feats of healing, but a few optional enhancements for color can also be added.

Firstly, depending on genre-appropriateness, the patient might be anesthetized effectively with a slug of whiskey, a blow to the head, a tea brewed from nearby flowers, a scientifically placed nerve pinch, or by being given a bullet to bite. Another slug of whiskey might also calm a surgeon's nerves, granting a bonus to Surgery!

The GM may elect to ignore life support needs except in serious cases, and even then, open-heart surgery might be performed safely without brain damage by cooling the patient's head in ice.

Finally, surgery will still cause injury if it fails, necessitating recovery, but otherwise the patient might be able to walk, fight, and jump out of moving vehicles again as soon as he wakes up.

General Surgery Modifiers

These apply to all operations:

Scrubbing: It often takes at least five minutes to thoroughly scrub down for surgery. -3 if the area or equipment cannot be properly cleaned and sterilized; -1 for a cursory clean-up.

Diagnosis: -5 for undiagnosed problems.

Physician Skill: If a surgeon lacks Physician skill, he is at -5 to do anything but "field-expedient" surgery (e.g., stitch wounds or extract arrowheads, bullets, and shrapnel).

Assistants: +1 per assistant with Physician, Surgery, or (if appropriate to the equipment used) Electronics Operation (Medical) at 12+; +2 for skill 15+. Maximum bonus is +6.

Repeated Attempts: On a failure, repeated attempts are at a cumulative -2 per attempt.

Equipment: Basic equipment gives -6 at TL1, -5 at TL2-3, -4 at TL4, -2 at TL5, and +(TL-6) at TL6+. TL5+ surgery assume that anesthesia (p. 135) is available. If not, apply a -2 penalty to skill. Use of less sophisticated anesthesia may have other penalties (see *Anesthesia Equipment*, p. 135). Additional quality modifiers apply for better equipment; see the surgical equipment, below.

Other Species: Apply physiology modifiers (p. B181) for working on other species.

Success and Failure

On a success, the operation proceeded without complications. On a failure, the patient took damage – 1d for a minor procedure such as most cosmetic surgery; 2d for most serious procedures performed on limbs or extremities, such as amputations, sex change operations, etc; 3d for most torso or head surgery, including organ transplants. Halve damage if using robotic surgery (p. 137).

The fee is the usual surgical fee charged at a clinic or hospital – ignore it for characters who do their own work.

Type of Operation: -2 if stabilizing a mortal wound if the patient at -3xHP or worse, or -4 if he's at -4xHP or worse; -3 to repair lasting crippling injuries; -1 per -10 points or fraction of disadvantages if repairing a medical condition.

On a critical success, halve the recovery time (p. 139). A critical failure usually inflicts double damage. The GM may also impose other effects: new disadvantages, loss of attributes, etc.

Surgical Equipment

Surgical equipment and technology changes dramatically through the ages. Many forms of nanosymbionts (p. 164) are also useful in surgery at high tech levels.

Surgical Instruments (var.)

Includes scalpels, forceps, etc. Basic equipment for Surgery skill. \$300, 15 lbs. LC4.

Portable Surgery (Var.)

A complete set of equipment that fits in the back of a utility vehicle or trailer or a hospital cart. These are often used as mobile field surgeries for military units. A portable surgery takes at least five minutes to pack or unpack; half an hour is more typical. It includes portable anesthesia equipment appropriate to the TL. It gives a +1 (quality) bonus to Surgery skill and +2 (quality) bonus to First Aid. \$50,000, 500 lbs. LC4.

Operating Theater (Var.)

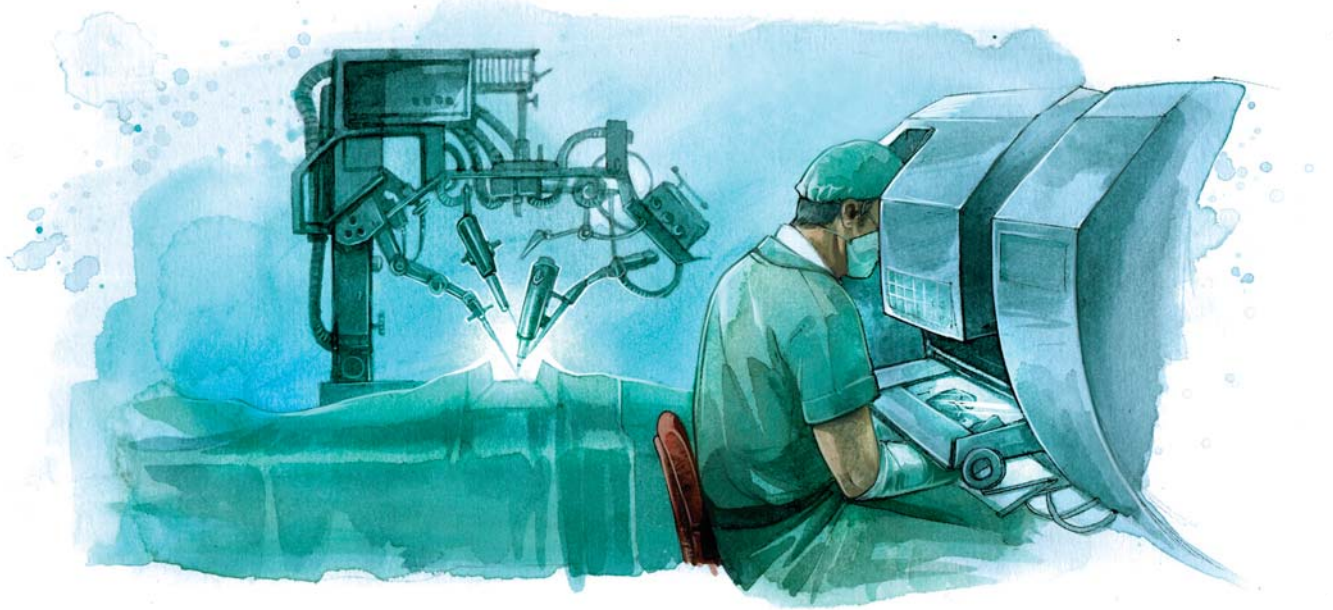
An entire room full of specialized equipment. It includes the best anesthesia equipment for the TL. It provides a +2 (quality) bonus to Surgery skill. \$200,000, 1,000 lbs. LC4.

Specialized Operating Theater (Var.)

As above, but dedicated to a particular Surgery specialization, e.g., neurosurgery or heart surgery. It gives a +TL/2 (quality) Surgery bonus in that specialization but is only basic equipment otherwise. \$1,000,000, 1,000 lbs. LC4.

Surgical Robot (TL8)

This is a set of cart-mounted teleoperated arms and imaging systems, plus the surgeon's control console, used for *Robotic Surgery* (p. 137). The surgeon uses remote controls to manipulate long, slim articulated surgical instruments and scopes that are inserted through small incisions in the patient. At TL8, teleoperated robot torso or head surgeries are slightly slower than hands-on surgery (multiply surgery time by 1.5) but the recovery time afterward is halved; in addition, any damage from a failed surgery roll



is reduced by -1 per die. At TL9+, no extra time is required, and this sort of remote-controlled manipulator capability is so ubiquitous they are built into all portable surgeries or operating theatres at no extra cost. 2000. \$1.3 million. 500 lbs. LC4.

Automated (TL9)

A coffin-sized trauma pod with robotic surgical tools, diagnostic sensors, and doses of dozens of drugs. Its programs have Diagnosis-12, Electronics Operation (Medical)-12, First Aid-13, Physician-11, and Surgery-13, each improving by 2 per TL. It can also sustain a patient on life support (p. 136) and act as a teleoperated surgery for a remote surgeon with higher skill (use surgical robot rules). \$100,000, 250 lbs. LC4.

RECOVERY

Before TL5 (and, at the GM's option, even during much of TL5), antiseptic practice is poor; check for infection (see *Infection*, p. 132) after any surgery.

If the patient has not lost any HP prior to or during surgery, recovery can be quick. General anesthesia will leave the patient Drowsy (p. B428) for (30-HT) minutes after waking up. For minor procedures, the patient will soon be able to walk and check out of the hospital, but often at least a day of rest is required to fully recover strength. Surgery on a limb will reduce its DX by 3 and ST by 30%, which is recovered by resting at a rate of 1 DX and 10% of ST per 10 days. Abdominal, chest, or back surgery results in the same losses for the whole body. Critically injured patients who leave surgery will be placed in intensive care until doctors consider them stable enough to be left without constant supervision.

Besides regaining strength, a surgery patient must take care not to tear sutures or promote bleeding. Any strenuous activity (e.g., running, climbing, combat) is likely to cause up to 1d of injury until the wounds heal; roll vs. HT-4 to

avoid this. With serious injuries, getting out of bed may be too strenuous!

If the patient has lost HPs, these must also be recovered before he is fit to leave medical care. Rules for this are under *Natural Recovery* and *Medical Care* (p. B424).

Psychological Effects

Once a patient has undergone surgery, the wait to recover can be stressful. The hospital environment has strange beds, food, equipment, and people. Combine this with the stress of missed work, inability to help family, and the financial burdens medical treatment can add, and some people break.

A patient who doesn't rest sufficiently suffers a -3 penalty on his HT roll to regain lost HP for that day. Appropriate disadvantages such as Sense of Duty, Workaholic, or Miserliness (if faced with mounting bills) will make him literally restless to leave, unless overcome with a self-control roll (if the disadvantage has one) or someone else using Influence skills (e.g. doctor's orders or family pleading). Sedatives (p. 152) may help with sleep; access to a portable computer or aides to run errands will give bonuses to self-control or Influence rolls while risking the wrath of the treating physician.

AUTOPSY

Autopsy is the medical examination of a corpse to determine the cause of death. In many cases this takes nothing more than an external examination – knife and gunshot wounds tend to be obvious. If the examiner needs to cut open the body to examine internal organs, this requires a roll vs. Surgery+6 to avoid damaging any vital evidence. (Forensic pathologists will have studied surgery to gain their qualifications.) Determining the cause of death is a Diagnosis roll, with bonuses for obvious wounds, or penalties for especially subtle causes.

In some cases, an accurate diagnosis cannot be made without labwork on tissue samples. The job then changes

*What medicines do not heal,
the lance will; what the lance
does not heal, fire will.*

– Hippocrates

hands to people with skills in Biology (Biochemistry or Microbiology). In some cases zoologists are required to examine evidence such as insect larvae or marine growth to determine time of death.

In a criminal investigation, an autopsy also includes collection of medical and forensic evidence that may lead to clues about the circumstances of the death. This involves looking for bruising, abrasions, lacerations, foreign biological matter, and chemical residues such as gunpowder, acid, and so on. Finding these clues and recognizing their importance requires a roll vs. Forensics.

For identifying bodies, see *Biometrics* (p. 24) and *DNA Testing Procedures* (p. 8). See also **GURPS Mysteries**.

How Fast Does a Body Decay?

An exposed corpse goes through several stages of decomposition, beginning from the moment the body dies. These changes are important signs for forensic investigators.

0-24 hours: The body begins to cool toward the environmental temperature, at roughly 1.5°F per hour. Bodily sphincters relax; the bowel may release feces, while stomach contents can be regurgitated if the body is moved or the head is lower than the stomach. The skin becomes pale within an hour or two through lack of blood. The blood pools under gravity, causing a dark red to purple discoloration in the lower parts of the body after two hours. Three hours after death, the body begins stiffening with rigor mortis. Skin cells live (and can be collected and cultured, perhaps for cloning!) for up to 24 hours after death.

1-3 days: Normally harmless bacteria in the digestive tract begin digesting the organs around them. The body's own enzymes start breaking down cells and connective tissues. A corpse attracts flies immediately; they lay eggs around wounds and body openings. Maggots hatch within 24 hours and burrow into the flesh. Rigor mortis wanes after 36 hours.

4-10 days: The anaerobic breakdown of tissues and cells by bacteria releases fluids and gases into body cavities. The gases – including foul-smelling methane, hydrogen sulfide, and organic compounds – cause the body to bloat. This provides enough buoyancy for a human corpse to float even if initially held underwater with up to half its own mass in weights. Maggots move through the body, spreading bacteria and further tearing tissues. The smell attracts beetles and wasps, who prey on the maggots.

11-20 days: The body releases the bloating gases and collapses. A large amount of putrid fluid drains from the corpse into the surrounding area. The first generations of maggots pupate and emerge as flies. Wasps lay eggs inside maggots and pupae.

21-50 days: Most of the soft tissue is gone. What remains dries out and begins to ferment. This produces a carpet of mold as fungal spores germinate. There is no longer any food for maggots, but beetles continue to feed on skin and ligaments.

51+ days: All that is left is bones and hair. Moths and bacteria eat the hair over the next few months and the bones dry out. A year later, only a dry skeleton remains.

A body not exposed to insects will decay more slowly by bacterial action, taking twice as long underwater and four times as long underground. Burial in a coffin can lengthen the process by up to 10 times.

In unusually cold and dry conditions, such as mountaintops or in space, a corpse can desiccate quickly enough to prevent the latter stages of decay. This produces “freeze-dried” mummies such as Ötzi, the Alpine “Iceman.” Mummification can also occur in anaerobic conditions that kill bacteria, such as in peat bogs. Mummification is complete within six to 12 months.



MEDICAL TRANSPLANTS

Therapeutic? Sure. But you can also use an eye transplant to change your retina print. Even saw one guy who grafted on a new hand so he could get past a palm-print scanner.

– *Streethawk, alt.bio.upgrade.samurai*

The transplantation of organs from one body to another can treat many different conditions. The surgical techniques necessary for transplants had been developed by 1900. Surgeons experimented on animals and humans, but discovered that rejection of the foreign tissue by the body's immune system prevented success.

The first successful human transplant was performed in 1954, a kidney transplanted between identical twins to avoid tissue rejection. Lung, liver, and heart transplants followed in the 1960s, but available immunosuppressant drugs were not strong enough to prevent patients from succumbing within months to rejection and other complications. The discovery of the powerful immunosuppressant *cyclosporine* in 1970 (found in a species of fungus) paved the way for transplant recipients to recover and live full lives with their new organs. Unfortunately, cyclosporine has a number of unpleasant side effects, including increased susceptibility to infections.

ACQUIRING ORGANS

Before a transplant can proceed, the surgeon must have the limb or organ that is to be transplanted. Transplant organs at TL7-8 must be taken from living (or very recently deceased) individuals. At higher TLs, they might be grown with tissue-engineering or cloning technology (see below).

There may be faster ways to get a body part. See *Trade in Body Parts* (p. 194) for more organ sources.

The prices given for transplant procedures include the cost of purchasing or growing the body part as well as the operation itself; one-third is the cost of acquiring the part and the remaining two-thirds the cost of the operation. Thus, if someone donated a kidney to save his dying twin brother, or a group of cyberpunks murdered a victim to get an organ for a friend, they'd pay two-thirds as much. If they bought the organs, but one of them was a surgeon and they performed the operation themselves, they'd pay only one-third cost. If they did both, the process would be free.

Tissue Engineered Transplants

One way to avoid tissue rejection without resorting to immunosuppressant drugs is to use donor organs with the same genetic profile. Tissue engineering holds the promise of providing custom-grown organs specifically for transplantation – see *Transplant Organs*, p. 26. Organs with a listed “time to grow” assume the organ is custom-grown in a growth tank (p. 20) using samples from the subject's cells. If forced-growth technology exists, divide the required time by four. Custom-grown organ providers may require advance payment before they will begin growing a transplant. The organ can be transplanted as soon as it's grown, or stored until convenient.

Clone Transplants

An alternative method of producing tissue-compatible organs for transplantation is to grow an entire new set in a complete clone body. This is less desirable than tissue engineered organs for several reasons: clones take longer to grow, are more expensive, and raise more serious ethical problems that may make growing clones for spare parts controversial or illegal. See *Cloning* (p. 22) for details about creating clones, and *Spare Part Clones* (p. 196) for a discussion of the ethical considerations.

Xenotransplants

These involve grafting nonhuman tissue into a human body. This tissue may come from an animal or be vat-grown. One difficulty is that the immune response to non-human tissue is different than that to foreign human tissue. Different drugs are needed to suppress immune responses, and the risk is slightly increased. The goal is to replace a dying human organ with that of an animal anatomically and genetically close to humanity, such as a baboon.

Organ xenotransplants were begun experimentally in 1964 but first became reliable with heart valves transplanted from pigs and cows in 1975. Whole organ xenotransplants have not yet been successful, but the technology should mature by TL9. By TL10, genetic engineering can produce animals with tissues designed to produce minimal immune response in humans, reducing risks of rejection.

Medical xenotransplants are used for two reasons: First, they serve as a substitute for human organs that may be in short supply. Second, if the patient's organs are failing due to an infectious disease, the disease is less likely to cross species and reinfect the new organ than if human tissue were used. In such cases, a xenotransplant may repair damage and also cure the disease (allows a HT roll, at a penalty depending on the disease). The downside is the animal tissue may be susceptible to diseases of its own (“What do you mean I can catch distemper from my cat now?”).

Xenotransplants can be used to replace damaged or failing organs at 75% of the price of an ordinary therapeutic organ transplant and with no waiting period.

REJECTION AND IMMUNOSUPPRESSION

Rejection is a risk when using transplants that are from a donor who's neither the clone nor an identical twin of the recipient. The danger can be reduced by using genetic tests to find donor tissue that more closely matches the recipient (TL8). If genetically matched tissue is unavailable, then the recipient should only accept tissue from a donor of the same blood type. Use of donated tissue is usually combined with a cocktail of drugs to suppress the patient's immune system long enough for the transplant to become part of the body. Check for tissue rejection midway through the recovery period.

Rejection is automatic if the donor and recipient have different blood types. Otherwise, the patient must *fail* a HT roll to avoid rejection. Modify the patient's HT for this roll as follows:

- +2 if a xenotransplant, or -4 if a xenotransplant from an animal engineered for maximal compatibility (TL10+);
- +6 if no tissue matching was performed (cumulative with the xenotransplant modifier);
- any Resistant to Disease bonus (+10 for Immunity to Disease);
- -1-(TL/2) (round toward 0) if on a regimen of immunosuppressant drugs; this also halves (round down) any bonus from Resistant to Disease;

Success on this HT roll means that rejection starts halfway into the recovery period. The patient must make a HT roll (at -2 if the transplant is a vital organ) every day, or lose 1 HP; 1d HP on a critical failure. This continues until the transplant is removed or the patient dies. Removal requires an operation identical to the original at +2 to Surgery skill, but may leave the patient on life support until a new organ can be found.

Following a potentially rejectable transplant, the patient requires immunosuppression for life. This gives him Dependency (Immunosuppressants, Common, Daily) [-30] and Susceptible to Disease 3 [-12], though this is a good deal considering the buying off of Terminally Ill!

Telemedicine

Remotely-controlled diagnostic systems or surgical robots combined with a two-way communication link permit off-site "telemedicine."

Apply a -4 penalty for any such endeavors (-2 if using a neural interface, which may be available at TL9+). Each 186,000 miles (one light second) between the operator and robot imposes a one-second action-response delay (each way); this may not be a problem if everything goes right, but can make it difficult to correct minor errors; apply a -1 penalty for one light second, -2 for 10 light seconds, -3 for 100 light seconds, etc., unless an FTL communication system is available to allow zero-lag response.

TYPES OF TRANSPLANTS

Transplants of different complexity are possible at different TLs. Use the rules under *Surgery* (p. 135) for a transplant operation. The patient must rest and recuperate afterward; each procedure has a listed recovery time.

Organ Transplants (TL7)

Kidneys, lungs, livers, and hearts can be transplanted at TL7. At TL8, it is possible to successfully transplant most chest and abdominal organs (the stomach being the major

exception), corneas, and skin. As technology improves, transplants of the remaining organs should be possible.

Suitable transplant organs may be in short supply; see *Xenotransplants* (p. 141) and *Trade in Body Parts* (p. 194) for alternatives. At TL9, vat-grown organs take six weeks to grow and the entire procedure is significantly cheaper: divide cost by two at TL9, four at TL10+. If vat-grown organ technology does not exist (or the patient doesn't want to wait for them to grow), donated organs may be available at the same prices for TL7-8 organs.

Operation: Cornea: \$15,000, two weeks recovery. Kidney, digit, or genitals: \$150,000, four weeks recovery. Bone marrow: \$240,000, five weeks recovery. Any other organ: \$300,000, six weeks recovery. LC3.

Statistics: At the GM's discretion, replacing major organs can cure or arrest some diseases or the Terminally Ill disadvantage, or restore some or all ST or HT lost to aging, disease, or radiation.

Limb Transplants (TL7)

Surgical reattachment of severed arms, legs, hands, and feet is a common procedure, often successful if the body part has had little time to deteriorate. However, transplant of limbs from one person to another is much rarer: only a few such transplants have been performed since the first one (in 1964).

Limb transplant recipients must undergo intense physical therapy to recover anything approaching normal functioning, which requires TL9+ technology to achieve.

Operation: \$120,000 and 12 weeks recovery at TL7-8; \$60,000 and six weeks recovery at TL9+. LC3.

Statistics: Replaces a lost limb that was destroyed or otherwise unrecoverable. At TL7-8, the user should, at a minimum, take a Minor Handicap (p. B165). If the patient does not devote an additional period equal to the recovery time to intense physiotherapy, assigning up to -20 points of physical disadvantages, such as a -1 to DX or ST (for a transplant hand or arms) or -1 to Move (for a transplanted foot or leg) would be appropriate. At TL9+, there are no side effects.

Face Transplants (TL8)

This is the transplantation of the facial tissues down to the muscular level. The medical justification is to provide a natural face for patients suffering disfigurement; the inclusion of nerves and muscles allows sensitivity and movement, as opposed to skin grafts which produce a blank mask-like effect. The problem is the patient ends up looking like someone else. Depending on circumstances, this may qualify as Mistaken Identity. It is also possible that unscrupulous individuals will undergo this procedure to deceive others, or to lose their old identities. By 2006, this operation is possible, but has been performed only once.

Operation: \$20,000 and two weeks recovery; half cost at TL9+. LC3.

Statistics: Variable; usually a change in Appearance level [Variable] and/or Mistaken Identity [-5]. At TL9+, mass-produced tissue-engineered faces become available; this is Appearance with the Off-the-Shelf Looks (-50%) modifier.

Head and Brain Transplants (TL9/10)

Ultimately the head, or even just the brain, could be transplanted onto a new body. The heads of monkeys have been transplanted, but the ethical issues involved with attempting this on a human have so far prevented such an experiment. At TL8, a severed spinal cord cannot be reconnected, so any head transplant would leave the patient quadriplegic. At TL9, spinal cords can be regenerated using stem cells (p. 22), but this does not allow a full reconnection, leaving the patient Numb (p. B146). At TL10, this problem can be overcome with nanosurgery. This procedure transfers the patient's consciousness to a new body and can be used to extend lifespan and vigor, especially if a younger body is used. The brain cells are still the same age, though, so this is not a ticket to immortality.

For temporary storage before attachment to a new body, a neuropreservation unit or brain pod can be used.

Removing a brain safely takes six hours; reattaching one takes 24 hours. Attachment to a full cyborg body (see **GURPS Ultra-Tech**) is slightly easier since part of the work is already complete; this gives +2 to Surgery skill.

Operation: \$50,000 and eight weeks recovery for transplantation into a living or cyborg body. \$10,000 for removal and storage alone. Roll versus Surgery-5, with failure indicating damage to the brain (permanent loss of 1d points of IQ), and critical failure resulting in brain death. There is no need to grow an organ, since an existing brain is used.

Statistics: Use the rules for *Mind Transfer* (p. B296). The rule for modifying IQ given there under *Mind vs. Brain* does not apply, since the brain tissue is being transferred. However, the GM may decide that DX is either fully or partly controlled by neural response; if so, keep the DX of the brain or the average of the brain and body, respectively, and optionally require refamiliarization with physical skills with the new body. If brain transplants are likely, the GM may want to track the brain's age (which will control the frequency of rolls for IQ loss due to aging) and the body's age (which controls aging losses of ST and HT) separately; which controls DX depends on GM choice.

NEUROLOGICAL PROCEDURES

The brain is the most complex organ in the body, and the seat of consciousness. Procedures that alter brain structure or chemistry can produce profound changes in the subject's memory and personality, for good or for ill.

*Do not forget: in medicine,
there are more important things
than life and death: dollars and
cents.*

— Gerhard Kocher

Neuropsychology (TL8)

This is the study of brain function and how it relates to cognition and behavior. Neuropsychological therapies can help patients deal with conditions caused by abnormal or injured brain structure. This can include many disadvantages, especially Amnesia, Dyslexia, Epilepsy, Neurological Disorder, and Stuttering. Others may be added if the GM considers them caused by brain abnormalities.

Unlike psychotherapy, clinical neuropsychology aims to treat these conditions by using mental and behavioral exercises to develop improved brain function. Such exercises can "remap" the brain, using uninjured areas to take over the tasks of the impaired regions. An effective TL8 example is speech therapy, but other conditions may only become easily treatable at higher TLs.

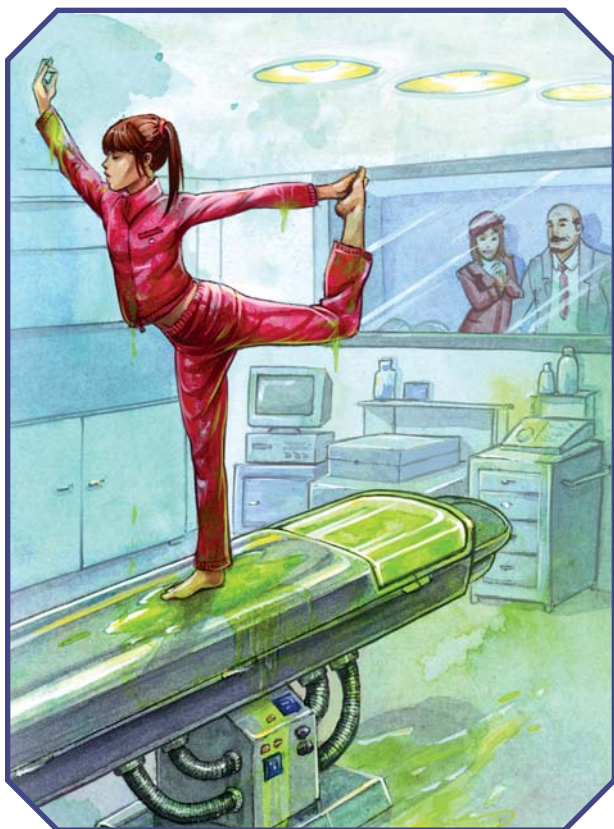
Statistics: At the GM's option, neuropsychological therapy can be used to justify buying off disadvantages caused by impaired brain function, as for psychotherapy, but substituting a HT-2 roll for the Will roll, and with no penalty for critical failures – it is slower, but not prone to undoing itself. Required treatment sessions and costs are similar.

Deep Learning (TL9)

Deep learning is an intensive process that works on a blank brain (one with no prior experiences outside an artificial womb), making extensive use of technologies such as sleep-teaching tapes, learning-enhancing drugs, and virtual-reality sessions to "program" someone with a synthetic set of skills and knowledge. This would be an ideal technology to combine with the accelerated growth of people (clones, bioroids, etc.) using forced-growth tanks or biofabs (p. 27).

Six weeks of deep-learning socialization can give someone basic life skills. This can take place while a person is growing in a growth or fast-growth tank. It gives the subject control over his own body and the ability to understand and speak one language at Native level.

Up to an extra year and a half can be spent in deep learning; more time imposes too severe a psychological stress. It counts as intensive training (p. B293), except that there is no HT requirement and it can last 20 hours a day, the remainder being simulated sleep, rest, or play. Thus, someone undergoing it is actually spending 600 hours a month training (equivalent to 1,200 hours of learning). Deep learning can also program a mental disadvantage into someone, with up to -3 points worth every month possible instead of skill training. This sort of programming is not entirely reliable, and may fail at the GM's option.



A deep-learning system requires a Complexity 6+ computer and specialized teaching programs that control the various virtual-reality simulations, drug doses, etc. Programs cost \$100,000 for basic life skills, \$12,000 per additional skill. Peripheral hardware must also be added to the growth tank, biofab, or forced-growth tank. This costs \$400,000 at TL9 or \$100,000 at TL10 (due to advances in neural-interface technology), with the cost being halved at TL11 and again at TL12. The fee charged for the deep-learning process itself costs \$4,000 per character point or point of disadvantage gained at TL9, halved at TL10, and again at TL11+.

Brain Scanning (TL10)

This uses diagnostic machines in conjunction with HyMRI (p. 129) to create a mental model of the way a person thinks (a “persona map”). The subject must be conscious, but cooperation is not required. Roll against Electronics Operation (Medical) at -2 or Brainwashing each day to make a full brain scan; subsequent scans to update the map with new data are performed at +1 and take a few hours. Careful study of a recent persona map requires a successful Psychology roll and at least two hours. It reveals the subject’s main mental advantages, disadvantages, and quirks, and gives a +2 (quality) bonus to Psychology and +1 (quality) to social or Influence skills when dealing with that person.

PRESERVATION

Preservation is the process of slowing down or stopping biological activity in humans, while doing as little damage to the body as possible. There are a few different ways in which this can be done.

These technologies may allow an injured, dying, or recently dead person’s body – or at least the information in his brain – to be preserved, perhaps long enough to reach a medical facility that can cure him. If no cure is available, he might possibly be suspended until future science can devise one.

The obvious non-medical use is for space travel. If a space voyage takes years, some sort of preservation technology may be necessary for manned flight. Even if it takes weeks or months, it would still reduce tedium and save on life-support costs. This technology may even be required for faster-than-light voyages if the FTL drive has side effects that would damage the life or sanity of a conscious passenger.

Healthy people may also use these technologies to “time travel” into the future, especially at TL9+. The motive could be unwillingness to wait for an event (“wake me up when you’re ready to marry me”), boredom (“wake me up in a hundred years”), or a desire to monitor a long-term process, such as a team of sociologists monitoring a culture’s development (“wake me up when the Tang Dynasty falls”).

If reliable preservation technology (suspended animation, nanostasis, or temporal stasis) exists, individuals – or entire

organizations – who live only for a specific mission may be kept preserved most of the time, being revived only when needed. For instance, a super-assassin or an entire army of bio-soldiers could be too dangerous or expensive to maintain in peacetime. Instead, such individuals could be kept in suspended animation, to be revived and briefed whenever a crisis threatens, then put back to sleep afterwards. (This might make an interesting campaign, as each adventure could be set progressively farther into the future.)

CRYONIC PRESERVATION

Cryonics is the practice of preserving recently dead bodies at extremely low temperatures, with the hope that future medical science – especially nanotechnology – will be able to revive them. At present, there are a handful of corporations or societies devoted to cryonic preservation, mostly in the United States. Only dead people are frozen, as TL7-8 cryonic techniques would kill a living subject.

If cryonic preservation is to be meaningful, it must take place as soon as possible after death. This is because a dead body’s tissues suffer progressive deterioration after breathing and blood circulation cease (see *How Fast Does a Body Decay?*, p. 140). A candidate should be placed on a heart/lung machine immediately after clinical death, to restore some circulation. The corpse can then be taken to a cryonics facility, where the actual cryonic process can take place.

Preservation at cryogenic temperatures prevents further tissue deterioration, but has its own problems. The most significant of these is caused by ice crystals forming in the cells. Even a dead human body is mostly water. When it is frozen, the water expands, rupturing the cells. This can cause cracks throughout the body, including the brain.

To minimize tissue damage, a special protective solution (at TL7-8, a glycerol-based solution) is slowly introduced into the subject's tissues, using a specialized heart/lung machine to pump it through the body. This takes four hours, during which the patient's brain is carefully monitored. Next, the patient's temperature is slowly lowered over five days using dry ice. When cold enough, he is then deposited in a liquid-nitrogen bath for permanent cryopreservation at -320°F. At this temperature, all biochemical and metabolic deterioration effectively halts. Subjects maintained at this temperature can be preserved almost indefinitely. Even so, there is a high risk of information loss (revived cryonauts may often suffer Total or Partial Amnesia); as such, vitrification (below) may be preferred.

A person in cryonic preservation is sometimes called a "corpsicle" (a word used by SF author Larry Niven, who credits Frederick Pohl for it). Advocates of cryonics may consider this impolite. A typical price for whole-body cryonic preservation, including both the operation itself and the promise of indefinite cryonic storage, is \$150,000. Companies may also charge an annual fee of a few hundred dollars while you are alive to cover the expenses of administration and recovering your body when you die. But there's a cheaper alternative . . .

Cryopreservation Units (TL7)

These storage units are basically giant thermos bottles designed for very low temperatures. Their extremely cold state is maintained by a reservoir of liquefied gas, usually nitrogen. Since they are intended for the long haul, cryopreservation units are normally made of two layers of steel separated by multiple layers of insulating material. This minimizes evaporation, but they require topping up with liquid nitrogen every 10 days or so. In an emergency, they can be left untended for a few months before the bodies begin to thaw. Bodies are stored head-down so that the brain is the last thing to thaw.

Gas refills and maintenance cost \$4,000 a year for a full body. A stable trust account returning enough to cover ongoing costs requires a capital investment of \$120,000, assuming the economy doesn't crash. Divide these figures by four for neuropreservation. At TL9+, cryopreservation units are more efficient, requiring refills only twice a year and dividing ongoing costs by 20.

Whole-Body Unit: A unit designed to preserve three to five whole bodies. \$10,000, 2,000 lbs. LC4.

Cryocase (TL8)

This is a portable cryogenic storage case, normally used for transporting organs, frozen embryos or similar fragile biological cargoes. Its interior can be configured to contain a human head or arm, up to three large organs (heart, kidney, etc.), or twice that many smaller organs (eyes, for instance). It will preserve them for as long as it has power,

after which they will spoil within 1d hours. The cryocase is also suitable for transporting other products that need to be frozen – evidence samples or certain drugs, for instance. The case is about the size of a large suitcase. \$2,000; when empty, it weighs 10 lbs. Batteries power it for 24 hours, but it can be hooked up to building power (negligible requirements) to run indefinitely. LC4.

Nonhuman Cryonic Suspension

As with all medical technologies, some people will want to apply cryonics to beloved pets or valuable livestock. For mammals, the procedures are the same; the only real difference is in the size of the storage container required. Scale the size and cost of an animal cryogenic unit according to body mass, assuming a standard human capsule can hold 200 lbs.

Simpler life forms can be frozen and revived more cheaply, as their bodies are more resistant to freezing temperatures and suspension of metabolic activity. Plants and invertebrates cost half as much to freeze and revive, while unicellular organisms can be suspended successfully for no expense beyond the storage cost.

Cryonic Vitrification (TL8)

The major problem with early cryopreservation techniques is that the ice crystals forming within the body destroy cells. Vitrification replaces water-based fluids within the body with a cryoprotectant concentration so high that ice does not even form; the tissue is vitrified in a glassy state. Vitrification offers better odds of preserving memories intact (usually no worse than Partial Amnesia), but physical revival has to wait for TL11+ technology.

Neuropreservation (TL8)

The usual form of vitrification is neuropreservation. This process involves preserving only the severed head (since the brain is the seat of memory), the idea being that a technology advanced enough to revive a body should be able to handle a brain transplant to a clone. On the other hand, this is controversial, for a couple of reasons. First, many consider the practice a little ghoulish. Second, it's possible that a future society might have ethical qualms about transplanting a brain into another body (even a clone), or might not consider a severed head to be worth reviving. Neuropreservation (including operation, vitrification and storage) costs about \$80,000.

Neuropreservation Unit: A storage unit for up to 10 heads. \$6,000, 1,200 lbs. LC4.

Cryonic Revival (TL9)

A corpse frozen using TL7-8 cryonic preservation techniques may be brought back to life with the help of advanced nanotechnology. Unfortunately, the primitive freeze techniques used mean that, in many cases, portions of memory and personality are irretrievably lost. At the GM's option, personalities reconstructed from frozen brains will inevitably suffer from Amnesia or other mental disadvantages; this may be less of a problem for vitrified brains. Even if the GM rules that perfect retrieval is possible, brain injury, radiation, or illness prior to freezing can still result in the loss of memories or personality.

Here's a possible schedule for revival:

TL9: A corpse's body can't yet be brought back to life. However, if the body was not vitrified, cell samples are well-enough preserved to allow a clone to be made. That clone won't have the original's memories.

TL10: The preserved brain's structure can be analyzed with advanced medical systems; usually this involves taking the brain apart and scanning individual bits of it with MRIs, anti-proton imagers, or other high-resolution imaging systems. If uploading technology exists (see **GURPS Ultra-Tech**) it may be possible to create a digital copy of the mind and run it on a complex computer (usually Complexity 10+). The resulting mind will have the mental traits of the original plus the Digital Mind advantage and a robot or computer body; see Mind Transfer (p. B296).

However, there's a good chance the uploaded mind will suffer from Partial or Total Amnesia due to incomplete recovery of memories.

TL11+: The original body can be fully restored using a chrysalis machine (p. 133), where advanced nanomachines will thaw it out, place it in a form of biostasis, and then repair any damage or disease suffered. This process takes one day for every hit point the corpse was below 0 HT at the time it was frozen. Since the body is being virtually rebuilt anyway, it's relatively trivial to also restore any losses that occurred due to aging. The rebuilt brain structure will hold whatever memories are still there to be retrieved.

SUSPENDED ANIMATION

Being able to revive a frozen corpse is one thing, but preserving people without killing them requires a far more advanced technology.

This process is *suspended animation*, sometimes called "biostasis." A suspended animation chamber uses a combination of chemicals, low temperature, and drugs to drastically reduce the occupant's metabolic rate. Progress toward suspended animation has been achieved with experimental animals (2006) using a mixture of air and hydrogen sulfide, but long-term suspension is still in the future, and may involve different technologies.



Whatever the means, a live person who has undergone suspended animation is not dead. Rather, his metabolic processes have been reduced to a nearly negligible level while within the chamber. Unlike cryogenics, revival simply involves opening the chamber (and possibly injecting various drugs). Long stays may require additional treatments, if the chamber is not equipped to keep the “sleeper” in shape. Systems often have automatic gas or drug dispensers built into the tube itself so that a person need only lie down and close the tube to be put into suspension within minutes.

Hibernation Chamber (TL9)

This houses a single person. It is equipped with a life support systems to keep the patient alive at his low metabolic rate, stimulate muscles, etc. Reduces metabolism by roughly a factor of 10. These must be connected to an external life support source, but the occupant has only one-tenth the normal life support requirement (they also age at one-tenth normal rate). \$20,000, 200 lbs., external power. LC3.

Suspended Animation Capsule (TL10)

This device is used to store people in suspended animation. It may also called a “freeze tube.” Reduces metabolic activity to nearly zero. Has a built-in six-month battery for backup. No other maintenance is needed. Capsule storage costs \$250/day for short periods, or \$50,000 annually; discounts of 10% to 60% off the annual fee are available for long-term storage of 50 years or more. This price includes a safe, well-guarded storage space. \$50,000, 500 lbs. (with external power) or 750 lbs. (with battery). LC4.

Portable Brain Pod (TL9)

A portable unit designed to keep a disembodied brain (and portion of the spinal cord) alive. It is used to store or transport living brains, generally prior to a brain transplant or total cyborgizing operation. A brain pod does not include any systems to keep the brain conscious, or any neural connections that would allow the brain to operate equipment such as communicators or sensors. In fact, it has systems designed to keep the brain *unconscious*, as a conscious brain would suffer total sensory deprivation, which could damage its sanity. This also allows the brain to be installed or removed from the pod without the expensive, time-consuming surgery required to make neural connections. \$40,000, 80 lbs. for a portable brain pod including a power supply (good for up to a month; a spare socket allows one cell to be removed while another is still operating) and a casing. Weight and cost are halved at TL10 and again at TL11. It uses negligible amounts of vehicle or building power. LC4.

NANOSTASIS

This is a means of safely and completely shutting down a person's metabolism, putting him into a state of *permanent* suspended animation, in which no special preservation tank is needed. It uses bio-nanomachines to install protective scaffolding and fixatives around and within every cell in the patient's body. Once placed in stasis, an organism will not require any oxygen or food, and cannot age or deteriorate, although it remains vulnerable to

physical damage. Reversal of nanostasis requires using similar bio-nanotech to remove the preservatives and restart bodily functions. It can be thought of as a highly advanced form of vitrification (p. 145).

A living being placed in nanostasis is not exactly dead, since genetics, memory, and personality are preserved. However, he is inanimate and unconscious, with IQ 0 and the Immunity to Metabolic Hazards, Unliving, and Unaging advantages.

Nanostasis can also replace the need for anesthesia during TL10+ surgery.

Nanostasis is safe, but the subject will usually be disoriented and confused for hours (sometimes days) afterward. Upon revival, the process supervisor makes a Physician roll. Critical failure means the patient has the Confused disadvantage for 20-HT hours, and Amnesia (Partial) for at least a week; roll vs. HT weekly to recover. Failure produces the same effects, but roll vs. HT daily to regain memory. On a success, Confused lasts only (20-HT)/2 hours and there is no memory loss. Critical success means full recovery.

Nanostasis Tank (TL10)

This is a device designed to place someone into nanostasis, or to revive him. It takes five hours for the process to radically slow and then completely stop his metabolism. Afterward, he can be safely removed. The tank can also revive someone; this takes eight hours. \$300,000, 250 lbs. It uses up a package of nano per patient (\$5,000, 0.1 lbs.). A chrysalis machine (p. 133) can also induce nanostasis; use the same rules. LC3.

Good medicine is bitter, but it cures illness.

– Chinese proverb

TEMPORAL STASIS

The ultimate in preservation is to stop the passage of time for the patient. This can be achieved with an individual-sized stasis web. The disadvantage for medical uses is that the stasis time must be set before the web is activated – physicians cannot elect to bring the patient out of stasis early or prolong the preset time. The advantage is that the patient experiences no time at all while in the web, and emerges in the same condition as he went in, with no recovery time.

Personal Stasis Web (TL^)

A coffin-sized (6' × 3' × 2') box containing a stasis web generator, convenient for suspending time for a single person. Like other stasis webs, a timer must be set and the stasis web cannot deactivate until that time has passed, unless a reality stabilizer (see *GURPS Ultra-Tech*) is used. Box cost and weight can vary. \$144,000, 15 lbs. LC3.

CHAPTER SIX

DRUGS

AND NANO

*In my darker moments,
I feel my bloodstream has
turned into an arms race.
Inject a few trillion gengi-
neered macrophage cells into
your body, and these “active
shields” will hunt down and
dismantle anything that looks
threateningly pathogenic or
toxic before it can do much in
the way of damage. It seems to
have worked – I haven’t aged
or gotten sick since the proce-
dure. Considering some of the
places I’ve been, this is surely a
miracle.*

– Tisephone Logos,
>warangel>heavenweb>solnet

This chapter describes various chemical or bio-nanotech agents that can be introduced into the body to affect its chemistry and physiology. Unlike biomods, the effects are usually either temporary, preventative, or the cumulative result of long-term usage.



CHEMICAL DRUGS

Ever try Adders? Cute, performance-enhancing drugs, but they're pretty limited. Sure, they'll make you smarter or stronger for a few hours, but then it's a big letdown. I mean, great for combat or acing a test, but that's not much use if you've got a long-term project like a marathon or finishing your thesis, is it? But there's some drugs out there that can give you that kind of life-long boost you want. 'Course, your life may not be that long, but at least you'll leave a good looking corpse.

– Genosibyl, alt.bio.upgrade.samurai

Humans have been using drugs since prehistory. The first drugs were chemical compounds found in plants or fungi. Herbalism – represented by the skill Pharmacy (Herbal) – is the practice of extracting these compounds into forms suitable to give to patients.

As technology advanced, people gained better understandings of the purification of active compounds and what they did. By TL5, pharmacists could extract and mix active substances in the laboratory to produce pills with concentrated or combined effects. Many treatments consisted of administering toxic inorganic compounds, relying on them being more dangerous to the disease organisms than to the patient.

Using TL6 chemical analysis and synthesis techniques on a herbal compound extracted from meadowsweet flowers, Felix Hoffman of the Bayer company produced the first artificial drug in 1897: aspirin. This opened the doors for the development of new synthetic drugs, which are often based on compounds extracted from nature, modified to enhance desired effects and reduce undesired ones.

THERAPEUTIC DRUGS

Most drugs are developed and used for medicinal purposes. They combat illness, relieve symptoms, or provide prophylactic protection against becoming sick.

Abortifacients

These are drugs that terminate pregnancy, causing the embryo or fetus to miscarry. Primitive societies have used herbal abortifacients for centuries, but these are risky as they are also toxic to the mother. Treat this as a digestive agent inflicting 2d toxic damage with a HT-2 roll to resist.

At TL8+, synthetic abortifacients become available, which allow safe termination within the first three months of pregnancy. If used after this period, the mother will require medical care as the fetus miscarries. Roll vs. the attending physician's Surgery+6; on a failure the mother takes 1d damage. \$10/dose. LC3.

Analgesics

These drugs relieve pain and come in several unrelated varieties. Rules for powerful generic analgesics such as morphine are given under *Painkillers* on p. B441.

Any of these drugs may also act as a mitigator (p. B112) for Chronic Pain (p. B126).

Anesthetic Drugs

Chloroform (TL5). If held against the face for one minute or breathed through a mask, will cause the patient (or victim!) to roll against HT-3 or fall unconscious. Cinematic chloroform works much faster! \$5/dose.

Ether (TL5). Normally breathed through a face mask; after several minutes causes the patient to roll against HT-3 or go unconscious. \$5/dose.

Aspirin (TL6)

Acetylsalicylic acid (ASA), introduced in 1897, became commercially available in 1899, and has since become the most popular over-the-counter analgesic, although how it worked was not understood until the 1970s (TL7). It inhibits prostaglandin production (chemicals that release pain signals). This also has some other advantages, e.g., reducing production of blood clots and thus risk of heart attacks. Unfortunately, it also affects the stomach lining; overdoses may result in nausea. Aspirin takes about a minute to take effect, and lasts for four to six hours. Low doses (a couple of pills) reduces the penalty from pain (p. B428) by 1 after any other modifiers for High or Low Pain Threshold have been applied. High doses (multiple pills, depending on the degree of pain) reduce the penalty by 2 but require a HT roll to avoid Nausea (p. B428), or on a critical failure, 1 point of toxic damage. Very high doses can affect the kidneys and liver, causing 1d to 3d toxic damage. \$3 per 100 tablets. LC4.

Narcotic Painkillers (TL5/6)

Natural opiate pain killers such as morphine (TL5) and similar synthetic narcotics (TL6) such as meperidine hydrochloride (Demerol) attach to opioid receptors found in the brain and spinal column to interfere with the transmission of pain. They also trigger the brain's pleasure

centers. They're used to treat chronic or surgical pain (and often abused as recreational drugs). Taken orally, there is a delay of 20 minutes; injected, there is *no* delay. Roll vs. HT-4 to resist. On a failure, the user acquires the High Pain Threshold (p. B59) and Unfazeable (p. B95) advantages, the Laziness disadvantage (p. B142), and experiences euphoria (p. B428). All effects last for hours equal to the margin of failure. \$3 per dose. LC3.

Acetaminophen (TL7)

Also called peracetamol and popularly known under the tradename Tylenol, this is a popular analgesic as well as a major ingredient in many cold and flu medications.

Its mechanisms are similar, but somewhat different, to aspirin: it does not damage the stomach lining, but has no effect on blood clots. It is safer in moderation, but an overdose (10-20 tablets depending on strength) can cause serious or fatal liver damage.

Treat as aspirin with no HT roll to avoid nausea. Deliberate overdoses may cause 1d to 4d of toxic damage. \$3 per 100 tablets. LC4.

General Rules for Drugs

General rules for alcohol and addictive drugs, including addiction, withdrawal, and overdoses, are on pp. B439-441. Drugs to treat illness and infection are described on pp. B443-444. Drugs that treat radiation exposure are described on p. B436. The drug Eraser, as used by the Infinity Patrol in the Infinite Worlds setting, is described on p. B540.

A simple design system for ultra-tech drugs is on p. B425; this system is general enough to use for many types of possible drugs for which no specific rules are given. Note that the prices given for designer drugs on p. B425 are for custom-designed drugs created in small lots (e.g., by inventors or gadgeteers). Mass-market drugs, especially generics, are 1% of the listed price!

If a drug that relieves a character disadvantage (e.g. Epilepsy, Manic-Depressive) is readily available, the disadvantage should be bought with an appropriate Mitigator limitation (p. B112).

Analine (TL9)

This is a strong painkiller with fewer side effects than drugs such as morphine. The user gains the High Pain Threshold (p. B59) for (25 - HT)/4 hours, but is also Drowsy (p. B428). It comes in pill (30 minutes to take effect) or injection form. \$2/dose. LC3.

Painaway (TL9)

An over-the-counter analgesic similar to acetaminophen or aspirin but safer and more reliable. Treat as aspirin except the HT roll to resist on a high dose is HT+3, and the effects last for twice as long for a given dose. \$10 per 100 tablets. LC4.

Antiallergens

Allergy sufferers take these to reduce symptoms of their allergies. (An allergy is usually no worse than a physical quirk, see p. B165). Antiallergens can be tablets or nasal aerosol sprays. Most are antihistamines, which control the symptoms associated with the release of the inflammatory protein histamine. They will remove the allergy reactions for a day. \$2/dose. LC4.

Drug Allergies

Most people in a technological society will know from past experience if they are allergic to a particular drug. Allergic characters should take Susceptible (pp. 213, B158) or Allergy (p. 212), depending on the severity of the reaction.

At the GM's option, if a patient takes a drug he has *never had a chance to be exposed to* before, make a HT roll. On a critical failure, he develops an allergy to that particular drug. The first exposure will often simply sensitize the subject without producing allergy symptoms. Later exposures have their usual effects. Record the allergy as a new quirk or disadvantage on the character sheet. Antibiotics are particularly prone to causing allergic reactions; make the HT roll at -1. This sudden discovery of an allergy should typically only occur for low-tech characters introduced to higher TL medicines.

Antibiotics

These are drugs that kill bacteria, thus helping to prevent and fight infection. The first antibiotics were natural products derived from microorganisms, originally mold. Since then, biochemists have learned to modify the natural chemicals to produce a wide range of synthetic antibiotics. Antibiotics are effective only against bacterial infections; they do not work against viruses, fungal infections, or non-bacterial parasites (e.g., the malaria protozoan).

Antibiotics are non-toxic to humans and other mammals, except to a few people who are allergic to them (see *Drug Allergies*). Any antibiotic may also kill beneficial bacteria, including natural intestinal flora and any engineered symbiotic bacteria (p. 120).

At the GM's option, if a patient taking antibiotics rolls a critical failure on the daily infection HT roll, he will suffer diarrhea until the treatment ends; treat this as constant moderate pain (p. B428). Also, when an antibiotic treatment begins, make one roll for each form of symbiotic bacteria the patient is using, against its HT score (usually 14, see *Storage and Handling of Drugs and Nano*, p. 153). On a failure, the symbiotic bacteria die.

Antibiotics were the wonder drugs of the mid-20th century, allowing doctors to treat diseases rather than just relieving symptoms. However, we now know that they are not a panacea. Under evolutionary pressure from antibiotics, many strains of bacteria that were vulnerable to

them were killed off, while new strains have arisen (or mutated) that are far more resistant. In turn, pharmaceutical laboratories have subjected antibiotics to processes designed to alter and change them, in a constant struggle to produce superior disease-fighting weapons.

At the GM's option, some particular infections can be resistant to antibiotics; this negates the HT roll bonus for using one or more specific antibiotic drugs. This is more likely at *higher* tech levels, as infectious organisms mutate to evolve resistance to existing antibiotics.

Sulfanilamide (TL6)

Developed in 1936, this was the first successful antibiotic. It is used as a powder that can be sprinkled on an open wound to prevent infection. It also comes in pill form, but can be toxic when ingested. It gives a +1 to recover from bacterial diseases and a +3 vs. infection. On a critical failure, the patient also suffers 1 HP of injury. \$0.50/dose. LC4.

Penicillin (TL6)

This is a natural product of the fungal mold *Penicillium notatum*, with powerful antibiotic properties first noted by Ernest Duchesne in 1896 (but whose discovery went unnoticed). Alexander Fleming rediscovered the effect in 1928, but abandoned research three years later after becoming convinced that it would not effectively destroy infection in a human body. In 1939, Howard Florey proved it could be made to work and began commercial production. Techniques were still primitive during World War II, but the trickle of penicillin produced made a significant difference to Allied casualties. Dorothy Hodgkin determined the chemical structure of penicillin in 1944, leading to mass production synthesis. Penicillin derivatives are still commonly used today, but bacteria are becoming increasingly resistant to older variants.

Penicillin and related antibiotics must be taken daily for two weeks to be effective. It gives a +3 to HT to recover from both bacterial diseases and infection. If the patient makes a HT roll and then neglects to take a subsequent daily antibiotic dose, he must make another HT roll at no modifier to see if the infection returns. If the patient completes the course of doses, the infection will not return. \$10 for a 2 week course. LC3.

Broad-Spectrum Antibiotic (TL8)

When simple and cheap antibiotics like penicillin don't work, new types developed with expensive R&D have to be used. By TL8 a wide variety of different antibiotics are available; this represents any of a number of drugs. If someone is unlucky enough to catch an infection resistant to inexpensive antibiotics, his physician will have to prescribe something like this. It provides the same benefits as penicillin – its only advantage is that it actually *works* on a wider range of infections. \$100 for a two week course at TL8, or \$10 for two weeks at TL9+. LC3.

Genericillin (TL10)

This is a very powerful, general-purpose antibiotic. It doesn't treat all diseases, but it's a good thing to try. A dose of genericillin gives a +5 to HT to recover from bacterial diseases and infection for a week. \$25 per dose. LC4.

Enzyme-Blocking Drugs (TL8)

Engineered enzyme production and gene cloning allow the design of specialized drugs which block enzymes that a particular virus or bacteria needs to replicate. The key to successful enzyme-blocker design is to find an enzyme that is vital to the target virus or bacteria but which is not used by human metabolism. In a few cases, this may prove difficult. If so, the enzyme blockers may have some side effects – typically, each daily dose will also require a HT roll to avoid taking one point of damage, whether the enzyme-blocker succeeds or fails. Some enzyme blockers used to combat HIV have this problem.

Enzyme blockers may either be targeted against a single species of virus or bacteria (e.g., influenza) or be broad-spectrum versions, designed to affect numerous common bacteria. Unlike a vaccine, a specific enzyme blocker is generally effective against mutant strains; a mutation is rarely drastic enough to alter the fundamental enzymes that a particular virus or bacteria uses.

A specific enzyme blocker, affecting only one microbe, gives a +8 to HT rolls to resist that particular illness; broad-spectrum agents give a +3. The effect is similar to that of an antibiotic, but is effective against viruses or parasites; HT bonuses are cumulative with antibiotics.

A typical course of enzyme-blocking drugs costs about \$100 at TL8, \$20 at TL9, \$10 at TL10, or \$5 at TL11+. Some (such as those used to treat HIV) are far more expensive, costing this much per day.

Interferon (TL8)

Interferons are a family of related proteins that are naturally produced in the body to boost the immune system to fight viruses. A variety of synthetic genetically engineered variants exist. They are used to treat lingering diseases, notably viral hepatitis, and also other hard-hitting viral infections, multiple sclerosis, and some cancers. A typical course of treatment involves regular injections over 4-12 months. The first injection often produces flu-like symptoms (fever, chills, aches) lasting four to eight hours. These may disappear as the body gets used to the extra interferon, but often persist for the course of the treatment.

Natural interferon is available in tiny quantities in TL7 on an experimental basis. Interferon treatment using genetically-engineered synthetic interferon is available at TL8 for about \$2,000/month. LC4.

If someone is diagnosed with a disease treatable by interferon, the GM should require two HT rolls, one at the start to avoid side effects, the other midway through the program to see if they responded. If the HT roll to avoid side effects fails, the patient will be -1 HT for the length of the treatment plus 1d months afterward (-1 DX, -1 IQ, and -2 HT on a critical failure); otherwise, these effects persist for only four to eight hours after injection, or not at all on a critical success. The second HT roll should be made at the mid-point of the treatment to determine if the patient is responding (after a minimum of two months). A successful roll can justify “buying off” disadvantages associated with the condition being treated; examples include Chronic Pain, Social Disease, Susceptible, Terminally Ill, Unhealing, and Unfit or Very Unfit. Patients should also be

examined periodically to see if their disease is in remission; a successful Diagnosis skill roll at the midpoint can reveal whether treatment should be continued (i.e., the HT roll succeeded) or terminated (if it fails).

Healing Drugs

These are various sorts of drugs that prevent injuries from becoming worse or aid healing and recovery.

Hypercoagulin (TL9)

When injected or applied to a patient with a bleeding wound, this causes instant coagulation and a cessation of bleeding within 1d+4 seconds. This is equivalent to bandaging (p. B424). Injection overdoses can be deadly; for each additional dose within 24 hours, make a HT roll at -1 per doubling of dosage. Failure indicates internal blood clots that cause stroke or heart attack (p. B429). Since the drug is unknown before TL9, it makes a good assassination tool in lower-TL societies. Injectable or contact agent only. \$25/dose. LC3.

Ursaline (TL9)

This drug prevents atrophy of bone tissue and muscles in low or zero gravity. It is safe but somewhat expensive. A dose provides a week of protection, equivalent to No Degeneration in Zero G (p. 211). \$25/dose. LC4.



Antirad (TL9/10)

This medication contains a number of different drugs, with the combined effect of partial protection against radiation. At TL9, this grants the user the Radiation Tolerance 2 (p. B79) advantage. At TL10, it gives Radiation Tolerance 5. Either effect lasts a day. It comes in injectable and pill form for \$50/dose. LC3.

Ascepaline (TL10)

This drug accelerates cellular regeneration. Anyone using it regenerates 1 HP every four hours. Each dose lasts a day. A week should elapse before using it again. If not, roll vs. HT+2 the second time it was taken, HT+1 the third, etc. Failure means the user's natural ability to heal *without* the drug is permanently damaged: the user gains Unhealing (Partial) (p. B160). He may still use Ascepaline, however. \$20/dose. LC3.

Sedatives

These relax the body and induce drowsiness. Rules for generic examples are given under *Sedatives* on p. B441. Some sedatives of particular interest to adventurers include:

Chloral Hydrate (TL5)

This drug was discovered in 1832 and has been used ever since in sleeping pills to overcome insomnia. It is also the most commonly known "knockout" drug delivered surreptitiously in a victim's alcoholic drink. When taken in this way, the victim becomes drowsy (p. B428) after HT minutes. A minute later he must make a HT roll. On a failure he falls into a deep sleep and cannot be wakened for (12 - HT/2) hours. Success also results in sleep, but for two hours less; critical success will allow the victim to stay awake but he will still be drowsy for this time. Chloral hydrate has a faint but distinct odor that can be detected with a Perception-based Poisons or Streetwise roll (modified by Taste/Smell modifiers) if the drinker consciously sniffs for it. Alone it is bitter, but this is masked by alcohol. \$1/dose. LC3.

Flunitrazepam (TL7)

Marketed since 1975 under the trade name Rohypnol, this is the strongest sedative available legally, although it is banned in many countries, including the United States. A clinical dose produces the same sleep-inducing effects as chloral hydrate, except that a critical success on the HT roll result in sleep for (8 - HT/2) hours (minimum two hours). Flunitrazepam also induces partial amnesia. On a failed HT-5 roll, the user forgets the details of events once drowsiness sets in. Recreational drug users take lesser doses – often combined with other drugs – to induce heavy intoxication; this results in severe lack of coordination (-4 to DX and IQ) and the amnesia effect. Some criminals use the drug on unsuspecting victims to facilitate sexual assaults. Game villains (or heroes) will find more subtle uses for the drug's amnesia effect. \$5/dose. LC2.

Stimulants

Stimulants increase the activity of the nervous system, producing a feeling of wakefulness and heightened awareness.

Smelling Salts (TL5)

These are ammonium salts with a powerful odor. They are usually stored in a small vial which can be uncapped under an unconscious person's nose. The penetrating smell stimulates breathing and revives the patient to consciousness on a successful HT roll. At TL5 and TL6 smelling salts are often perfumed with floral scents. \$0.20 per vial (good for 20 uses). LC4.

Modafinil (TL8)

This drug (sold as Alertec, Provigil, or other trade names) is a central nervous system stimulant. It is intended to treat sleep disorders such as narcolepsy, but is also useful for anyone who wishes to stay awake for long periods, e.g., shift-workers, truckers, and soldiers. It can keep the user awake and alert for up to two and half days; unlike most other stimulants, it seems to have minimal side effects. (The health effects of sustained usage of modafinil to put off sleep are uncertain, however.)

It takes an hour or two for effects to occur, and gives the user the Doesn't Sleep advantage for the next 24 hours; up to three doses can be taken in succession before it ceases to provide benefits. After taking two or more doses, the GM may wish to roll vs. the user's HT; a critical failure may result in nausea or mild pain (headaches or backaches) until the user gets at least eight hours sleep. Pill; \$2/dose. LC3.

Revive Capsules (TL9)

These small, easily breakable capsules are the descendants of smelling salts. When held under the nose of a stunned or unconscious person and snapped open, the vapor inside will usually revive him completely – roll against HT+5 to regain consciousness or recover from stun (p. B420). This is also effective against mental stunning; roll vs. HT+5 as above, not IQ, as the stunned person is forced out of his state by the physical stimulus. The patient does not regain any hit points, but is awake. He may fall asleep again within minutes if tired and given the chance. \$5/dose. LC4.

Superstim (TL9)

This drug instantly restores 1d Fatigue Points. Roll vs. HT; the fatigue is banished for a number of hours equal to the margin of success (at least one, even for a failure). The only side effect is that when the time is up, the user gets all that fatigue back, plus 2 more FP. If the user takes another dose within 24 hours of the previous one, the HT roll is made at a -1 penalty. Multiple doses can cause the user to "crash" when he finally stops taking it; if FP would drop below 0, the extra points are taken off HP instead. Any form, \$10/dose. LC4.

Wideawake (TL10)

An extremely effective stimulant, this drug time-releases controlled doses of stimulants that prevent the user falling asleep, without causing any side effects. It provides the Doesn't Sleep advantage for a week. Any form, \$20/dose. LC4.

Toxic Compounds

These are in common use as therapeutic drugs at TL5. The doses are small enough not to cause serious problems

Storage and Handling of Drugs and Nano

Drugs and medical bio-nanomachines do not last indefinitely. Simple, cheap drugs might last years before losing potency, while complex ones may be useless in a few weeks or less if not stored under ideal environmental conditions. Bio-nanomachines have indefinite shelf life unless exposed to radiation (which mutates the macromolecular machinery) or extreme situations. In some cases (e.g. being immersed in lava), the drug is obviously destroyed instantly. In intermediate cases, use the following rules.

Chemical drugs, nanodrugs, and nanosymbionts have HT 14 for purposes of withstanding adverse conditions – see *Damage to Objects*, p. B483. At the GM's option some can be more delicate or robust. If a chemical drug is exposed to heat or humidity, or if nano is exposed to *extreme* heat (500° F+) or more than 10 rads of radiation, make a HT check. For drugs, apply a -4 penalty if the heat is extreme. For nano, use a -1 penalty for every full multiple of 100 rads up to a maximum of 1,000 rads (beyond which it is simply destroyed) but add +1 to its HT per TL after introduction. On a *failure* the dose breaks down and loses potency; it will fail to work at all when used. On a *critical failure* a drug produces some toxic substance as it breaks down while bio-nanomachines malfunction; in either case, when used it will have a nasty side effect, defined at the GM's option.

For chemical and nanodrugs, side effects could range from a poison doing toxic or fatigue damage (see p. B438) to acquiring mental disadvantages like Paranoia or Short Attention Span until the dose wears off. The side effect of malfunctioning nanosymbionts is typically 1d-2 (minimum 1) points of injury per day until they wear off or are destroyed.

The shelf life of chemical drugs is up to the GM. In the real world, this is a controversial subject. Drug companies have been accused of excessive caution in the use-by dates marked on their products. If there is any question over whether an old drug is still useful, make a HT check as above.

Cheap Drugs

The listed prices for drugs and nano listed are for commercially produced mass-market examples. One TL after a drug or type of nano is introduced, "black" labs can copy it and sell it for half the listed price. These labs lack quality control and may deliberately cut a drug with a cheaper substance, reducing its potency or introducing toxic compounds. Make a HT check as above for each batch when it is used, *no matter how it has been stored*. Cheap nanosymbionts have a -2 penalty for every additional nanosymbiont type that the patient is using at the same time.

for the patient, and hopefully to poison the microbes causing a disease. To administer toxic compounds as a drug, use the following rules *instead* of the poison rules on pp. B437-439.

The treating doctor makes a Physician/TL5 roll per day of treatment:

Success indicates the patient takes 1 HP of toxic injury but receives a +1 on his next HT roll to recover from the disease.

Critical success means the patient does not suffer the toxicity effect, and receives a +2 bonus on his next HT roll to recover the disease.

Failure means the patient suffers 1 HP of toxic damage but no healing effect.

Critical failure is an overdose causing *full* toxic effects for the compound: the user takes 1 HP of toxic injury plus is treated as having ingested 1d-3 doses of the poison (minimum 1 dose).

In all cases, the patient gets a HT roll to resist the toxic effects. The healing effects only occur if the patient is suffering a microbial or parasitic disease susceptible to the toxin. Multiple doses may be given; roll once and multiply the healing and damage by the number of doses.

Arsenic (TL5)

This causes vomiting and diarrhea, believed to be good for purging the body of disease, as part of its toxic effect.

The body retains arsenic; reduce HT permanently by 1 for each 3 points of toxic damage. Critical failures causing overdoses use the rule for arsenic on p. B439. \$1/dose. LC4.

Calomel (TL5)

The chemical mercurous chloride, or calomel, also causes vomiting and diarrhea. Toxic damage totaling half or more of HP in one course of treatment loosens the teeth; roll vs. HT. One tooth falls out for each point in the margin of failure. Treat overdoses as arsenic. \$1/dose. LC4.

Quinine (TL5)

This extract of cinchona bark suppresses malarial symptoms, but does not cure it; malaria is likely to recur. It also reduces fevers. Quinine is not as toxic as some compounds; it causes damage only on a failure of the prescribing doctor's Physician roll and provides healing on any roll but a critical failure. Toxic effects from any damage also include blurred vision (Bad Sight) or ringing in the ears (Hard of Hearing) until the damage heals. On an overdose, make a HT roll. Failure means respiratory paralysis, causing suffocation unless artificial breathing assistance is provided. \$2/dose. LC4.

Tartar Emetic (TL5)

Antimony potassium tartrate has symptoms similar to arsenic and is also effective against parasitic worms. Treat overdoses as arsenic. \$1/dose. LC4.

CAPABILITY ENHANCING DRUGS

Some people take drugs not to relieve medical conditions, but to boost their natural capabilities. Some of these effects are temporary, while others are treatments that grant permanent improvements. These often come with significant side effects.

Everything is a drug; it depends on the dose.

– Paracelsus

Growth Hormone (TL7)

Human growth is controlled by a hormone secreted by the pituitary gland. Children who do not produce enough of the hormone, either because of genetic defects or disease, do not develop to full adult height and strength – this is represented by the disadvantage Dwarfism. If children with this condition are diagnosed early enough and injected with the hormone, they will develop normally.

Such treatment was first available in the 1950s, using growth hormone painstakingly harvested from cadavers, making it affordable only for the very rich. From 1960, government agencies in several countries coordinated the mass collection of growth hormone from autopsies, producing enough to make the treatment available to the merely wealthy. In 1985, four patients treated with growth hormone developed the prion-transmitted Creutzfeld-Jacob disease (p. 104). The U.S. government quickly banned growth hormone collected from cadavers and approved a synthetic version developed by Genentech.

A child who would otherwise develop Dwarfism must be injected daily until he stops growing to gain the full benefit. If treatment is discontinued, the child will stop growing at that point.

The hormone is an expensive treatment that will last a decade or more, costing \$50,000 per year at TL7, falling to \$20,000 per year at TL8. LC3.

Anabolic Steroids (TL7)

These are the best-known strength-boosting drugs, synthesized from the natural sex hormone testosterone. They have a marked anabolic (growth-promoting) effect on muscle tissue, especially when taken in large doses. That's why they're so popular with athletes and body builders who wish to "bulk up" rapidly.

Anabolic steroids (there are several different varieties) are taken orally or injected, typically in cycles of weeks or months ("cycling"), rather than continuously. The user will take multiple doses of steroids for a period of time, stop for a period, and then start again. Successful use requires a combination of hard physical training, diet, and steroid use – taken on their own, few or no positive benefits are gained.

The GM can allow a character who is taking steroids to double the hours of learning (see pp. B293-294) while

studying any HT-based skill (e.g., Lifting or Swimming); other skills (especially some Sports skills) may be added to that list if the GM feels they are appropriate. In addition, both Strength and Fatigue Points may be improved through study while taking steroids, as if these attributes were learnable advantages (p. B294); steroids double the usual rates as for skills. The beneficial effects of steroids are hotly debated, with controlled studies not matching the claims of some athletes who combine heavy steroid use with intense physical training. However, since **GURPS ST** is quadratic, even a +1 bonus to ST will indeed have a greater effect (in terms of absolute performance) on an already-strong athlete.

Initially, the only effects may seem positive, but continued high doses of steroids have a "negative feedback" effect on the body – it stops making some of its own hormones, since it's getting them from outside. The problems associated with prolonged steroid use include sterility, aggression, muscle spasms, and in some cases, cancerous tumors. In men, additional side effects can include acne, balding, shrinkage of the testicles, and breast growth, although the effect on appearance is mitigated by a muscular physique. In women, extra side effects are more severe: cessation of menstruation, body hair growth, and development of a more masculine body shape and coarser voice. In both sexes, liver damage has sometimes resulted.

To avoid side effects, roll vs. HT every six months (or fraction) steroids were used. Failure means gaining *one* of these negative traits: -1 HT, Bad Temper (p. B124), Bully (p. B125), Sterile, loss of Voice advantage (if possessed), loss of a level of Appearance (if female). On a critical failure, suffer all of them! The Bad Temper or Bully disadvantages starts at self-control roll 15; if the character already has it, reduce it a step, e.g., to self-control 12.

The typical cost of black market steroids is \$5-\$30 per day; if legally available, they'd be about \$3/day. Anabolic steroids (for human use) are grey-market items with LC3.

Anabolic Steroid Regime

Someone who used steroids for several months while body-building might have these traits: ST +1 [10]; FP+1 [3]; HT-1 [-10]; Bad Temper (15) [-5]; Sterile [0]. -2 *points*. If female, add Appearance (Unattractive) [-4]; -6 *points*.

Erythropoietin (TL8)

Erythropoietin (EPO) is a hormone produced in the kidneys and liver. It stimulates the production of red blood cells, producing an effect identical to blood doping (p. 131). Since it is naturally produced by all humans, it is impossible to detect if someone has used it. EPO is also used in the treatment of anemia and kidney failure. Synthetic EPO has been available since 1985, but is expensive. \$500/dose. LC3.

Nootropic Drugs (TL8)

These are "smart drugs" (mostly experimental at TL8, but widely available by TL9) – chemicals that enhance brain performance. Most nootropics were originally designed to treat mental problems, repairing damage to the brain caused by things like alcohol poisoning, stroke and senility. They may also fight senility by clearing out cellular

waste products, improving oxygen flow to the brain, or neutralizing free radicals that interfere with brain function. In healthy people, they can enhance the ability to grow connections between neurons, improving the ability to memorize (which is partially the process of setting up these connections). Some nootropic drugs also increase the levels of neurotransmitters that carry electrical signals from neuron to neuron.

TL8 nootropics include piracetam, l-dopa and vasopressin, among others. Most are delivered by pill or nasal spray. Their long-term effectiveness in healthy people remains controversial, but here's a conservative interpretation of their benefits:

For as long as the drug is taken daily, and for one day afterward, it allows one to buy the Mitigator limitation (\$20/week, -65%) for any of the following disadvantages: Absent-Mindedness, Confused, Distractible, Dull, Hidebound, Indecisive, Short Attention Span, or Staid, and justifies buying off the disadvantage whenever the character has the points to do so. *Optionally*, the GM may allow a character who has taken nootropics while studying either mental skills or Eidetic Memory (p. B294) to add 50% to his hours of learning. The GM may also require a HT roll to gain the benefit.

Nootropic smart drugs cost about \$20 per week. To benefit from smart drugs, the user must take the nootropic continuously for the period in question. Side effects are negligible, although hypertension and twitching are occasionally known to occur. LC4.

Adders (TL9)

This is a generic name for a group of drugs that temporarily add to ST, DX, IQ, HT, or Basic Move. One dose adds 1 point, but multiple doses can be taken together. After it wears off, the affected attribute suffers a penalty equal to the original bonus and lasting twice as long.

To obtain the desired effect, a user must make a HT roll at -1 for every dose taken. If the roll is successful the attribute is raised by the number of doses taken for (25 - HT)/4 hours. If the roll fails, the attribute is raised by 1 for one hour, regardless of the number of doses taken. On a critical failure, the drug *decreases* the attribute by the number of doses taken, for one hour.

As long as any attribute bonus or penalty is in effect, using any other type of adder results in adverse side effects. If the user takes the same type of adder within 24 hours of a dose, he must make a new HT roll at a penalty equal to the total of all doses taken in that period. The bonus is only that of the new dose, but the letdown period is that of all the doses combined.

Adder users often feel very good under the effects of the drug – similar to the Overconfidence advantage – and are at least mildly depressed when it wears off.

Poor quality or black market adders can be addictive. Pill or injection, \$25/dose. LC3.

Bone Stimulation (TL9)

Make your bones stronger! This biochemical process stimulates bone cell growth – I heard it's a development of some of the technologies the orbitals developed to replace bone

decalcification in zero-G, before they all got their genes twanked to avoid such mundane problems.

– *Streethawk, alt.bio.upgrade.samurai*

This treatment gives +1 HP (it can't be repeated). It does not increase ST, but does allow muscle grafting or reinforcement to increase Lifting or Striking ST by two points more than the normal limit. It can also cure one point of ST or HP loss due to bone degeneration in zero-G (see *No Degeneration in Zero-G*, p. 211).

The treatment is \$10,000 (and two weeks). Repeated treatments will not have any further benefits, except to cure further ST or HP losses due to decalcification.

Mnemosin (TL9)

This drug boosts the production of cyclic-AMP response element binding proteins (CREB) in the brain, enhancing the user's memory. It gives him Photographic Memory for things experienced while under its effects, and temporary Eidetic Memory to recall anything experienced in the past. Effects last (25 - HT) minutes. Pills: \$20/dose. LC4.

Treating Gigantism

Unlike Dwarfism, Gigantism has no direct genetic basis. It is caused by pituitary tumors that secrete excess quantities of growth hormone. These are rare in children, and can be treated by neurosurgery to extract the tumor, with followup drug or radiation treatment if necessary. Such tumors in adults cause enlargement of the hands and feet, but no increase in height.

Peter Pan Process (TL9)

The Clinique Rouge does not advertise this service, but for a regular client such as yourself, we will make an exception. Such a sweet child. How old is he? 11? 12? No, that is not too late – as long as he has not left puberty, the Peter Pan process can be initiated. Simply put, our course of synthetic hormone therapy will ensure certain growth-controlling genes do not switch on. As long as treatments continue, he will never enter adolescence. Eternal youth? Do not mistake me, monsieur. This is not an immortality process. Organs eventually fail, and after several decades, his skin will wrinkle under gravity's tug, unless cosmetics or bodysculpt are used. But for the next two or three decades, he will be a young boy.

– *Mme. Madeleine Rouge, the Clinique Rouge*

We had the motel under surveillance for dust dealers when I spotted Mr. Suit heading for a room with a girl who definitely looked a few years pre-jail bait. Hooking's legal in this town, but not with kids. Looked like a righteous bust, so I blew the door just in time to catch the Vice President of AresKorp with his pants down. Bad move. Turns out little Wendi is 26 years old. Now the D.A. says I'm facing her lawsuit for false arrest and interfering with licensed commerce, and the captain says AresKorp wants my badge. I hate stunts.

– *Detective Cody Chase, Nevada DPS*

These drugs can be taken by anyone who is not yet an adult. They retard physical growth (and the onset of puberty, if it has yet to occur). They do not halt aging. See *Children* (p. B20) for realistic attributes for pre-adolescents and young teens.

The course of hormone treatment requires \$500 per month to “stunt” apparent age. Child actors, teenage gymnasts, male singers and others may be stunted to lengthen their careers, but many legal systems consider the practice to be child abuse. LC3.

Super-Steroids (TL9)

Advanced protein engineering may produce performance-enhancing drugs with similar but more extreme effects to those of anabolic steroids (p. 154). These statistics can also represent the less credible claims of efficiency attributed to contemporary steroids.

Super-steroids are twice as effective as anabolic steroids – each hour of learning an appropriate physical skill or trait while using steroids counts as four hours. Side effects are the same, but the steroids themselves are more expensive; at least \$50-100/day. LC3.

Super-Steroid Regime

Someone who used super-steroids for several months while body-building might have these traits:

Statistics: ST +2 [20]; FP+2 [6]; HT-1 [-10]; Bad Temper (15) [-5]; Sterile [0]. *11 points.* If female, add Appearance (Unattractive) [-4]; *7 points.*

Xenodrugs

Alien biochemistries react differently to drugs and present different problems for medical nanomachines. Chemical drugs, nanodrugs, and nanosymbionts designed for one type of biochemistry will usually have no effect on aliens, and will sometimes have harmful effects. The GM may decide if an alien drug or nano product is dangerous, or may roll 3d: 6 or less indicates a deleterious effect.

Once an alien biochemistry is understood, labs can design and synthesize drugs and nano suitable for the species. Depending on how common the species is in the manufacturer’s region of space, alien drugs and nano may command a premium over the price for the standard varieties.

The economic factors that set relative costs are too complex for a simple rule. The basic guideline is the more common an alien, the cheaper its drugs will be, but realistically the GM is free to set almost any price, which can be justified by differing R&D requirements, profit margins, production monopolies, investor choices, social discrimination, and so on. The final price could be anywhere from slightly cheaper to thousands of times more expensive!

Basic (TL10)

A mild and relatively safe psychoactive combat drug, Basic has two effects: it provides Combat Reflexes (no effect if someone already has it) and suppresses the Pacifism disadvantage (exception: Total Nonviolence degrades to Reluctant Killer). Anyone who has Total Nonviolence who seriously injures or kills someone, or someone with Cannot Kill who kills must, *after the drug wears off*, roll to avoid a nervous breakdown as described under the Cannot Kill disadvantage. It requires a HT-2 roll to resist and has short-term effects lasting (25 - HT)/4 minutes. \$12/dose. LC1.

NERV (TL10)

This drug chemically alters the neuro-endocrine system to improve reflexes and coordination. After taking NERV for 20 weeks, the user gains +1 DX. Then he must roll vs. HT. If successful, there are no side effects.

If the roll fails, the user suffers one level of Ham-Fisted [-5] (p. B138) as the drug increases overall reaction speed and agility, but fails to make the neural connections needed to improve fine motor coordination. (If the user already has Ham-Fisted [-5] it increases to [-10] level. If he already has Ham-Fisted [-10], or if the roll was a critical failure in any event, neural damage was inflicted. If neural damage is suffered, the user gains a Neurological Disorder (p. B144): a mild disorder unless he already has one; if so, increase the level of the disorder one stage, up to a maximum of crippling.

The treatment is \$2,000 per week. “Street NERV,” at half cost, is similar – but there is a -4 on the HT roll to avoid side-effects. LC3, or LC2 for Street NERV.

Hypoxyline (TL10)

Humans suffer lung damage when breathing gases with high partial pressures of oxygen, which can occur in a very dense atmosphere (p. B430) or while diving. This drug allows a human to operate with comfort in dense atmospheres without requiring a respirator to reduce oxygen pressure, or to breathe compressed air rather than special diving gas mixtures without ill effect. Only available in injectable form, lasting a day per dose. \$50/dose. LC4.

Tempo (TL10)

Tempo works by altering the user’s perception of time, so that everything around him (including both his own actions and those of others) seems to be happening extremely slowly. This gives him time to react to other people’s movements – he can see a blow coming, for example, and think about the best way to block it. It grants the user Enhanced Time Sense (p. B52) for (25 - HT) minutes. The only side effect is that this rapidly exhausts the user, leaving him a nervous wreck. After the drug wears off, the user loses 1d FP and 1 IQ and DX; DX and IQ losses are recovered after four hours. Injectable only, taking effect immediately. \$45/dose. LC2.

Gravano! (TL10)

This drug lets the user function more normally under increased gravity. A dose of gravano! lasts a week and eliminates any medical hazards of two G-increments of extra gravity (see p. B350). This means the -1 penalties to IQ and HT at two to three G-increments of high gravity (1.40 to 1.59 Gs for normal humans) are eliminated. Gravano! does not help the user cope with increased weight or DX penalties! \$70/dose. LC4.

ESPIONAGE DRUGS

Some people use drugs for nefarious purposes, either to influence other people or to protect themselves from the dangers they face when engaging in undercover activities.

“Truth Serum” (TL6)

A variety of fast-acting barbiturates such as thiopental sodium (sodium pentathol) and scopolamine, used for both for general anesthesia and to lower a subject's inhibitions for drug-assisted interrogation or psychiatric analysis. The drug is a yellow crystal that can be dissolved in water or alcohol; it has a garlic-like odor. It depresses the central nervous system (like any sedative) and in mild doses produces a state of relaxation, leaving recipients susceptible to suggestion. Its utility as a functional “truth serum” is limited because subjects under its influence can just as easily start to fantasize or be led into telling falsehoods as a result of an interviewer's leading questions . . . or become groggy and fall unconscious, from repeated doses. After 30 seconds, the subject suffers 1d FP and must succeed with a HT-1 roll or be at -2 to Will and also to all self-control rolls for mental disadvantages lasting for a period of (20 - HT)/2 minutes. \$10/dose. LC3.

Dimethyl Sulfoxide (TL7)

This chemical (also known as DMSO) is a byproduct of the wood-pulping industry, used from the 1950s as an industrial cleaner. In 1963, medical researchers discovered that it penetrates the skin and sinks deep into underlying tissue. It can carry other drugs not normally absorbed through the skin. This makes it useful in many ways, converting many other drugs into effective topical agents. This includes offensive or surreptitious uses such as delivering contact poisons. \$1/dose. LC4.

Aware (TL9)

This is a stimulant that acts on the sensory nervous system to sharpen the senses and heighten awareness. It grants +2 to Perception for 24 hours. \$50/dose. LC4.

Anti-Sed (TL9)

This is a prophylactic drug taken before encounters in which the user suspects he might be drugged. It lasts for 24 hours and grants a +6 bonus to HT rolls to resist sedatives and psychoactive drugs such as amnesiants and truth drugs. \$50/dose. LC2.

Crediline (TL9)

This psychoactive drug makes the user feel that everything around him makes sense, and everyone is a trusted friend. He must succeed with a HT-3 roll or suffer Euphoria (p. B428) and Gullibility (9) for (25 - HT) minutes. \$24/dose. LC2.

Torpine (TL9)

This puts the subject into a death-like trance during which metabolic functions are slowed. Roll vs. HT to resist going under (if taken involuntarily). The subject can go without food and water for 32 times as long as usual, and uses up only 50% as much oxygen. Anyone trying to tell he is still alive must succeed with a Quick Contest of Diagnosis vs. his HT+5. Each dose lasts a day; multiple doses can be taken. \$20/dose. LC3.

Lethe (TL10)

This drug disturbs the storage of information in the brain, inducing temporary amnesia. He must roll HT-2 or suffer the Partial Amnesia disadvantage for (25 - HT) minutes. \$24/dose. LC2.

Neurovine (TL10)

An antidote for nerve poison, available as a pill or injection. If taken within 15 minutes of poisoning, a Neurovine injection adds +3 to HT on rolls to avoid taking further damage. \$30/dose. LC4.

LIFESTYLE DRUGS

Some drugs are benign and have effects that provide minor conveniences. As technology advances, the variety and capabilities of such drugs may make them commonplace.

Oral Contraceptive Pills (TL7)

Hormone pills to prevent ovulation in females. Contraceptives designed for other species may also be available. \$20 per month's supply. LC4.

Vitamins (TL7)

Vitamins are organic molecules required in regular food intake for the proper functioning of the body. Casimir Funk postulated their existence in 1912, to explain various diseases caused by diets deficient in particular types of materials. By 1934, several chemists had isolated vitamin C and paved the way for its mass production as a dietary supplement. At TL7+ most vitamins are available in pill form. They can be used to compensate for poor diets and allow people to subsist on nutritionally inadequate food like algae or mycoprotein (p. 78). B group vitamins also provide a mild and short-lived burst of energy for people who have not eaten recently. \$0.10/dose. LC4.



Aphrozzine (TL9)

This drug reliably increases the recipient's sexual pleasure – it has the same effect as the Eros Plus biomod (p. 171) for one hour. \$20/dose. LC3.

Male Contraceptive Pills (TL9)

A man who has been taking these pills for at least a week cannot sire children. \$20 per month's supply. LC4.

Melatan (TL9)

This drug promotes melanin levels in the skin, creating an artificial suntan without requiring exposure to ultraviolet radiation. Unlike TL8 "fake tan" products that merely dye the skin's surface layers and do not provide additional protection against radiation, melatan stimulates the body's own tanning mechanism to produce a real tan. It comes in a liquid form that is smeared or sprayed onto the skin, producing the tan in 48 hours. Multiple doses can make the skin as dark as desired, but the effect fades like a natural tan, gradually over a month. \$50/dose. LC4.

Musk (TL9)

This is the generic name for a group of drugs that cause the sweat glands to produce chemical compounds that alter the user's scent. Basic versions produce subtle and pleasant aromas that go partway to countering body odor. More complex versions produce compounds that effectively mask the user's own natural odor, giving them a -3 to any roll to be tracked by scent. Another popular type produces a compound that insects find repellent. They all come as pills that last 12 hours. Basic versions cost \$5/dose; scent masking or insect repellent versions cost \$10/dose. LC4.

Sex Pheromones (TL9)

This is a group of hormone-based drugs that are detected subliminally by the human sense of smell. They give all victims within one yard Lecherousness (12) while in the presence of the pheromones if they fail a HT roll. Pheromones are usually worn on the skin like a perfume, and wear off after two hours or a shower. Prospective victims with No Sense of Smell/Taste are immune! \$60/dose; aerosol delivery. LC3.

Sobriety Pill (TL9)

This nullifies the intoxicating effects of alcohol. It comes in pill form only, and costs \$2/dose. LC4.

Genetically Targeted Pheromones (TL10)

The problem with normal pheromones is that they are just as likely to attract unwanted attention from passersby as the intended target. This can be solved with pharmacogenomic technology (p. 160) if a DNA sample from the target is available. Using this, a lab can synthesize pheromones designed to maximize response from the target and reduce it in anyone else. The resulting drug gives Lecherousness (6) to the target, resistible with a HT-4 roll, and has a 1 in 6 chance of affecting any other person in the same way as normal sex pheromones (above). The initial analysis takes a week and costs \$2,000, after which doses can be synthesized for \$1,000/dose. LC1.

Deep-Sleep (TL10)

Most sleep-inducing sedatives produce an anomalous sleep state in which regular dream processes cannot occur, which makes them less restful than natural sleep. This drug works differently, providing hormones that enhance the dream state and allow the body to refresh itself more quickly. Two hours of sleep after taking a dose is equivalent to a full night. \$5/dose. LC4.

LONGEVITY DRUGS

Aging is a complex process not yet fully understood. Several mechanisms are known to be involved, including the ravages of disease and injury, cellular damage by chemicals (including oxygen!), and the buildup of unremovable waste chemicals in the body by cell activity. There are also some genetic factors – see *The Genetics of Aging*, p. 183.

A treatment designed to halt or reverse the effects of aging must counter as many of these causes as possible, ideally all of them. Since many of them are unrelated, anagathic technology has been slow to develop and will be complicated if and when it arrives.

The longevity drugs described below are wonder drugs that allow the user to live an extended lifespan, or even stop

aging altogether. Some societies might reserve them for leaders, key scientists, or a wealthy elite. In others, they are available to anyone who can pay the price.

In science fiction, these drugs are often portrayed as coming from a rare natural source that is difficult and dangerous to harvest, and very hard or even impossible to synthesize. They may even be the central pillar of some future economies.

Some longevity drugs may be addictive or have other dangerous or even fatal side effects if the user ceases to take them.

Life Extension Drugs (TL9)

These drugs slow down but do not entirely halt the aging process. Someone who is on a life extension drug regime will age half as fast as usual (for his medical TL), effectively doubling the usual lifespan. Make aging rolls every other year if aged 50-69; yearly if aged 70-89, and every six months if aged 90+. The user must have been taking the drugs for at least the same period of time beforehand; e.g., if aged 70-89, the user must have been on life extension drugs for a year before he can benefit. A year's supply (usually a compound of several drugs and hormones) is \$30,000. Injectable or pill only. LC3.

Longevity Drugs (TL10)

Longevity drugs slow down the aging process through various means. A year-long regime of regular monthly doses of longevity drugs (usually a compound of several drugs and hormones) mean that the user effectively has the Longevity advantage (p. B66). The advantage is maintained for as long as the user continues to take the drugs; if he misses any monthly doses, it takes (missed months, up to a maximum of 12) months before Longevity will be regained. For better results, combine this drug regime with *Mutation Repair* genetic surgery (p. 182). Injectable or pill only. \$3,000/dose. LC3.

Insenium (TL^)

A cinematic anti-aging drug. Each dose effectively stops aging for one year. (Actual aging is at a rate of about one week per year.) Unfortunately, it also causes physiological dependency: once an individual stops taking it, his body deteriorates; he must make up all the aging rolls he skipped, at a rate of one roll per week. Thus, he rapidly ages to his actual chronological age, which often results in death. \$25,000/dose, any format. LC2.

Stasine (TL^)

Realistic anti-aging drugs can only slow down the aging process. Stasine is a superscience drug that halts it *completely* for as long as the monthly injections are maintained. If the treatment is stopped, the user continues aging normally, with no adverse side effects. \$10,000/dose. LC3.

Name That Drug!

Ultra-tech games often feature drugs that don't exist in the real world. Drugs used for recreational or illicit purposes will acquire a street name – something short and pithy, that captures the essence of what the drug does or where it comes from. To come up with a drug name like this, a thesaurus is a good start. For example, if a drug knocks people out, looking up “knockout” will suggest names like Slam and Punch. If a drug is derived from a plant, it may inherit an innocuous-sounding name like Daisy or Chlorophyll.

But drugs will also have technical names, granted by scientists and used by doctors. Medical drugs not used on the street will only have such names. Generating a convincing technical name is not as easy, so the following table can help. Roll two dice and read them as digits to make a two-digit number, once for each column, and combine the three word fragments in that order to form a new drug name. If desired, the name can be made longer by adding more choices from the table, or adding a number at the end. For example: Amylbenzocyclophan-7.

11	Aceto	arseno	bactin
12	Adreno	bacilla	bonate
13	Amino	barbi	cillin
14	Amorpho	benzo	cin
15	Amoxy	bio	deine
16	Amyl	buta	done
21	Batracho	ceta	drate
22	Beta	chole	drine
23	Cardio	cyclo	lene
24	Dextro	cyto	lic acid
25	Ferro	dexe	loxene
26	Gastro	droxy	loxin
31	Generi	endo	mine
32	Glaxo	ephe	mol
33	Hydroxy	fera	myacin
34	Hypo	fluro	myophin
35	Iso	geri	nate
36	Levo	gluco	nil
41	Lithium	hydro	noxonol
42	Meta	kao	pectate
43	Methyl	loxo	phan
44	Myco	mmonio	phine
45	Neo	mor	profin
46	Nitro	myo	rax
51	Novo	penta	spirin
52	Para	phago	sporine
53	Pheno	pro	sterol
54	Poly	sorbo	stol
55	Propyl	sporo	tan
56	Pseudo	steri	thol
61	Sodium	strepto	tol
62	Strepto	sucro	xanthate
63	Styro	tetra	xcedrin
64	Tetrodo	tolu	xic acid
65	Xeno	trypto	zax
66	Zeo	viro	zine

PHARMACOGENOMIC DRUGS

These are chemical drugs that have been tailored to suit specific patients. The efficacy of drugs and the presence of unwanted side effects both depend on the patient's genetic profile. By taking a DNA sample and detecting key gene sequences, a pharmacist can modify a drug on an individual basis so that it is effective and produces minimal or no side effects.

Even if time or expense prevents a drug from being tailored to a patient, a genetic test can determine which existing drugs and what dosages will best suit his needs. This sort of pharmacogenomics comes into use at TL8, while individually tailored drugs become common at TL9.

Designing Drugs

How does one design a designer drug? Or test a drug that may have side effects too dangerous to allow human trials? At the dawn of the biotech era, trial and error based on a few basic principles and guided by animal testing is state of the art. These methods slowly become more refined, but remain essentially the same until some breakthrough technology supersedes them.

The first major change is likely to be when cell cultures can be built into or sustained in systems similar to those in living subjects. A lump of cortical tissue – removed from a subject or artificially constructed – may provide crucial insights into the effects of a drug on brain chemistry.

More gruesome is sustaining an entire brain in a vat, or using whole-body blank mind clones for testing. This is treading close to simply using live human subjects against their will, which would probably be cheaper and easier, and only marginally more morally objectionable. These systems are thus unlikely to appear except in cinematically dystopian societies.

At high enough TLs, the chemistry of the brain and other body systems may be understood to a level that allows the reactions within them and their physiological effects to be simulated by a computer. Such a program would be a valuable research and development tool, costing millions of dollars initially (though as technology advances it may become cheap). In a full circle, such a program might be so complex that it can only be run on an organic computer (p. 28).

Pharmacogenomic Toxins

Another application of this technology is the creation of toxins or allergens designed to affect specific individuals. This is not as precise as a target-seeking pathogen (p. 115), since the chemical basis of a toxin works on proteins and enzymes in the body rather than the genome itself. A poison

can be designed to work on a broad genetic type of susceptible victims, such as all those carrying particular alleles of a gene, or racial groups.

A drug is neither moral nor immoral – it's a chemical compound.

– Frank Zappa

PSI DRUGS

In campaigns where psionic powers have some basis in biochemistry, there may be drugs that can affect the relevant processes in the body, granting abilities otherwise unavailable. Drugs that grant a specific psionic ability can be built using the ultra-tech drug design system on p. B425 and the psionics rules on pp. B254-257. More likely are drugs that increase psionic talents or interfere with psi powers, such as those listed below. These drugs all grant temporary changes in psionic abilities. A treatment that causes permanent changes is also possible, but the GM should be aware of how drastically character abilities (and point costs) may change if they are readily available. If they exist, such treatments are likely to be hideously expensive!

Blocker (TL^)

This drug gives Resistant to Telepathy (+3) for six hours. It requires a HT roll to avoid a headache causing mild pain (p. B428) for the same period. \$100/dose. LC4.

Boosters (TL^)

These come in varieties specific to each psionic talent, e.g., Teleportation. A single dose adds a level in one specific psionic talent for a day. \$250/dose. LC2.

Muffler (TL^)

This drug shuts down all psionic neural pathways in the body, rendering the user incapable of exercising any psi powers if he fails a HT-4 roll. It comes in injectable form only, and wears off after (25 - HT)/4 hours. \$800/dose. LC2.

Window (TL^)

Given to anyone who has a Telepathic power, this drug enhances his ability, adding +2 to his Telepathy talent, but it also dissolves their normal psychic barriers, resulting in the Supersensitive (p. B158) disadvantage and completely suppressing any levels of psionic Mind Shield (p. B70) the user may possess. Roll vs. HT-3 to resist if taken unwillingly. It lasts for (25-HT)/4 hours. Injectable, pill, or inhaled only. \$250/dose. LC2.

MAGICAL AND MYSTICAL DRUGS

In a fantasy campaign, drugs might have magical properties. Drugs that give the user magical abilities can be created using the same drug design system as other drugs, but prices are likely to vary widely, depending on how common the knowledge required to make them is and what ingredients are required. In a technomagic setting,

magical drugs could be commonly available from multinational manufacturers; in a pseudo-medieval fantasy world they may be closely guarded secrets available to a select circle of elder mages.

Drugs that produce magical effects on the user are a different thing. They are often not considered to be *drugs* – they are called potions or alchemical elixirs. See **GURPS Magic** for a full treatment of potions and elixirs.

NANODRUGS

Nanodrugs are encapsulated nanomachine factories that can operate for a short time within a user's body, manufacturing proteins or nanoviruses (p. 184) to adjust the user's biochemistry. After a few hours or days, the nanomachines wear out and are broken down by the body's normal defense and excretion systems.

Using bio-nanomachines has several advantages over normal drug manufacture and delivery methods. Many high-tech drugs are based on proteins or other complex macromolecules that are fragile and have short shelf lives, especially in adverse storage conditions (see *Storage and Handling of Drugs and Nano*, p. 153). As they decompose they lose effectiveness, or worse, turn into substances with toxic effects. Bio-nanomachines, on the other hand, are much tougher and can survive in field medical kits for years without losing potency.

Secondly, delivering conventional drugs to a precise location or organ with the body is often difficult, as the bloodstream spreads it to most regions indiscriminately, while various cellular barriers – such as the blood-brain barrier – keep it out of particular tissues. Bio-nanomachines can be designed to seek out the appropriate place to produce their drug and manufacture it only there, where it will be most effective and produce the fewest side effects. For this reason, nanodrugs can produce therapeutic or enhancing effects that cannot be achieved with conventional drugs.

Another advantage is that nanodrugs can self-regulate the dosage they produce, using biofeedback mechanisms to monitor the effects on the body's chemistry and adjust their production to suit. This means greater control over the results and no chance of overdose. Multiple doses of the same nanodrug generally behave the same way as a single dose.

Finally, some nanodrugs act by *using up* some specific hormone or other chemical within the body, taking it in as a raw material and converting into a harmless byproduct. In this way, chemical imbalances in the body can be attacked from the other side, by reducing the amount of some substance that is present in too great a quantity rather than introducing an additional substance. When combined with nanofactories that produce other compounds, this can drastically alter the body's biochemistry in multiple ways with a single dose of a nanodrug.

Designing Nanodrugs

Nanodrugs can be designed using the same system as conventional drugs (p. B425). The main difference in terms of play is that a nanodrug can have a more complicated effect, combining several advantages and disadvantages into one package, including specific mental states and neurological effects that are difficult or impossible to achieve with chemical drugs. Nanodrugs are also more robust in long-term storage than chemical drugs.

EXAMPLES OF NANODRUGS

These drugs all require bio-nanotechnology. In games where nanotech is retarded or nonexistent, drugs that have these effects will likely not exist.

Antitox (TL10)

This nanodrug consists of nanomachines programmed to break down toxic molecules. Because the bio-nanomachines can seek out, recognize, and actively destroy the toxin, this is more effective than chemical antidotes. It immediately gives another HT roll after injection to resist the effects of most poisons, with a +8 bonus. If given prophylactically, it grants Resistant to Poison (+8) for 24 hours. \$400/dose. LC4.

Atman (TL10)

This drug is used by animal lovers or those wishing to feel at peace and in harmony with the natural world. It grants Animal Empathy and the Delusion that the user can communicate with animals. Long term (one day), pill (HT-6 to resist). \$500/dose. LC4.

BodyHeat (TL10)

This stimulates the metabolism to boost heat production, while also causing mild peripheral vasoconstriction to reduce heat loss. This confers Temperature Tolerance 2 [2] for cold temperatures, but also gives a -1 DX penalty and Increased Consumption 1 (double food requirement). Long term (one day), injection (HT-6 to resist). \$1,100/dose. LC4.

Destruct Nano (TL10)

These “khaki goo” bio-nanomachines disperse throughout the body when injected, then wait in a dormant state until triggered. The trigger depends on the exact brand of destruct nano, but various possibilities include: eating a specific food; sexual arousal; the touch of a particular person (whose genome was programmed into the poison); a particular chemical scent, or even the use of another type of drug or nano (either a specific type or any type). Once the destruct sequence is triggered, they immediately begin the job of sabotaging and dismantling cells. The victim gets a HT roll to resist every minute; failure results in 1d damage. This continues indefinitely until the victim is dead, or the poison is stopped by a nanotech counter-agent such as Guardians (p. 165).

Most insidiously, the nano can be switched off by another pre-set biochemical trigger. \$100 for a customized dose with a particular trigger. LC1.

Focus (TL10)

Focus is a common nanodrug used by workers in hazardous conditions such as wearing vacc suits in space or diving underwater. It makes the job safer by increasing the user’s awareness and reducing panic reactions. It can also make users *too* cautious to perform a job. Grants Perception+2, Fearlessness 2, and Careful. Medium term ([25 - HT]/4 hours), pill (HT-6 to resist). \$160/dose. LC4.

Hepaclean (TL10)

This quickly removes the aftereffects of too much alcohol, curing hangovers by converting the acetaldehyde produced by the liver’s metabolism of alcohol into B-group vitamins and easily removed byproducts. It also restores normal brain chemistry to reduce hypersensitivity to noise and light. The pill cures all effects of a hangover 30 minutes after being taken with several glasses of water. \$30/dose. LC4.

Morlock (TL10)

This is a “regression” nanodrug designed specifically for uplifted animals, which makes them behave more like their unmodified brethren. Depending on the campaign world, it may have been developed by anti-uplift campaigners as a way to reverse the uplift process, or by animal rights activists to allow uplifts the choice of a more “natural” existence. Unfortunately the drug didn’t work as hoped, and is psychologically addictive. It adds Bestial while in effect, but also has a permanent damaging effect on brain chemistry. After each use the user must roll vs. HT+4. On a failure either add Stress Atavism (15; Mild), decrease the control number of existing Stress Atavism by one step, or (if the control number is already 6) increase the severity one step. Once Stress Atavism is severe and has control number 6, the next failure gives the user a permanent Bestial [-10] disadvantage.

Morlock also works on unuplifted animals and humans! If the user is already Bestial, it adds Berserk (12) [-10] and triggers an immediate berserk episode. Medium term ([25-HT]/4 hours), pill (HT-6 to resist). \$450/dose. LC2.

Verazene (TL10)

This powerful drug gives the recipient the Truthfulness (6) disadvantage for (25-HT) minutes. It can be resisted on a HT-4 roll. Injection only. \$16/dose. LC2.

Tailored Immune Machines (TL10)

Ultra-tech medicine may use bio-nanomachines (TL10) or nanobots (TL11) to seek out and destroy disease-causing microorganisms or tumors. It’s possible to get expensive nano-symbionts that stay in the body for weeks or permanently, warding off these problems – see *Panimmunity* (p. 164), nano-bacteriophage (p. 165), and virus hunters (p. 166) for examples. Alternatively, medics may use much cheaper tailored nano machines designed for a specific purpose.

This requires successfully diagnosing the problem (see p. 125). After it is diagnosed, prescribing the correct nano-treatment requires a successful Physician roll. A dose of tailored nano specific to a particular disease is \$50/dose and LC4; pharmacies, automeds, and hospitals usually stock a large range. However, tailored immune machines for exotic ailments such a rare disease or biological weapon may be difficult to get, and cost \$500/dose. Immune machines for *unknown* diseases require a new invention (but see *Programmable Immune Machines*, below). If the correct nano is taken (by injection or pill) it cures the patient in 3d hours at TL10 or 1d hours at TL11+; if it was incorrectly prescribed, it will have no effect. Another try (requiring a different selection) may be possible. If one dose works, the GM may allow the same nano to work on any patient with an identical problem.

Programmable Immune Machines (TL11)

These are general-purpose nanomachines that can be programmed to eradicate disease-causing microorganisms or tumors. They work just like tailored immune machines, except that a successful diagnosis followed by a Physician roll lets the user program the nano dose to treat a specific disease, whether known or unknown – there’s no need to buy or make new nanomachines for each illness. Programming usually takes an hour per attempt (apply a -2 penalty to skill for rare diseases); unknown diseases (once successfully diagnosed) take at least a day per attempt (and -4 to skill), and possibly longer (GM’s option). \$500/dose. LC3.

TRANSFORMATIONAL NANO

Taking a person apart, even at the molecular level, is relatively easy these days. The trick is to store enough information that you can put him back together again. Assuming you want to.

– Dr. Lucien Locke, *Nanovirus for Dummies*

Advanced TL12 nanomachines are capable of near-miraculous feats. They can do just about everything that a chrysalis machine (p. 133) can do, without requiring a controlled environment.

Disassembly Nanovirus (TL12)

Disassembly nano dismantles a person in a more precise and thorough manner than crude “gray goo” nano weapons. It also reports back to a central computer with coded and compressed data representing the arrangements of the molecules in the body.

Storing this information requires *at least* a million terabytes for a human, perhaps much more depending on the GM’s assumptions about how detailed the data needs to be – it should be as much (or slightly more) than state-of-the-art computers are capable of storing. The brain and genome maps require the most data, followed by distinctive physical features such as scars, fingerprints, and retina patterns. Bulk body tissue such as muscles and bones can get by with sparser data sampling. The nano will also record the presence and configuration of any implants.

Unfortunately, this process is destructive, and at TL11 there is nothing that can be done with all this data, other than running a ghost mind emulation (see *GURPS Ultra-Tech*). Still, it can be a method of preserving all information about a deceased individual for future use.

Applied to a corpse, disassembly is disconcerting enough, as the body slowly melts into a pool of writhing goo over 24 hours. A living person infected with disassembly nano suffers a high fever and agony (p. B428). Once unconscious due to loss of FP, the victim loses 1 HP every 10 minutes until dead.

Availability: A dose of disassembly nanomachines (enough for a body up to 200 lbs.) costs \$100,000. If the nano is used in a controlled environment, e.g., a biofab or chrysalis machine, 90% of it can be recovered for reuse. LC3.

Reassembly (TL12)

With a complete molecular map of a body, supplied either by disassembly nano or a full body HyMRI scan (p. 129), assembler nano can reassemble a copy of the body from raw materials. This requires a supply of organic matter and trace minerals twice the weight of the final body – dead bodies or compost work fine. The assemblers must have continuous access to the stored body data for the week the process takes. At the end of this time, the nano will have created a body indistinguishable from the original by any means short of a comparison at greater resolution than the data map. The

body is not alive, and will not respond to standard resuscitation techniques, but even that can be overcome . . .

If the original person who supplied the molecular map is still alive, the existence of a duplicate body could create interesting identification scenarios.

Availability: Reassembly nanovirus costs \$500,000 for enough to assemble a body up to 200 lbs. If the nano is used in a controlled environment, e.g., a biofab or chrysalis machine, 90% of it can be recovered for reuse. LC3.

Reanimation (TL12)

These nanomachines can resurrect dead bodies. Reanimation nano is smart enough to make subtle changes to body structure and chemistry to reverse any immediately fatal conditions. As well as returning the body to a viable state, it restarts neural impulses beginning with the autonomous nervous system that controls heartbeat, breathing, and other reflex actions. Once life support is established, the nano begins switching on brain activity and finally the voluntary nervous system.

This nano can be used in two ways:

Bringing a dead person back to life: If the nano is applied within 10 minutes of cessation of breathing, it can stabilize the brain and restore vitality without brain damage. After 10 minutes, the revived patient must make a successful HT roll to avoid brain damage, at a -1 penalty per hour of delay. Brain damage results in reduced IQ, and possibly mental disadvantages, at the GM’s option. Once the body has begun to decay significantly, the nano cannot restore life.

Reviving an inert body constructed by reassembly nano. Reassembly nano can keep the brain in a state identical to when it was stored after the assembly process has finished. Injecting reanimation nano at this point restores the body to

life, in the same state as when it was recorded. Assembly and reanimation functions can also be combined in one set of nano for the combined cost.

Availability: Reanimation nano costs \$1,000,000 a dose (suitable for any weight body). . If the nano is used in a controlled environment, e.g., a biofab or chrysalis machine, 90% of it can be recovered for reuse. LC3.



NANOSYMBIONTS

Nanosymbionts are colonies of nanomachines installed in a host's body to perform useful services. Appropriately designed nanosymbionts can be used by any being with a biological body. The bio-nanomachines may be permanent residents or temporary lodgers.

Unlike nanodrugs, nanosymbionts don't simply produce chemicals – they interact directly with cells and other structures in the body. Some roam the body, seeking infections or tumors and then producing drugs to combat them, while others physically manipulate objects, manhandling them into desired configurations.

Properly designed nanosymbionts do not normally interfere with one another (except for those *meant* to do so) and can safely be used in combination. Cheap versions produced by black labs might not work so well – see *Storage and Handling of Drugs and Nano* (p. 153).

Temporary Nanosymbionts

At TL10+, these are a common way to treat illnesses. A doctor will analyze the patient's condition and prescribe appropriate nanosymbionts. They typically come in a sterile package housing a bee-sized capsule. This contains an applicator-programmer and billions of tiny nanomachines.

The user may set a treatment duration for anywhere from one day to two weeks; once set it cannot be changed. The patient then swallows the capsule and the bio-nanomachines take effect within an hour. The applicator-programmer capsule is digested and excreted normally, while the nanosymbionts take up residence in the body. At the end of the treatment they shut down, and within another few weeks are cleansed by the body's normal waste elimination functions.

Permanent Nanosymbionts

These perform ongoing maintenance or improvement functions in the body until removed. Permanent nanosymbionts are more expensive than temporary ones, as the bio-nanomachines must be designed with long-term durability and self-repair capabilities.

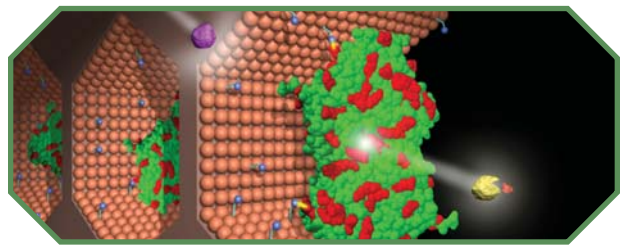
Designers periodically release upgrades for some types of nanosymbionts, to add new capabilities. This is particularly common for those that deal with known bacteria or viruses, as new varieties are discovered or infectious strains mutate. Registered users can get an upgrade installed for 1% of the original purchase price.

Even inside a user's body, bio-nanomachines remain vulnerable to radiation. If the user is exposed to a single dose of radiation above 100 rads, roll a HT check as per *Storage and Handling of Drugs and Nano* (p. 153) to see if they stop working, or worse, malfunction disastrously. Roll for each type of nano in the body, but ignore the penalty for multiple types.

Waste Heat

Realistically, symbiotic bio-nanomachines are restricted in how much work they can perform inside the body by the laws of thermodynamics. Shifting around molecules takes energy, which must be extracted from the environment somehow. Bio-nanomachines can be assumed to use the same energy reserves as the body – molecules such as adenosine triphosphate. The inevitable result of using this fuel is the production of waste heat. A little bit of heat can be tolerated, as the body dissipates it naturally, but produce too much and the user will feel feverish. Raise the body's temperature by just a few more degrees and vital enzymes will begin breaking down, leading to massive failure of body systems.

Exactly how much work bio-nanomachines can do before these effects start to be felt depends on how active they are, and assumptions made by the GM. The new quirk *Nano-Fever* (p. 212) can be used to represent this condition if desired. The deactivation or removal of bio-nanomachines will eliminate this condition.



Designing Nanosymbionts

The cost of nanosymbionts varies extensively. As a guideline, a treatment with temporary nanosymbionts costs from \$50 to \$100 per absolute point value of advantages and disadvantages granted. Permanent ones cost 50 times as much as temporary ones. The GM should judge the costs of nanosymbionts that perform tasks not expressible as character traits on a case by case basis, following the examples given below.

EXAMPLES OF NANOSYMBIONTS

These nanosymbionts are available in both temporary and permanent forms unless indicated otherwise. Where two costs are given, the first is for a temporary treatment, the second for a permanent dose.

Panimmunity (TL9)

Panimmunity injections contain smart artificial organisms or bio-nanomachines, tailor-made for each individual. They recognize friendly cells, and attack others.

Availability and Statistics: Depending on the bio-engineering techniques of the society:

Level 1 Panimmunity (TL9): Gives Resistant to Disease (+3) [3]. \$150/\$7,500. LC4.

Level 2 Panimmunity (TL10): Gives Resistant to Disease (+8) [5]. \$250/\$12,500. LC4.

Level 3 (Total) Panimmunity (TL12): These are highly potent defenders that unfailingly seek out and destroy any harmful microorganism. They provide the proverbial “cure for the common cold” – users simply don’t get sick. This gives the recipient the equivalent of Immunity to Disease [10]. \$500/\$25,000. LC4.

Artery Cleaners (TL10)

These use tiny biomechanical brushes, cilia, and rotors to clear plaque and fatty deposits from arterial surfaces, reducing the risk of heart disease.

Availability: \$50/\$2,500. LC4.

Statistics: If someone who has been using artery cleaners for at least six months would lose a point of HT due to a failed aging roll (p. B444), roll 1d: on a 1-3 he doesn’t lose the HT. 0-point feature.

Nano-Bacteriophages (TL10)

These bio-nanomachines patrol for and destroy any known bacterial and parasitic pathogens, but have no effect on viruses.

Availability: \$250/\$12,500. LC4.

Statistics: Immunity to Known Bacteria [5].

Blood Cops (TL10)

These are engineered macrophage cells designed to patrol the bloodstream, seeking out and destroying pathogens, toxins, and harmful free radicals before they can damage the body.

Availability: \$850/\$42,500. LC4.

Statistics: Blood Cops provide Longevity [2] and Resistant to Metabolic Hazards (+8) [15]. 17 points.

Carcinophages (TL10)

These are programmed to search the body for cells that have mutated into a cancerous state and destroy them before they can develop into tumors. They can also safely remove existing tumors, no matter how delicately placed, such as deep within the brain.

Availability: \$250/\$17,500. LC4.

Statistics: Immunity to Cancers [5]. Permanent carcinophages also grant Extended Lifespan 1 [2].

Guardians (TL10)

In a world where hostile nano can be used as insidious weapons, people will want to protect themselves. Guardians are adaptive bio-nanomachines that will recognize any other bio-nanomachines already present in the body when they are first introduced.

If they come upon any new examples, they’ll attempt to destroy them. This specifically includes proteus virus (p. 184), nanodrugs (p. 161), and enhanced viruses (p. 115) built as nanoviruses. If a nano agent allows a HT roll to resist, guardians give a +8 bonus to the resistance roll.

Availability: \$100/\$5,000. LC3.

Statistics: Resistant to Bio-Nanomachines (+8) [2]. 2 points.

Lung Cleaners (TL10)

These roam the lungs, removing inhaled debris by encapsulating it and carrying it through to the body’s normal excretory systems.

Availability: \$250/\$12,500. LC4.

Statistics: Filter Lungs [5].

Nanosymbionts Versus Symbiotic Bacteria

Many permanent nanosymbionts do jobs similar to those that can be achieved by symbiotic bacteria (p. 120). Just one or the other may be available, depending on biotech development pathways in a given campaign, or users might have the choice from both. Each option has advantages and disadvantages.

Nano can often be upgraded to deal with new threats and some can be controlled or reprogrammed directly. Additionally, bio-nanomachines are immune to chemical hazards like antibiotics that kill bacteria. On the down side, nano reacts badly to radiation, and can cause interaction problems when new nano is injected.

Bacteria are generally cheaper because they self-reproduce. They can also mutate, perhaps causing hostile infections that need to be treated.

Microgravity Biochemistry (TL10)

By maintaining muscle tone and bone density at a microscopic level, these nanosymbionts prevent any degeneration of these tissues under microgravity or zero-g conditions.

Availability: \$100/\$5,000. LC4.

Statistics: No Degeneration in Zero-G [1] (p. 211).

Pore Cleaners (TL10)

A favorite example of cosmetic nano, these inhabit skin pores and keep them clean. They also eliminate body odor by killing the bacteria that cause it.

Availability: \$50/\$2,500. LC4.

Statistics: Sanitized Metabolism [1].

Tooth Cleaners (TL10)

These simple engineered bio-nanomachines keep the user's teeth clean and healthy without any need for brushing or toothpaste.

Availability: \$20/\$1,000. LC4.

Statistics: This is a 0-point feature.

Virus Hunters (TL10)

Similar to bacteriophages, these are programmed to hunt and destroy known viral pathogens, but have no effect on bacteria.

Availability: \$250/\$12,500. LC4.

Statistics: Immunity to Known Viruses [5].

Brain Boosters (TL11)

These take up residence in the synapses where nerves pass chemical signals to one another and increase the speed at which the signal crosses the synaptic gap. They do a similar job within the brain itself, improving neural connectivity so that the brain can process the faster influx of sensory data.

Availability: \$4,500/\$225,000. LC2.

Statistics: Enhanced Time Sense [45].

Cell Surgeons (TL11)

Hey, more nanoguys! These are programmed with details of your anatomy, and form a distributed, multi-cellular neural-net throughout the body. Most of the time, they just drift around, powered by your bloodstream. But when you get hurt, they'll shift into high gear and start fixing things, herding cells into place with tiny manipulators or sending signals that stimulate regrowth, while clearing away damaged tissue before it can get infected. These symbiotic cell-sized nanocritters let you heal real fast, but you sweat like the dickens.

– Dr. Lucien Locke, *Symbiotes for Success!*

Availability: \$1,200/\$60,000. LC4.

Statistics: Regeneration (Regular; Nuisance Effect, sweat heavily while regenerating, -1 reaction, -5%) [24].

Electroreceptors (TL11)

These nanosymbionts reside in nerve tissue just beneath the user's skin. They are sensitive to electrical and magnetic fields and initiate artificial nerve pulses under certain conditions. This allows the user to detect magnetic fields as well as electrical emanations, like those from electric fish or equipment, and determine the direction and approximate power level.

Availability: \$500/\$25,000. LC4.

Statistics: Detect (Electric and Magnetic Fields; Vague, -50%) [5].

DNA Repair (TL11)

Radiation causes damage on the cellular level by mutating the DNA, which then propagates the mutations when it divides and copies. DNA repair nano compares the DNA between cells throughout the body and repairs any that have accumulated significant mutations. This also repairs mutations caused by old age.

Availability: \$300/\$15,000. LC4.

Statistics: Regeneration (Slow; Radiation Only, -60%) [4] and Extended Lifespan 1 [2].

Metabolic Regulators (TL11)

These are responsive nanosymbionts that provide the user with voluntary control of many of his own metabolic processes.

Availability: \$700/\$35,000. LC4.

Statistics: Metabolic Control 2 (Mastery, +40%) [14]. The Mastery enhancement means the user can make precise adjustments to his metabolism and body chemistry instantly, helping him cope with even extreme or unexpected stresses. As long as he is conscious, he may add the level of Metabolism Control to *any* HT roll.

Respirocytes (TL11)

These function like oxygen-carrying red blood cells, but with many times the transport capability. They store extra oxygen, transport it around the body, and release it in intelligent fashion in response to need. They also extract carbon dioxide and absorbed nitrogen from muscle tissue and carry it rapidly to the lungs for excretion.

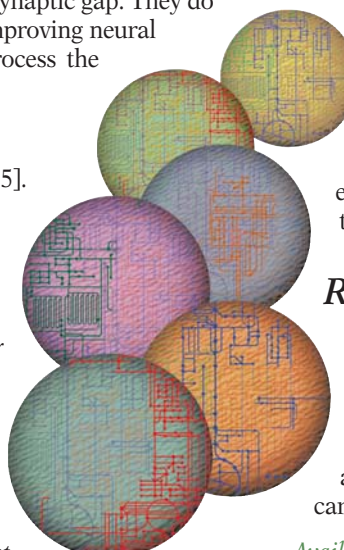
Availability: \$300/\$15,000. LC4.

Statistics: +2 FP [6]; Doesn't Breathe (Oxygen Storage $\times 25$, -50%) [10]. Respirocytes are an exception to the rule that nanosymbionts take an hour to take effect – they begin working one minute after injection.

Cell Communion (TL12)

I know why the NSA never caught them. Why the wiretaps and the laser mikes found nothing. I know the truth, because I borrowed Doctor Avery's scanning, tunneling microscope and used it on the sample. That's how I figured it all out – how the UFO people, the Men in Black, and the True Illuminati communicate. It's their cells that are talking. Not talking exactly. Hormones? This is much more sophisticated, doctor. Not just emotions. More like images, concepts, memories, all at once. It's exchanged by sweat, saliva, blood, when they shake hands, touch, kiss. Don't you get it? Can't you see? They can conspire in crowds, in broad daylight!

– Statement by Walter Jorgenson, BSc in molecular biology, now a patient at Kingston Psychiatric Hospital



Availability: \$900/\$45,000, LC4. Infectious version is \$1,150/57,500. LC1.

Statistics: This is Telesend (Blood Agent, -40%; Melee Attack, Reach C, -30%; Racial, -20%; Universal, +50%) [18]. In this instance, the Racial limitation means that cell

communion only allows communication with someone else who has the symbionts. Some types of cell communion are actually contagious – the communion can spread out from the infected individual's body. Add Infectious Attack [-5] (p. B140).

DRUG AND NANO DELIVERY METHODS

Producing drugs and nano is only part of the job. They need to be introduced to the body so that they can work.

Oral (Pill)

The simplest method of taking drugs is to swallow them. This is suitable for some analgesics, antibiotics, hormone-based drugs such as contraceptives, recreational drugs, and many poisons. Other drugs are neutralized by the stomach or not absorbed into the bloodstream. Depending on robustness, nano may be able to overcome these problems and navigate to the tissues where they can operate.

Oral drugs have the advantage that unskilled patients can self-administer them. They are also easy to give to others, either with consent or surreptitiously. Knockout drugs in particular are a common item to slip into an enemy's food or drink.

Injection

Many drugs are most effective if injected. Injections can be *intravenous* (into a vein), *intramuscular* (into muscle tissue), or *subcutaneous* (into subskin fat deposits). Intravenous injections rapidly spread the drug throughout the body, giving a short onset time before it becomes effective; most drugs are suitable for this method. Intramuscular and subcutaneous injections result in slower assimilation of the drug over a longer time, and are used for vaccines and regulatory drugs such as insulin that must be taken periodically.

The hypodermic needle was invented in the mid-19th century (TL5), and remains the most common injection device throughout TL8. Needles are difficult to sterilize; reusing them brings risks of infection and transmitting blood-borne diseases – a fact recognized in the late 19th century. At TL8, painless microinjection devices are invented, which use compressed gas to inject drugs subcutaneously.

Contact

Some drugs can be absorbed into the skin. This works for corticosteroids and other anti-inflammatory drugs. The compound dimethyl sulfoxide is often used as a carrier for topical drugs, as it penetrates deeply and rapidly into biological tissue, taking other compounds with it. Topical drugs are easy to apply, resulting in localized effect or slow diffusion much like subcutaneous injections.

Contact drugs can also be used for nefarious purposes, by applying a cream or ointment to a surface that a victim is likely to touch. In many cases the target of this action may be aware of an oily feel to the surface (on a successful Per roll). Whether the victim interprets this observation correctly depends on his experience with contact drugs and his paranoia level.

Aerosol

Drugs may be delivered via inhaler or (in some cases) even as a gas. They're generally double cost if they have to be inhaled, or 10 times cost if they are aerosol contact agents that can penetrate the skin. Inhaled agents may be smoked as a cigarette or pipe (often taking at least 10 seconds to take effect), or, at TL8+, delivered via an inhaler (with immediate effect). A one-dose inhaler is \$5, neg. weight.

Implants

Some patients need a drug to be delivered at regular intervals, while others require it on demand, controlled by automatic body chemistry monitoring. And some people would like a convenient drug delivery system that could be triggered at will, for performance enhancing or recreational drugs. These requirements can be met by an implant.

A standard drug implant system is a reservoir of the drug and a release mechanism. Most rely on the natural rate of osmosis across a barrier to deliver a steady dose. More sophisticated designs may be triggered either by an internal timer, a biochemical monitor, or external stimulation by physical pressure or electromagnetic signal. Depending on the drug, the implant can deliver it intravenously or intramuscularly. The disadvantage of such an implant is that the supply of drug can run out. When this occurs, another operation will be required to replace it. A more sophisticated implant may be refillable with a targeted hypodermic injection into the drug reservoir.

A better solution is to manufacture the drug within the implant. This can be done using tailored microorganisms; see *Encapsulated Cell Implants*, p. 120.

If a character has a disadvantage bought with a Mitigator limitation to reflect drug treatment that prevents it from manifesting, and acquires an implant that permanently "cures" the condition, the GM should require that the disadvantage be bought off completely. Similarly, characters created with a disadvantage mitigated by a drug implant do not qualify for any points from that disadvantage.

CHAPTER SEVEN

BIOMODS

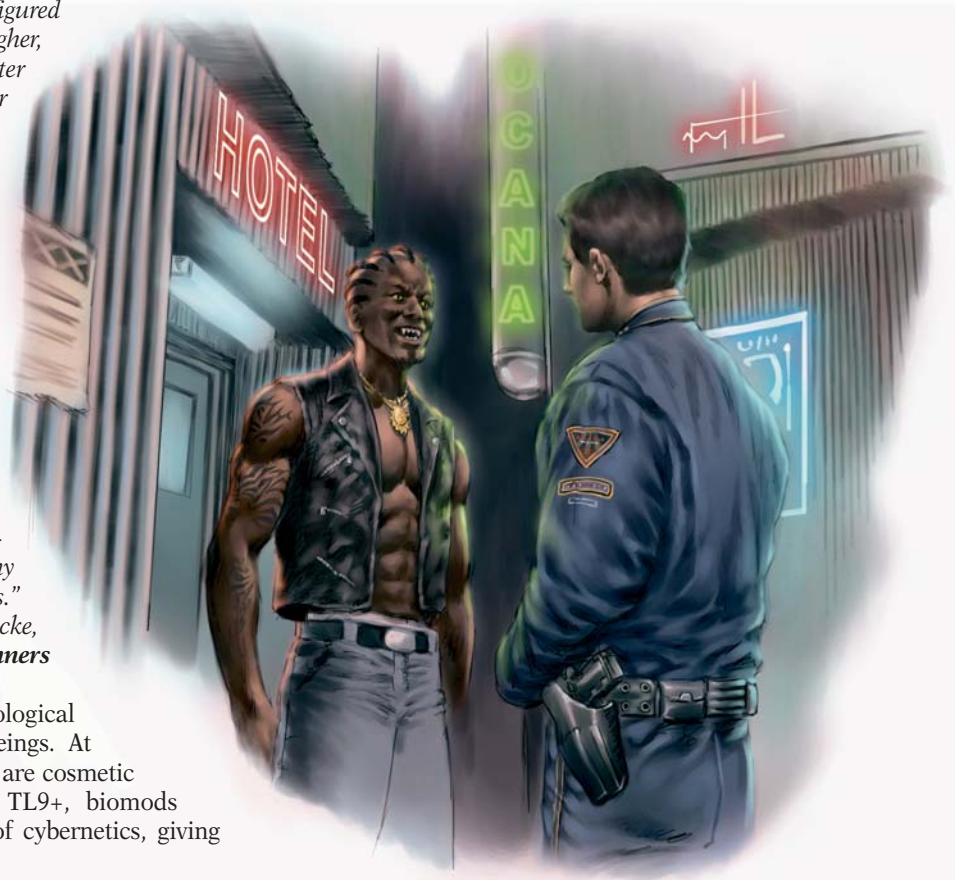
"Okay, so the gengineers have figured out the right way to build a tougher, smarter liver that provides better resistance to toxins, or some other little upgrade to the human genome. Fine, that's great, insert the genes for it in the next generation and raise some enhanced superbrats. But that doesn't do squat for the current generation of people."

"No way! I got loads of cash, but my parents didn't have the cred to have my genes twanked. Heck, they couldn't do that then. You telling me I'm obsolete because I'm already born?"

"Stay frosty, kids. We haven't even mentioned gene implants, bio-mod transplants, surgery, and my favorite, metamorphosis nanovirus."

*– Dr. Lucien Locke,
Biomods for Beginners*

Biomods are permanent biological modifications made to living beings. At TL7-8, the major biomods in use are cosmetic surgery and gene therapy. At TL9+, biomods become the organic equivalent of cybernetics, giving people many new abilities.



ELECTIVE SURGERY

The Rabid stepped out of the shadows. His slit-pupiled eyes were feline transplants, and as he grinned, he showed me a mouth full of canine tooth bud implants. I was impressed: The gangs must be doing well here, to afford all that surgery.

– Detective Cody Chase, Nevada DPS

Elective surgery involves reshaping, modifying or transplanting tissue, bone, organs and limbs.

In some cases, elective surgery may also involve neurosurgery to ensure that certain transplants, such as limbs, function properly. Each surgical procedure ("biomod") is described with these characteristics:

Operation: The cost to hire a surgeon (or medical team), along with the time required to recuperate following the operation. This period is measured in weeks. For every TL over the minimum required, reduce this by one day per

week. Thus, if six weeks were required at TL8, this would be reduced by six days at TL9, by 12 days at TL10, and so on. Some operations require less than a full week to recover from. If so, reduce the period by three hours per TL over the minimum.

The recovery period required is also a rough guide to how long the operation itself takes: assume about two hours for every week of recovery required (before modification by TL). Any operation requiring less than a week of recovery takes an hour to perform.

Both recovery and operation time from multiple operations is consecutive rather than concurrent; e.g., two procedures with two-week recovery times require eight hours of surgery and four weeks of recovery.

Statistics: The game effects and character point cost of each surgical procedure – for instance, what advantages it grants or removes.

BODYSULPTING

Bodysculpting (also called “biosculpting”) includes cosmetic surgery, muscle grafting, and sex-change operations. While some changes may shock the traditional, bodysculpting is usually available and legal in all but the most conservative societies.

At TL7-8, cosmetic modifications rely on surgery, tissue grafts taken from other parts of the patient’s body, and injections or implants of inorganic material. TL9+ bodysculpt is more precise, with CT scans (p. 128) to produce 3-D “before and after” models, laser scalpels, and vat-grown collagen implants.

Disguised Appearance (TL7)

It’s possible to simply change someone’s facial features without altering their Appearance or making them an exact copy of someone else. This change may be combined with surgery for an *Altered Appearance* (below).

Operation: \$1,000 (one week recovery). There is no extra time or cost if this procedure is combined with *Altered Appearance*. LC4.

Statistics: An acquaintance needs an IQ roll to recognize you.

Eyesight Correction (TL7)

Vision problems caused by focusing defects in the shape of the cornea can be relieved by a number of procedures that reshape the lens. The principles were understood as early as TL5, but technology did not allow successful correction until TL7, when radial keratotomy using a diamond scalpel was developed. At TL8, this was largely replaced by safer and more accurate laser procedures that can eliminate myopia and astigmatism completely.

Operation: \$2,000 (one day) per eye. You can be up and around after surgery, but treat as One Eye (or Blindness if both eyes were done) while recovering, and vision may be blurred at times for a few weeks – treat as Bad Sight (Nearsighted).

Statistics: Bad Sight (p. B123) is eliminated.

Hair Transplant (TL7)

Used by balding men (and, more rarely, women) to give the impression of normal hair growth. The technique of transferring plugs of skin containing hair follicles to the scalp was pioneered in the 1950s. At TL7 the results are obvious and artificial, but this improves rapidly by TL8, where natural-looking results are possible.

Operation: \$1,000-\$10,000 depending on extent of baldness. No recovery time.

Statistics: Depending on social mores, may remove Distinctive Features or be a prerequisite for an increase in Appearance (see *Altered Appearance*, below).



Acquiring Biomods

Biomods chosen during character creation are bought with points rather than cash. For biomods acquired during play, use the rules for *Body Modification* (p. B294). These rules replace the *Surgical Modifications* (p. B295) rules.

Each biomod’s availability (TL, LC, and means of acquisition) is summarized in its description. In theory, one simply has to locate someone who can make or install it, pay them, then undergo the operation. This might be as easy as visiting a neighborhood clinic and plunking down a credit card, or as complex as finding an outlawed scientist who’s the only one who can perform the operation. Usually, it depends on the TL and LC of the biomod.

Altered Appearance (TL7/8/9)

My parents were both neo-goths, and they had me engineered to fit the ideal – you know, pale and thin, with these huge, dead-poet eyes and ink-black hair. It was just so tacky. The day I turned sixteen, I went down to the Novabody and got it changed.

– Gabrielle Ravenwood

A person’s facial looks, hair color, eye color and ethnic features can all be altered – often with the goal of improving on nature or repairing ravages of time or injury. To specifically *duplicate* another person’s appearance, see *Copied Appearance* (p. 170).

Operation: Minor changes cost \$4,000 (one week recovery); major changes are \$8,000 (two weeks recovery). Halve the dollar cost if any increase in Appearance results in acquiring Off-the-Shelf Looks, or for an modification that results in lowering Appearance or removal of a trait. Double the dollar cost for any modification that increases Appearance to Very Handsome, or results in Honest Face or Pitiable. LC4.

Statistics: Each minor change can involve one of the following: a shift in Appearance by one level, or somewhat altered features (so that it requires an IQ roll to recognize the character). Each major change may increase Appearance by two levels up, or down as far as desired (minimum Monstrous), or grant or remove one of the following: the Androgynous or Impressive options; the traits Honest Face (p. B101) or Pitiable (p. B22). Appearance cannot be reduced below Monstrous or above Very Handsome.

Altered Bulk (TL7/8)

When I told the doc I wanted to gain weight, he was shocked. I told him it was for a movie – well, I wasn't going to admit I needed some extra room to hide my flesh holster, was I?

– Detective Cody Chase, Nevada DPS

Fatty tissue can be removed surgically through techniques such as liposuction, or it can be grafted onto the body.

Operation: \$5,000 (one week recovery). LC4.

Statistics: Bulk can be safely altered up or down by one step. The steps range from a maximum of Very Fat [-5], to Fat [-3], Overweight [-1] and normal weight, down to a minimum of Skinny [-5], in that order. After the operation, adjust weight accordingly.

Copied Appearance (TL8)

When I was back in LA, we'd run into poser gangs where everyone looks like Nixon or Cthulhu or whatever – or almost look, this being street medicine. I helped shut down this black clinic that was kidnapping street people and turning them into doubles of famous grid stars, then renting or selling them as toys.

– Detective Cody Chase, Nevada DPS

This procedure transforms someone's face into a recognizable copy of another person (real or fictional). The subject must already have the same Appearance (including options like Androgynous or Impressive) as his model, as well as the same facial traits such as Honest Face (p. B101), Pitiable (p. B22), and any facial Distinctive or Unnatural Features. If these traits do not match those of the original, they must first be changed through the Altered Appearance (p. 169) procedure before additional surgery can proceed.

Operation: To turn someone into a fairly close duplicate ("you look like Elvis"), enough to qualify for Mistaken Identity, is \$5,000 (one week recovery). An *exact* duplicate (as much as height and build permit) is \$50,000 (three weeks recovery). Halve the cost and recovery time if the patient's facial features are fairly similar to the features being copied (GM's option). Copies of a real person or trademarked character may be a legal violation (LC2) or require additional licensing fees that further increase the cost. Otherwise, LC3.

Statistics: A copy will have the Mistaken Identity trait (p. B21). A mass-produced copy of someone who is Handsome or better also gains the Off-the-Shelf Looks (-50%) modifier on their Appearance.

Extreme Sexual Dimorphism (TL7/8)

Would you like to make onlookers pant with lust or moan with envy? Come to Novabody, where we can turn you or your partner into the stuff of fantasy. Striking results achieved in hours!

– Novabody: Nirvana is Now

Yes, you too can be stacked like a pleasure bioroid. No thanks. I've heard rumors that the majority of Novabody's clients work for, quote, escort services, unquote, and that some of the surgery is a little less than elective, if you take my meaning. Custom cuties, anyone?

– Detective Cody Chase, Nevada DPS

These procedures exaggerate primary male and secondary female sexual attributes. They are often preceded or followed by surgery to increase Appearance.

Operation: \$5,000 (one week recovery). It requires Average or better Appearance (or the modifications just appear grotesque). LC3.

Statistics: Sex Appeal +1 [2] plus Distinctive Feature (Exaggerated sexual features) [-1]. 1 point.

Sex Change (TL7/8)

It's fashionable for hetero parents to swap sexes after each child, so they can both have a try at being pregnant. This is perfectly healthy, but do be cautioned that some people seem to be predominantly male or female, and won't be comfortable in the other gender for the months that a natural childbirth requires. See your psychogenetic counselor first!

– Dr. Lucien Locke, *Sexmorphing and You*

The procedures and effects depend on the level of sex change:

Superficial Sex Change (TL7/8): Masculinization or feminization of facial and body features, but without genital reconstruction. The subject retains his/her own sex, but when fully dressed appears to be a member of the opposite sex.

Gender Reassignment (TL7/8): The subject completely resembles his/her new gender. Only a medical examination would reveal that a sex change had taken place. To all exterior appearances and for all social interactions, the change is total, except that reproduction is impossible.

Genital Reassignment (TL7/8): As above, but without any masculinization or feminization of features (though this may be added later via a superficial change).

Complete Sex Change (TL9): This is a total sex change, with full capacity for reproduction being possible. This requires tissue-engineering organs and transplanting them into the recipient's body, although at TL11+, proteus nanoviruses can design working reproductive organs and cells within the patient's own body.

Sex Neutralization (TL9): Complete removal of sexual characteristics.

Operation: A superficial sex change is \$2,000 (one week recovery). A gender reassignment or neutralization is \$10,000 (and two weeks). A genital reassignment is \$8,000 (and two weeks). A complete sex change is \$30,000 (and three weeks) for a male-to-female change, or \$100,000 (and four weeks) for a female-to-male, the latter requiring the creation of an artificial Y chromosome, which is trickier. There is often a requirement for psychological counseling prior to any sex change operation. LC3.

Statistics: Gender or genital reassignment results in the Sterile [0] feature; gender neutralization in Sexless [-1]. For

superficial sex change, gender reassignment or neutralization, and complete sex change, if Appearance is at the Handsome/Beautiful or Very Handsome/Very Beautiful level, switch the descriptor (e.g., Handsome becomes Beautiful) or, optionally (especially in the case of gender neutralization) add the Androgynous (p. B21) special option. Any sex change, especially beyond the superficial level, can sometimes alter personality, as a result of the hormones used and the change in self-image. At the GM's option, a sex change can justify buying off or exchanging a few mental disadvantages. In some societies it may also qualify as a Secret or Social Stigma.

Altered Height (TL8)

Height can be altered surgically by up to 3" in either direction through adjustments to the long bones of the arms and legs. Slight modifications to the spine can add an extra 3".

Operation: \$8,000/inch (one week recovery, or three weeks if spinal). LC3.

Statistics: No point cost unless the modification results in Dwarfism or Gigantism (or adjusts height surgically so that the character no longer qualifies for such a disadvantage).

Fingerprint Removal (TL8)

Early methods of surgical fingerprint removal result in scar tissue that leaves prints just as distinctive. By late TL8, the skin of the fingertips can be replaced by patternless skin grafts, providing blank and unidentifiable prints. Of course, if only one suspect for a crime has had this procedure, blank finger smudges will provide circumstantial evidence.

Operation: \$1,000 (two weeks recovery). You can be active while recovering, but no tasks requiring fine manual dexterity can be performed. LC2.

Statistics: Removes fingerprints. This is a 0-point feature. At TL8 this reduces DX by 1 for tasks requiring fine sensitivity, such as Lockpicking, but the fingertips are also insensitive to pain. At TL9 fingertip sensitivity is not compromised.

Archwork (TL9)

This bold fashionmod from the spring collection of Milan bodysculptor Fox Delamere coaxes you into a ballerina's delicate, toe-first walk with modifications to the tendons and arches in the feet! Thanks to supplementary bone reinforcement, you'll be fully comfortable – and if you wear high heels, this makes a day spent walking in them as ache-free as if you'd worn flats.

– Noriko Hayakawa, host of *Cyberia Beat*

Sure it's striking on a supermodel like Alicia Lordes, but didn't this silliness die out in pre-space China? Still, at least Delamere set it up so it isn't physical torture any more.

– Chance Mackintosh, *Posthuman Consumer Review*

Operation: \$5,000 (two weeks recovery). You can be active after surgery, but treat as Lamé while recovering. LC4.

Statistics: Adds 2" to height when barefoot, and you can wear high heels or dance shoes indefinitely without pain; regular footwear is uncomfortable (0 points).

Jointwork (TL9)

Net-gossip says Macrotech caught a cat burglar picking the lock on their VP's Manhattan suite. She'd squirmed her way through the air ducts on the way in, and when Security found her, she jumped two stories and landed running. Nearly made it, too. Seemed the thief had gotten bodywork at a back-alley clinic in Kyoto: extra joints, genemod connective tissue, even some work to modify the ankles and knees for improved shock absorption. Nice job, and no patent. So they dissected her, studied the design, and reverse-engineered it into their newest product. Ironic, huh?

– Streehawk, alt.bio.upgrade.samurai

Operation: \$20,000 (two weeks recovery) for a single advantage, or \$40,000 (four weeks recovery) for a combination of two or more. LC4.

Statistics: Any of Catfall [10], Flexibility [5], or High Manual Dexterity +1 [5], or raise an existing Flexibility advantage to Double-Jointed [15].

Eros Plus (TL9)

With the new Eros Plus, you and your partner can climb undreamt-of peaks of sensual pleasure! Let our trained biotechs improve on nature's gifts. Available for all sexes.

– Novabody: Nirvana is Now

The subject's erogenous zones are significantly more sensitive to erotic stimulation than an ordinary person's. This can be enjoyable.

Operation: \$5,000 (two weeks recovery). Only two days bed rest is required, but you will suffer the Sexless quirk until the entire recovery period is over. LC3.

Statistics: If your partner is using Erotic Art skill with you, they get a +4 bonus; however, you are also -4 to resist Interrogation or Fast-Talk during such activity. The net cost is 0 points. This biomod can be addictive. For the first 1d months after it is added, the GM can require a Will roll to avoid acquiring the disadvantage Lecherousness (15) [-7], or having the self-control roll for an existing disadvantage reduced one step, e.g., Lecherousness (12) becomes Lecherousness (9).

Hair Graft (TL9)

An exotic hair graft permits living hair or fur strips to be grafted to certain parts of the body, such as the spine, ankles or wrists.

Operation: \$1,000 (one day recovery). LC4.

Statistics: Usually a 0-point feature, if that, but may qualify as Distinctive Features or Unnatural Features depending on social mores.

Muscle Graft (TL9)

Tired of getting sand kicked in your face? Want the body your lover has always dreamed off? Try SpaTek's muscle grafting! Bulk up in record time while avoiding the metabolic hazards of conventional muscle-enhancing drugs and the risks of transplant rejection. Strong, safe and swift: It's SpaTek.

– SpaTek advertisement

Way I see it, muscle grafting is kind of the surgical version of steroid pushing – a quick and dirty way to bulk up real fast, if you don't have the self-discipline or the time for body building or the cash for something more subtle. Graft's the sort of thing you'd see on Mafia muscleboys or some simstar's bodyguards. Kind of low class. Por favor, chum: Don't tell "Mountain" Mahoney I said that, or he'll break my spine.

– Streethawk, alt.bio.upgrade.samurai.livechat



Operation: \$20,000 (four weeks recovery). If using a muscle-boosting nanovirus, half the ST gain (round down) occurs after two weeks, with the remainder at the end of the growth period. LC4.

Statistics: Select from +1 to +3 Lifting ST and the same level of Striking ST. This reflects the fact that this ST only applies to limb muscles, not to internal muscles like heart or lungs or to the skeleton. Boosting ST by muscle grafts adds 10 pounds to weight per point of ST increase. Characters who gained +3 ST from muscle grafts can take the Unsupported Strength limitation (p. 215).

Testicle Tuck (TL9)

SpaTek markets this biomod for male boxers, hockey players, and other such jock types, but it's a favorite streetmod as well. I've been thinking of getting one myself.

– Streethawk, alt.bio.upgrade.samurai

Hey, hawk-baby – don't go to a street doc, okay? You make sure those blood-vessels get re-routed dolphin-style so your cajones stay cool. Don't want to bake your spunk, you know.

– Genosibyl, alt.bio.upgrade.samurai

This modification eliminates the special vulnerability of the male groin to injury. A cheaper version exists which leaves the recipient sterile.

Operation: \$4,000 (two weeks recovery). Treat as Sexless while recovering from surgery, but no bed rest is required. LC4. The cheap version is \$1,000 (and one week); LC3.

Statistics: Injury Tolerance (No Vitals; Partial, Vitals, Groin only, -60%) [2]. The cheap version adds Sterility [0]. 2 points.

Xenosculpting (TL9)

You look surprised? I guess it must be a shock finding out your little sister has perky fox ears, fur that matches her hair and a bushy tail. And working in a hostess bar, too. I came to Tokyo with all those dreams, be a pop singer, an idol – sure, big sister, laugh. You try sleeping in Ueno Park for a few weeks. After that, well, the Kitsune Club was advertising for exotic hostesses. True, the surgery and cell grafts weren't much fun, but I needed money. If I signed a four-year contract, the 'sculpt was free. Now I earn 50K a year in tips from jaded sararimen like your friend. In a year or two, I should have enough to change back. If I want to. Excuse me, sis . . . Welcome to Club Kitsune, sir! I'm Marie, your foxy hostess for this evening.

– Marie Detroit, Club Kitsune

This gives someone nonhuman features, ranging from pointed “elf” ears to an animal-like face or head. Minor cosmetic xeno-features include such modifications as elf- or cat-like ears, tiny horns (too small to do damage), a forked tongue, or a birdlike crest – that is, any features that don't require bone or nervous system alterations. Adding a small patch of fur or feathers (e.g., to the scalp or ears) is also a minor cosmetic change. Major xenosculpting may include altered facial bone structure, like an animal-like jaw or muzzle, or

modifications to skull shape. For claws, sharp teeth and so on, see *Xenostriker Grafts* (p. 178). For full-body fur, scales and so on, see *Skin Transformation Virus* (p. 186). A bunny tail or a non-functional tail that simply hangs there is a minor cosmetic modification; a tail with bone and muscle that can be wagged is a transplant; see *Tail Grafts* (p. 178). Most changes to features like the eyes or nose do not improve senses – they are cosmetic only. (Due to the need to modify the brain as well as the sense organs themselves, improvements to senses require either genetic engineering, cybernetics, or bio-nanotech). An exception is large ears, due to the funneling of sound; these *can* improve hearing.

Operation: This depends on the extent of the change. Minor cosmetic xeno-features are \$1,000 (one day recovery) each. A set of related minor modifications (e.g., giving someone rabbit ears, buck teeth and a button nose) is \$10,000 (one week recovery). Altered facial bone structure is \$30,000 (and 2+ weeks). LC3.

Statistics: This is a 0-point feature, but may count as Distinctive Features [-1] or even Unnatural Features [-1 to -3] if such biomods are rare or no “real” existing race resembles you. Some changes – e.g., bug eyes and a sucker-like mouth surrounded by writhing tendrils – could also give a negative Appearance or Social Stigma. If you are disguised as a known alien or variant race, this may also qualify as a Secret if you are passing yourself off as one of them. Large ears can provide Acute Hearing +1 [2].

Xeno-Voice Box (TL9)

Baby, you may be a hot nightclub singer, but no one, no one, betrays the Family. Well, your pretty mouth won't get you in trouble again. This automed you're strapped into? Benni's gonna replace your voice box. Hey baby, don't cry! Sure, you won't be able to talk no more, but you'll still be able to sing. See, we're gonna give you a songbird's syrinx instead of a larynx. Bit of brainwork, a few biochips in your skull, and you'll make us a lot of valuta at Big Al's other joint, maybe even sell recordings, you know? Object lesson, we call it.

– Nanobug recording of Don C. Magaddino, from federal grand jury transcript

This technology doesn't have to be used for sinister purposes. For instance, a human diplomat might have his voice box modified so that he can speak an alien language that's impossible for a human larynx to pronounce. Then he'd be modified back after completing his tour of duty.

Operation: \$10,000 (two weeks recovery); only a day of bed rest is required, but the subject will be Mute for the entire recovery period. Reversing the effects of a xeno-voice box operation takes the same time and cost as the original procedure. A person can also be surgically rendered Mute with no ability to make sounds; this can be done quite safely at TL6, and is \$500. LC4.

Statistics: A human voice box altered to make vocal animal sounds – trills, barking, purring, etc. – gives

Disturbing Voice [-10] if speech is still possible, or Cannot Speak [-15] if it permits only animal sounds. Cannot Speak *can* be combined with Voice [10], if the animal sounds are pleasant. Modifying a human to speak an alien language is also treated as Disturbing Voice, as human speech will be garbled.

Hermaphromorphic Surgery (TL10)

Gender is obsolete with Matsai's latest bioengineered marvel. Creation of a fleet of sphincters, voluntary muscles, and hormone pumps allows fully functional sex-switching in a matter of hours, as well as full fertility control.

– Matsai Corporation advertisement

Word of warning: *If you become pregnant in female mode, you'll automatically switch back and be locked into female morphology about a week into the pregnancy unless you voluntarily choose to reabsorb the fetus, like I did.*

– Chance Mackintosh, *Posthuman Consumer Review*

Operation: \$150,000 (and four weeks). LC3.

Statistics: Hermaphromorph [5] plus Reproductive Control [1]. 6 points.

BIOMOD TRANSPLANTS

Need a new or better body part? Why not just graft one on?

Biomodification transplants use the same rules for surgery and recovery as medical transplants (p. 141).

These are transplants of completely new or modified internal organs. They've been grown from engineered clones or in special organ vats, then harvested to be ready for transplant.

Eye Upgrade (TL8)

If your eye offends thee, pluck it out and get a better one. Biomod ears or noses aren't something you can really graft on and hope for anything other than a cosmetic change, due to a lot of the processing being wetware – i.e., in the brain – but since we're better wired to handle enhanced visual input, and most of an eye's modifications are in the rod and cone cells, they're fairly easy to improve through transplants. Mind you, you can't get something exotic like infravision unless you want to mess with nanoviruses and stuff – cyber's much easier there.

– Streethawk, *alt.bio.upgrade.samurai*

Operation: \$2,000 per character point it costs, with a minimum of \$5,000 (six weeks to grow, two weeks recovery). LC4 (LC2 if duplicating a retina pattern).

Statistics: Cures (rather than mitigating) Bad Sight, Blindness, Colorblindness, Night Blindness, or No Depth Perception (adjust point cost). Can add Acute Vision up to +(TL-7), to a maximum of +5 [2/level]. It will also alter the retina print. If a specific retina pattern is known, it can deliberately match another person's.

Bio-Booster (TL9)

Spring into battle with the Cheetah bio-booster! New from VeldtKorp's ace Johannesburg design bureau, the "Cheetah" adrenal pump is designed to store up and voluntarily release abnormal levels of adrenaline and noradrenaline in emergencies, supercharging you in situations where seconds mean lives. Currently under evaluation by South African, Nigerian and Israeli special forces, the VeldtKorp Cheetah epitomizes cutting-edge combat biomods at a price that can't be beaten by first-world mega-korps!

Warning: Use of the Cheetah for extended periods is suggested only for those in good health and with normal blood pressure. We also recommend a VeldtKorp Pacesetter or other boosted heart.

– VeldtKorp advertisement

"I had a friend who got a Cheetah. Worked fine until he got into a drawn-out fire fight in Kabul. Then his heart exploded. Guess he should have gone easy on that cholesterol."

– Captain (ret.) Dana Martello, Marine Force Recon

Operation: \$31,000 (four weeks to grow, two weeks recovery). LC4.

Statistics: Basic Speed +1.00 (Cardiac Stress, every minute, -30%, Costs Fatigue, 1 FP, -5% [13], Lifting ST +3 (Cardiac Stress, every minute, -30%) [7], and Striking ST +3 (Cardiac Stress, every minute, -30%) [11]. 31 points.

Boosted Heart (TL9)

Why stick with what nature gave you? VeldtKorp's Pacesetter transplant features genemod muscle tissue and modified ventricle construction for greater strength and longer endurance. Say goodbye to cardiac unrest with VeldtKorp's Pacesetter!

– VeldtKorp advertisement

Fine if you want to undergo heart surgery just to get a few minor improvements, but I must say I'm personally a teeny bit skeptical. I'd suggest waiting until Biotech Euphrates develops the nanosurgeons to do the modifications without cutting you open. A little bird tells me they're working on it in their Cairo facility right about now.

– Chance Mackintosh, *Posthuman Consumer Review*

Operation: \$15,000 (six weeks to grow, four weeks recovery). LC4.

Statistics: HT +1 [10], FP +1 [3], and Hard to Kill +1 [2]. 15 points.

Cold-Adaptive Fur (TL9)

This gives the user a thick coat of fur. Besides being available in fashion patterns, it provides protection against the cold. (For an alternative, see *High-Biotech Fur*, p. 185.)

Operation: \$10,000 (four weeks to grow, no recovery). LC4.

Statistics: Fur [1]; Temperature Tolerance (Cold) 2 [2]. 3 points.

High-Efficiency Kidney (TL9)

Planning to live as a drylander? You can't always depend on canteens – even the best vapor models can malfunction, forcing you to rely on stored water. So be safe rather than sorry, and conserve water the natural way, using a High-Efficiency Water-Cycle Kidney, from Colonial Genetics.

– Colonial Genetics advertisement

Never used one in the desert, but it made long road trips a lot more comfortable.

– Copernicus Jones, *Roughing It on Mars*

Kidneys filter everything out of the blood and then selectively reabsorb those substances that your body needs, while excreting waste material into the urine. There's some waste in the cycle, though, so this modification super-concentrates urine to reclaim as much water as possible. This will cut water requirement to one-third (and similarly reduce bathroom trips).

Operation: \$20,000 (six weeks to grow, two weeks recovery). LC4.

Statistics: Reduced Consumption 2 (Water Only, -50%) [2]. 2 points.

Hyper-Lungs (TL9)

Gain the stamina of an Olympic athlete with Colonial Genetics' new Marathon-series augmented lung transplants! Specially strengthened with extra gas-exchange efficiency, human trials have demonstrated a substantial increase in breath-holding capacity and a boost to overall stamina. Perfect for outdoor sports and activities, the Marathon is the lung of choice among augmented professional lifeguards. Various models available, with wide range of custom features.

– Colonial Genetics press release

The last volume of Jane's Combat Biomods says the Marathon is standard-issue for the U.K.'s Royal Marines, with a few extra upgrades, like a filtration membrane. Now I know why Brigadier Lisa Rutherford-Hodge was so blasé about smoking six packs a day. 'Course, that's nothing – I hear Navy SEALs have gills these days.

– Captain (ret.) Dana Martello, Marine Force Recon

Hyper-Lungs comes in both civilian and military ("milspec") models.

Operation: \$16,000, or \$26,000 if milspec (six weeks to grow, eight weeks recovery). LC4.

Statistics: Breath-Holding 1 [2], FP +2 [6]. 8 points. Milspec hyper-lungs add Filter Lungs [5]. 13 points.

Liver Upgrade (TL9)

The liver is a chemical factory and purification system where enzymes restructure molecules into substances useful to the body, and in which detoxification of harmful substances occurs. "Team Babylon," led by Dr. Sayyid Iqbal, is proud to announce that we have once again improved upon nature. Enjoy faster and safer metabolism with Biotech Euphrates' new liver upgrade!

– Biotech Euphrates press release

One of my best hoverjocks had a drinking problem. His own business, until he smashed up the rig and lost me six pharm goats worth sixty grand. So I said if he wanted to keep working for me and wouldn't get a rehab chip, maybe he should make an appointment with Dr. Iqbal.

– Eden Harrier, Harrier Import/Exports

Operation: \$12,000 (six weeks to grow, two weeks recovery). LC4.

Statistics: Alcohol Tolerance [1] and Resistant to Ingested Poison (+8) [5]. 6 points.

Perfume Glands (TL9)

New from body designer Lee Pong, with chemical coding by Medea Cosmetics. Perfume your bodily excretions with a neutral deodorant, or produce one of a half-dozen musks and fragrances (custom-selected when the glands are ordered).

– Noriko Hayakawa, host of *Cyberia Beat*

The user can change between perfume or deodorant, or if desired, go back to his own, natural body odor (but an earlier choice will linger for several minutes). By changing his scent, the user can also mask his natural odor or confuse beings that rely heavily on their sense of smell for personal identification and tracking prey.

Operation: \$6,000 (four weeks to grow, two days recovery). LC4.

Statistics: Racial Bonus to Sex Appeal +2 (Scent-based, -20%) [4] and Obscure 1 (Smell) [2]. 6 points.

Skeleton Tongue (TL9)

Alters the patient's vocal cords, allowing him to precisely mimic any familiar sound. Once the user has memorized a person's voice and has had a chance to practice it, he will be able to fool voiceprint scanners.

Operation: \$30,000. (four weeks to grow, four weeks recovery). The patient only requires a week of bed rest, but is Mute for the entire recovery period. LC2.

Statistics: Mimicry [10].

Spleen Augmentation (TL9)

Fresh out of Exon-Horizon's Barcelona genetics lab comes the augmented macrospleen: An integral part of the body's defense mechanisms has been further modified to produce enhanced versions of disease-fighting white blood cells! Enjoy a longer and healthier life with Exon-Horizon biotechnology.

– Exon-Horizon press release

Operation: \$5,000 (three weeks to grow, four weeks recovery). LC4.

Statistics: Resistant to Disease (+8) [5]. 5 points.

Limb Replacement Transplants (TL9)

Avatar Klusterkorp knows true belters and voidflyers agree: In zero-G, feet are dead mass. If you're a spacer who's

vowed to never get sucked down a gravity well again, you owe it to yourself to replace both feet with another pair of hands! Modified joints and digitigrade morphology allow knees to double as elbows for these fully-prehensile feet, while cutting-edge neurotransmitter injections ensure trouble-free nerve connection. Reject dirt-mode vestigals for posthuman morphs now!

– Avatar Klusterkorp promotion

Gengineered arms, legs, hands or feet can be grown to replace the body's own limbs. The original limbs are surgically amputated, then modified limbs are grafted onto the stumps. If the subject intends to return the limbs to normal later on, the amputated limbs can be preserved for potential reattachment, saving the time required to grow new ones. Nanomachines and neural surgery are used to create new nerve connections that enable the modified limbs to be used.

Operation: This costs \$50,000 × (TL-8), where "TL" is the minimum TL required for the gengineering. Thus, prehensile toes (TL9) would cost \$50,000. Recovery time is eight weeks.

Statistics: These are based on the genemods described under Morphological Changes (p. 51). Both legs or feet can be replaced with altered limbs, and arms can be replaced with gengineered wings (see *Arms to Wings*, p. 52). The statistics and point costs are as described in Chapter 2; the genetically-engineered body parts take six weeks to grow.

Androwomb (TL10)

Michael, you know I don't believe in exowombs, and a surrogate is out of the question. Who did you think would be carrying our Dana to term? The doctor is ready.

This modifies a male or a bioroid to safely carry a transplanted embryo to term and give birth without caesarean section. It is included in a male-to-female full sex change.

Operation: \$16,000 (four weeks to grow, two weeks recovery). LC4.

Statistics: 0-point feature.

Auxiliary Heart (TL10)

She's not dead, damn it! Feel that slow heartbeat on the right side of her chest? Her auxiliary heart just kicked in. It's smaller than her main heart, but it should keep her alive until we can medevac her.

– Lt. Dana Martello, Marine Force Recon, mission data log upload

Operation: \$30,000 (four weeks to grow, six weeks recovery). LC4.

Statistics: No Vitals (Only to prevent first heart attack, -40%) [3]. The user will still need to seek medical treatment to repair his primary heart; until this is done, any new heart attack will have full effect. 3 points.

Muscle Reinforcement (TL10)

You wish to enhance your strength in a manner that leaves no visible traces? You have come to the right place, mon vieux: the Clinique Rouge. Here, the finest nanobots will pleat high-strength elastic fibers into the muscles of your body, using a protein macromolecule that DuPont Orbital will release next month. Of course, we have it now. The Clinique Rouge prides itself on being the cutting edge of black medicine.

– Mme. Madeleine Rouge, the Clinique Rouge

Aussie smuggler, name of Sally Strang – maybe you've seen her? Tiny little redhead with cute braids, ex-navy hover-jock. Well, we were walking along the Tokyo waterfront, eating squid and talking biz, when 200 kilos of Kobe beef starts hassling us. Meatboy puts his paws on Sal. Bad move. She grins, lifts him up and sumoboy goes head-over-heels over the rail. Splash! Guess he hadn't heard Sally'd gone to Marseille, gotten her muscles done as well as her hair. The meatboy? Hey, you know what Tokyo Bay's like these days. The bacteria ate him.

– Eden Harrier, Harrier Import/Exports

Operation: \$8,000 per level of Enhanced Muscle (three weeks recovery). LC4.

Statistics: Select from 1 to 4 levels of Enhanced Muscle (p. 213) (or double that if you have skeletal strengthening (p. 189) [8/level]). Unlike a muscle graft (p. 172), weight and looks will not change when this process is used. Optionally, characters who gained +3 to +4 ST from muscle reinforcement (or +6 to +8 ST, with skeletal strengthening) can take the Unsupported Strength limitation (p. 215).

Neural Augmentation (TL10)

Do you want to move faster than a jackrabbit on amphetamines? We at Kerensky Labs recommend our Max-9 neural augmentation process, which fuses adjacent nerve cells together to improve the diffusion of neurotransmitters across synaptic junctions and enhance nerve impulse transmission speed. To ensure optimum performance, we recommend periodic use of the neurotransmitter hormone PK-28N (Pink Noise).

– Kerensky Labs advertisement

They aren't kidding. Crank yourself up with the old Max-9 and you move so fast your brain can't handle it without some kind of help. I was partnered with this 'Maxed-out Russkie panzerbabe, name of Leona. Greased lightning – or so I thought, until one day when she tripped in a fire fight and shot her foot off. Turned out she'd run out of Pink Noise the day before.

– Streethawk, alt.bio.upgrade.samurai

Operation: \$110,000 (two weeks recovery). LC3.

Statistics: Basic Speed +3.00 [60] and Total Klutz (Mitigator, weekly dose of PK-28N, -65%) [-5]. 55 points. Each dose costs \$200. The Basic Speed increase is cumulative with other sources of this advantage, with the exception of cybernetics that replaces the organic nervous system with electronic systems. A user can eventually get used to the

Basic Speed increase and buy off the Klutz disadvantage using earned points.

Pheromone Glands (TL10-11)

When Colonel Chang enters the room, all heads turn to look at her, and we hang on her every word. It isn't just her fine aristocratic features, or the black and silver uniform of Special Projects. It's something else, a natural air of command, even of awe, that she projects to all those around her.

– Ensing Chun Yuan, war diary

The Overlord-series super-pheromone gland has performed admirably in all test subjects, releasing controlled amounts of synthetic pheromones via the sweat glands. These are tailored to induce states in human or near-human metabolisms that correlate not merely with attraction, as in early pheromone gland designs, but also dominance and awe. Obvious applications are in intelligence-gathering operations and command and control.

– Dr. Tse Chang, Special Projects Division

These glands can produce a chemical cloud powerful enough to induce a mind-altering emotional effect upon anyone nearby.

Operation: \$25,000 (four weeks to grow, one week recovery). A combination of pheromone types are possible; \$10,000 per extra type. LC2.

Statistics: Trust Hormones (p. 48) [29], or Sex Pheromones (p. 48) [28], or Xeno-Pheromones [2]. Most pheromones are available at TL10. At TL11, Dominance Pheromones (p. 48) [15] are available. *Variable cost.*

What a piece of work is a man!

– William Shakespeare,
Hamlet

Thin Atmosphere Lungs (TL10)

This genemod lung and support organ transplant gives the user the ability to breathe *Thin* atmospheres without suffering any of the adverse effects listed on p. B429, provided the atmosphere contains at least 20% oxygen. Unfortunately, it makes the user uncomfortable in normal atmospheres. At TL11, further modifications provide the ability without sacrificing comfort at normal pressures.

Operation: \$14,000 (five weeks to grow, seven weeks recovery). LC4.

Statistics: Treat very thin atmospheres as thin, thin as standard, standard as dense, and dense as very dense. 0 points.

Sensa-Skin Grafts (TL11)

Sensa-skin is artificial, vat-grown living tissue with an affinity for living flesh. Sensa-skin placed in extended contact with flesh will actually grow into it over time. Sensa-skin makes biomod transplants simpler and safer, due to its unique ability to bond with living flesh.

The effects of Altered Appearance (p. 169), Altered Bulk (only to gain in bulk; p. 170), Extreme Sexual Dimorphism (p. 170), Sex Change (Gender Reassignment or Superficial; p. 170), Skin Transformation Virus (p. 172), and Xenosculpting (p. 172) can all be produced through sensa-skin at TL11+. Treat these as normal surgical or transplant procedures, except that there is no “surgery” as such – the sensa-skin is simply carefully attached. There is no need to wait to grow transplants, no chance of rejection and no recovery time. The application time for a pre-designed sensa-skin graft is one hour for every week that a normal transplant or surgery would require to recover from. All sensa-skin grafts can be removed without surgery up to HT × 3 hours after the operation takes place, using the same procedure; after that they are permanently attached and would require surgery to remove.

POLYKERATIN GRAFTS

Polykeratin is a form of synthetic, vat-grown, biomimetic bone, cartilage or muscle tissue, based on sensa-skin and advanced memory bioplastic technology. Sometimes described as “memory tissue,” polykeratin cells can “remember” a second shape, and switch between shapes upon receiving certain muscular signals (which depend on the graft). Polykeratin implants permit a limited form of flesh-morphing – an individual with one will have the ability to alter a particular body part between two specific, different forms.

Polykeratin grafts are treated as surgery. They have no chance of rejection, but (unlike sensa-skin) are not removable without surgery.

Arm Blade (TL10)

Macrotech Biocybernetics’ weapons division is proud to announce the arrival of our latest polykeratin combat implant! Clench your fist while extending your index finger, and your forearm morphs into a lethal, serrated fighting blade! Perfect for situations where guns are illegal, but a blade is too inconvenient or obvious to carry.

– Macrotech advertisement

Operation: This is a single arm replacement transplant. \$45,000 (four weeks to grow, eight weeks recovery). LC3.

Statistics: Striker (Cutting; Long, +1 SM, +100%; Switchable, +10%; Temporary Disadvantage, One Hand, -15%) [14]. 14 points.

Battle Jaw (TL10)

You can’t take any weapons into Darkside Arcology – their security is too good. But we can transform you into a weapon, agent Yukio. We’ll replace your jaw with a polykeratin graft. Bite your tongue and grin – that signals the implant. Your



jaw and face will morph into a battle jaw that you can extend out like an egg-eating snake. This should impress those down-siders and give you an inroad with the Cthulhugangs.

– Dr. Mara Omokage, Omokage Labs

Operation: \$22,000 (two weeks to grow, three weeks recovery). LC3.

Statistics: Striker (Impaling; Cannot Parry, -40%; Long, +1 SM, +100%; Switchable, +10%; Temporary Disadvantage, Appearance (Monstrous), -20%; Temporary Disadvantage, Cannot Speak, -15%) [11]. 11 points.

Polykeratin Disguise (TL10)

Connective tissue throughout your body, and particularly your face, stomach and chest, has been partially replaced by multiple polykeratin grafts and sub-dermal inflatable pouches. With the proper exercises and biofeedback regime, these will enable you to vary your apparent shape and bulk, and hold this appearance for a short period of time. Additional modifications to your spinal discs allow voluntary compression for a 5% decrease or 2% increase in height. The polykeratin implants have been supplemented by chameleon-like responsive chromatophores in all surface tissues, which can slowly alter pigmentation, while your altered hair cells can stiffen or lie flat, varying apparent length.

– Dr. Mara Omokage, Omokage Labs

So, basically, I can look like someone else. But not for very long.

– Agent Yukio

Operation: This is treated as surgery. \$200,000 (eight weeks recovery) for TL10 type, twice the cost for TL11. LC3.

Statistics: Elastic Skin (Costs Fatigue, 1 FP, -5%), [19]. At TL11+, Elastic Skin [20] that can hold a shape indefinitely is possible. 19 or 20 points.

Quadragraft (TL10)

Macrotech Biocybernetics is happy to present the next in its series of polykeratin implants. Designed for the colonial and street markets, our transplant techs will replace your arms and legs with patented polykeratin limb grafts. When triggered, your legs become digitigrade, and your hands transform into walking paws. Why walk the dog when you can run with him? Perfect for high-speed scouting and wilderness fun. Enjoy posthuman thrills with Macrotech Polykeratin!

– Macrotech advertisement

My last Earthside hunt was for the killer of two of our missionaries, who had been torn apart. I suspected a psycho killer, but I must say I was caught by surprise when my apparently human quarry transformed into a four-legged werebeast. It was an interesting fight. After I analyzed the remains, it turned out he had also had a polykeratin battle jaw and some of that high biotech fur. It's amazing the kind of contraband that gets through our blockade.

– Tisephone Logos, >warangel>heavenweb>solnet

Operation: \$65,000 (four weeks to grow, eight weeks recovery). This includes four replacement limb transplants. LC4.

Statistics: Enhanced Move 1 (Ground; Switchable, +10%; Temporary Disadvantage, Quadruped, -35%) [15]. 15 points.

XENOTRANSPLANTS

Like medical xenotransplants (p. 141), these use tissue from animals, either from a live animal or engineered from cell animal cultures. If xenotransplants are common, some facilities may have these transplants “in stock,” so no growth time would be required.

Cat's Eye Transplant (TL9)

It's cheaper and snazzier than a cybernetic eye, although it does look a bit obvious, especially in dim light when it glitters. 'Course, it can't be upgraded.

– Streethawk, alt.bio.upgrade.samurai

Operation: \$5,000 per eye (six weeks to grow, eight weeks recovery). Only a week of bed rest is needed, but the user will be blind in the transplanted eye until the full time has elapsed. LC4.

Statistics: Night Vision 1-3 [1-3]. A set of feline eye transplants may count as a Distinctive or Unnatural Feature [-1]. There is a -2 to Vision rolls unless both eyes are modified.

Xenostriker Grafts (TL9)

My kid sister runs with the Unicorns, a gang of biopunks and genehackers down at the Cloisters. Vicious in a rumble, but real twisted – who else would be crazy enough to clone up nar-whal fetuses and transplant the tusk buds into their foreheads?

– Streethawk, alt.bio.upgrade.samurai

Operation: Costs \$5,000 × (TL-8), where “TL” is the minimum TL required for engineering the same advantage (six weeks to grow, three weeks recovery). LC3.

Statistics: Select any natural weapon except a bioelectric organ from the *Transgenic Natural Weapons* section of the *Cosmetic and Minor Transgenic Modifications* table (p. 46). To make any obvious trait (e.g., talons) retractable, add the Switchable enhancement (+10%, p. 214). Otherwise, they may count as -1 or -2 point Distinctive or Unnatural Features if exotic biomods are uncommon. Before the operation, the claws, talons, horn buds, or tooth buds must be acquired.

Tail Grafts (TL10)

I'm always excited by Lee Pong's creations, but this time he's outdone himself: The Novabody fall collection is stunning in its simplicity, and getting transrock diva Lyla Feng to model was a stroke of genius! Isn't her new tail just darling?

– Noriko Hayakawa, host of *Cyberia Beat*

Operation: This costs \$25,000 × (TL-8), where “TL” is the minimum TL required for engineering that type of tail. Thus, a prehensile tail (TL10) would cost \$50,000. All tails take three weeks to grow before the transplant. Recovery time is four weeks for prehensile or scorpion tails, two weeks for ordinary tails. Tails are LC4, except for scorpion tails, which are LC3.

Statistics: Any of the tail types described under *Engineered Tails* (p. 51) can be vat-grown and then transplanted. If biomods of this sort are unusual, a tail may also qualify as Distinctive Features or Unnatural Features.

Winged Retromorphosis (TL10)

Replaces arms with a functional pair of biogenetically grown feathered or batlike wings, and grafts additional muscles into the shoulders to power them. The wing bones arch well above the head to allow normal walking. The wings are not powerful enough to fly with under normal Earth gravity, but can be used in low-G environments.

Operation: \$30,000 (eight weeks to grow, four weeks recovery). LC2.

Statistics: Flight (Requires Low Gravity, 0.5 G, -25%; Winged, -25%) [20]. See *Accessibility* (p. 215) for the low gravity limitation. 20 points. The wings are assumed to have handlike manipulators by default; if they are more clumsy add No Fine Manipulators [-30].

Tentacle Transplant (TL11)

Okay, it's a gene-altered transplant. What I want to know is, what kind of thing did they transplant it from? I mean, does that black clinic have a basement with some sort of stunted octopoid/human hybrid floating in a growth tank?

– Streethawk, alt.bio.upgrade.samurai

Hai. Some of our customers have unique tastes.

– Mara Omokage, alt.bio.upgrade.samurai

Operation: \$50,000 per arm replaced by a tentacle (six weeks to grow, eight weeks recovery). LC3.

Statistics: Tentacles can replace one or both arms. This is Extra-Flexible [5] per arm (see p. B53).

NEUROMODS

Surgical modifications to the brain and central nervous system may be performed for non-therapeutic reasons, either to enhance the way the brain functions or, more commonly, as a form of behavior modification. If neurosurgery is performed on someone with the Compartmentalized Mind advantage, the GM should decide whether it will only affect one “compartment” or the entire mind. In general, a neurosurgeon who is unaware of the subject’s ability will only be able to affect one of the compartments.

Cybernetic neuromods (brain implants) are described in **GURPS Ultra-Tech**.

Prefrontal Lobotomy (TL6)

Doctor, what are you doing with that ice pick?

This radical and controversial procedure involves damaging the prefrontal lobe of the brain, an area that generates certain aggressive tendencies. Some types of mental illness may be cured, but at the result of brain damage and personality destruction.

Operation: \$500 (one week recovery). LC2.

Statistics: Will usually eliminate aggressive mental disadvantages, including Bad Temper, Berserk, Bloodlust, Bully, Compulsive Behavior, Curious, Greed, Fanaticism, Impulsiveness, Megalomania, Obsession, On the Edge, Paranoia, and Stubbornness. (Note that Callous is not removed, and may occasionally even result from the lobotomy). The cost is severe: at least -2 IQ [-40], -1 Will [-5], Hidebound [-5], along with the removal of the Daredevil and High Purpose advantages (if possessed). Talents will often also disappear, and many other personality-related mental traits, e.g., Trademark or mental quirks, will vanish.

Killjoy (TL9)

Don't worry, you won't feel anything . . .

This procedure burns out or removes the brain’s pleasure center, usually via microsurgery.

Operation: \$8,000 (four days recovery). LC2.

Statistics: Someone who undergoes a Killjoy should replace any disadvantages that drive him to seek physical pleasure (e.g., Compulsive Carousing, Lecherousness) with the Killjoy disadvantage [-15], and pay off any point difference.

Brain Tissue Graft (TL9)

Dr. Sergei Volk, he of the bulging brain? Yeah, he is a bit weird. Not his fault. They locked him up in an institution in Dushanbe. We busted him out, but he couldn't tie his own shoelaces without a map - they'd lobotomized him. So we got him a brain tissue graft. Now he's a genius again . . .

– Streethawk, alt.bio.upgrade.samurai.livechat

Extra brain tissue is grafted onto the frontal lobes to increase the brain’s surface area. The skull is surgically

enlarged to accommodate the additional gray matter. Exhaustive brain monitoring and therapy are used to ensure the smooth integration of the brain tissue into the cerebrum and prevent the impairment of existing cognitive functions.

Operation: \$20,000 (two weeks recovery). Even generic brain tissue grafts won’t be attacked by the immune system (due to the blood-brain barrier). However, the difficulty of assimilating new brain matter means *de facto* rejection is possible – make a HT-1 roll to avoid it (HT+2 if using fetal brain tissue), with failure resulting in -1 IQ times the margin of failure. Critical failure causes death within 1d days. LC3.

Statistics: Adds +1-2 to IQ [20-40]. The bulging forehead is an Unnatural Feature [-1]. If the brain tissue was a transplant from a person (as opposed to vat-grown tissue), there’s a 1-in-6 chance that a few “memories” of the original donor may survive. This is reflected by giving the recipient 1d points worth of the donor’s skills, plus the Flashbacks disadvantage.

Hotshotting (TL9)

Your daughter is having trouble with her mathematics program? She spends all her time in parties, with her boyfriend or living sensies? Perfectly understandable. These activities are more pleasurable to her, you see. But we at the Clinique Rouge can repair that for you. We will simply rewire her pleasure center to that part of her brain that governs mathematical and analytical activity. As long as your daughter is working on such problems, she will be excited, even aroused, as if she were with a lover, or eating chocolate. Sign this consent form, and our operatives will pick her up after school.

– Mme. Madeleine Rouge, the Clinique Rouge

*I not only think that we will
tamper with Mother Nature, I
think Mother wants us to.*

– Willard Gaylin

This is a specialized form of psychosurgery. You can get hotshots for almost anything: cooking, washing dishes, sports, fighting, even netrunning. They monitor you and find the deep structures laid down in the brain as you do things. The result's the ultimate in positive reinforcement. Existing reinforcers like sex or eating can be hotshotted to make them even more pleasurable, too. Heck, half the hookers on the strip are sex hotshots, so their pimps don't even have to buy 'em drugs. I've heard some korps will pay an employee a bonus if he agrees to the procedure. Yep, hotshotting makes you happy, eager, and more productive. It also makes you less human.

– Professor C. Eric Gideon, sci.bio.posthuman.rant

Operation: \$10,000 (one day recovery). LC3.

Statistics: The user is addicted to the endorphins produced in the brain when the hotshot activity is performed. To get his daily fix, he must spend at least two hours on the activity. He also becomes Single-Minded while doing so (+3 to skill if concentration is required). Missing the hotshot activity causes withdrawal. This is usually Compulsive Behavior, but other disadvantages may be appropriate: Bad Temper (if hotshot toward combat activity), Lecherousness (if a sex hotshot) or Workaholic (if the hotshot is related to his job). A hotshot may also have tertiary effects, at the GM's discretion. Within months of hotshotting, some personalities may eat less (losing any Fat or Overweight disadvantages and eventually becoming Skinny), neglect grooming (lowering Appearance) or talk of nothing but their hotshot activity (Odious Personal Habit).

Myelin Replacement (TL9)

This procedure replaces the fatty myelin sheath around neurons in the brain with an inert organic substitute. It provides immunity to the adverse neurological effects of breathing high-pressure gases, such as nitrogen narcosis and high-pressure nervous syndrome. This is a common biomod for divers and explorers of dense atmosphere worlds.

Operation: \$5,000 (one week recovery). LC4.

Statistics: Immunity to High-Pressure Gases [5]. 5 points.

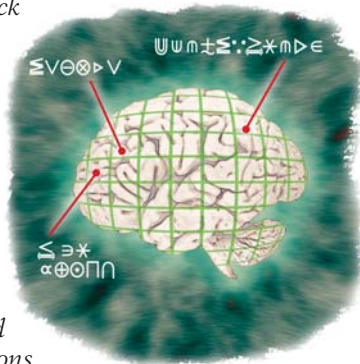
Psychosurgery ("Nanotherapy") (TL10)

Prison? Don't be a fool. In our country, we don't have political prisoners, just sick people who need to be cured. Now lie down here and we'll hook you up to the holographic brainscan. I'll ask you a series of questions. Won't talk? Don't worry. We can measure your neurological responses, and we'll know exactly which area of the brain to . . . Hold him, nurse! No, I'm not going to "cut" your brain. We once used laser or meson beam cauterization, but we've progressed far beyond that. I'll inject cellular microsurgions, which will operate on certain areas of your brain. Your fanatical obsessions will be cured for good. You'll become a normal, productive citizen. It's quite painless, and you won't feel a thing. Never, ever again.

– Dr. Tse Chang, transcript of psychosurgery session

This uses precisely focused HyMRI fields in conjunction with cellular microsurgions to selectively obliterate or connect tiny parts of the brain. Before psychosurgery can take place, successful persona mapping is required.

Operation: \$1,000 times point change (one day recovery), minimum \$10,000.



Statistics: Psychosurgery can destroy most mental advantages (e.g., Charisma or Intuition) and any mental disadvantage that is not self-imposed. It can give someone disadvantages that represent loss of a mental faculty (e.g., Amnesia or No Sense of Humor). It can cure a mental disadvantage that does not represent such a lack; thus, it could "cure" a Delusion but not Amnesia. A cure must be balanced by adding a new disadvantage representing a lack of faculties (or removing an existing advantage) whose point total is worth at least half as much as the disadvantage cured. Thus, you could burn Bad Temper (12) [-10] out of someone's brain, but leave him Confused (15) [-5].

Sleepless (TL10)

With a combination of neural modifications and encapsulated cell implants (p. 120), this procedure provides biochemical stimulants that reduce the desire for sleep as well as neurological changes allowing the brain to function effectively with less "down time."

Operation: \$40,000 (six weeks recovery). LC2.

Statistics: TL10 version: Less Sleep 4 [8]. TL11 version: Doesn't Sleep [20].

Wetware Sub-Personality (TL11)

People say I'm too careful, too honest, too soft. I admit I hate the sight of blood, and I'd rather err on the side of caution. So? It makes me human. But this was too important. The ELF had the Lucifer Plague, and there were only two days left before their deadline. So before I led my team in, I had the GRA labs give me a new wetware sub-persona: the Executioner.

– Tatiana Belenko, Genetic Regulatory Agency

A development of procedures to treat multiple personality disorder, this uses neurosurgical and RNA viral techniques to construct a sub-personality – or "inner daemon" – in the user's mind. Unlike a Split Personality, this is under his conscious control. Each daemon is, in effect, a *mental* Alternate Form, with its own set of attitudes and mannerisms, but each also shares the original's skills, memories and overall goals. Also, shifting to a new personality will fool psychological profilers, polygraphs, and brainscans that were designed to catch or predict the actions of an earlier personality.

Operation: \$4,000 times the point cost of the Alternate Form. Minimum cost is \$20,000 (one day recovery). LC4, or possibly lower if the daemon is dangerous or antisocial.

Statistics: Create each sub-persona as an Alternate Form (p. B83) in which the new racial template is the same as your existing racial template – *plus* a set of new mental advantages and mental disadvantages. You may also specify that the Alternate Form *negates* a number of mental disadvantages you already have; these cost the same as buying off the disadvantage, e.g., Negates Pacifism (Cannot Kill) costs 15 points.

Example: Tatiana Belenko is a human (so her racial template is worth no points). She has a number of mental disadvantages and quirks, including Careful, Honesty, and Squeamish. To remove those “flaws” she can activate her “Executioner” Inner Daemon Alternate Form, whose template consists of Combat Reflexes [15], Fearlessness +3 [6], Negated Careful [1], Negated Honesty (15) [5], Negated Squeamish (12) [10] and the disadvantages Bloodlust (-15) [-5], Callous [-5], No Sense of Humor [-10], for a total of 17 points. Her Alternate Form costs her 31 points (15 points + 90% of 17 points).

GENETIC SURGERY BIOMODS

Genetic surgery (p. 14) may be performed on a fetus, child, or adult to repair defective genes or insert new ones. Genetic surgery cannot produce gross anatomical changes, but it may have subtle effects. For instance, it may alter the way a certain hormone is produced, with a marked effect on the recipient’s behavior. At TL8, genetic surgery is usually used to replace defective or missing DNA sequences, repairing genes so that they can produce whatever missing enzymes or proteins caused a genetic disease. At TL9+, non-therapeutic genetic surgery techniques may be developed.

One technique used is the cell transplant. Cells are removed from the appropriate organ of the patient (e.g., bone marrow cells, if trying to modify how blood is produced). Gengineering techniques – usually tailored RNA viruses – are then used to introduce new genes into them, as described above. These altered cells are reintroduced into the patient, where they will hopefully thrive and replicate.

At TL8, the subject is given drugs to help his body accept the new cells (see *Rejection and Immunosuppression*, p. 141, for the effects). At TL9+, cell implants are encapsulated in a specialized membrane that masks them from the immune system until they have become safely integrated into the body, while still allowing proteins to pass through – the advantage being that no immunosuppression treatments are needed. In some cases, the controlled release of cells is orchestrated by biochips (p. 109).

In some cases, removing cells may not be necessary, and a modified RNA virus can simply be injected into the patient. This depends on how specific a change needs to be made, and how confident the genetic surgeons are in their ability to target the specific cells they want to alter.

Enhancements or therapies may be made hereditary if the modifications take the form of implanted artificial chromosomes (see p. 12). This is not difficult (it was achieved with mice in 1999). Such chromosomes can be passed on to offspring, but may cause birth defects unless both parents possess the extra chromosome. The problem is that as soon as any descendants breed with baseline individuals, the new chromosomes risk causing genetic defects. If the carrier of a genetic disease is treated by adding a new chromosome to mitigate or eliminate its effects, rather than by modifying the genes that cause the disease itself, that carrier may be unable to have children naturally without this risk.

Genetic surgery processes have a listed cost and time. The required time is spent in a hospital facility. During this period, genetic surgeons are taking cell samples, running tests, performing the actual RNA injections or cell transplants (often a series of them), waiting for modified cells to replicate, observing the results, and taking any necessary corrective measures. The patient will be confined to bed (often with diagnostic sensors attached), but conscious most of the time.

So what can you do with genetic surgery? Some of the many possible applications are described below.

Gene Therapy (TL8)

If someone is born with faulty or missing genes, his body may lack the capability to make enzymes or other proteins that it needs. Depending on which genes are missing, this deficiency may cause a hereditary metabolic disease, such as cystic fibrosis or hemophilia. There are almost 3,000 such genetic disorders.

In fact, most humans and other animals carry a few defective genes. However, humans and similar higher animals have two duplicate sets of almost every chromosome and the genes they carry, one from each parent. (The exception in humans is the male “Y” chromosome; as a result, men are more vulnerable to “sex-linked” disorders.) Even so, genetic disorders affect as much as 10% of the human population, although the effects of some do not manifest until quite late in life.

Until the late 20th century (TL8), the symptoms of genetic disorders could be treated, but the disorders themselves could not be cured. Thanks to genetic surgery, it becomes possible to remove the root cause of a genetic disease using cell transplants (above). Even so, a basic limitation on gene therapy is the need to know exactly which genes code for which enzymes or proteins, and how they relate to the body’s functioning. While considerable progress has been made in cases involving a single gene, multiple genetic interactions are often involved. As human genome mapping progresses (through TL8), more complex genetic therapy procedures will become possible.

Operation: \$1,000 per point of disadvantage cured (two weeks recovery), e.g., a hereditary disadvantage worth -10 points would cost \$10,000 and take two weeks to cure. LC3.

Statistics: Gene therapy can remove certain disadvantages, if they result from hereditary conditions. By mid-TL8, this includes some forms of Hemophilia, Neurological Disorder, Susceptible to Disease, and Terminally Ill. In addition, if applied to a fetus or baby, early gene therapy may be able to prevent any hereditary problems that cause disadvantages like Gigantism, Bad Sight, Colorblindness, Dwarfism, Dyslexia, and No Sense of Smell/Taste. At some point during TL9, gene therapy may be able to cure inherited learning or behavioral disorders that are linked to particular genes. Where these disadvantages have a genetic cause, they can be removed: disadvantages such as Cannot Learn, Chronic Depression, Gluttony, Manic-Depressive, Non-Iconographic, Paranoia, and Short Attention Span might be especially susceptible.

Emotional Regulator (TL9)

Get into too many bar fights? Suffer from poor impulse control? Then you're the kind of personality that can use a Jen-Goku Rage Damper! Unlike cruder systems, this bio-implant doesn't prevent you from feeling emotions. Instead, this cluster of biochip-regulated cells is capable of sensing hormones and follows them up with tailored enzymes that cut them off at the pass.

– Jen-Goku Corporation advertisement

Joji 'Madboy' Saiko got one of these cell transplants after his last assault conviction. Was it a court order? Not this time. The Oyabun's decision. The Russki-Yakuza don't admire a man with no self-control. Besides, Jo had run out of little fingers.

– Eden Harrier, Harrier Import/Exports

Operation: \$4,000 (four days recovery, although it takes effect within one day). LC3.

Statistics: Hormonal dampers can justify increasing the self-control number or buying off Bad Temper, Berserk, or Lecherousness. The point cost is equal to the cost of increasing the self-control number or buying off the disadvantage.

Bone Marrow Upgrades (TL9)

When I completed boot camp, the fun began. After they finished growing the new muscles, the doctors implanted modified cells into my bone marrow, altering it to manufacture erythrocytes with boosted oxygen-transport capacity. Of course, then they had to do a bit of tinkering with my gastrointestinal tract to make sure I got enough iron from our diet to keep my bone marrow happy . . .

– Captain (ret). Dana Martello, Marine Force Recon

Bone marrow cells may be modified to produce engineered blood cells with improved capabilities. Two main procedures are available:

Enhanced Erythrocytes: The bone marrow is modified so that the red blood cells it produces possess hemoglobin with greater oxygen transport capacity.

Enhanced Thrombocytes: Blood platelets are redesigned for superior wound-clotting ability.

Enhanced White Blood Cells: Modified to produce enhanced versions of disease-fighting cells.

Macromarrow: Modified to produce all three upgrades.

In each procedure, care is taken to ensure that the modified marrow is “smart” enough to adjust cell production so that complications like excessive clotting and other disorders do not occur.

Operation: Enhanced erythrocytes are \$12,000; enhanced thrombocytes are \$30,000; enhanced white blood cells are \$10,000. Macromarrow is \$52,000; all require one week recovery. LC3.

Statistics: Enhanced erythrocytes give +2 FP [6]. Enhanced thrombocytes give Very Rapid Healing [15]. Enhanced white blood cells give Resistant to Disease (+8) [5]. Macromarrow combines all these traits; 26 points.

Metabolic Reset (TL9)

Back in prehistoric times, people used liposuction and surgery to remove fat, or took pills to suppress their appetites. No, really! And afterwards, they often went right back and regained what they lost. Today, we know what genes make your body want to be a certain weight, and how to make RNA injections to change them.

– Noriko Hayakawa, “Fun Ways to Change Weight,” *Cyberia Beat*

Operation: \$4,000. The reset operation itself requires four days recovery, but losing (or gaining) weight takes the time discussed below. LC4.

Statistics: Build-related disadvantages can be altered up or down one or more steps: Very Fat [-5] to Fat [-3], to Overweight [-1], to normal, to Skinny [-5] or vice versa. Adjust weight in pounds accordingly. Lose or gain one step every three weeks until the chosen stage is reached. Reduce it to two weeks if the subject works with the virus via diet and exercise (or lack thereof); double the time if he tries to fight it!

Cancer Elimination (TL9)

Resetting the genes in cancer cells can make them behave like normal cells, with controlled division and eventually cell death. This means a tumor will naturally be destroyed and safely absorbed by the body.

Operation: \$50,000 (one week recovery). LC4.

Statistics: Cures cancer (which may be represented by Terminally Ill). See Terminally Ill (p. B158) for the consequences of receiving a “miracle cure.”

Radiation Damage Repair (TL9)

Radiation damage to cells can result in tumors or widespread failure of bodily systems. Resetting the cells effectively heals the damage to the DNA caused by radiation. This procedure also incidentally destroys cancerous tumors. The process is longer and more complicated than cancer elimination, as many more cells are affected and reconstructing the original DNA requires comparative lab work rather than simply taking a single cell sample.

Operation: \$80,000 (two weeks recovery). LC4.

Statistics: Resets accumulated radiation dose to 0 rads. At the GM's option, 1d rads may remain that cannot be healed.

Mutation Repair (TL9)

When cells divide, the DNA replication process reduces the length of the chromosome telomeres and can introduce random mutations into the daughter cells. Over time, these changes build up and lead to cellular senescence (see *The Genetics of Aging*, p. 183). Comparing the divergent genetic sequences of several cells will allow the patient's original genome to be calculated, and gene therapy to be targeted to reverse any mutations, as well as attaching new telomere sequences. This is part of the necessary treatment to fully

reverse the effects of aging, but not in itself a complete “potion of youth” – it does not restore neural functions.

Operation: \$100,000 (two weeks recovery). LC4.

Statistics: Resets an adult patient’s cellular age to the age of maturity (e.g., 18 for a human). This immediately restores any IQ or HT points lost to aging rolls (p. B444). ST and DX lost to aging may also be restored; this requires four weeks of exercise and physiotherapy (p. 132) per point regained. Secondary characteristics, skills, and techniques based on the attribute recover as well, with the exception of IQ-based skills and techniques. This represents irreversible loss of experience and memory, which simple structural repairs can not erase. Adjust point cost accordingly.

Corrective Gamete Production (TL9)

Prospective parents with genetic defects may be unwilling to have children, knowing that they will inherit those genes and potentially debilitating conditions. Genetic surgery on the gonads can make sure the gametes carry a normal copy of the defective gene instead. This is straightforward on males, since sperm are continually produced by the testicles and can inherit the corrected gene. For females, existing ova in the ovaries must be treated or destroyed, increasing cost.

Operation: For a male: \$25,000; for females, \$35,000; (four days recovery). LC4.

Statistics: Any future children will not inherit the corrected genetic defects.

Genetic Vaccination (TL9)

Some people have genes that make them naturally immune or resistant to some diseases. When introduced to other people, these genes provide them with the same protection. At TL10, it will also be possible to design new genes to provide immunity to specific diseases. A complete program of genetic vaccination is an alternative to nanosymbiont panimmunity (p. 164), and may be available earlier depending on relative technological development.

Operation: \$7,500 (four days recovery). LC4.

Statistics: Immune to (Specific Disease) [1]. This is a 1-point perk for a group of closely-related diseases, e.g., “known flu viruses” or “hemorrhagic fevers.” A *single* disease may be a 0-point feature instead of a perk.

Angiogenesis (TL9)

This is the growth of new blood vessels, used to strengthen blood supply to muscles – particularly the heart – either to prevent or recover from a heart attack. Reactivating the genes that cause blood vessels to grow results in better oxygenation of the muscles.

Operation: \$25,000 (four days recovery). LC4.

Statistics: Can cure a patient Terminally Ill with heart disease. See Terminally Ill (p. B158) for the consequences of receiving a “miracle cure.” Can also give a healthy patient Fit [5], or improve Fit to Very Fit [15]. This improvement can only occur once.

The Genetics of Aging

Genetic surgery may be used to deal with aging. Among other factors that cause an organism to age, there are at least two distinct genetic causes.

DNA Damage

DNA can be damaged by radiation, chemicals, or errors introduced during replication. Cells contain mechanisms to detect and repair this damage, but over time the errors occur faster than they can be fixed. Eventually, the DNA can become so damaged that it no longer functions properly. Cells that inherit such DNA become senescent (unable to divide), and eventually die without producing new cells. If the senescence mechanism breaks, the cells grow into a cancer. Degradation of DNA in the mitochondria is also suspected to be a significant cause of aging effects.

Gene therapy could be used to improve the correction of these errors, postponing cell death and some of the effects of old age.

Telomere Length

Telomeres are repetitive DNA sequences up to 20,000 base pairs long on the ends of chromosomes. They

serve as caps to prevent the loss of genetic data during DNA replication, and are necessary because every time a DNA strand is copied, the DNA polymerase reaction stops a few hundred bases before reaching the ends. Without telomeres to pad the protein-encoding bases, meaningful data would be lost.

Over time, the telomere chain shortens, and may eventually vanish. At this point, the cell detects DNA damage and becomes senescent. Since it cannot repair this damage, it will eventually undergo apoptosis. As an organism grows older, more and more cells throughout its body suffer this fate, organs begin to fail at an increasing rate, and the organism eventually succumbs to age.

Preventing or reversing the loss of telomeres is likely to be an important part of staving off the effects of old age. This could be achieved with genetic surgery or proteus viruses, to regulate the enzyme telomerase in adult cells. Telomerase exists naturally in gametes, and acts there to extend the telomere chain, ensuring offspring inherit DNA with sufficient telomeres to live a full life. In adult cells, it needs to be produced and then controlled carefully to avoid producing immortal cancerous cells!

Alternate Gamete Production (TL10)

Not content with correcting possible genetic defects (see *Corrective Gamete Production*, p. 183), some parents want to give birth to designer genetic upgrades. This treatment modifies the gametes to produce genetically upgraded sperm or ova, allowing them to produce upgraded children. At TL11 gametes can produce sperm or ova of different *species*: parahumans, nonhuman animals, or even more bizarre options.

Operation: For males, \$25,000; for females \$35,000; in either case, add the cost of genetic engineering the species model. At double cost, males can be modified to produce two different species. one week recovery. LC4.

Statistics: Any future children will inherit the new designer genome.

Body Part Regrowth (TL10)

By reactivating the growth genes for a missing body part, gene therapists encourage the regrowth of the part directly on the body, without transplant surgery. As with tissue engineering, this is easiest for cosmetic tissue such as ears and noses (TL10), followed by small parts like digits and genitals (late TL10), and ultimately entire limbs (TL11). Small parts take four weeks to grow, limbs up to eight months. After the first week this time does not need to be spent in a medical facility; regular checkups 2-3 times a week suffice.

Operation: For a small part: \$50,000. For a limb: \$100,000. Recovery time as described above. LC4.

Statistics: Regenerates the missing body part. This will often remove a physical disadvantage.

PROTEUS NANOVIRUS

Don't want to spend a couple of weeks making a pilgrimage to some super-clinic to undergo genetic surgery? At TL10, proteus viruses become available. These "para-viruses" allow a form of genetic surgery through a single injection, with no fuss, lab tests or surgical cell transplants. On the other hand, because the virus hasn't been specially tailored, it may not always work!

Proteus nanoviruses, which are also used in germline engineering at TL10+, are specialized bio-nanomachines, capable of being programmed to perform complex tasks. This includes rapidly replicating throughout the body, replacing entire cell nuclei, completely resequencing DNA and stimulating the rapid growth of newly-modified cells.

An almost infinite variety of proteus viruses exists. At TL10-11, a proteus virus can perform relatively "soft" changes, whose effects will be seen in altered skin cells or blood cells, modified neurochemistry and so on. At TL12, an extremely sophisticated kind of proteus virus, called a

metamorphosis virus, can produce actual changes in the body's anatomy.

A proteus nanovirus takes 1d×5 minutes to multiply. There is a chance that the recipient's immune system may fight it off. This occurs on a HT-6 roll. If the roll is successful, nothing happens. Contact with the bodily fluids of someone who is being altered by a proteus virus may also cause infection (HT-3 to avoid). In both cases, bonuses for Resistant to Disease or Resistant to Metabolic Hazards apply. If the HT roll fails, the virus begins resequencing the subject's DNA and altering his body.

Each proteus virus has a cost and a time required. This time is the number of days it takes the virus to replicate throughout the body and finish its work; there is no "operation" – one merely takes a pill or receives an injection. Unless using a metamorphosis virus, no rest is required – the nanovirus performs the work quietly and without fuss.



Various customized forms of proteus virus are also possible, such as a nanovirus that spreads like a plague or which is specifically designed to affect a particular person (which means that his immune system has less chance to resist it). See *Proteus Virus Options*, p. 190.

GROWING NANOVIRUS

A proteus virus designed to produce a particular biomod (or a set of nano-symbionts – see p. 164) can be “home grown” rather than purchased. This requires a genetics lab (p. 16) of a TL equal to or greater than that of the biomod or symbiont the nano are being designed to produce.

The proteus virus will cost about 50% of the listed cost if the characters are paying for commercial blueprints, or 25% of the cost if they are reverse-engineering someone else’s virus. It takes about one hour per \$1,000 the nano normally costs.

This requires a successful skill roll against the lowest of Biology (Biochemistry), Computer Programming and Bioengineering (Genetic Engineering) skills, although members of a team can contribute one skill each. Apply any modifiers for lab quality, plus -1 if the nanovirus would cost \$1,000, -2 if \$2,000, -3 if \$4,000, -4 if \$8,000 and so on. Failing the roll to build a proteus virus just wastes time; a critical failure produces a bad batch that seems good, but which will have dangerous or unusual side effects (GM’s option).

TYPES OF PROTEUS VIRUS

Birth-Control Virus (TL10)

If the Third World can't be bothered to control their own fertility, then I suppose we'll have to do it for them. Let's see: birth control implants, vasectomies, pills . . . but they're all so crude and time-consuming, and then there's that problem of enforcement. How about isoimmunization, in which the mother's immune system attacks any fetuses, triggered after the onset of her first pregnancy? Spontaneous and usually undetectable early abortions; she'd probably never notice. One woman, one child. As for mass post-natal dissemination, a contagious proteus virus should do the job.

– Dr. Tse Chang, address to the Genetic Planning Council

Availability: \$500 (and two days). LC3.

Statistics: Sterile (after one child) [0].

Cosmetic Virus (TL10)

Bored with your current hair, skin or eye color? Need to alter your appearance in a hurry, or fix pattern baldness? Try McCoy AestheTech's viral cosmetics, and let RNA resequence your genes. Permanent, safe and undetectable, but reversible with a second dose! Each treatment produces a single, specific change. Also available: eyelash and fingernail modifications – your choice of length and color! Now available in handy tablet or ointment form – see your pharmacist today!

– McCoy AestheTech promotion

Availability: \$200 (and one day) for a batch of virus that can produce a single cosmetic change; e.g., turn eyes green or hair metallic pink. \$1,000 to alter fingerprints or retina patterns. Multiply the cost and time by the number of features it produces. The occasional bad batch of viral dye may cause a piebald look, hair to fall out, and other minor nuisances. LC4.

Statistics: The effects of a cosmetic virus are usually 0-point features or Distinctive Features worth -1 point. Cosmetic virus can also alter fingerprints or retina patterns (making these forms of identification less useful at TL10+). At TL11, exotic colors are also possible; e.g., blue skin, metallic nails, or green hair. If unusual, these may count as Unnatural Features (-1 or more points). A cosmetic virus can also produce the same effects as a hair graft (p. 171).

Genetic Surgery Nanovirus (TL10)

Any of the effects that can be produced by regular TL8-9 genetic surgery (pp. 181-183), such as gene therapy or metabolic reset, can be produced much more rapidly via a proteus nanovirus.

Availability: Cost is 50% of TL9 genetic surgery procedures or 25% of TL8 genetic surgery procedures. The virus engineers the changes in a number of days equal to twice the number of weeks of recovery required for actual genetic surgery. For example, a bone marrow upgrade that took three weeks would take only six days if using a nanovirus.

Statistics: Produces the same effects as regular genetic surgery.

High-Biotech Fur (TL10)

Colonial Genetics' ShonTec/Mars division announces the arrival of viral-grown high-biotech fur, the ultimate in stylish thermoregulation! Features fully-retractable, subdermal, self-regenerating pseudohairs. Choose no or short fur for indoors or summer, but lengthen it as night begins to fall, then retract it as temperatures return to normal. Why bother with bulky thermosuits or outmoded clothing? Perfect for outdoor conditions, and presently available in numerous attractive patterns, including tabby, mink, panda, leopard, and tiger!

– Colonial Genetics press release

My sources at ShonTec say they originally designed this feature as a post-natal upgrade for the 10th Mountain Division's bioroids, so it's probably pretty reliable, and provides some thermal camouflage as well. Oddly enough, it's also available on their second-generation pleasure 'morphs. Have you seen those ads? 'Stay warm at night: Take a Kitsune to bed.'

– Captain (ret.) Dana Martello, Marine Force Recon

Availability: \$30,000 (and two weeks), LC4. Side-effects of the high-biotech fur transformation are the same as for other skin transformations.

Statistics: Fur (Switchable, +10%) [2] plus Chameleon (Infravision) 1 [5] and Temperature Tolerance 1 [1]. 8 points.

Methuselah Program (TL10)

Methuselah Inc. is pleased to offer its new life-extension process. A specialized proteus nanovirus injection can adjust or even reset the biological clock on your cells, modifying their ability to survive repeated replications. In partnership with Biotech Euphrates, our Forever Project staff is now working on nucleotide sequences that will hard-wire these modifications into unborn generations.

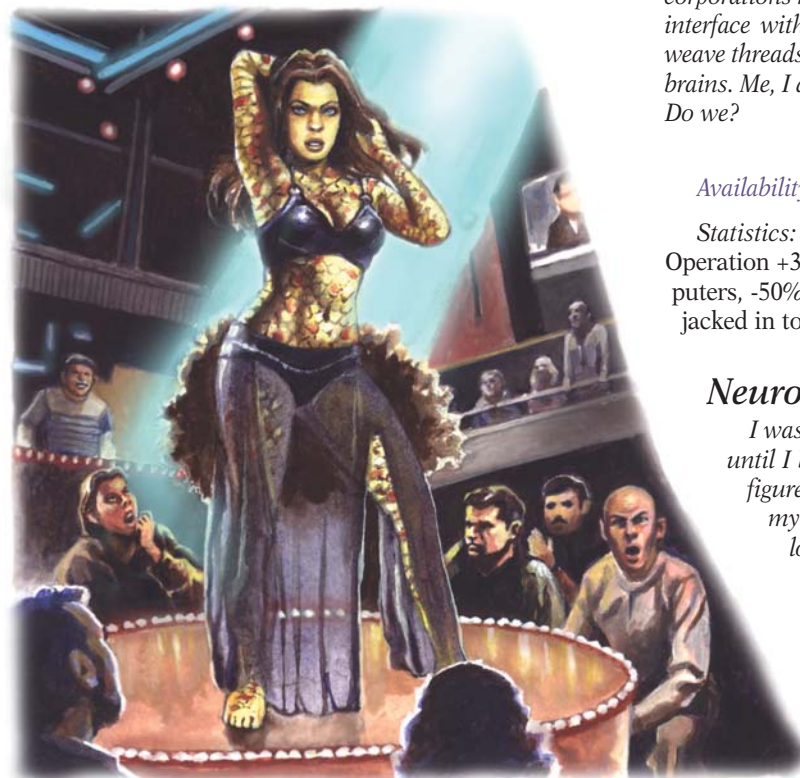
– Methuselah Inc. press release

Their nanovirus is more expensive than those mythical so-called immortality drugs you see in the sensies, and there's none of that nonsense about super-accelerated aging if you stop taking it. Of course, some of the companies that build bioroids use a similar process to build in a biological suicide clock to ensure good turnaround of new product. As soon as they start to get old, zap! Cells start to die, resulting in massive, multiple-organ cell failure, and they're dead in a few weeks. Bioroids get a little morbid about this, so few companies actually tell them their exact termination date.

– Dr. Sayyid Iqbal, interviewed on *Cyberia Beat*

Availability: \$100,000 (and four weeks). LC4.

Statistics: This halts aging (no aging rolls, and no growth if still growing) for a year after undergoing the process. It can be repeated. A perversion of this process can also be used to artificially shorten a lifespan, giving someone the disadvantage Self-Destruct, set to trigger after a predetermined point in their future. At TL12, the program can not only halt aging but reverse it to any given age. Have a growth tank or surrogate mother handy if de-aging to a fetal or embryonic stage.



Nerve Boosters (TL10)

This replaces neural myelin sheaths with a synthetic biopolymer designed to speed up nerve impulses.

Availability: \$125,000 (and two weeks). LC2.

Statistics: Basic Speed+1.00 [20]. 20 points.

Skin Transformation Virus (TL10)

So you're dating Lilith, huh? Isn't she that exotic dancer transform at Club Naga – the brunette with the red and gold scales?

– Streethawk, alt.bio.upgrade.samurai

This proteus virus alters skin cells. It can change skin color or texture, or even give someone fur or scales. Undergoing a skin transformation process is extremely uncomfortable. For the duration of the process, the subject will be at -2 DX and IQ (which affects skills) due to the constant itching and irritation as the fur or scales grow.

Availability: Cost is (TL-8) × \$20,000, and it takes (TL-8) weeks for the skin transformation to take effect, where “TL” is the minimum TL for engineering that advantage. Thus, Fur (TL9) would take one week to grow and cost \$20,000.

Statistics: Select Distinctive or Unnatural Features, or any one of the traits listed under Other Transgenic Traits on the Cosmetic and Minor Transgenic Modifications table (p. 45).

Biotronic Virus (TL11)

Protein-based biotronic circuitry – biochips – are being used in more and more computers. Rumor has it that a few corporations have been creating living superhackers who can interface with these things directly, using nanoviruses that weave threads of DNA-based biotronic circuitry through their brains. Me, I don't believe it. We don't have the technology yet. Do we?

– Streethawk, alt.bio.upgrade.samurai

Availability: \$27,000 (and four days). LC2.

Statistics: Accessory (Interface Jack) [1]; Computer Operation +3 (Accessibility, Only when “jacked in” to computers, -50%) [3]; Enhanced Time Sense (Aspected, when jacked in to computers, -50%) [23]. 27 points.

Neurovirus (TL11)

I was having trouble getting on with my comp study, until I bought a Chinju-Gentek neurovirus and reconfigured my brain. Now I'm earning 20K a month in my summer job training AIs! Jump on the biologic bus with Chinju-Gentek, and take a ride to success.

– Chinju-Gentek commercial

Last year, Evolutionary Liberation Front terrorists hacked into the mainframe controlling the labeling on 2,000 vials of Chinju-Gentek RNA virus. 127 people who hoped to become musicians,

many of them children, were instead transformed into mathematical geniuses, and 1,873 would-be Einsteins were left to sing the blues. The relationship between mathematical and musical talent was close enough that the quality-assurance software missed it. Bio-terrorism aside, this is obviously another example of the need for tighter controls in the civilian RNA-nanovirus sector.

– Tatiana Belenko, Genetic Regulatory Agency

A “neurovirus” is a specialized form of proteus virus, optimized for performing subtle changes in personality and mental structure by altering the connections between

neurons and adjusting the neurochemical balance of the brain and body.

Availability: \$10,000 × (TL-8) per advantage or disadvantage, where “TL” is the minimum TL required for that genetic modification. Requires 12 hours to take effect. LC3.

Statistics: A neurovirus can grant any of the traits described under *Brain Modifications* (p. 42), *Behavioral Modifications* (p. 43), and *Sleep-State Modifications* (p. 44). It can also duplicate effects of Psychosurgery (p. 180) or Hotshotting (p. 179). Where they conflict, more recent neuroviruses overwrite previous ones.

METAMORPHOSIS VIRUS

Captain's Log, 18-11-2447. It's been six days since our landing party was exposed to the nanovirus while exploring the ruined alien city. All remain in comas, within the cocoons their bodies have somehow secreted. Sonograms taken by Doctor Pretorious show significant anatomical changes, of which the most advanced are in Officer Melinda O'Reilly. Her legs have fused together into a tail, and wing buds are forming on her shoulder blades. I can no longer deny it; she is beginning to resemble the creatures depicted in the wall paintings we found. In an earlier log entry, I expressed my sadness at finding the aliens long dead, and being denied a chance at first contact. It appears I spoke too soon.

– Captain Zeke Morrigan, free trader Antares

Instead of simply reconstructing a body in the same shape as before, what about completely changing it, as a caterpillar turns into a butterfly?

A metamorphosis nanovirus is a highly advanced proteus virus. Like a proteus virus, it can resequence DNA, switch genes on or off, and take over cell nuclei, replacing entire genomes.

Unlike more primitive proteus viruses, it can also actively alter the gross structure of existing cells, using physical or chemical means to simultaneously herd cells around the body, kill off existing ones, and force new ones to grow. This allows it to break down or build up connective tissue and bone. Using a metamorphosis virus, new organs can be grown within the body, existing organs and limbs can be transformed, and new limbs and appendages can be grown. A metamorphosis can even reduce body mass (leaving a gooey puddle of extra material after the change).

In game terms, a metamorphosis virus effectively allows the type of human genetic engineering described in Chapter 2 to be performed on a living person rather than an egg cell. The virus is described as adding or removing a specific set of attribute modifiers, advantages, disadvantages and features – a “metamorphosis template.” Select from those modifications that are possible via germline engineering (Chapter 2) or biomods in this chapter. The time and cost of a metamorphosis virus depend on its complexity:

Time: the duration of the metamorphosis process is typically (TL-8) weeks. That TL is not the current TL, but

rather the minimum TL required to perform the changes via ordinary genetic engineering (see Chapter 2) or other biomods. If the changes are described as radical species modifications (p. 42) double the time required.

Example: A “cat-girl nanovirus” might produce a metamorphosis template with DX+2; Acute Hearing, Appearance (Beautiful), Fur, Perfect Balance, a male-to-female full sex change, Sharp Claws, Sharp Teeth, and transgenic cat features. The highest TL trait is DX+2 (requiring TL10) and no modifications are radical, so the process will take 10-8 = two weeks.

Cost: Calculate time as above, then multiply the number of weeks by \$50,000 to get the cost. Thus, a virus that requires two weeks would cost \$100,000.

TL: The basic TL of a metamorphosis virus is TL12, but some options may allow lower-TL viruses – see *Proteus Virus Options* (p. 190).

A “dose” of the virus can be delivered by injection (including drugged darts or needles) or oral tablet. The rules for administration, HT rolls to resist, and accidental infection used for other proteus viruses (p. 184) also apply to a metamorphosis virus. Any of the proteus virus options (p. 190) can also be applied to it, altering the final cost, time and TL.

The Transformation

The nanovirus takes the indicated number of weeks to transform its subject. While the metamorphosis is occurring, the patient may experience “nanofever” – itching, sudden sweats, hunger pangs or other odd sensations. Often, he sees odd shapes and patterns forming on his skin, or suddenly feels hungry, thirsty, hot or cold. This is distracting; see the Nano-Fever quirk (p. 212).

If the change is a radical modification (see Chapter 2), or is, in the GM's view, any process that induces significant alterations in body shape (including extra limbs) or mass, the subject will fall into a coma after 1d days. This lasts for the remainder of the transformation. If this happens, the nanovirus will often secrete a protective chrysalis from the patient's skin pores or other orifices, cocooning his body. When the transformation is complete, he will wake up and break out of it.

A metamorphosis nanovirus is not always safe. Roll vs. the user's HT each week after the first. Failure means some sort of accidental defect occurs. Keep track of the number of failures. Each one inflicts -1d points worth of unintended disadvantages on the subject (GM's option; see *Unintended Disadvantages*, p. 61, for suitable possibilities); these can also be taken as reductions in the value of attributes or advantages, if desired. For example, failing three HT rolls would inflict -3d points of disadvantages. Any critical failure means the subject dies, often very messily: the patient may transform into a mass of cancer cells or be cooked in his own blood by excess heat from over-worked nanomachines. There are, however, safer ways to transform – see *Clinical Metamorphosis* (p. 190).

Cybernetics or biomod implants that would be incompatible with the new form are excreted from the body or result in death or injury to the subject – details are up to the GM.

Types of Transformation

Practically any transformation is possible with the aid of a metamorphosis nanovirus – for instance, it could turn a human into any of the variant races described in Chapter 2, make him into an alien, transform an alien into a human (either involves replacing one racial template for another), or give someone any of the biomod surgeries or transplants in this chapter. With complex enough nanotechnology, living beings can be completely disassembled – and put back together in working order!

Several examples of complex anatomical modifications and transformations are described that might be produced through metamorphosis virus.

Aquaskin (TL12)

Who needs a breather, wetsuit, or clumsy artificial gill? Glide like a dolphin through the blue infinity while clad in GenTec Pacifica's Aquaskin, a smooth, high-biotech epidermal graft derived from marine mammal DNA. The skin is modified to selectively absorb and filter oxygen into the blood, bypassing the lungs and acting as a full-body gill. Available in several elegant shades of gray, brown and black.

– GenTec Pacifica promotion

Availability: \$600,000 (and six weeks). LC4.

Statistics: Amphibious [10], Doesn't Breathe (Gills, -50%) [10], and Unnatural Features 1 [-1]. 19 points.

Chloramorphosis (TL12)

The green-skinned woman lay naked in the forest clearing, as if basking in the warm, noonday sun. I walked over and knelt beside her. If she was breathing, I couldn't tell. An ant walked across her face. She didn't react. I looked closer. Fine tendrils connected her body to the soil. She was rooting.

– Derin Skay, *Life Among the Dryads*

Availability: \$800,000 (and eight weeks). LC4.

Statistics: Deep Sleeper [1]; Doesn't Breathe (Temporary Disadvantage, No Legs (Sessile), -50%) [10]; Doesn't Eat or

Drink [10]; Dependency (Lie in fertile soil and sunbathe for at least eight hours; very common, daily) [-15]; Unnatural Features 1 (Green skin) 1 [-1]. 5 points.

Merging Virus (TL12)

"Do you, Rashid, and you, Zoë, consent to become one forever, to share one body, one mind, and possibly (though with no guarantees) one soul?"

"We do."

"Then I pronounce you One Being."

– Medical biocomputer Raphael-3000

This nanovirus must be applied to two or more separate individuals, human or otherwise, who are in physical contact and remain so for the duration of the process. For this reason, the accelerated nanovirus option (p. 190) is usually required. It merges them into a single body. The general intention must be specified when the metamorphosis virus is designed, but the exact result is usually somewhat unpredictable – it is up to the GM to decide how the merged entity's traits turn out. Any extra biomass or nonliving material (implants, clothes, etc.) are left behind as a gooey puddle.

Availability: \$800,000 (and eight weeks). For double cost, the process can be reversed.

Statistics: The new body may be identical to one of the donors, or include traits from more than one. Similarly, the resulting mind may possess the mind of only one of its original donors – treat as a brain transplant (p. 143) – all minds separately (gain levels of Compartmentalized Mind), a Split Personality, or a new single consciousness (it's up to the GM what traits are shared).

Necromorphosis (TL12)

They can still think. Eat. Drink. Breathe. Speak. Fight. Make love. But they call it a resurrection? It's a cruel joke. Have you looked at the diagnostic scans? Most of their organs are redundant. They barely remember their own names. They can't reproduce, and their bodies would fall apart if they weren't being constantly regenerated. Face it, Kathy, they're all dead! The only reason the flesh is warm is the heat generated by the swarms of nano inside them. And the smell . . .

A corpse with a reasonably intact brain that has been dead less than a day (or any length of time, if preserved via appropriate technology) can be resurrected using this transformation process. Sufficient memory is recovered to permit a partial restoration of consciousness. It brings them to life as a form of bioroid.

Unlike most metamorphosis viruses, this process is performed on a dead body. All normal rolls (including HT rolls) should still be made, however, if not using a clinical metamorphosis process – use HT 12 instead of the body's HT.

Availability: \$800,000 (and eight weeks). LC2.

Statistics: Bad Smell [-10]; Bioroid [-5]; Injury Tolerance (Unliving) [20]; IQ-1 [-20]; Longevity [2]; Partial Amnesia [-10]; Resistant to Metabolic Hazards +8 [15]; Sterile [0]. -8 points. For an alternative resurrection, see Reanimation Nano (p. 163).



Skeletal Strengthening (TL12)

Tisephone Logos, if you look closely at the image produced by my T-ray scanner, you will clearly see the changes the nanosurgeons have produced in your body. Note the semi-feline skeletal structure and extra muscle attachment flanges, while the dark shading is the denser bone tissue. None of this will be visible unless your skeleton is physically examined or scanned, although you will notice a minor gain in mass due to the heavier structural tissues you now possess.

– Medical biocomputer Raphael-3000

Availability: \$300,000 (and three weeks). LC4.

Statistics: HP+5 [10]; Lifting ST+5 [15]. 25 points. Skeletal strengthening also increases actual body weight by 10% without increasing height or apparent bulk. The redesigned bone structure will also be noticeable on medical scanners, and by any doctor trying to set a broken bone. If someone has skeletal strengthening, then muscle reinforcement or muscle grafting can add double the usual amount of ST for their TL, since the biomod skeleton can support it. The effects are cumulative with bone stimulation (p. 155).

Smart Cardiovascular Net (TL12)

Next, the viral nanites construct smart, switchable arterial bypass networks to allow blood flow to be rapidly shut off to traumatized areas. As high-gravity accelerations cause blackouts when the blood pools in the lower body rather than reaching the brain, the arteries feeding the lower body have been redesigned to react to g-forces by pinching off blood flow to legs and abdomen while enhancing it to the brain. The same modification also produces faster recovery from unconsciousness.

– from FM-592, Military Biomedical Enhancement

This is one thing those Marine jar-heads don't get. When I joined the Navy, I knew I'd get a neural jack – but I never figured becoming top gun would mean being dumped in a vat of nanosurgeons, dismantled and rebuilt. There's rumors that the spacekorps are working on bioroids born with these things.

– Lt. Majid Asad, VF-17, USSN

Availability: \$300,000 (and three weeks). LC4.

Statistics: Resistant to Acceleration (+8) [2]; Recovery [10]. 12 points.

Solarskin (TL12)

Freedom is the gift our Icarus-type symbiotic solarskin gives when you merge with Avatar Klusterkorp's engineered ecosuit to become a true spacedapted form. Features closed-ecosystem waste-product recycling, solar wings and vacuum-sealed skin designed for protection against ultraviolet radiation.

– Avatar Klusterkorp advertisement

Naked, space-black dolls with enormous pseudo-wings, drifting through the vacuum on light pressure like dark angels: Avatar's latest vision of humanity, I guess. At least they designed it so you can fold up your solar sail when you don't need it – makes a hump on your back.

– Copernicus Jones, *Beyond Pluto*

This modification adapts the subject to live and maneuver in space. With his solar sail unfolded, he can accelerate at up to 0.01 G indefinitely, although he can never exceed the speed of the solar wind (about 900,000 mph at 1 AU from the sun).

Availability: \$800,000 (and eight weeks). LC4.

Statistics: Space Move -9 [-18]; 3D Spatial Sense [10]; Enhanced Move 19 (Space; Accessibility, Only if exposed to solar wind, -5%; Handling Penalty -5, -25%; Temporary Disadvantage, +6 SM, +0%) [266]; Flight (Accessibility, Only if exposed to solar wind, -5%; Space Flight, +50%; Space Flight Only, -75%; Temporary Disadvantage, +6 SM, +0%) [28]; No Degeneration in Zero-G [1]; Regeneration (Slow, Radiation Only, -60%) [4]; Sealed [15]; Temperature Tolerance 19 [19]; Unnatural Features 2 [-2]; Vacuum Support [5]. Home gravity is 0 G. 328 points.

PROTEUS VIRUS OPTIONS

There are lots of ways that the basic proteus nanovirus technology can be modified. Unless otherwise noted, these options are available for all proteus virus, neurovirus, or metamorphosis virus technologies.

Accelerated Nanovirus (TL12)

"You mean I'm going have to wait days or months for the nanovirus to grow my new face and improved heart? I got tickets to go skiing on Nix Olympica two weeks from now – but I can't go like this – I'm not in shape! What the fozz am I going to do?!"

"Well, if you're that desperate, there's a black clinic that might help you . . ."

– Dr. Lucien Locke, *Nanovirus for Dummies*

A nanovirus normally takes it slow and easy, because herding all those cells around and forcing growth is a major strain on a living being's metabolism. It doesn't have to be this slow.

At double cost, an accelerated proteus nanovirus is available. An accelerated nanovirus takes days instead of weeks (or 1/7 the time, if it takes less than a week). For example, if it normally took two weeks, the accelerated virus would do it in two days.

If using any proteus virus, the accelerated growth process is stressful. The user will experience "nanofever" symptoms (p. 212). In addition, the user will suffer 1 FP each hour, until he passes out (he'll be unable to rest to regain this until after the virus has run its course).

Using a metamorphosis virus is more dangerous. Use the same rules for side effects as for a normal metamorphosis virus, but occurring if the virus takes 2+ days (rather than 2+ weeks). In addition, HT rolls to avoid suffering side effects are made at HT-3 rather than HT. Get too ambitious, and there's a good chance of a messy death.



Clinical Metamorphosis

"Uh – a messy death? 'Scuse me, Dr. Luce, I'm outta here. Isn't there a way the virus can grow a new part safely?"

"It isn't the virus that doing the growing, livewire; it's just directing things. It's your cells that are doing the work. Remember, it's got to keep you alive. Imagine trying to do repairs on a car while the engine is running – heck, while you're still driving the thing around."

"Okay, okay – so why not stop the engine first? Or do the work from outside the car – I mean, the body?"

"Ooh, good one. Let's try it."

– Dr. Lucien Locke, *Nanovirus for Dummies*

*Life is just bytes and bytes
and bytes of digital information.*

– Richard Dawkins

A metamorphosis nanovirus can work a lot more swiftly and safely if it has help from outside. This is clinical metamorphosis. First, the patient is placed in a life-support environment, usually a growth tank (p. 20) or chrysalis machine (p. 133).

Next, the patient is put into a state of complete biostasis, similar to suspended animation. A solution of specialized bio-nanomachines is pumped into the tank with him. Some of these may be similar to a nanovirus, while others might be actual robots, either autonomous models or guided externally by a controlling computer. These nanomachines are in charge of keeping the subject alive and speeding up the transformation by working both internally and externally.

Once the patient is in biostasis, more radical nanosurgical procedures can be used. If body mass is to be altered, intravenous tubes may be attached to the body and the necessary materials carted in or out by transport nano. Some tubes, made of nano-active material, may penetrate directly into the patient's body without breaking the skin. In radical transformations, the patient may actually be dismantled on the cellular level, turning him into a loose "puddle" of cells, then reassembled.

The process takes the same amount of time as a normal nanovirus, but it's completely safe (assuming no sabotage and no glitches in building and programming the nano). There are no HT rolls required.

If using an accelerated virus, it takes the usual 1/7 time, but is no more dangerous than a normal metamorphosis virus. The user rolls vs. HT, rather than HT-3, and there is no FP loss. After the operation is over, the nanomachines will break up; their debris leaves the body via sweat or excretion.

While the process may be safe, it isn't cheap. Add the cost of disassembly nano (p. 163) and reassembly nano (p. 163) to the usual price quoted for metamorphosis nanovirus.

Other Proteus Virus Options

"Hey, Doctor Luce – this proteus nanovirus stuff – isn't it supposed to, you know, go out of control infecting and transforming everyone, and like that?"

"Of course not. Not unless you design it to. Here's how."

– Dr. Lucien Locke, **Nanovirus for Dummies**

Various options are available to change the way in which a particular nanovirus works. Unless noted, these may be applied to all procedures that use proteus virus, including metamorphosis virus. These will modify the price and TL of the nanovirus, as shown in parentheses.

Aerosol (10 times price): The nanovirus doesn't require injection. It can be used in a chemical warhead or aerosol spray. It uses the normal rules for biochemical weapons, and affects anyone who breathes it and fails a HT-6 roll. At TL+1, it may be a contact agent, penetrating the skin of anyone exposed on a HT-3 roll, or HT-6 if also breathed. An aerosol can will spray one dose at a time and holds five doses; 10 doses fill a chemical grenade. Halve LC (round down).

Delayed: The nanovirus is designed with a time delay. Instead of taking effect within a few minutes of infection, it remains dormant for a pre-set time period after infecting someone – anything from hours to years. This option has no effect on cost or TL, but the dormancy period must be chosen when that particular batch is designed.

Heredity-Changing (TL-1, 1/2 cost): The nanovirus has no effect on the person it transforms – no twinges, sweats, coma, or biomodification! However, it does alter genetic heredity, and the effects will be passed on to the subject's children. Since children have genes from both parents, inheriting virus-induced traits is much more likely if both parents have been infected by the nanovirus.

Nanobot (Double cost): The "virus" is composed of unliving nanobots rather than biological machines. HT rolls to resist infection are made at a -2 penalty, and time required is halved. Resistant or Immunity to Disease and similar measures intended to defeat biological pathogens have no effect against it! Resistant or Immunity to Metabolic Hazards or Nanomachines would be effective, however.

Plague (10 times price): The virus can spread through skin contact and via breathing infected air. Anyone in direct skin-to-skin contact with a person who has been infected but not yet transformed can catch it on a HT-3 roll, or HT-6 if they exchange bodily fluids. LC0.

Random Metamorphosis (TL12⁺, special price): This superscience metamorphosis virus has a semi-random series of effects on different subjects. It may give one person an exotic biomod, transform another into a different form, change a third person's sex, and so on. The GM should decide what percentage of victims suffer what type of effects, whether there are any other side effects, and the maximum possible character points of change. Cost is up to the GM, but should be based on the maximum number of points that can potentially be changed.

Species-Crossing (10 times price unless nanobots, then double price): Nanoviruses are generally effective only on a single species (and any variant races thereof) or a few

closely-related ones – this is more a matter of programming in the case of nanobots. A virus that works on humans won't affect cats or dragons, for instance. This modification makes it pan-specific, capable of affecting multiple species provided they share the same basic biochemistry. Thus, a nanovirus designed to affect terrestrial life probably won't work on aliens, unless there's a good reason (e.g., if by sheer coincidence or design, we are amazingly genetically similar to them).

Target-Specific: A nanovirus can be designed to target specific characteristics; see *Target-Seeking Pathogens* (p. 115) for possible designs. A plague may still be target-specific – people other than the target(s) will become carriers if they fail HT rolls, but suffer no other effects. This option has no effect on cost or TL.

Nanowarfare

The ability to create proteus virus plagues raises the specter of exotic nanoplagues that transform rather than kill. For example, imagine spreading one that turned humans into compliant sex toys (like the Eros, p. 72) or "green" entities like the product of a Chloramorphosis virus.

The threat of proteus plagues is lessened by the availability of sophisticated treatments and defensive nanotech such as guardians (p. 165), although these are ineffective against nanobot nanoviruses. However, humans don't have to be the target – imagine the havoc that even a "benign" intelligence-boosting neurovirus could cause if a species of pets, farm animals, or wild animals became more intelligent! In fact, targeting nanoplagues at animals may be a viable surprise attack strategy, if humans have engineered defenses.

Temporary: A neurovirus (p. 186) can be designed to produce only temporary effects by interfering with neurochemistry and hormonal balances rather than altering the structure of the brain. The effect will last for a number of hours equal to twice the amount the initial HT roll to resist was failed by (maximum one day). This sort of nanovirus is often used as a form of brainwashing or biochemical weapon. This option has no effect on cost or TL. Not available as a metamorphosis virus.

Xeno-Species Crossing (20 times price): Capable of crossing between extremely different forms of life, such as terrestrial and alien life forms. Xeno-Species Crossing nanoviruses may still not work if the aliens are very alien; e.g., a virus designed to work on carbon-based life wouldn't affect silicon-based "living rocks." Given the (probable) drastic differences expected between human and alien life, a Xeno-Species Crossing nanovirus is more cinematic than realistic, and may be considered superscience, but is nevertheless very common in science fiction.

CHAPTER EIGHT

CHARACTERS AND SOCIETY

Both cops wore smart blue arachnofiber vests and carried shock sticks and holstered Glockes. One was overweight and pushing 40; her face was red from climbing the stairs. The other was an uncertain-looking rookie, his youthful good looks only slightly spoiled by acne. Still, kind of cute, Mara decided.

"Dr. Mara Omokage?" the fat cop puffed, staring down at her.

"Is this about the parking ticket?" Mara said coolly. She adjusted her kimono, wishing she'd had time to put on makeup. They were only police, but she was as fastidious as a cat. "If so, bother my attorney."

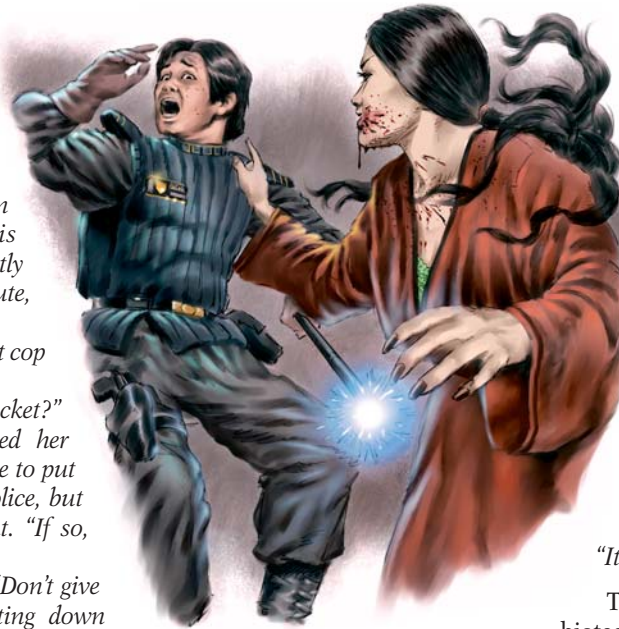
The cop fingered her stick. "Don't give me any lip, lady. We're shutting down your little clinic. Under the Uniform Code of Criminal and Civil Justice, I place you under arrest for unlicensed genetic surgery and tax law violations."

"I don't think so," Mara said.

The cop activated her stick. Sparks crackled from the tip.

"Make my day, bitch. You gene hackers think just because you're rich as all damn, you're different –"

Mara grinned, wide. Then wider. Her jaw snapped out like an egg-eating snake, then retracted. The female cop's body hit



the floor with a wet thump. Mara spat out a chunk of esophagus, then turned her smile on the trembling, blood-spattered rookie.

"She was right – we are different." As the shocked rookie stared, Mara's waist-length hair drifted out, coiling around the rookie's Glock. "You won't need this, little boy . . ."

But the cop was no longer looking at her. He was looking at the thing that had slithered in behind her. Mara turned, glanced over her shoulder.

"Don't worry, copper," she said. "It's just one of my babies."

To the average person, future biotech may be essentially invisible. Panimmunity shots he had as a baby keep him healthy. He pours milk from transgenic cows onto his cereal made from nitrogen-fixed grain, and complains about how much of his salary goes toward health care plans that will keep him alive for an ever-increasing span. Perhaps his parents even had him genefixed, to remove any genetic defects. But biotechnology won't be invisible to everyone – there will be some people for whom biotech may be a business, a way of life, or even a crusade.

BIOTECH CORPORATIONS

These include companies (or divisions of larger corporations) that specialize in gengineering, protein engineering, biomimetics, cosmetics, genome mapping, genemod drugs, tissue engineering, and other processes. Large scale biotech industry is an early TL8 phenomena (historically, dating to circa 1975-1980); in some future Earth settings, expanding biotech corporations may come to dominate the economy, driven by social trends such as healthcare for the aging populations of wealthy nations.

Some biocorps are large enough to cover the entire field, but most specialize in a particular area, such as health care, gengineered crops, industrial bacteria, improved animals,

and or at high TLs, in bioroids, terraforming or adapting alien plants and animals. Biotech corporations may also specialize in developing biomodification procedures for use by hospitals and clinics – if a process isn't yet available on the street, someone with contacts in a corporate lab may be able to arrange for it anyway.

Small corporations are often undercapitalized "whiz-kid" operations. These develop a single brilliant idea . . . and are then bought out by a bigger company, usually to market their new invention – but sometimes to suppress it! A certain amount of research may also be contracted out to university labs, in exchange for grants and funding.

Today, the majority of the biotech industry is involved in human health care, animal husbandry, and agriculture. In some settings, big research dollars could be in military biotech, either for defensive or offensive purposes. “Bioweapon” projects may range from killer viruses to cloned combat bioroids. In a spacefaring culture, captured alien life forms may also be studied and modified for military purposes.

Because of the high value and leading edge technology involved in biotech products, industrial espionage is common, so security at many firms is tight. The controversial

nature of biotechnology means firms engaged in seemingly innocuous activities such as agricultural research may have to deal with militant ecological activists or animal rights groups. Defense contractors will have truly paranoid security, since they are worried not just about industrial espionage and activists, but also foreign spies and saboteurs. It’s possible that ultra-tech corporations which develop military bioweapons may have examples of them deployed to defend their own facilities – or might use them (often without the actual military’s knowledge) in corporate espionage or warfare.

MEDICAL FACILITIES

When you’re lying on a table with a doctor’s hands on your heart, you want her to have a steady power supply and all the equipment she needs. Most complex medical procedures are best performed at a dedicated medical facility.

HOSPITALS

A hospital is an institution providing professional health care, with facilities to look after patients while they recover. *Outpatients* visit a hospital for diagnosis and/or treatment and then leave. *Inpatients* stay overnight or for lengthy periods. The ability to provide inpatient care distinguishes hospitals from other medical facilities.

The medical equipment available in all but the most basic hospitals qualifies as “best equipment at your TL” for medical skills requiring equipment (see p. B345).

Hospitals can make good adventure locations. Injured heroes are likely to end up in hospital, as can Enemies and

Contacts. A recuperative stay need not be a boring waste of time, as the number of people encountered provides opportunities to learn rumors and gossip, or to pick up vital information.

A hospital is also a good choice for making a last stand in the defense of a town, as it is a sturdy building with lots of medical supplies, as well as food stores and emergency power generators. If the desperate survivors of an invasion or apocalypse haven’t made their stand in a hospital, it is a logical target for a supply gathering expedition or raid.

Ambulances

An ambulance gets patients to a hospital for treatment, as safely and quickly as possible. Modern ambulances (TL7+) are motor vehicles with specialized equipment to allow first aid, resuscitation, and basic life support for patients. The medical gear in an ambulance qualifies as “fine” equipment with a +2 (quality) bonus for first aid procedures.

The Medical Rescue Campaign

Many television dramas and real-life shows are based on rescue, recovery, and trauma treatment. Their enduring popularity raises the question of why the theme of present-day rescue drama has not been explored in detail as a roleplaying opportunity.

Although it seems to have all the right elements for a gripping game – action, tension, and opportunities for emotional involvement – the rescue genre suffers from being inherently reactive. One of the major decisions available to players in other settings, namely what to do next, is always provided for them in a rescue campaign. The plot never has an opportunity to develop along lines dictated by the players, as they constantly race to the next disaster, always with the same goal in mind: save the victims. Added to this is the fact that rescue situations are unpleasant and may raise negative reactions based on past player experiences or simple horror.

Some players might not mind being railroaded from one awful situation to another, but for many the fun will wear thin quickly. There are methods of making a rescue campaign more accessible and plot-oriented, however.

Firstly, the field operations themselves can be run in a cinematic style, where derring-do and a chance to look good for the press are stressed more than the actual rescues and subsequent medical treatment – in stark contrast to the gritty reality of TV dramas. It should be clear that people never get seriously hurt, even if the rescue attempt goes awry, and the action should be based more on overcoming novel physical obstacles to reach a trapped person, rather than cutting open yet another twisted car wreck to find half-dead victims.

The GM can introduce variety by adding exotic elements or complications to rescues. These include physical hazards (e.g. fire, imminent building collapse, risk of detonating a weapon), human drama (hostage situations, family members, riots), and political complications (cover-ups, corruption, funding worries). Downtime between rescue calls can be used to add subplots and provide the players with a chance to use their own initiative. Who’s responsible for the stocks of morphine being missing, and what if the next call comes in before it’s replaced?

Since the 1970s, ambulance drivers have been trained paramedics, qualified to give advanced first aid and administer some drugs on the advice of physicians via radio. Earlier ambulance drivers typically had no medical training.

Ambulances can be tempting vehicles for adventurers to commandeer. They are high-powered vehicles kept in good condition, with sirens and markings allowing them to ignore many traffic laws, and come with useful and expensive equipment. In appropriate situations and tech levels, ambulances can also be air, water, or space vehicles.

BODYSCULPT CLINICS

These are clinics that specialize in legal bodysculpting jobs (p. 169), although at TL10+ they also carry cheaper proteus viruses, such as metabolic reset (p. 182) and cosmetic virus (p. 185). Some are large, upscale establishments catering to the middle and upper classes, often with psychological counselors as well as surgeons to ensure smooth integration.

Others are walk-in places that specialize in generic face jobs based on knock-offs of the latest vid star or virtual soap opera character. Those that offer the most radical mods may be descendants of tattoo and body-piercing parlors, catering to subcultures that want to physically distinguish themselves (counterculture, sailors, yakuza, etc.). Of course, in some cultures, an “original human” body may be radical, in which case places might specialize in modifying people back to “normal.”

Most clinics will only perform LC3 or LC4 procedures.

Black Clinics

In the future, designer drugs aren't the only things being made in secret labs – so are designer bodies, animal or human, as well as customized life forms. A *black clinic* is a laboratory, clinic, or hospital that performs illegal or ethically dubious biomod and engineering procedures. If cyberwear exists, some may specialize in cybernetics, others in biological procedures, and many in both. Some black clinics are also “body banks,” involved in illegal organ theft (see *Organlegger*, p. 207).

Black clinics may range from basement or mobile labs to full-fledged hospitals. The latter are usually disguised as legal body parlors, clinics, or biotech companies, but offer extra services to special clients. A black clinic may be able to dispense with secrecy entirely if it can find a location beyond the reach of the law. For example, a black clinic may be based in an orbital habitat, or in a jurisdiction not signatory to international regulations on bioengineering ethics. Security and intelligence agencies may maintain secret black clinics to provide assistance to their agents – often, these also do freelance work on the side.

The biggest danger of going to a black clinic is the risk of shoddy work, followed by being asked to consent to some experimental process that hasn't been debugged. Finding a disguised black clinic requires appropriate Contacts or Streetwise skill; a critical failure might lead to a police sting operation or, worse, a clinic that looks good but is incompetent, enjoys experimenting on its clients, or uses them for spare parts.

BIOETHICS

Legal and ethical dilemmas offer many motivations and plot ideas for games. The intersection of biotechnology and society provides these in abundance. Characters in biotech-heavy settings will have opinions on all these issues, as will everyone around them, including the makers and enforcers of the law.

TRADE IN BODY PARTS

Human bodies have been precious resources ever since Vesalius resorted to stealing corpses from the gallows to study anatomy in 1530s Italy.

Cadavers

Cadavers are of most use in low-tech settings for medical dissection and steampunk settings for creating life. Acquiring a body or its parts in such settings can, however, be illegal, heretical, and dangerous. Citizens of good standing will have family and friends who want to see their bodies treated respectfully after death and disposed of in a manner consistent with religious beliefs. This precludes anatomical dissection and use in experiments.

A desperate scientist may resort to other means to procure cadavers. Depending on the law, dead criminals

and execution victims may be fair game for purchase. If not, bodies will have to be collected by underhanded means. Execution sites, prisons, hospitals, morgues, and cemeteries are the prime locations for stealing a body. If someone would rather pay for cadavers than steal them, this gives rise to professional body-snatchers and grave robbers. Such an occupation would be risky, but potentially lucrative. In the 19th century, anatomy schools paid from £2 to £8 sterling (\$200 to \$800 in *GURPS* \$) for a cadaver – more than a week's wage for many professions. An underground network of body traders may spring up, providing either enemies or contacts for researchers on both sides of the law.

Live Organs

As long as patients need transplants that cannot be grown by tissue engineering, there will be a demand for live organs.

In most places, organs and other tissues can be legally taken from a deceased person only if he agreed to be a donor beforehand (often indicated by a donor card), or if his relatives make the decision. Some jurisdictions use an opt-out system, which improves donor rates! For personal or religious reasons, many people are unwilling to donate. Others die in circumstances (old age, disease, major trauma) where



their organs are damaged or unhealthy. A supply of suitable transplant organs requires finding people who died in good health. As this is almost a contradiction in terms, locating organ donors can be difficult.

At present, the number of altruistic people who die healthy is insufficient to meet the demand for new organs. This will probably get worse as transplants become more common around the world. (It may get a lot worse if cryonics becomes popular, since if you hope to be frozen after you die, you may need those organs later!) While this demand may be mitigated if bionic organs become cheaper and smaller, it may not go away entirely.

Because of this demand, hospitals often have to put needy patients on month- or year-long waiting lists for high-demand tissues, such as the body's vital organs or eyes. The GM can decide how long a wait is necessary, or roll randomly. Before cloning is widespread (reducing the demand), a 1-in-6 chance of matching major organs being available might be typical, with a further chance rolled each month. After cloning, artificial organs, or bionic replacements become common, a 1-in-6 chance per week is more likely. Things like fingers or limbs will be in less demand, and may be available without a wait in most cases.

Societies may develop other methods for increasing organ supplies: dismembering criminals, prisoners, and various malcontents; free market incentives (“\$5,000 prepayment for signing your body to Organs’R’Us!”); or religious or civic duty. Closed systems like space colonies may routinely recycle organs. Scarce transplants can also mean a black or gray market trade in body parts (see box).

PLAYING GOD

A frequently cited objection to human biotechnology and genetic engineering is that scientists are “playing God,” with the unspoken assumption that this is something to be avoided for moral reasons. Patients who rely on new treatments for their health and the researchers who are applying their

skills in an effort to give it to them may feel somewhat aggrieved by this attitude. The conflict between these viewpoints will likely be fought over many different issues.

Black Market Organs

In some settings, dealers may resell “used” (salvaged or repossessed) body parts, often on the black market. These can be purchased with no waiting period. Tissue matching is a problem, except in cinematic games where rejection is not an issue – the source will either have a matching organ in stock or not. Unscrupulous operators may foist mismatched organs on clients, but won’t stay in business long that way.

Typical costs are \$30,000 for a healthy vital organ (heart, lung, kidney). Arms and legs are half that price, since there isn’t as much demand for them. Eyes, genitalia, and other secondary organs are \$3,000 to \$6,000 each, with mostly cosmetic pieces like fingers or ears going for \$1,000 to \$3,000. A recently dead corpse, in good shape (no diseases, not riddled with bullets), may sell for \$10,000 to \$60,000 depending on supply and demand, while a live body sells for up to \$150,000.

These are retail prices – organleggers, hospitals, and so on purchase bodies or parts for 10-60% of this. If cloned or bionic parts are widely available, reduced demand halves prices.

If an organ trade exists, dealers may find it advantageous to arrange for living organ banks – people engineered or biomodded to carry extra organs as part of their bodies. This is also a convenient way to transport live organs, especially through customs!

Human Cloning

Many people feel a revulsion at the idea of cloning humans. This often stems from a misunderstanding over the science involved. In popular culture, clones are represented as being identical copies of the person cloned, right down to personality and intellect, and that they will somehow share one identity. Since a clone will be raised in different biochemical and social environments than the original, they will likely be less identical than a pair of twins (and certainly no more so) – something many of us are comfortable with. Yet unless cloning becomes routine and people gain experience with clones, this uneasiness may remain and color social attitudes to cloning.

There are more compelling reasons not to clone people. Early cloning technology is imperfect, and it would be hard to justify producing a clone who is doomed to live a short and sickly life. Even given safe and reliable cloning, the

Cloning and Religion

Do clones have souls? To genetic science the question is meaningless, but to some people and religious traditions it is an important issue and the answer is disturbing either way.

A human being without a soul is a source of horror, utterly amoral, and a threat to society. It would also be an empty vessel, a tempting target for possession by malign spirits, and a perfect human disguise for such entities. Clearly, bringing such a being into the world is an outrageous thought.

Perhaps worse is the idea that clones do have souls. Where does a clone's soul come from? If science is in the business of creating souls, that is stepping on the toes of greater powers. By creating clones we risk the wrath of the gods, or we may begin to contemplate challenging them – either way the comfortable status quo is under dire threat. Perhaps humanity is only capable of making corrupted souls. More tragically, a created soul may be stigmatized by its origin and doomed to a life without the opportunities it deserves.

For believers, these are strong arguments that human cloning is immoral and should be stopped at all costs. Even in a world with no supernatural forces, clones and the people who make them will be subject to outrage and perhaps violence by those who subscribe to these beliefs. This can be a source of conflict in any game world that features cloning technology.

If souls, spirits, or gods are real, then the believers have a point! Cloning could open the gates to supernatural horrors never seen before. Having a scientific breakthrough be the catalyst that propels a campaign into a new phase of supernatural activity can produce an unusual and creative game.

practice can lead to overall long-term damage to the species (see *Risks of Cloning*, p. 24).

Finally, there are social arguments for regulating cloning. Certain people will want to produce clones out of vanity or for exploitation. Most would agree that preventing such abuses is desirable – but on the other hand society allows people to have children naturally, no matter what their motivation (indeed, sometimes even if they don't *want* a child). Cloning advocates will argue that a clone produced by a person wanting a child to raise in a loving environment is better off than the progeny of many unwanted pregnancies. How society ultimately handles these conflicting opinions can set the tone for many different campaign settings.

Spare-Parts Clones

One of the most controversial uses for clones would be to raise them for the purpose of serving as spare parts for the original. As organs wear out, they could be replaced by compatible, healthy organs from the clones. This reduces the clones to a form of livestock, a practice likely to be outlawed by many societies. But if cloning is possible in a campaign setting, it's a good bet that someone rich and powerful is at least contemplating the idea . . .

Batch Cloning

A fiction staple is the society that uses cloning to raise *batches* of identical children. Rather than a new way to have a child, this creates dozens or hundreds of people with the same age and genetic makeup. This would have several unique aspects: finding a tissue-matched organ donor is not a problem, while identifying a criminal becomes much harder; adolescent clones may rebel and want to become as *different* as possible. There is little reason to produce such a society, except in places with limited genetic resources – such as may occur on colony worlds.

Designer Babies

A *designer baby* is a baby produced with at least part of its genetic makeup actively chosen by its parents (or perhaps by an external authority). Should parents be allowed to choose the genes present in their offspring? Or should they be made to accept what fate offers them?

To the disgust of some, the world already has designer babies of a fashion. In 2001, a couple used embryonic tissue typing to select specific embryos from a series of *in vitro* fertilized zygotes for implantation in the mother. The goal was to produce a baby with tissues suitable for transplant into its sick sibling. In 2002 a British court ruled that another couple there could not use the same procedure, so they had it performed in the United States, where it was legal. At the cost of a few other embryos, these couples produced babies who held the keys to curing their first children.

The loss of a few embryos is a common occurrence in *in vitro* fertilization procedures, yet few these days make a fuss over it. The concept at the heart of many people's revulsion over designing babies is the exercise of *choice* over what offspring will be produced. This can be interpreted as making a value judgment on one person's possible existence over that of another. Nobody likes to be told that they are worth less than someone else, and the objectors to designer babies

project this onto the embryos that have not been allowed to develop.

Another (arguably contradictory) argument is that babies created by choosing from a set of possible embryos are being treated more as a commodity than as a new life to be accepted unconditionally, thus devaluing the worth of the child that is selected. This argument also applies to the more common use of the term “designer baby” – a baby whose genome is chosen by selecting traits from a menu of options.

Parents may want a designer baby for many reasons: to prevent inheritance of known genetic defects; to adjust the child’s appearance; or to give the child genetic advantages. In isolation, these can be admirable goals and many people may desire them. This sort of designing is not a reality yet, but will soon be possible. How society reacts to these different possibilities and motivations will follow from our experiences so far. Some people will always want the latest that technology has to offer, and some will always want to prevent it. In a biotech campaign world, there are endless possibilities for how these differences of opinion can play out.

EUGENICS

Widespread practice of human eugenic engineering can easily have a profound effect on society.

If it is available to anyone who can afford it, engineering may be used by wealthy parents who want to have “better” children. The descendants of the elite would not only think they were superior, but would actually be so, genetically speaking. This could turn the gulf between rich and poor into a gaping chasm, or lead to a backlash if demagogues attempt to parlay resentment against the gene-enhanced into political power.

In a socialist or authoritarian regime, engineering might be subsidized or even mandated by the government, perhaps as part of a massive eugenics project. A benign program may subsidize genefixing to eliminate “defective genes” such as hemophilia. A society could expand that into a full-scale eugenics program aimed at producing a homogeneous population or developing specialized “genetic castes” for different roles (see *Specialization and Genetic Castes*, p. 40). Perhaps a limited number of “approved” genotypes would exist, from which parents must choose (or have chosen for them). Or maybe everyone (except the leaders) must use the same genotype; it would end racism, but it might make the population easier to predict and control.

Even if only one generation is altered, this affects the overall gene pool, as their children will inherit their genetics. Societies concerned with genome preservation might allow engineering but mandate sterilization, so that if a gene-altered person is to have children, they’d have to be artificially inseminated or cloned.

A concern raised by people who advocate eugenics is that modern medicine allows people with disabling genetic conditions to survive and reproduce. Instead of these “weaker” specimens dying young and not being able to have children, they are now able to propagate their genes into a new generation. As medical technology improves, this effect will increase, with the result that the human gene

pool will contain an ever larger proportion of disabling genes. In some cases, such as a small colony or post-disaster survivor population, this is a genuine concern that needs to be addressed. But often eugenics advocates are people with prejudiced agendas, seeking to justify their intolerance by appealing to “survival of the fittest” as a societal principle.

Fetus Farming

Embryonic stem cells are so useful for tissue engineering and therapeutic purposes that medical researchers will want a steady supply of them from a variety of sources with differing genomes. The cells can be taken from legal abortions, miscarriages, and umbilical cords. Once a cell line is available, it can be cloned easily at TL8+.

Procuring the stem cells may, however, be regulated or banned, resulting in a demand that cannot legally be met. With a twist of technology, it might also be possible that cloning stem cell lines is not feasible for some reason. In these cases, conditions are ripe for the development of less ethical methods of obtaining embryos for stem cells. A horrific possibility is *fetus farming*: enslaving healthy women, impregnating them, then aborting the fetus – over and over again. This is likely only in deliberately dystopian settings that ignore the simpler possibility of cell cultures.

The opposite argument is that humanity shares a large and diverse set of genes, and as a whole is robust to the many mutations that occur every generation. The artificial spread of debilitating genes will take thousands of generations (maybe *millions* of years) to have any appreciable effect on the population at large. And we are very near to having the technology to repair those genes anyway, so denying a few people the same care and reproductive rights we grant everyone else is shortsighted and unethical. Again, however, there are exceptions, such as the abovementioned small populations of a colony or survivor group, in which a propagating genetic defect could cause havoc. The interplay and relative power of the sides who make these arguments will determine how a campaign world will react to the early stages of genetic technology. In some more advanced backgrounds, there is a conflict between societies that utilize engineering and more “natural” ones, placing the ethical struggle into a larger context.

Selective Breeding

Even without high technology, humanity can be modified (slowly) by the same principles of selective breeding as livestock. This would be an effective way to “improve” the species – if the people will stand for it. Attempting to control who is allowed to breed with whom is a recipe for disaster in all but the most totalitarian regimes or pliable societies.

From 1896 to 1967, various laws in the United States prevented the marriage of mentally retarded people, epileptics, or couples of mixed race. Interracial marriages were banned in South Africa until 1985. Although these laws were aimed at preventing the spread of genes considered undesirable, rather than positively modifying the species, they were largely ineffective and have since been denounced as unethical.

It's possible to imagine a fictional society in which everyone agrees that breeding should be controlled, but any real historical or contemporary society would flout the regulations enough that the breeding goals would be neutralized. Even if a society does agree to the experiment, there may be conflict over who gets to make the decisions.

Sterilization

From 1907 to as recently as the 1960s, the U.S. government allowed states to forcibly sterilize individuals who were mentally retarded, mentally ill, or physically deformed. Several other western nations had similar programs. Nazi Germany sterilized over 400,000 people. The goal in all these cases was to prevent "undesirable" genes from spreading throughout the population.

Nowadays we consider such programs barbaric. This is because regard for the freedom of individuals has come to be seen as more important than the costs of allowing genetic diseases to be passed on to a new generation. But there is no guarantee that this attitude will prevail in the future, or in a fictional campaign setting.

Removal of "Undesirable" Traits

Another method of eugenically engineering humanity is to forcibly remove undesirable genetic traits from individuals, so that they will not be propagated. This is just beginning to become possible through gene therapy and screening of embryos. This will lead to a physically healthier population, but again at the cost of personal freedoms.

One major difference between this and other forms of eugenics is that the population at large *need not know it is occurring*. With high enough technology, embryos can be screened during routine early pregnancy checkups without the knowledge of the parents, and genetically tweaked to remove any disadvantageous mutations. Adults with genetic diseases can be treated on the sly by their doctors. Since everyone will be healthy and able to have children, a government using this method could eugenically modify its population without them being aware of it. And even if someone finds out, is it actually *bad* that everyone is healthy and long-lived?

DNA PROFILING AND IDENTIFICATION

Whose genetic records end up in a genetic database, and to whom are they accessible? This is a major legal question for the 21st century.

Some genetic profiling is performed under legal auspices, generally for forensic purposes – especially in

rape cases, and to determine parentage in custody or paternity suits. At present, genetic identification usually requires a search warrant, or may be administered on a voluntary basis to prove one's own innocence, and only people who have undergone these tests end up in law-enforcement genetic databases. In the mid-1990s, the FBI had DNA profiles on over 100,000 people, mostly prisoners. By 2005, this had grown to 250,000 people. The U.S. Army also stores DNA records of its personnel to make it easier to identify the remains of dead soldiers.

But medical facilities or corporations may also begin storing genetic identification, and using it for their own purposes. Just how widespread DNA profiling becomes may vary from country to country (or planet to planet). In many countries today, there is political support for laws to limit profiling in order to protect genetic privacy. In a "dark future" these laws may be repealed to serve the interests of megacorporations and repressive governments, but it is also possible for an open society to agree to widespread profiling for peace of mind and security.

Privacy and Discrimination

The question of whether employers can test workers or job candidates is controversial. For example, current genetic tests can determine susceptibility to some hereditary diseases. If testing showed that someone had a greater-than-usual risk of developing medical problems (even late in life), then they might be perceived as a potential burden on company productivity and corporate health care plans. As a result, they might not be hired, and could even lose existing jobs or health insurance. As testing gathers more data on genes that influence human behavior, discrimination could be extended toward people with hereditary tendencies toward "undesirable" mental traits.

Insurance companies may wish to test applicants too. This can be to the clients' benefit if the company wants to reduce risk by making sure they use appropriate medications, but there will be a temptation to use genetic data to make riskier clients pay higher premiums.

Genetic Copyright

Who owns the rights to a particular genetic sequence? It seems logical that a person owns his own genome, but several legal precedents say otherwise. In 1990 the California Supreme Court ruled that a patient had no right to cell samples cloned from his body without his knowledge, or to any of the money made by the company that had developed the cell line into a profitable bioproduct. The company in fact patented the cell line, granting it exclusive rights to profit from the patient's genetic sequence.

This decision rested on two long-standing principles that the judges saw as overriding any questions of genetic ownership. Firstly, a ruling in favor of the plaintiff would have stifled important medical research beyond the bounds of the case in question, rendering much of it legally intractable or impossible. Secondly, since the abolition of slavery, it had never been possible in the United States to own even a part of a human body. A feature of common law in most countries, the prohibition against ownership

means human body parts cannot be *stolen*. Many courts have upheld this principle, ruling that a person maintains no property rights on any part of his body once it has been detached. In other cases as disturbing as the illicit use of a couple's embryos by an IVF clinic, rulings for the plaintiffs have so far been based on emotional damages, *not* on theft of property.

As biotechnology becomes ubiquitous, there will be increasing pressure to address the issue of genetic ownership. Once public awareness reaches a threshold capable of political action, the status quo may change, causing an economic and legal upheaval in the biotech industry. Biotech companies which stand to lose their livelihood will fight such changes tooth and nail. A probable outcome will be that people will maintain property rights in their own genomes, and be able to licence them to biotech companies for a fee. This will raise biotech operating costs, particularly for access to rare gene sequences, and make research on rare genetic conditions or diseases more expensive and difficult. For people *with* rare genes, it will be a windfall, as they suddenly find themselves owning a valuable resource. Market forces will settle the value of genetic information. People with particular genes may try to form genetic "trade unions," withholding their genes from research until presented with suitable incentives – although it will take only one altruistic or greedy dissenter to spoil their efforts. Withholding genetic material from biotech companies is ultimately counterproductive, as it will slow development of life preserving technologies, so some people may freely donate it anyway, possibly with conditions on use ("You can use my genes for cancer research, but not for making cloned organs.").

On the other hand, the biotech lobby may entrench current law indefinitely, so that the first commercial user of a genetic sequence owns it. Doctors may get kickbacks for supplying cell samples from patients, and people could become wary of using advanced medicine for fear of being exploited, or rush to patent their own genomes as a form of protection. The other end of the spectrum is an "open source" approach, in which genetic material and technology based on it is deemed to be public domain information. This would reduce biotech profitability and potentially lead to either stagnation or government subsidy of research.

GENETIC TESTING

Currently, most genetic testing is done by hospitals, at the request of patients who want to see whether they have any hereditary defects, usually because there is a history of such problems in the family and they are considering having children.

Other issues related to genetic testing include the screening of the unborn. If an embryo or fetus tests positive for a birth defect – or just isn't up to par – should it be aborted? Or should genetic surgery be attempted? Then there's the question of whether a person would want to know that he has a higher risk of coming down with a disease – or that his genes say he has less potential for intelligence or mental stability than is the norm. Finally, there are worries about the security of genetic information. If a cautious couple gets tested to ensure they won't pass on

hereditary conditions to their children, can they be sure that their genetic data won't also find its way to insurance companies or employers?

Human beings have always been afraid of their own creative power, and the idea of man-made life was scary long before science was in any position to think of procedures that might make it reality.

– Martha C. Nussbaum
and Cass R. Sunstein

Genetic Counseling

Once a person knows that he carries a genetic disease, he must deal with that knowledge somehow. Some disorders develop into debilitating or fatal conditions later in life. Knowing one's own fate has always been regarded as a curse, and the mental burden when that fate is horrible is too much for some people. This is where genetic counselors are needed, to explain the facts behind what a patient may experience, and prepare him for the future.

Someone who knows he carries a genetic defect has an even heavier burden, as it's possible that any children he has will share the same fate. Many people yearn to reproduce, but nobody wants his children to suffer. The choice is a difficult one that weighs heavily on those forced to make it. Counselors can again help, offering advice on probabilities and what technology can do to help. Even if the expertise exists to ensure a child will not inherit the defect, does embryo screening or engineering fit in with the prospective parent's ethical views?

BIOROIDS, PARAHUMANS, AND UPLIFTS

Biotech holds the promise that we may be able to produce sapient beings with intellects similar to ours, but designed and built from scratch (bioroids), different enough to be considered separate species (parahumans), or created *from* different species (uplifted animals). But should we? And if we do, how will we treat our creations?

Some segments of society will argue against the creation of these new beings. Religious orthodoxy is an obvious source of objection, but there will also be well-argued cases on purely ethical and social grounds. In the infancy of the technology, many researchers will advocate a slow approach, as there will be a significant danger of producing creatures cursed with unhealthy and miserable lives. This is unlikely to stop maverick researchers from going ahead and creating them anyway.

A likely scenario would involve the first bioroids, parahumans, or uplifts produced in secret or in a loosely regulated nation. When international authorities learn about this, they may mount a raid and rescue effort (an ideal task for a group of adventurers!). Once retrieved and safe in the hands of more sympathetic guardians, the subjects of the rescue present a serious dilemma. They will be innocent victims and symbolic of a call for sapient rights, so keeping them in custody will be distasteful, but they are also completely new life forms, with unknown capabilities and motives, so governments will be reluctant to release them.

Integration and Persecution

If bioroids, parahumans, or uplifted animals become common, they will likely begin to integrate into human society. Anyone with a sense of history can foresee the result of introducing humanlike beings who are also distinctly not human. While some people will accept them, others will harbor hatred, and soon there will be discrimination, persecution, and violence against the newcomers.

Exploring this in a campaign brings a fresh look to an age-old theme. The obvious cause for the heroes to champion is the fight for sapient rights and equal recognition. For a more thought-provoking setting, this moral high ground can be sullied with technological complications. There is no biological justification for racial or religious discrimination, but there *are* significant differences in

physical and mental capabilities of the different species. *Should* bioroids be given the right to vote, or are they too childlike and tractable?

IMMORTALITY

They used to say the only sure things in life are death and taxes. Well, now we can take care of the easy one. Taxes will have to wait.

– Dr. Mara Omakage

Cryonics

Since cryonic preservation (p. 144) costs \$50,000–\$150,000, an up-front payment is out of reach for many people. One solution practiced by current cryonics corporations is to encourage their customers to take out life insurance policies, payable to the corporation. For a few dollars a week, immortality may be yours.

Most cryonics companies take great pains to ensure their financial stability, investing a portion of all fees in trust funds. (This gives a new meaning to the term “brain trust”!) These precautions are to ensure they can maintain their patients and, hopefully, will have the funds to pay for whatever medical procedures prove necessary for future revival.

However, there’s always a chance that something may go wrong. Besides the obvious problems of fly-by-night

Defining Who Is Human

What is “human”? This is a philosophical question, but it will also be an important legal and social issue in many campaign settings. In legal terms, a human is entitled to certain rights and privileges that are currently denied to nonhumans (i.e. animals). When people become more like animals, and animals become more like people, the lines will blur, and some more practical definition will be needed.

Definitions could be based on the amount of human vs. nonhuman DNA (i.e., “eugenic vs. species modification”). Other common criteria include:

Anatomy: Certain standards may be set, such as being physically indistinguishable from a normal human or, perhaps more loosely, having a generally humanoid appearance. This doesn’t work for uplifts, and may be championed by those who don’t want uplifted animals to be granted “human rights.”

Birth: This might exclude “non-borns” who came out of incubators or clone tanks, as opposed to “test-tube babies,” conceived artificially but gestated inside a surrogate mother.

Intelligence: A racial IQ modifier of -5 or worse (i.e., enough to make the average person non-sapient) could disqualify someone as legally human. One problem here is that individual humans can have IQs this low, while members of “nonhuman” species might be

exceptionally bright. Another difficulty is that IQ needs to be measured somehow if it is to be used as a discriminator, and intelligence testing has a long history of controversy over what it is actually measuring. IQ tests are always taken in some cultural context and are notorious for biasing results in the direction favored by those who set them.

Social Factors: People have a long history of dehumanizing others based on nothing more than class, caste, nationality, race, or religion. In a world where people of other social backgrounds may literally carry modified genes, this only becomes easier to justify in the minds of those who subscribe to it. On the inclusive side, uplifts might be considered human if they display certain social graces or abilities.

Theology: Belief systems may have their own criteria, related to things like the presence or absence of a soul, or whether the person fits a definition of man in a religious text.

All of these methods suffer from the problem that not everyone will agree on the definitions used (except in the most uniform societies). Any sort of discrimination – or an attempt to remove discrimination – will make someone unhappy. If enough people disagree, the seeds of social revolution are sown.

operations and the possibility that future science may not be up to the task of resurrecting people, here are a few other scenarios:

Financial Disaster: Someone goofs (or the entire national economy collapses!) and the organization runs low on money. It's possible that whole-body preservations may be converted to cheaper-to-maintain head-only neuropsychopreservation (p. 145), or that some or all bodies may have to be allowed to thaw.

Problems with the Law: Preserving corpses "without decent burial" rubs some people the wrong way. Currently, most cryonics firms have good lawyers and emergency plans. But if laws or morals change, they could find themselves having to look for new homes in a hurry, and perhaps hiring some professional help. Smuggling a dozen steel containers out of state may be an interesting challenge for a group of street ops, especially if each holds a ton or so of liquid nitrogen and a dozen human heads.

Future Nightmares: Future societies may have lucrative and unpleasant uses for "corpsicles" – e.g., reviving the brain, only to incorporate it into a cyborg starship or computer matrix. In several of his stories, author Larry Niven has suggested that if freezing techniques become good enough to preserve bodies without much tissue damage, then a future society might look upon cryonauts as a potential source of organ transplants. This could be the case if tissue-engineered transplant organs are expensive or impossible.

Living Forever

How does a society deal with people who never die of old age? A world in transition as anagathic technology becomes common faces several crises never dealt with before. Power and wealth naturally accumulate in elders, being relinquished to younger generations as the holders retire and die. But when one can remain healthy for hundreds of years – or forever – there is no obvious motivation to hand over that hard-earned influence. People also become more conservative as they age and the world changes around them. The result is a society ruled by conservative cadres of the first generations to benefit from anagathics. The next generations face decades or centuries of life before they can hope to reach a senior role in business or politics, if ever.

Such a situation is ripe for intergenerational conflict, as well as social dysfunction and mental stress. Later generations may react with rebellion, with childish and irresponsible attitudes maintained for decades, or by attempting to withdraw and cut themselves off from their elders, either socially or geographically.

The other problem occurs at the opposite end of life: birth. If age claims no victims (and accidents severe enough to defeat advanced medicine will be rare too), the population will grow to an unsustainable level unless the birth rate is reduced. Although contraception may be reliable, people will still *want* to have children. There are many opportunities for conflict, with scenarios ranging from massive overpopulation and the breakdown of resource supplies to anti-birth legislation and social upheaval.

Anagathic technology will lead to activists advocating that it not be used, for fear of these stagnative and

destructive effects. This *mortalism* movement could be peaceful, but may also breed murder and terrorism as tactics. This will be accentuated by the likelihood that early anagathics will be expensive, restricting their use to the wealthy and creating resentment and hostility amongst poorer people. These social conflicts may spur bloody revolution, become entrenched in a split-class society, or lead to massive government-funded anagathic programs for all.

Bio Law

With so many ethical issues raised by biotechnology, it is inevitable that governments will attempt to regulate, control, or ban various expressions of it.

A legal ban on cloning or designer babies is fundamentally different from other prohibitions, in that they address methods of making a human being. When such a ban is flouted, as it inevitably would be, the result is to create a class of potential outcasts – people whose very existence has been condemned by society. Even if the "victim" of this illegal reproduction is treated with the sympathy of an innocent by some, the treatment of illegitimate offspring in historical times shows that children born by socially unacceptable means are stigmatized and persecuted. At least bastards are natural, though – a clone or designer baby may suffer the worse fate of being branded a freak or *intrinsically* morally flawed. The law will have reinvented an original sin, but one which no baptism can redeem.

And even these problems may fade into relative insignificance if a gengineer illegally creates an entire new parahuman *species*. See *Bioroids*, *Parahumans*, and *Uplifts*, p. 199.

One possibility for a sustainable society is enforced euthanasia at a specified age. This has been presented as a dystopia in *Logan's Run*, and could certainly turn out that way, complete with "runners" who buck the system. Despite our horror, with the right attitude it may be workable; after all, a guaranteed 100 years of robust health followed by a painless death is a much better deal than most of us get at the moment. Now we just have to convince the citizens . . .

MESSING WITH THE ENVIRONMENT

A consequence of gengineering plants and animals is that the new germlines may escape into the wild. Once there, interbreeding with wild specimens can spread the artificial germline throughout the population. Most people agree that extinction of species is undesirable, and many would extend this to an extinction of the natural genome by gengineered variants.

More worrying is the thought that engineered variant species may outcompete natural ones, driving them to extinction. It may be all too easy to release some hyperefficient plant or superpredator that dominates an environment – like kudzu or coral-eating starfish – driving hundreds of species into decline.

Is Anything Natural Any More?

With a biodiversity crisis caused by the invasion of engineered organisms, or simply if mankind continues to degrade the environment, it may be *necessary* to modify wild organisms in order to maintain a viable and diverse ecosystem. Creatures that could no longer survive could be engineered into what would effectively be new species, capable of competing on an even footing and of handling pollution or climate change.

But if we do this, there may come a time when humans have modified the germlines of *most* macroscopic species on Earth, either deliberately in order to maintain their viability, or accidentally. Is this something humanity should do, or is it unconscionable meddling with nature? There will

be arguments on both sides of this coin, and no obvious answer that will satisfy everyone.

We may not even have a choice. Once transgenic organisms are out there, horizontal gene transfer mechanisms (p. 13) may contaminate every living thing on Earth within a few human generations.

Terraforming Other Worlds

Messing with our own environment might be bad enough, but what about other worlds? Do we have the right to alter a planet's biosphere to suit us? If a world is inhabited by intelligent aliens, the answer seems a clear-cut no. But if the only things alive are microbes and it's a really nice planet and we've come so far from home . . .

Some will maintain that any life forms are precious and have a right to exist without interference (although few have lived up to that principle on Earth). Others will argue that keeping a sample alive while creating a whole new world to live on is perfectly justified. Once again, bioengineers will find themselves at the center of conflict.

CHARACTER TEMPLATES

These archetypes are typical of people intimately involved in biotech and engineering. They are presented as templates, using the rules on pp. B258-259.

Most of these templates define actual occupations and have attached job descriptions. Monthly pay ranges vary according to TL as per p. B517.

ACTIVIST

70 points

*Listen up, pigs! Unless you free **all** the political prisoners in three hours, the Neo-Anarchist Kommando will release a bio-engineered strain of hantavirus in New York City.*

Activists in a world with biotechnology come in two distinct types: those motivated by biotech and those who use it to further their own goals. Some people oppose some or all types of biotech on social, ethical, or religious grounds. These range from peaceful lobbyists or picketers to violent extremists. They may be associated with groups as diverse as animal rights activists and eco-guerillas to conservative religious movements. In some worlds, biotech may be legally or socially repressed, and activists seeking to *promote* research and development of life extension or trans-humanism would emerge.

Some activists and extortionists instead *use* biotech, either to “fight fire with fire,” to attempt to discredit their foes, or to promote other agendas altogether. Such bioterrorists range from lone madmen with a grudge to highly organized movements with dozens of members and thousands of supporters. A terrorist bioweapon could be a lethal plague, nonlethal disease, nanomachines, proteus viruses, insect swarms, or mutant monsters. Often, these are cooked up in bargain-basement labs, stolen, or bought on

the black market. As a result, they might be more or less virulent than the terrorists hoped for, or have other unexpected side effects.

Attributes: ST 10 [0]; DX 10 [0]; IQ 12 [40]; HT 11 [10].

Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 13 [5]; Per 12 [0]; FP 11 [0]; Basic Speed 5.25 [0]; Basic Move 5 [0].

Advantages: A total of 20 points in Allies [Varies], Charisma [5/level], Clerical Investment [5], Contacts (Radical groups) [Varies], Fearlessness [2/level], Fit [5], Indomitable [15], Reputation [Varies], Outdoorsman [10/level], Smooth Operator [15/level], Tenure [5], and Zeroed [10].

Disadvantages: -20 points chosen from among Bad Temper [-10*], Fanaticism [15], Gullibility [-10*], Impulsiveness [-10*], Intolerance (Varies) [-1 or -5], No Sense of Humor [-10], Obsession [Varies], Overconfidence [-5*], Pacifism (any) [Varies], Selfless [-5*], Sense of Duty (Every living being) [-20], Stubbornness [-5], and Trickster [-15*].

Primary Skills: Pick *two* of: Forced Entry (E) DX+1 [2]-11, Law (Bioethics or Environmental) (H) IQ-1 [2]-11, Propaganda (A) IQ [2]-12, Stealth (A) DX [2]-10.

Secondary Skills: 6 points chosen from among: Acting (A) IQ-1 [1]-11, Biology (Ecology) (H) IQ-2 [1]-10, Computer Operation (E) IQ [1]-12, Current Affairs (Headline News or Science & Technology) (E) IQ [1]-12, Fast-Talk (A) IQ-1 [1]-11, Leadership (A) IQ-1 [1]-11, Lockpicking (A) IQ-1 [1]-11, Naturalist (H) IQ-1 [2]-11, Photography (A) IQ-1 [1]-11, Observation (A) Per-1 [1]-11, Teaching (A) IQ-1 [1]-11, and Writing (A) IQ [2]-12.

Background Skills: A total of 5 points from Bicycling (E) DX, Boating (any) (A) DX, Driving (any) (A) DX, Climbing (A) DX, First Aid (E) IQ, Hiking (A) HT, Meditation (H) Will, Philosophy (any) (H) IQ, Politics (A) IQ, Psychology (H) IQ, Public Speaking (A) IQ, Scrounging (E) Per, Survival (any) (A) Per, and Theology (any) (H) IQ, or additional points in primary and secondary skills.

* Multiplied for self-control number; see p. B120.

Lens

Bioterrorist (+20 points): Add +1 DX [20]. Add Danger Sense [15], Languages [Varies], Patron [Varies], and Signature Gear (Terrorist bioweapon) [Varies] to the choice of advantages. Add Fanaticism [-15] as a compulsory disadvantage, and Bloodlust [-10*], Callous [-5], Enemy (Security forces) [Varies], Paranoia [-10], Reputation [Varies], and Social Stigma (any) [Varies] to the list of optional disadvantages. Add one more primary skill chosen from Bioengineering (Genetic Engineering) (H) IQ [4]-12, Poisons (H) IQ [4]-12, and Smuggling (A) IQ+1 [4]-13. Add an additional 6 points in secondary skills and the following choices: Beam Weapons (Pistol or Rifle) (E) DX+1 [2]-12, Explosives (Demolition) (A) IQ-1 [1]-11, Forgery (H) IQ-2 [1]-10, Guns (Pistol, SMG, or Rifle) (E) DX+1 [2]-12, Holdout (A) IQ-1 [1]-11, Knife (A) DX [2]-11, Interrogation (A) IQ-1 [1]-11, and NBC Suit (A) DX [2]-11. Add an additional 5 points in background skills and the following choices: Electronics Operation (Communications, Medical, or Scientific) (A) IQ, Hazardous Materials (any) (A) IQ, Soldier (A) IQ, and Tactics (H) IQ.

BIOENGINEER OR GENGINEER

90 points

Don't you see? My discovery will change the world!

A scientist or engineer working in gengineering or industrial biotech. Most bioengineers are employed by corporations, while others work in university labs or even as freelance “genehackers.” A bioengineer may be anything from a lab technician to a Nobel-prize winning researcher.

A common genre convention is the idealistic scientist who develops a process to benefit mankind, only to see it stolen and perverted by a rival or treacherous co-worker who is in the pay of a big megacorporation's bioweapons division. Another is the obsessed genius whose cutting-edge project was so controversial that he was fired from his job or driven out of the field. Now he lives alone somewhere and continues his ground-breaking work in private, often without adequate biohazard safeguards.

Attributes: ST 10 [0]; DX 10 [0]; IQ 13 [60]; HT 10 [0].

Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 13 [0]; Per 13 [0]; FP 10 [0]; Basic Speed 5.00 [0]; Basic Move 5 [0].

Advantages: A total of 30 points from Additional IQ [20 per +1 IQ], Contacts (Professional) [Varies], Eidetic

Memory [5], Intuition [15], Less Sleep [2/level], Reputation [Varies], Security Clearance [Varies], Single-Minded [5], Status [5/level], Wealth [Varies], Unfazeable [15], and Versatile [5].

Disadvantages: -25 points chosen from among Absent-Mindedness [-15], Bad Sight (Mitigator: Glasses, -60%) [-10], Callous [-5], Curious [-5*], Enemy (Anti-biotech Activists) [Varies], Jealousy [-10], Oblivious [-5], Obsession [-1, -5, or -10*], Pacifism (Reluctant Killer) [-5], and Workaholic [-5].

Primary Skills: Bioengineering (Cloning, Genetic Engineering, or Tissue Engineering) (H) IQ+1 [8]-14; and either Biology (Biochemistry or Microbiology) (H) IQ [4]-13 or Pharmacy (Synthetic) (H) IQ [4]-13.

Secondary Skills: Computer Operation (E) IQ [1]-13; Diagnosis (H) IQ-1 [2]-12; Electronics Operation (Medical or Scientific) (A) IQ [2]-13; Research (A) IQ-1 [1]-12; Writing (A) IQ-1 [1]-12.

Background Skills: 6 points chosen from among Animal Handling (any) (A) IQ, Current Affairs (Science & Technology) (E) IQ, First Aid (E) IQ, Hazardous Materials (any) (A) IQ, NBC Suit (A) DX, Physician (H) IQ, Physiology (H) IQ, Psychology (H) IQ, Public Speaking (A) IQ, Surgery (VH) IQ, and Weird Science (VH) IQ.

* Multiplied for self-control number; see p. B120

Lenses

Academic Bioengineer (+3 points): Add Tenure [5] to the list of advantages. Increase Research to IQ+1 [4]-14. Add Teaching (A) IQ to the background skills.

Colony Bioengineer (+15 points): You help keep an outpost alive by designing suitable crops, livestock, terraforming organisms, or human genemods. Increase HT to 11 [10]. Add Survival (any) (A) Per [2]-13 as a secondary skill. Add 3 points in background skills and add Free Fall (A) DX, Leadership (A) IQ, and Vacc Suit (A) DX to the list.

Genehacker (-5 points): Add Alternate Identity [15] and Zeroed [10] to the list of advantages. Remove Security Clearance and Status. Reduce Bioengineering to IQ-1 [2]-12. Replace Writing with Streetwise (A) IQ [2]-13.

Job Description: Bioengineer

Bioengineers employed by research or medical companies are often financially better off than those in academia or government service.

Prerequisites: Bioengineering 14+.

Job Roll: Bioengineering. On critical failure: demoted, reduce income by 10%.

Wealth Level: Corporate: Very Wealthy. Supports Status 3. Academic or colony: Wealthy. Supports Status 2.

Job Description: Genehacker

No reputable company or university will employ you, so you use your skills on the street, supplying biotech to the disenfranchised, criminals, and extremists.

Prerequisites: Bioengineering 12+.

Job Roll: Bioengineering. On critical failure: displease a client or suffer an accident; suffer 3d of injury.

Wealth Level: Comfortable. Supports Status 0.

BIOTECH EXECUTIVE

125 points

I'm afraid we cannot permit you to continue that research, doctor. The way public opinion has swung, such work on human germ cells would be detrimental to Metazyme's corporate image.

A senior manager in a bioengineering company. Small, dynamic companies are often helmed by former or current scientists, until they make it big and get bought out by or turn into huge conglomerates. Often the new managers are businessmen, pure and simple, which can lead to conflict between the scientists (who enjoy pure research projects) and the executives (who'd rather see a profit in the next fiscal year or two).

It can be fun to play the head of a small, struggling company, especially if the competition is doing everything – up to and including biological warfare – to wipe you out. The biotech exec also makes a good villain: He's the guy who orders the ruthless cover-ups when something controversial or dangerous escapes from the lab, or who arranges expeditions to alien worlds to find deadly new species for the Bioweapons Division.



Attributes: ST 10 [0]; DX 10 [0]; IQ 12 [40]; HT 10 [0].

Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 13 [5]; Per 12 [0]; FP 10 [0]; Basic Speed 5.00 [0]; Basic Move 5 [0].

Advantages: Wealth (Filthy Rich) [50]; 30 points chosen from among Business Acumen [10/level], Charisma [5/level], Fit [5], Less Sleep [2/level], Fashion Sense [5], Reputation [Varies], Security Clearance [Varies], Smooth Operator [15/level], Status [5/level], and additional Wealth (Multimillionaire) [25/level].

Disadvantages: -30 points chosen from among Callous [-5], Debt [-1/level], Enemy (Anti-biotech Activists) [Varies], Greed [-15*], Obsession [-1, -5, or -10*], Overweight [-1], Pacifism (Reluctant Killer) [-5], and Workaholic [-5].

Primary Skills: Pick two of the following: Administration (A) IQ+2 [8]-14, Bioengineering (Cloning, Genetic Engineering, or Tissue Engineering) (H) IQ+1 [8]-13, Finance (H) IQ+1 [8]-13, or Propaganda (A) IQ+2 [8]-14.

Secondary Skills: Current Affairs (Business or Science & Technology) (E) IQ [2]-13; Diplomacy (H) IQ [4]-12 or Intimidation (A) Will+1 [4]-14; pick two of the following: Accounting (H) IQ-1 [2]-11, Biology (Biochemistry or Microbiology) (H) IQ-1 [2]-11, Economics (H) IQ-1 [2]-11, Market Analysis (H) IQ-1 [2]-11, Pharmacy (Synthetic) (H) IQ-1 [2]-11, or Public Speaking (A) IQ [2]-12.

Background Skills: 4 points chosen from among Carousing (E) HT, Computer Operation (E) IQ, Connoisseur (Any) (A) IQ, Detect Lies (H) Per, Electronics Operation (Medical or Scientific) (A) IQ, First Aid (E) IQ, Hazardous Materials (any) (A) IQ, NBC Suit (A) DX, Physician (H) IQ, Physiology (H) IQ, Psychology (H) IQ, Public Speaking (A) IQ, and Sports (Any) (A) DX.

* Multiplied for self-control number; see p. B120.

Lens

Struggling Executive (-30 points): An executive of a company that is in trouble or just starting out. Downgrade Wealth (Filthy Rich) to Wealth (Wealthy) [20].

Job Description: Successful Executive

A biotech executive either owns his own company, or operates one on behalf of other owners and investors.

Prerequisites: Administration 14+.

Job Roll: Administration. On critical failure: lose 3× base income.

Wealth Level: Filthy Rich. Supports Status 4.

Job Description: Struggling Executive

Some executives run biotech concerns that are struggling to get by in a competitive market.

Prerequisites: Administration 12+.

Job Roll: Administration. On critical failure: company folds, lose job.

Wealth Level: Wealthy. Supports Status 2.

ECOLOGICAL ENGINEER OR ECOTEUR

90 points

A planetary ecosystem is a complex entity, a synergistic whole. Even seemingly insignificant changes have the potential to send shock waves that ripple across the entire biosphere.

Ecological engineers are specialists at redesigning regional or planetary ecosystems for the purposes of terraforming. They also work to correct the depredations of environmental disasters such as pollution, overpopulation, failed terraforming experiments and deliberate sabotage by ecoteurs. They combine a knowledge of genetic engineering or nanotechnology, with an understanding of how even minor changes can effect entire planetary ecosystems.

Ecoteurs are the dark side of the ecological engineer – sometimes even former eco-engineers “gone bad.” These are mercenary, corporate or government agents who specialize in ecological sabotage (“ecotage”) aimed at disrupting or destroying the relationships between species. Ecotage is typically aimed at destroying a competitor’s economically valuable crops or livestock, but it might also be intended to force the current occupants of a sabotaged region to leave or surrender.

Some ecotage activities may be very straightforward. A “rabbits in Australia” ploy may introduce a new species into an ecosystem in order to displace or kill livestock, crops or people. Ecotage can also be subtle. For instance, an ecoteur who has been hired to disrupt a region’s economy might release a bacteria that kills birds that prey upon a species of insect, resulting in the insects multiplying rapidly and devouring an economically important crop. This sort of ecological sabotage can be hard to trace back to the source, and in some cases, an enemy may never learn that sabotage has taken place!

Attributes: ST 10 [0]; DX 10 [0]; IQ 13 [60]; HT 10 [0].

Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 13 [0]; Per 13 [0]; FP 10 [0]; Basic Speed 5.00 [0]; Basic Move 5 [0].

Advantages: 30 points chosen from among Eidetic Memory [5], G-Experience [1-10]; Intuition [15], Less Sleep [2/level], Tenure [5], Reputation [Varies], Single-Minded [5], Status [5/level], Wealth [Varies], Versatile [5].

Disadvantages: -20 points chosen from among Absent-Mindedness [-15], Bad Sight (Mitigator: Glasses, -60%) [-10], Curious [-5*], Enemy (Environmental activists or security forces) [Varies], Oblivious [-5], Obsession (A particular project or cause) [-1, -5, or -10*], Pacifism (Reluctant Killer) [-5], and Workaholic [-5].

Primary Skills: Biology (Ecology) (H) IQ [4]-13; two of Bioengineering (Genetic Engineering) (H) IQ [4]-13, Engineer (Nanotechnology) (H) IQ [4]-13, or Geography (Physical) (H) IQ [4]-13.

Secondary Skills: Pick three of the following: Animal Handling (any) (A) IQ-1 [1]-12, Computer Operation (E) IQ [1]-13, Farming (A) IQ-1 [1]-12, Gardening (E) IQ [1]-13, Mathematics (Applied or Statistics) (H) IQ-2 [1]-11, Research (A) IQ-1 [1]-12, or Writing (A) IQ-1 [1]-12.

Background Skills: 5 points chosen from among: Electronics Operation (any) (A) IQ, Environmental Suit (any) (A) DX, First Aid (E) IQ, Hazardous Materials (any) (A) IQ, Hiking (A) HT, Observation (A) Per, Public Speaking (A) IQ, and Teaching (A) IQ.

* Multiplied for self-control number; see p. B120.

Job Description

Ecological engineers can be employed by private companies specializing in local ecosolutions, or by governments engaging in large-scale engineering or terraforming operations.

Prerequisites: Biology (Ecology) 13+ and one of Bioengineering (Genetic Engineering) 13+, Geography (Physical) 13+, or Engineer (Nanotechnology) 13+.

Job Roll: Biology (Ecology). On critical failure: lose 3× base income.

Wealth Level: Wealthy. Supports Status 2.

EPIDEMIOLOGIST

90 points

The victims don't live near each other, don't work together, and have never met, but every one of them was in Rachaelow Park less than a week before their symptoms hit. I suggest we move the search to there.

You study the distribution and determinants of morbidity, mortality, disability, and injury, and apply this knowledge to controlling health-related issues in populations. You might work for a government health department, federal disease control agency, hospital infection control, academia, private industry (particularly pharmaceutical companies), or the military.

Depending on your employer, you may be called upon to determine the cause of a mysterious outbreak, to figure out if the latest version of a certain bioroid is less prone to pyromania, or to test the effectiveness of a new drug.

Attributes: ST 10 [0]; DX 10 [0]; IQ 13 [60]; HT 10 [0].

Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 13 [0]; Per 13 [0]; FP 10 [0]; Basic Speed 5.00 [0]; Basic Move 5 [0].

Advantages: 20 points chosen from among +1 to IQ [20], additional Perception [5/level], Charisma [5/level], Common Sense [10], Cultural Familiarity [1 per culture], Fearlessness [2/level], Intuition [15], Languages (any) [Varies], Less Sleep [2/level], Resistant to Disease (+3 or +8) [3 or 5], and Status [5/level].

Disadvantages: -20 points chosen from among Curious [-5*], Honesty [-10], Insomniac [-10 or -15], Obsession [-1, -5, or -10*], Overconfidence [-5*], Sense of Duty (Humanity) [-15], Stubbornness [-5], Truthfulness [-5*], and Workaholic [-5]. Other stress-related disadvantages may apply as well.

Primary Skills: Expert Skill (Epidemiology) (H) IQ+1 [8]-14; Mathematics (Statistics) (H) IQ+0 [4]-13; Research (A) IQ+1 [4]-14.

Secondary Skills: Select three from: Biology (any optional specialty) (H) IQ-1 [2]-12, Chemistry (H) IQ-1 [2]-12, Computer Operation (E) IQ+1 [2]-14, or Electronics Operation (Scientific) (A) IQ [2]-13.

Background Skills: 8 points chosen from among: Area Knowledge (E) IQ, Current Affairs (Science & Technology) (E) IQ, Diplomacy (H) IQ, NBC Suit (A) DX, Physiology (H) IQ, Public Speaking (A) IQ, Sociology (H) IQ, Teaching (A) IQ, and Writing (A) IQ.

* Multiplied for self-control number; see p. B120.

Lenses

Research Epidemiologist (+5 points): Add Reputation [Varies], Tenure [5], and Wealth [Varies] to the choice of advantages. Select one more Secondary Skill. Add 3 more points in background skills and include Bioengineering (any specialty) (H) IQ and Pharmacy (H) IQ as options.

Disease Hunter (+10 points): Add Danger Sense [15] and Reputation [Varies] to the choice of advantages. Add Biology (Microbiology) (H) IQ-1 [2]-12 and NBC Suit (A) DX+2 [8]-12 to primary skills. Add Cartography (A) IQ, Linguistics (H) IQ, Physician (H) IQ, and Veterinary (H) IQ to the list of background skills.

Containment Specialist (-5 points): Drop IQ to 12 [40] and raise HT to 12 [20]. Add Danger Sense [15] and Security Clearance [Varies] to the choice of advantages. Add Duty (often Extremely Hazardous) [Varies] and Nightmares [-5*] to the list of disadvantages. Replace all primary skills with NBC Suit (A) DX+2 [8]-12; Hazardous Materials (any) (A) IQ+1 [4]-13. Add Expert Skill (Epidemiology) (H) IQ-1 [2]-11 and First Aid (E) IQ [2]-13 to the list of secondary skills. Drop 1 point from background skills and add Animal Handling (any) (A) IQ, Diagnosis (H) IQ, Driving (any) (A) DX, Forced Entry (E) DX, and Guns (Shotgun) (E) DX to the list.

Job Description: Epidemiologist

Many epidemiologists work at health departments or with health care facilities, focusing on disease surveillance and public health measures, such as vaccinations and patient quarantines. They also respond to local epidemics and educate the public regarding health-related subjects.

Prerequisites: Expert Skill (Epidemiology) 12+, Mathematics (Statistics) 11+, and Research 11+.

Job Roll: Worst prerequisite. On critical failure: make an error that potentially costs lives; lose job.

Wealth Level: Average. Supports Status 0.

Job Description: Research Epidemiologist

Whether you are a grant-funded academic employed by a university or a high-priced scientist with private industry, you work with your team to design studies, collect data, and analyze results.

Prerequisites: Expert Skill (Epidemiology) 14+, Mathematics (Statistics) 13+, and Research 14+.

Job Roll: Worst prerequisite. On critical failure: publish incorrect data or accused of research fraud; gain -1 Reputation in research community.

Wealth Level: Academic: Comfortable. Supports Status 1. Private: Very Wealthy. Supports Status 3.

Job Description: Disease Hunter

Yes, it's morbid, but you live for a good outbreak. Be it a natural infection or a bioengineered plague, when the call comes in, you're sent out. You travel around the world and work with people from almost every field, uncovering the causes of epidemics and stopping the spread of disease. You will typically be employed by a federal disease-control center, but military positions are also possible.

Prerequisites: Expert Skill (Epidemiology) 14+, NBC Suit 12+, and Research 12+.

Job Roll: Worst prerequisite. On critical failure: infected with a disease.

Wealth Level: Comfortable. Supports Status 1.

Job Description: Containment Specialist

Once a biohazard is identified, it's your job to contain and eliminate it. It might be a disease, or engineered pest

species gone rogue. You may work for a disease-control center, police force, military unit, or corporation, or be a freelancer hired to clean up others' messes.

Prerequisites: Hazardous Materials 12+, NBC Suit 12+.

Job Roll: Hazardous Materials. On critical failure: suffer 2d of injury or contract a disease.

Wealth Level: Comfortable. Supports Status 1.

It has become appallingly obvious that our technology has exceeded our humanity.

– Albert Einstein

FORENSIC PATHOLOGIST

95 points

This was no suicide.

You use your knowledge of causes of death and disease to help police catch criminals, or to build legal cases against them. You might specialize in performing autopsies, doing the followup labwork and analysis, or studying the decay of a body in detail to determine time of death. Sometimes you'll be called into the field to examine a crime scene, or be present at an exhumation. It's a job that takes dedication, thoroughness, and a lack of squeamishness.

After putting the evidence together you're likely to be called into court to present it to a jury. Explaining complex scientific findings to average people so they can come to the right conclusions is an important part of your job.

Attributes: ST 10 [0]; DX 10 [0]; IQ 13 [60]; HT 10 [0].

Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 13 [0]; Per 14 [5]; FP 10 [0]; Basic Speed 5.00 [0]; Basic Move 5 [0].

Advantages: A total of 15 points in: additional Will or Perception [5/level], Contacts (Police) [Varies], Fearlessness [2/level], or Less Sleep [2/level].

Disadvantages: -20 points chosen from among Curious [-5*], Enemy (Convicted Criminal) [Varies], Honesty [-10*], Sense of Duty (Crime Victims) [-5], Stubbornness [-5], Truthfulness [-5*], and Workaholic [-5].

Primary Skills: Biology (Biochemistry, Entomology, or Microbiology) (H) IQ [4]-13; Diagnosis (H) IQ [4]-13; Forensics (H) IQ+1 [8]-14; Physiology (H) IQ [4]-13.

Secondary Skills: Criminology (A) IQ-1 [1]-12; Pharmacy (Synthetic) (H) IQ-2 [1]-11; Physician (H) IQ-1 [2]-12; Savoir-Faire (Police) (E) IQ [1]-13; Surgery (VH) IQ-2 [2]-11; Writing (A) IQ-1 [1]-12. *One* of Chemistry (Analytical) (A) IQ-1 [1]-12 or Electronics Operation (Medical) (A) IQ-1 [1]-12.

Background Skills: A total of 6 points from Anthropology (H) IQ, First Aid (E) IQ, Guns (Pistol) (E) DX, Law (Local Criminal) (H) IQ, Poisons (H) IQ, Public Speaking (A) IQ, and Research (A) IQ.

* Multiplied for self-control number; see p. B120.

Job Description

Forensic pathologists usually work for law enforcement agencies. This could be a local police department, or a broader federal or international group charged with investigating crimes that cross jurisdictions.

Prerequisites: Diagnosis and Forensics 13+.

Job Roll: Worst prerequisite skill. On critical failure: demoted, income reduced 10%.

Wealth Level: Comfortable. Supports Status 1.

NURSE

65 points

This will only hurt for a second.

Nurses are the primary point of contact between the patient and the world of health care, working directly with patients and their families. They perform evaluations, administer medication and IVs, and develop care plans for inpatients as well as at-home care (after release). Because the nurse is in frequent contact with patients, he is usually the first to notice any problem. Nurses are rarely supervised directly by a doctor; the head nurse coordinates the nursing team, while the doctor makes adjustments to the patients' medical charts.

Attributes: ST 10 [0]; DX 10 [0]; IQ 12 [40]; HT 10 [0].

Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 11 [0]; Per 11 [0]; FP 10 [0]; Basic Speed 5.00 [0]; Basic Move 5 [0].

Advantages: A total of 20 points chosen from Common Sense [10], Empathy [5 or 15], Healer [10/level], Languages [Varies], Less Sleep [2/level], Lifting ST [3/level], Resistant to Disease (+3 or +8) [3 or 5], Resistant to Sickness (+3 or +8) [5 or 10], and Wealth (Comfortable) [10].

Disadvantages: A total of -20 points chosen from Charitable [-15*], Debt (Student loan) [-1/level], Guilt Complex [-5], Honesty [-10*], Insomniac [-10 or -15], Pacifism [Varies], Sense of Duty (Patients) [-10], and Workaholic [-5].

Primary Skills: Physician/TL (H) IQ+1 [8]-13.

Secondary Skills: Diagnosis/TL (H) IQ [4]-12; Diplomacy (H) IQ [4]-12; Electronics Operation/TL (Medical) (A) IQ-2 [2]-12.

Background Skills: A total of 7 points in Administration (A) IQ, Biology (Biochemistry)/TL (H) IQ, Body Language (A) Per, Chemistry/TL (H) IQ, Computer Operation/TL (E) IQ, Physiology/TL (H) IQ, Psychology (H) IQ, Teaching (A) IQ, and Writing (A) IQ.

* Multiplied for self-control number; see p. B120.

Lens

Paramedic/EMT (+25 points): Add DX+1 [20]. Add Combat Reflexes [15] to optional advantages. Add First Aid (E) IQ+3 [6†]-15, Area Knowledge (Operational area) (E) IQ+1 [2]-13, and either Driving/TL (Automobile) (A) DX [2]-11 or Piloting/TL (Helicopter) (A) DX [2]-11 to primary skills. Reduce Physician to IQ-1 [2]-11. Add another point in background skills.

† Bought up from default from Physician.

Job Description: Nurse

You care for patients in a hospital, nursing home, the military, or perhaps privately.

Prerequisites: Physician 12+, Diagnosis 10+.

Job Roll: Physician. On critical failure: Medicate a patient incorrectly, lose job.

Wealth Level: Comfortable. Supports Status 1.

Job Description: Paramedic/EMT

You are usually the first responder in an emergency situation, dispatched from the hospital that you work for.

Prerequisites: First-Aid 12+, Driving or Piloting 11+.

Job Roll: Lowest prerequisite. On critical failure: Injured in a hazardous situation or vehicle accident, 1d-2 damage.

Wealth Level: Average. Supports Status 0.

Posthuman Clothing

Visit Jeremy Fogg's Vacshop on Ceres for all your custom needs. We'll convert the gloves, sleeves, pant legs, and boots of all your clothing, armor and space-suits to fit your prehensile feet, tails, tentacles, or whatever! See our new line of toe-gloves, tail socks, and flexisleeves! Jeremy Fogg: Meeting the needs of posthuman morphs everywhere.

Full-body suits, armor and clothing for people who require extra sleeves, legs or "tail socks" are +10% to weight and cost per extra limb. There is no extra cost or weight if the extra arm, leg, or tail is outside it (e.g., a tail sticking through a flap) – this only applies if the suit must cover it.

ORGANLEGGER

105 points

19 years old, good heart and lungs, healthy kidneys, no diseases . . . a jogger, huh? Good choice, Charlie. Problem with snatching street people, they've got so many retroviruses and defects, it's not worth the trouble these days. Now this is prime stuff: at least two hundred Gs. Break her up, and burn the brain.

Organleggers kidnap people and break them down for spare parts, or – more subtly – loot the organs of sick or dying patients during hospital visits.

As the populace ages and immunosuppressant drugs improve, organs sell for huge profits on the black market to people desperate for transplants. The demand may slacken after bionic or cloned organs become available at TL9+, but organleggers can still compete by offering their wares at lower prices. At TL10+, organleggers could exploit a new market for adult human brains enslaved inside cyborg spaceships, biocomputers, or factories.

Attributes: ST 10 [0]; DX 11 [20]; IQ 12 [40]; HT 11 [10].
Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 13 [5]; Per 12 [0]; FP 11 [0]; Basic Speed 5.50 [0]; Basic Move 5 [0].
Advantages: Choose 30 points from among +1 to IQ [20], Allies [Varies], Alternate Identity (Illegal) [15], Contacts [Varies], High Manual Dexterity [5/level], Languages (any) [Varies], Patron (Crime boss) [Varies], Wealth [Varies], and Zeroed [10].
Disadvantages: Callous [-5] and -20 points chosen from among Addictions (Tobacco, alcohol, or stimulants) [Varies], Enemies (Law enforcement or rival gangs) [Varies], Greed [-15*], No Sense of Humor [-10], Sadism [-15*], or Secret (Imprisonment) [-20].

Primary Skills: Electronics Operation (Medical) (A) IQ-1 [1]-11; Streetwise (A) IQ [2]-12; Surgery (VH) IQ [8]-12.
Secondary Skills: Diagnosis (H) IQ-1 [2]-11; First Aid (E) IQ [1]-12; Merchant (A) IQ [2]-12; Pharmacy (Synthetic) (H) IQ-1 [2]-11; Physician (H) IQ-1 [2]-11.
Background Skills: 5 points from Beam Weapons (Pistol) (E) DX, Biology (VH) IQ, Detect Lies (H) Per, Fast-Talk (A) IQ, Forgery (H) IQ, Guns (Pistol) (E) DX, Knife (E) DX, Physiology (H) IQ, and Shadowing (A) IQ.

* Multiplied for self-control number; see p. B120.

Job Description

Organlegging is a dangerous freelance occupation, that pays off in big scores interspersed with quiet periods.

Prerequisites: Streetwise and Surgery 12+.

Job Roll: Worst prerequisite. On critical failure: arrested and suffers 1d of injury.

Wealth Level: Comfortable. Supports Status 1.

PHYSICIAN

95 points

Say 'Aaaah . . .'

You've dedicated your life to healing the sick. You examine patients, diagnose their conditions, and prescribe various treatments. If necessary, you'll order lab tests or refer them to a specialist. You'll also need to advise patients on various options and new treatments, which requires keeping up to date in a changing world.

Attributes: ST 10 [0]; DX 10 [0]; IQ 13 [60]; HT 10 [0].
Secondary Characteristics: Damage 1d-2/1d; BL 20 lbs.; HP 10 [0]; Will 13 [0]; Per 13 [0]; FP 10 [0]; Basic Speed 5.00 [0]; Basic Move 5 [0].
Advantages: Choose 20 points from among +1 to IQ [20], additional Perception [5/level], Charisma [5/level], Common Sense [10], Empathy [5 or 15], Fearlessness [2/level], Healer [10/level], High Manual Dexterity [5/level], Languages (any) [Varies], Less Sleep [2/level], Resistant to Disease (+3 or +8) [3 or 5], Status [5/level], Wealth [Varies].
Disadvantages: -20 points chosen from among Addiction (Tobacco, alcohol, or stimulants) [Varies], Code of Honor (Hippocratic) [-5], Curious [-5*], Debt (Student loan) [-1/level], Greed [-15*], Honesty [-10*], Sense of Duty (The Sick) [-5], Stubbornness [-5], Truthfulness

[-5*], and Workaholic [-5]. Other stress-related disadvantages may apply as well.

Primary Skills: Diagnosis (H) IQ+1 [8]-14; Physician (H) IQ+2 [12]-15; Physiology (H) IQ-1 [2]-12.

Secondary Skills: Electronics Operation (Medical) (A) IQ-1 [1]-12; Pharmacy (Synthetic) (H) IQ [4]-13; Surgery (VH) IQ-1 [4]-12.

Background Skills: 4 points from Bioengineering (Tissue Engineering) (H) IQ, Biology (VH) IQ, Current Affairs (Science & Technology) (E) IQ, Forensics (H) IQ, Law (Medical) (H) IQ, Poisons (H) IQ, Psychology (H) IQ, Research (A) IQ.

* Multiplied for self-control number; see p. B120.

Lenses

Ship's Doctor (+5 points): Add Cultural Adaptability (Normal or Xeno-Adaptability) [10 or 20] to the list of advantage choices. Add Seamanship (E) IQ [1]-13 to secondary skills and 4 points chosen from among Broadsword (A) DX; Guns (Pistol) (E) DX, Knot Tying (E) DX, Navigation (Sea) (A) IQ, and Swimming (E) HT.

Spaceship's Doctor (+5 points): Add Cultural Adaptability (Normal or Xeno-Adaptability) [10 or 20] to the list of advantage choices. Add Spacer (E) IQ [1]-13 to Secondary Skills, and 4 points chosen from among Astronomy (H) IQ, Beam Weapons (any) (E) DX, Free Fall (A) DX, and Vacc Suit (A) DX.

Specialist (+5 points): A specialist medical practitioner can be created in one of two ways. The simplest is to take Physician, Diagnosis, and Surgery, and give him optional specialties in the relevant fields. For specialists in less related fields, remove 4 points from Physician and add 8 points in the relevant field's skill, including various specialties of Bioengineering, Biology, Expert Skills, Pharmacy, Physiology, and so on; change Diagnosis and perhaps Electronics Operation (Medical) and Pharmacy to give them optional specializations; and add a further 1 point in background skills.

Surgeon (+55 points): Add DX +2 [40]. Add Reputation [Varies] to the list of advantages. Increase Surgery to IQ+2 [16]-15, change it to a primary skill, and add 3 points between primary, secondary, and background skills.

Military Doctor (+5 points): This lens may be taken in combination with any other lens except for *Illegal*. Add Military Rank 3 [15] and Duty (Military; 12 or less) [-10], plus the option of extra Rank [5/level] in the advantage choices.

Illegal (+10 points): Take either the standard Physician or a lens, not including *Military Doctor*. Add another 10 points in advantages. Add Alternate Identity (Illegal) [15], Contacts [Varies], and Zeroed [10] to optional advantages. Add Callous [-5], Enemy (law enforcement) [Varies], and Secret [Varies] to optional disadvantages. Add Forgery (H) IQ, Merchant (A) IQ, Streetwise (A) IQ, Fast-Talk (A) IQ, and Detect Lies (H) IQ to background skills.

Job Description: General Practitioner

Physicians can work for salary in a public health system or set up a private practice and earn freelance income.

Prerequisites: Diagnosis and Physician 12+.

Job Roll: Worst prerequisite. On critical failure: sued for malpractice, lose 5× base income and gain -1 Reputation.

Wealth Level: Wealthy. Supports Status 2.

Job Description: Ship's or Spaceship's Doctor

You see all sorts of things in this job. Crewmen come to me with broken bones, plasma burns, strange alien viruses picked up from god knows where. And that's just after they get back from shore leave.

You are dedicated to healing the sick, but also have an adventurous spirit tled you to a life of travel. Depending on tech level, this could be on an ocean-going vessel or a spacecraft. You could be part of a medical staff, or the only person on board with any medical knowledge at all. Working with limited facilities, you have to deal with every sort of medical problem under the sun. In the good times you can get away with prescribing antibiotics for "social" infections, but when things get rough you'll be facing diseases nobody has ever seen before or treating fellow crewmen injured in combat. In a pinch you may even have to help man the vessel.

A ship's doctor can be enlisted in the military and assigned to a naval vessel, or can hire on with a civilian crew. The former has greater job stability, but can be riskier!

Prerequisites: Diagnosis and Physician 12+.

Job Roll: Worst prerequisite. On critical failure: fired and gain -1 Reputation.

Wealth Level: Wealthy. Supports Status 2.

Job Description: Specialist

The bad news is your condition doesn't respond to any established treatment, and experience shows you probably have about six months to live. The good news is we have an experimental procedure that we'd like you to consider agreeing to try.

You know everything there is to know about a particular field of medicine, and general practitioners send their patients to you when they are not sure about something. You're the last line of medical care when patients have an unusual or life-threatening condition – if you can't help them, no one can. As such, you need to keep on top of all the latest developments in your field. You are also likely to be involved with advancing your chosen specialty through research and conducting clinical trials on patients with nothing to lose.

Your chosen field could encompass a specific condition (cancer, degenerative diseases, sleep disorders) or a particular type of patient (pediatrics, gynecology, geriatrics). As a leader in the area, your research may provoke public interest – or outrage – and you may be called upon to defend your work.

A specialist may be tenured at a university or medical research center, and see only a select few patients, or could operate a medical practice and contribute less to research.

Prerequisites: Diagnosis and Physiology 14+.

Job Roll: Worst prerequisite. On critical failure: sued for malpractice or research fraud, lose 5× base income and

gain -1 Reputation.

Wealth Level: Very Wealthy. Supports Status 3.

Job Description: Surgeon

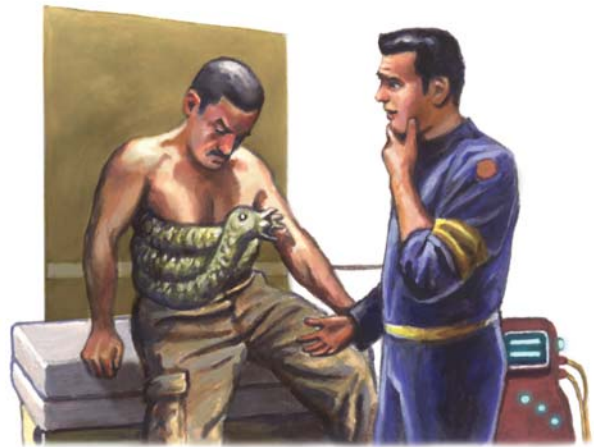
You use your skill and dexterity to perform operations on patients. Your specialty might involve trauma surgery, therapeutic operations, or elective biomodifications. Either way, it's a stressful job with long hours. You might do it for the satisfaction of applying your talents to improving the lives of others. On the other hand, surgeons are the elite of the medical profession, and you earn high social standing and considerable wealth, which may be motivation enough.

Surgeons are often eagerly sought by both public and private hospitals. The military also requires surgeons.

Prerequisites: Diagnosis and Surgery 14+.

Job Roll: Worst prerequisite. On critical failure: sued for malpractice, lose 5× base income and gain -1 Reputation.

Wealth Level: Very Wealthy. Supports Status 3.



Job Description: Splicer

Welcome to the Clinique Rouge, monsieur. Our discretion is assured.

If you don't quite have the talent, or the connections, or you made one mistake too many and were ejected from the medical fraternity, you could still practice your trade on the streets. Congratulations, you're an outlaw medic. A street doc. A "splicer." There are any number of reasons to walk this road. You could just be an out-of-work or struggling student moonlighting for extra cash, and as ethical as any licensed physician. Or maybe you enjoy working in the shadows, for an ultra-tech black clinic, for the opportunity to test cutting-edge procedures on live subjects, or to perform experiments that would never be approved by government regulators.

Splicers take whatever work they can get, usually on a single contract basis, making their pay freelance. They may be employed on a recurring basis by wealthy individuals wanting multiple operations on themselves or their subordinates.

Prerequisites: Streetwise 12+ and Surgery 13+.

Job Roll: Worst prerequisite. On critical failure: arrested and suffers 2d of injury.

Wealth Level: Wealthy. Supports Status 2.

SENIOR CITIZEN

-15 points

Well, son, I'm 97, and most of the last 15 years have been spent in hospitals like this one. Now you're telling me that if I let you pump that million dollars worth of nano-gook through my body, there's an even chance it'll either make me fifteen again or kill me. Gotcha, son. Where's that consent form?

The desire of elderly people to escape death may be the driving force behind radical advances in human biotechnology. The aged will actively follow the latest life-extension treatments (and vote more money for health care subsidies, if these exist). The extremely rich can afford to sponsor competing lines of cutting-edge research, ranging from anagathic drugs and brain or organ transplants to cryonics, nanotechnology, and uploading. When it is a question of trying out these treatments or dying, they may well be the guinea pigs for experimental therapy.

Sometimes even illegal therapy . . .

Attributes: ST 9 [-10]; DX 9 [-20]; IQ 12 [40]; HT 8 [-20].

Secondary Characteristics: Damage 1d-2/1d-1; BL 16 lbs.; HP 9 [0]; Will 12 [0]; Per 11 [-5]; FP 8 [0]; Basic Speed 4.25 [0]; Basic Move 4 [0].

Advantages: Choose 40 points from among +1 to IQ [20], additional Will or Perception [5/level], Ally (Loyal relatives, caregivers, or employees) [Varies], Common Sense [10], Less Sleep [2/level], Reputation [Varies], Social Regard 1 (Venerated) [5], Status [5/level], and Wealth [Varies].

Disadvantages: -40 points chosen from among Absent-Mindedness [-15], Appearance [Varies], Bad Sight [-25], Chronic Pain [Varies], Enemies [Varies], Hard of Hearing [-10], Hidebound [-5], Obsession (Immortality) [-10*], Restricted Diet [Varies], Short Attention Span [-10*], Stubbornness [-5], Susceptible to Disease [4/level], Terminally Ill [-50, -75, or -100], and Unfit or Very Unfit [-5 or -15].

* Multiplied for self-control number; see p. B120.

You will usually have high skill levels in former job skills. Diagnosis (of your own symptoms) and Current Affairs

(Science & Technology) (for keeping up with cutting-edge health care and life extension plans) are also appropriate.

JOBS

Here are a few more biotech-related jobs for which full character templates are inappropriate, or which might be taken by non-adventuring citizens.

Lab Assistant

You do the menial gruntwork in a biotech lab, under the direction of a senior researcher. This is likely to be in a private biotech company, but could also be in a government agency such as a disease-control center.

Prerequisites: Electronics Operation (Scientific) 11+, and either Biology (any) or Bioengineering (any) 12+.

Job Roll: Worst prerequisite. On critical failure: lose 2x base income.

Wealth Level: Average. Supports Status 0.

Surrogate Mother

You offer the service of your womb as the growth environment for someone else's baby. Although it's sometimes considered a degrading job, the employers are usually grateful and it pays reasonably well.

Prerequisites: Female (or male with androwomb implant, p. 175), HT 11+.

Job Roll: HT. On critical failure: miscarriage; lose job and suffer 1d damage.

Wealth Level: Average. Supports Status 0. (If illegal: Comfortable. Supports Status 1.)

Test Subject

You volunteer for experimental biotech procedures. This can be risky, but it provides income for people with no skills or other opportunities. You might get access to new biomods or vaccines before they are released to the public – or declared safe.

Prerequisites: HT 11+.

Job Roll: HT. On critical failure: lose job and suffer 2d damage or contract a disease.

Wealth Level: Struggling. Supports Status 0.

ADVANTAGES, DISADVANTAGES, AND SKILLS

Some advantages, disadvantages, and skills can be interpreted to represent different things in a biotech setting. New perks, enhancements, and limitations provide additional customization for biologically modified characters.

ADVANTAGES

Cultural Familiarity

see p. B23

The details of Cultural Familiarity in a campaign with multiple parahuman species and uplifted animals depends on just how alien the species seem to each other. In many cases, genetic upgrades and parahumans will be fully integrated into global society; if so, buy Cultural Familiarity for social cultures, not races.

Example: Cultural Familiarity (Western) [1] gives familiarity with baselines, upgrades, and parahumans raised in the western culture.

It may be possible that some parahuman species are stigmatized to the extent that they withdraw from or cannot participate in mainstream cultures and establish a culture of their own. Such a culture qualifies for its own familiarity, with a cost of 1 point because the species is close to human.

Example: Cultural Familiarity (Ariadne) [1] gives familiarity with an insular culture of Ariadne parahumans.

Uplifted animals are different enough from humans that they may qualify as having alien cultures, costing 2 points for a cross-species familiarity. This depends on how the GM interprets uplifts in the campaign. Uplifts who are essentially “talking animals” and integrate easily into human cultures are not alien, and may be included in a human culture like parahumans. Uplifts who have a distinct nonhuman psychology and find humans baffling do count as alien; such an uplift would need 2 points in Cultural Familiarity to understand a human culture – even if he was raised in one!

Dominance

see p. B50

This can be used to represent an attack that infects victims with nanobots that allow the attacker to control them.

Perks

These new perks represent unusual biochemistry or biotechnological improvements.

Immunity to a Specific Disease [P]

You are totally immune to a *single* specific disease that exists in the campaign setting. This can occur in low TL settings; Immunity to Plague would be useful at TL4! At high TLs this could be granted by a vaccine, but see Resistant (below) for broader protection.

Low Rejection Threshold [P]

Your body can easily accept foreign tissue transplants, with no roll for rejection required. This is only applicable in TL7+ settings, and only if cloned or synthetic organs are unavailable or are significantly more expensive than other types. Since this is due to an abnormally lax immune system, you may not have HT higher than 12 or Resistant to Disease (but may acquire it through treatments such as Panimmunity).

No Degeneration in Zero-G [P]

Humans and other animals which evolved in a gravity field suffer from a slow loss of bone density when they live in microgravity or zero gravity. The bones become fragile as they lose calcium. This can be prevented by vigorous daily exercise or drug treatments. If someone lives in microgravity without taking these precautions for six months, make a HT roll. A failed roll indicates a loss of one point of ST; a critical failure gives Vulnerability (Crushing Attacks 2) [-30]. Genetic engineering may be used to prevent this problem, granting this perk.

Pressure-Tolerant Lungs [P]

Your lungs and other organs can handle a wider range of atmospheric pressures than a baseline human's. Add either thin or dense atmospheres to the range of pressures you can breathe without penalty, and shift the penalties for thinner or denser atmospheres respectively by one class.

Example: If you can breathe thin and standard atmospheres without penalty, you treat very thin atmospheres as merely thin.

*We now have discrimination
down to a science.*

– Vincent, Gattaca

Reputation

see p. B26

“Mass produced” bioroids or clone families may have to live down reputations based on what other examples of their type have done, due to a public perception that they are a puppets to their genes. This is especially likely if they are treated as products or slaves. For example, if it made the news that a Tiger Lily-series pleasure bioroid killed her owner and ran away, all Tiger Lily models may get a reputation as “dangerously unstable,” regardless of the events (e.g., that particular bioroid was being abused by her owner, and acted to save her life).

In a society where genetic testing is common, those known or believed to have a genetic defect may also face prejudice, even if they look perfectly normal. This differs from Social Stigma, where the stigma must be obvious to anyone (see p. B155) for it to be worth points.

Some bioroids or parahuman species may enjoy a positive reputation if members of their type have performed notable good works in the public eye.

Resistant

see p. B80

A particular subset of infectious diseases counts as *Rare* for purposes of calculating the cost of Resistant, as per the rules on p. B81. Since drugs or nanosymbiont treatments that provide resistance to disease often provide no protection against diseases new to science or caused by particular agents, this is a common rarity level for such treatments. Immunity to a *single* disease is a perk.

Examples: Resistant to Known Diseases (+3) [1]; Resistant to Bacterial Infection (+8) [2]; Immunity to Viruses [5].

Social Regard

see p. B86

In a world where engineered people are regarded with awe, visibly altered people might enjoy Social Regard.

New Features

Early Maturation: You mature at the same rate as if you had Short Lifespan (p. B154) without affecting the frequency of aging rolls. This is a 0-point feature, but up to 5 levels are possible:

Level	Maturity
1	9 years
2	4 years
3	2 years
4	1 year
5	6 months

Low-Pressure Lungs: You treat very thin atmospheres as thin, thin as standard, standard as dense, and dense or superdense as unbreathable; you may have a noticeably large chest. This feature includes eye adaptations so that Vision penalties are similarly shifted.

High-Pressure Lungs: This feature has an opposite effect to Low-Pressure Lungs: you treat atmospheric pressures as one stage lower.

DISADVANTAGES

In a society that practices genetic selection and gene therapy, certain disadvantages are probably very rare at TL9 and nonexistent by TL10+.

These include Bad Sight, Bad Smell, Colorblindness, Dyslexia, Hemophilia, some forms of Chronic Pain, No Sense of Smell/Taste, and Neurological Disorder. In addition, Dwarfism, Fat, and Gigantism are likely to be almost unknown, unless one's parents or creator deliberately wanted such a disadvantage.

A character born into a society like this should justify any such disadvantages in his character story. For example, his family might have been poor, or their religion forbade engineering, or he could have been subjected to some mutagenic or nano-tech bioweapon, and so on.

Chronic Pain

see p. B126

This can represent many types of disease or injury. Suitably advanced biotech can cure this: surgery for shrapnel, gene therapy for cancer, neurological biomods for migraines. If cured during play, the GM should require the disadvantage to be bought off with character points.

Intolerance

see p. B140

Intolerance toward gene-altered people may become a common form of racism. This is worth -5 points if genetic engineering is common, -1 if rare. The reverse is also possible, with gene-altered people being prejudiced against unmodified humans; this is worth -5 points except in settings where baselines are a tiny minority.

Mistaken Identity

see p. B21

This is especially appropriate for identical clones that are the same age (via forced growth, or just being born at the same time). It's also suitable for bioroids or other genetic constructs if a run of identical copies were mass-produced, even if the variant race itself has some diversity. Surgical doubles could also be mistaken for one another.

Neurological Disorder

see p. B144

This can represent various conditions such as Parkinson's disease, multiple sclerosis, and Tourette's syndrome. The disorder may be controlled with neurological implants (p. 179) or cured by gene therapy (p. 181). Such treatments will require either buying a Mitigator limitation or buying off the disadvantage altogether.

Quirks

These are new biologically based quirks.

Allergy [P]

You have some sort of allergic reaction to a substance. This is annoying, but rarely dangerous. If exposed to the cause of your allergy, make a HT roll. On a failure you become miserable and suffer coughing, sneezing (p. B428), or itching (same game effect) for a number of minutes equal to the margin of failure. *Severe* allergies that can lead to damage or death should be bought as Susceptible instead (pp. 213, B158).

Examples: Hay fever that causes red eyes and sneezing; food allergies causing hives; insect bites causing severe itching.

Nano-Fever [P, X]

This is hot flushes and fatigue caused by two or more types of nanomachines working, and possibly interacting, in your body. You become feverish whenever the GM rules that multiple types of nano must work in concert, and will lose 1 FP per active nano type in excess of a GM-defined "safe level" (the GM should customize this depending on his take on the waste heat problem; see p. 164). Fatigue points lost in this way cannot be regained until the situation ends. Deactivating or removing the nanobots will end the bout of nano-fever.

Restricted Diet

see p. B151

Biogenetic or neogenetic organisms may be unable to digest normal food because of a radically different biochemistry, requiring a special diet. This is additional to the Unusual Biochemistry disadvantage.

Secret

see p. B152

If a society has laws or prejudices against engineered people, someone with hidden modifications will have a

Secret. It may also be possible that *non-gengineered* people are the exception, and a baseline human will harbor a dangerous Secret.

Social Stigma

see p. B155

People who are visibly gene-altered – especially those who are very exotic – may suffer a Social Stigma in some societies. Mass-produced clones, bioroids, chimeras, and uplifted animals are likely to have this disadvantage. If such beings are uncommon and the majority population is prejudiced against them, they will be classed as Second-Class Citizens or a Minority Group. An exotic who is the result of an experiment is probably Valuable Property; even if he's legally a person rather than an animal or slave, people will want to study him, protect him, etc. Some beings may even be Subjugated or classed as Monsters.

Of course, in a world where gengineering is the rule rather than the exception, visibly unaltered people may suffer from a Social Stigma!

Stress Atavism

see p. B156

This is a classic disadvantage for uplifted animals. In some cases it may be appropriate for parahumans with mental modifications.

Susceptible

see p. B158

This can represent *severe* allergic reactions to particular substances, of the sort that land you in hospital or are life-threatening. A typical severe allergy is triggered by a substance that is often harmless to others, even in large doses. If exposed to it, roll against HT+1 minus your level of susceptibility. Failure causes an allergic reaction (see below) for a number of minutes equal to the margin of failure; after this time roll again to recover, with failure repeating the whole process until recovery or death. Any critical failure is a heart attack (p. B429). This *replaces* the effect normally associated with Susceptible. An injection of epinephrine (usually carried by people with allergies this severe) allows another HT roll to recover immediately, at a +2 bonus.

An allergic reaction is represented by any of the Incapacitation or Irritant effects listed under Affliction (p. B36); choose which effect you suffer at character creation. Treat this as a modifier equal to (the percentage cost of the effect minus 100%); e.g., if your allergy only causes coughing (+20%), treat that as a -80% limitation on this disadvantage. The most common reaction – anaphylaxis – is either choking (+0%) or unconsciousness (+100%).

Any allergy worth less than -2 points should be bought as the physical quirk *Allergy* instead (p. 212).

Terminally Ill

see p. B158

In a high-biotech world where nearly any condition may be cured, this disadvantage must be used with discretion. If a cure for a terminal condition is a commonly available procedure, characters should not be allowed points for it. On the other hand, if the cure is experimental or illegal, the disadvantage can be allowed, perhaps with a Mitigator limitation reflecting the likelihood of undergoing the cure.

Terminally ill characters in a campaign with suspension technology may want to suspend themselves during adventuring “down time” to prolong their active lives. This can be allowed at the GM's discretion, but reduce the point value for the disadvantage with a Mitigator limitation. The GM should also be sure to take advantage of the fact that situations requiring immediate response can occur when the adventurer is inconveniently frozen! If the GM does not wish to deal with this, he may simply rule that Terminally Ill is not allowed.



Unnatural Features

see p. B22

A modified person who can still pass for a human being will possess Unnatural Features for any obvious differences from the species baseline. Someone so changed that he no longer resembles a human does not have this disadvantage. This applies to other species too: if an almost-dog is treated differently by baseline dogs because he looks or smells funny, that's an Unnatural Feature, but if they don't even recognize him as a dog, then it isn't.

Unusual Biochemistry

see p. B160

You experience different effects from drugs than normal humans (or whatever the common campaign biochemistry is) but can still subsist on human food by default. If you cannot digest human food and require a special diet tailored to your biochemistry, use Restricted Diet to represent this.

NEW META-TRAITS

Enhancement Meta-Traits [P, X]

These are common combinations of advantages that are associated in biologically enhanced individuals.

Enhanced Muscles: Each level provides Lifting ST +1 [3] + Striking ST +1 [5]. 8 points per +1 ST.

Enhanced Reflexes: Combat Reflexes [15] + Basic Speed +1.00 [20]. 35 points.

Biotech Meta-Traits [P, X]

These meta-traits are the (sometimes inadvertent) results of particular biotechnologies used to create life-forms:

Bioroid: You are an artificially constructed living organism who was assembled via biogenesis (p. 26) nanotechnology rather than grown from an embryo. Early Maturation 3-5 [0]; Sterile [0]; and Unusual Biochemistry [-5]. -5 points.

Chimera: You are the result of a fusion of two different-species blastocysts. Due to metabolic problems that result from this fusion, you have Restricted Diet (Very Common; Substitution, -50%) [-5]; Sterile [0]; and Unusual Biochemistry [-5]. -10 points.

Medicine! (IQ)

This optional wildcard skill (p. B175) replaces all specialties of Biology, Diagnosis, Electronics Operation (Medical), Expert Skill (Epidemiology), First Aid, Hypnotism, Pharmacy, Physician, Physiology, Poisons, Psychology, Surgery, and Veterinary. It may also include Bioengineering and/or Esoteric Medicine at the GM's option.

This skill is possessed by cinematic doctors such as Leonard "Bones" McCoy or Doc Savage.

SKILLS

Bioengineering

see p. B180

In a biotechnological society, there may be additional specializations of this skill. Possibilities include:

Biogadgets: The creation of living equipment or vehicles.

Microbioengineering: The development of new strains of microbes for commercial, medicinal or hostile purposes.

Uplift: The modification of species to increase sentience.

Vaccines: The research and development of vaccines.

Diagnosis

see p. B187

The -5 penalty for diagnosing internal injuries should also be applied for internal diseases with subtle or ambiguous external symptoms. This penalty can be removed by exploratory surgery (p. 127).

Physician

see p. B213

Optional specializations include Physiotherapy – see p. 132.

Surgery

see p. B223

Standard modifiers to Surgery skill are listed on pp. B223, B424.

The GM can assume that commercial hospitals are well enough trained and equipped that no skill rolls are required to perform surgery. If characters do their own work, or a back-alley surgeon is hired, use the Surgery rules on p. B223, but instead of the modifier listed there, assume the roll is at -1 for every week of recovery required (if less than a week, no penalty).

A success means the surgery was performed properly. A critical success halves the recovery time. A failure means the biomodification failed; a later attempt is possible after the patient recovers (full recovery time still applies). Failure also inflicts 1d damage for every two weeks of recovery (or fraction thereof) that would be required. Use the hit location rules; e.g., surgical damage in excess of HP/2 to an arm or leg is ignored, but may cripple the limb. A critical failure may double this damage or, at the GM's option, result in other side effects instead of direct damage (e.g., surgery to improve eyesight might cause Blindness, cosmetic surgery could reduce Appearance).

MODIFIERS

NEW ENHANCEMENTS

Switchable

+10%

This enhancement only exists for physiological features (e.g., Claws), defenses, and other traits that are normally "always on." It lets you switch your advantage off and on by taking a Ready maneuver. Be sure to specify whether it switches on or off when you're knocked out, or simply remains in its current state.

You cannot add Switchable to an advantage that lists special modifiers that let you turn it off and on, regardless of whether *your* ability has those modifiers. If an advantage already notes Switchable as a special enhancement with a different value, use that value instead. Switchable isn't permitted on meta-traits, either. To get a switchable meta-trait, buy an Alternate Form.

Switchable is unnecessary if an advantage was limited with Costs Fatigue (p. B111), Emergencies Only (p. B112), Limited Use (p. B112), or Trigger (p. B115); such abilities are effectively switchable by default.

LIMITATIONS

Accessibility

see p. B110

Requires Low Gravity: Your ability doesn't function in gravity fields over a certain strength. This can be appropriate for engineered morphological modifications that work better in lower gravity, such as Clinging or Flight. This is worth -5% for each 0.1G under 1G at which the ability does not work (-5% at 0.9G, to -50% if the ability only works in zero gravity).

Switchable Body Parts

Many physical advantages represent body parts, including Claws, Extra Arms, Extra Legs, Extra Mouth, Nictitating Membrane, Spines, Striker, and Teeth. These are "always on" by default, whether they're due to racial makeup, genetic engineering, implants, or super-mutation. The GM may permit shapeshifters and those with retractable implants to add Switchable (+10%), however.

Not every option is immediately obvious. Some changes are subtle, such as being able to darken the eyes to gain Protected Vision. Others involve body parts implied by a special modifier; e.g., Doesn't Breathe (Gills, -50%) and Flight (Winged, -25%). A few even represent the *absence* of a body part, like switchable Payload as the ability to create a new body cavity. Be creative!

Melee Attack

see p. B112

This can be applied to traits such as Telecommunication if the user must touch the recipient.

Mitigator

see p. B112

If drugs are readily available in a campaign for the treatment of any given disadvantage, then that disadvantage must be bought with this limitation.

Temporary Disadvantage

see p. B115

An advantage that is not normally switchable, but was given Costs Fatigue (p. B111), Emergencies Only (p. B112), Limited Use (p. B112), or Trigger (p. B115) can be given this limitation.

Aftermath: This is a Temporary Disadvantage that takes effect once your advantage switches off. You can only add this to an advantage that you can and *must* eventually

switch off – whether because you'll run out of FP to maintain it, its duration is fixed by Limited Use or Trigger, or leaving it on indefinitely would negatively affect your health. Find the limitation value as usual, and halve it. A disadvantage with no self-control roll will be in full effect for as long as you used the modified trait, with a minimum of 10 minutes per use. A disadvantage with a self-control roll leaves you with an urge that endures until you get into a situation where you have to make that roll. Success means you fight the urge. Failure means you give in for at least 10 minutes. Either way, there are no further effects.

Trigger

see p. B115

This is useful for advantages granted through the use of biomods or implants, to represent the need for enabling drugs or hormones.

NEW LIMITATIONS

Cardiac Stress

Variable

You can only take this limitation on an advantage that is used for a short period of time and then turned off. While in use, the advantage places undue stress on your heart, and you must make periodic HT rolls (a roll of 14+ always fails). Failure means loss of 1d fatigue; critical failure means a heart attack – see p. B429.

Cost depends on how often you need to make the HT roll:

Every second: -50%

Every 10 seconds: -40%

Every minute: -30%

Every 10 minutes: -20%

Every hour: -10%

Unsupported Strength

-25%

You have increased strength through engineering or biomods, but the engineers did a shoddy job of muscle attachment or you haven't bothered to build up your bone mass to support the additional strength. You may take this limitation on some or all of any ST, Lifting ST, or Striking ST increase of +3 or more that's due to biomods or engineering. Keep track of your fully supported ST and the higher "unsupported" ST. Use the unsupported ST score to determine Basic Lift for purposes of sustained carrying. However, for any transitory feat of strength – including lifting, jumping, grappling, throwing, or attacking – you can choose to use either the safe, supported ST score, or your unsupported ST. No roll is required to use the unsupported strength, but in the next second, roll vs. HT. Success means no problem occurs, but a failure causes 1 point of injury; critical failure, or two failures in consecutive seconds, does 1d injury and causes any one limb you are using to be crippled.

About Our Commentators

"Aquagrll" is the alias of amateur marine biologist/ecologist Cherry Lake. Aquagrll denies rumors that she was once a member of the outlawed eco-warrior group Blue Shadow.

Lt. Majid Asad is a biomodified FS-26 Black Widow 2 driver, serving with Navy squadron VF-17 aboard the space cruiser *USS George W. Bush*.

Tatiana Belenko is a Special Agent with the Genetic Regulatory Agency, based in Geneva, Switzerland.

Dr. Tse Chang was Senior Academician of the Genetic Planning Council.

Cody Chase is a detective with the Nevada Department of Public Safety's Investigations Division, where he has dealt with a wide variety of genetic code violations and surgical assault cases.

Marie Detroit is an aspiring pop-singer working as a hostess at the Club Kitsune in Tokyo, Japan.

Genosibyl is the alias of a well-known poster to alt.bio.upgrade.samurai.

Professor C. Eric Gideon of the Antarctic School of Economics is a genome-preservationist and professional gadfly.

Eden Harrier is an expatriate New Zealander, the owner/operator of Harrier Exports. His firm has been investigated for biohazard and customs violations in Asia-Transpacific.

Noriko Hayakawa is an Ishtar-sequence genetic upgrade who hosts the popular talk show, *Cyberia Beat*.

Doc Hobo was stripped of his medical license after removing "spare" organs from patients. Having served 12 years, he now makes a risky living as a street splicer in the ganglands of New Chicago.

Ictinos of Alexandria has been a priest of Asclepius for 19 years. He has a pet snake, Cassandra, whose intelligence he favorably compares to that of novice acolytes with the temerity to question his hard-earned wisdom.

Dr. Sayyid Iqbal is a scientist at Biotech Euphrates' Human Genetic Engineering division. He is a frequent talk-show guest.

Copernicus Jones was born in a growth tank on the moon, but is now bumming around the solar system as a travel writer for the best-selling *Lonely System* guidebook series.

Walter Jorgenson was a brilliant young student in molecular biology, until he developed a series of delusions relating to alleged paranormal activity. Arrested in connection with a burglary and arson at Dogstar Genetics, he claimed that the Ottawa engineering company was a front for "ETs" and "Men in Black." Found not guilty by reason of insanity, he is now confined in an Ontario mental hospital.

Dr. Lucien Locke is the president and sole employee of Genehackers Inc., an R&D firm specializing in customized biomodification for private clients, and author/star of a number of interactive sensies, including

Playing God for Fun and Profit: Home Study Gengineering and Nanovirus for Dummies.

Tisephone Logos serves the Church of Seventh Heaven (an L-5 colony) as one of its elite "warrior angel" biosoldiers. Although born human, Tisephone has been continuously updated with the latest combat biomods, and is equally at home stalking criminals and genetic heretics in the decadent bubble cities of Luna or the wildzones of post-Nanoclysm Earth. Despite her youthful appearance, she is at least a century old.

Chance Mackintosh speaks her mind in *Posthuman Consumer Review*, a virtuality infodump covering the latest trends in elective surgery from a transgendered perspective. Now in her fourth consecutive clone, she plans to live forever.

Charlie "Big C" Magaddino is an alleged Mafia crime boss, presently under indictment for numerous state and federal felonies, including tax evasion, conspiracy, surgical assault, and kidnapping.

Captain Dana Martello is a former Marine Force Recon medic, now pursuing a career as a defense analyst. Twice decorated for bravery under fire during the Andes conflict, she is assistant editor of *Jane's Fighting Bioroids*.

Captain Zeke Morrigan is a gengineered spacer parahuman, and master of the free trader *Antares*.

Corporal NB-SEK-0172 is a Felicia-series combat bioroid. She is assigned to the Indian Army's elite 152nd Paratroop Regiment.

Dr. Mara Omokage is the mysterious and seemingly ageless founder of Omokage Labs, and a specialist in exotic bioweapon design.

Raphael-3000 is a vatbrain computer installed in the Sisters of Mercy hospital on Seventh Heaven.

Madeleine Rouge is one of the owners of the Clinique Rouge, "the finest underground clinic in Marseille."

Derin Skay, a writer, was one of the few humans to be unchanged by the Antarctica Nanoclysm.

Streethawk, an outspoken ex-gang member turned self-proclaimed mercenary, is known for his frequent postings on alt.bio.upgrade.samurai.

Tizbeth Sung-Morton is a Camazotz parahuman. She grew up on a seedship in the Darktree Colonization Fleet.

Gibson Wallace is the CEO of Quarticum Ltd., an agribusiness making billions with aggressive marketing of GM crops in Third World nations.

Ensign Chun Yuan was a soldier in the People's Self-Defense Forces Bio-weapons Directorate. Their labs were a priority target during the conflict, and Yuan's war diary is one of the few primary sources to survive the orbital strikes.

Yukio is an Alpha-series genetic upgrade working as an agent for Gomi Crash, a company specializing in macro- and micro-biohazard exterminations, and the tracking, recapture, or termination of escaped or outlawed genetic constructs.

CHAPTER NINE

BIOTECH SETTINGS

Ictinos looked sadly out over the harbor toward the lighthouse on the island of Pharos. He had warned the doctors of the Great Medical School that the gods were displeased with their mad arts. Dissecting human corpses was anathema to Asclepius. The secrets of true medicine were to be learned through devout prayer and ritual, not by squinting through strange lenses at flesh torn from the living and dead.

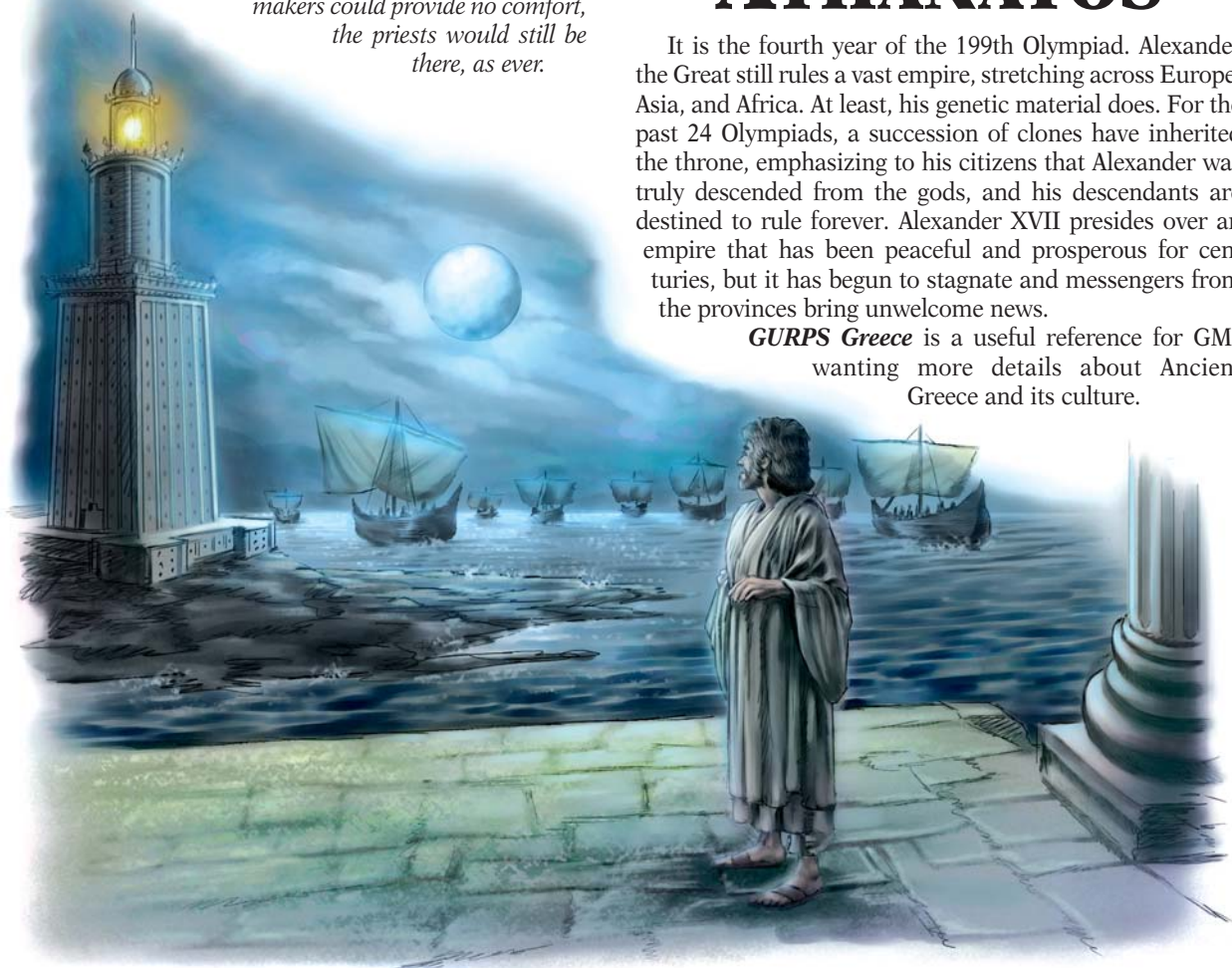
Now, a fleet of sails broke the eastern horizon, bearing down on Alexandria. There was to be a reckoning. Ictinos had heard the rumors: the clones of Alexander had joined forces and were ready to wage war on the Emperor. When blood ran in the streets of the capital, there would be need for healers – and when the monster-makers could provide no comfort, the priests would still be there, as ever.

Biotechnology cannot occur without a world and the people who inhabit it. It is easiest to think of biotech in a near or far future science fiction setting, but this does not have to limit the tech levels or types of worlds in which it can play a role. The world of Paradise described in Chapter 3 of *GURPS Fantasy* is an example of a biotech world with an unusual premise and technology level.

ALEXANDER ATHANATOS

It is the fourth year of the 199th Olympiad. Alexander the Great still rules a vast empire, stretching across Europe, Asia, and Africa. At least, his genetic material does. For the past 24 Olympiads, a succession of clones have inherited the throne, emphasizing to his citizens that Alexander was truly descended from the gods, and his descendants are destined to rule forever. Alexander XVII presides over an empire that has been peaceful and prosperous for centuries, but it has begun to stagnate and messengers from the provinces bring unwelcome news.

GURPS Greece is a useful reference for GMs wanting more details about Ancient Greece and its culture.



HISTORY

It began with the father of medicine. Hippocrates was intellectually far ahead of his time, but rather than instituting the idea of patient confidentiality and embodying the Hippocratic Oath, he performed experiments on his patients.

He was still the first to apply scientific methods to medicine, but took a more pragmatic and less ethical approach. To test myths about the gods, he surreptitiously tried to impregnate women with various materials of inorganic and biological origin. It quickly became clear that chimeras could not be created so easily, but he learned that humans could be produced even from virgins. Soon after Ol. 95, Hippocrates was offering artificial insemination services to farmers wanting to breed desirable livestock as well as to barren men – using his own sperm.

Following his death in Ol. 100,1, Hippocrates' students continued his process of medical experimentation, encouraged by King Philip II of Macedon, who had a strong interest in medical technology. They took the traditional poultices used to stem infection and produced more potent extracts through fermentation. These were the first antibiotics – dubbed *nosopharmaka* by the physicians – and successfully treated a range of diseases.

Philip's son Alexander grew up and inherited the throne at the age of 19. In little more than a decade, he conquered Greece, Egypt, and Persia, and earned the name Alexander the Great. When he fell ill in Ol. 114,2, the physicians of his court treated him with *nosopharmaka*. Alexander made a full recovery and ruled for another 34 years in robust health.

The Greek Calendar

The Ancient Greeks number years by *Olympiads*, periods of four years between successive Olympic Games. The first Games were held in 776 B.C. in our calendar. This is the first year of the first Olympiad (abbreviated Ol. 1,1), which is followed by the second (Ol. 1,2), third (Ol. 1,3), and fourth (Ol. 1,4) years. The next year (772 B.C.) is the first year of the second Olympiad (Ol. 2,1). This makes 1 A.D. the first year of the 195th Olympiad, and the current year in Alexander Athanatos equivalent to 21 A.D. The Games that mark the beginning of the Olympiad occur at the eighth full moon after the winter solstice, so the 200th Olympiad will begin in August, 21 A.D.

The Great Medical School

The ruler of the empire eventually returned to his Egyptian capital at Alexandria. In Ol. 118,3, he dedicated the Great Medical School in that city, founded by Herophilus and Erasistratus. The two physicians began the first formal studies of anatomy, vivisectioning hundreds of Alexander's prisoners in their quest to understand how the body worked. Using live subjects, the students of the school

learned the functions of the organs and the basics of surgery. Experience showed that opium could dull pain and instruments treated with fire produced fewer infections, but surgery remained risky and brutal.

Under Alexander's rule the empire flourished into an age of unprecedented glories. With the aid of the medical knowledge coming out of the Great School, Alexander conquered the Roman Republic, the Samnites, and the Etruscans while sustaining fewer casualties than in his previous conquests.

Meanwhile, students of the Great School added to anatomical knowledge of complex organs such as the brain and nervous system by dissecting both live animals and prisoners. The desire to examine ever smaller parts of the body and discover Democritus' *atoms* led researchers at the School to adapt the well-known magnifying properties of water in glass bowls and invent simple one-lens microscopes. With these, Erasistratus became the first person to observe microorganisms and cells. Unsatisfied with the green-tinted glass available to him, he used School funds to commission experiments in glassmaking, resulting in the discovery that some ores could be added to make the glass clear. He also used glass scalpels, finding their edges suitable for the finest work.

After the deaths of Alexander (in Ol. 122,4) and the School's founders, the work continued, supported by a stable empire inherited by Alexander's son, Alexander IV, and a series of strong heirs. Over the following centuries, students of the School developed compound microscopes, discovered the roles of ova and sperm, and produced lever-operated glass microscalpels and needles suitable for manipulating cells. A surrogate mother gave birth to the first *in vitro* fertilized baby in Ol. 141,1.

Researchers also developed the germ theory of disease and successfully administered vaccines against smallpox, cholera, rabies, and tetanus by Ol. 157. When bubonic plague appeared in Athens in Ol. 159,4, it was halted in its tracks within four months by an effective vaccine, and the disease never darkened Europe's door again.

Genetikosophia

By this time, the School had several well-developed theories of heredity and genetics. Most postulated that *something* within the cells contained a vital essence that passed characteristics from parent to offspring, but nobody could yet see what it was. A new generation of microscopes finally provided the ability to resolve structures inside cells on the scale of the chromosomes. Knowledge followed quickly, as experiments showed how chromosomes duplicated themselves during cell division, and that extracting them with a microneedle crippled the cell's ability to divide. The discoverers called them *genetikones*.

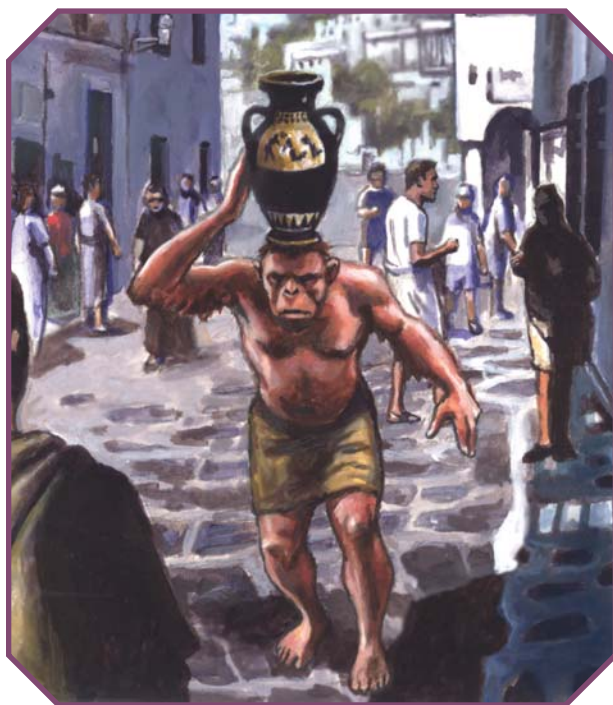
School researchers created the first cloned frog in Ol. 162,4, the first mammal (a goat) in Ol. 165,4, and the first human in Ol. 167,1. Within a decade, they had discovered that *genetikones* could be extracted from corpses and used to make children of the dead person. When King Philip VI visited the School in Ol. 171,3, expressing concern that he could not sire an heir, the head of the School made an audacious suggestion.

Philip, worried that he might pass his sterility on to a cloned son, authorized the disinterment of Alexander the Great, and the production of a clone to carry on the royal bloodline. Fortunately, when Alexander had died, the embalmers preserved his body by interring it in a casket full of honey. This meant much of his flesh remained undecayed, providing ample material for the extraction of his *genetikones*.

The School produced several clones of Alexander, and Philip raised them as his sons, teaching them to run the empire that was their heritage. (Each clone takes the name Alexander, along with a second name reflecting his own accomplishments or personality.) When he died, the eldest assumed the title of Alexander VIII and the imperial throne at the age of 22. Unfortunately, this incarnation developed chronic arthritis three years later and died of what was essentially old age when only 32. One of his younger clone siblings took over as Alexander IX. Ever since, clones of Alexander have ruled the empire in succession. They share his mental strength and leadership, but not his physical condition. Improving the health of the clones is the major research project currently being undertaken at the School.

Chimerae

The Great Medical School had been experimenting in chimerization since it was established, by mixing ova and sperm from different species, with no success. Soon after the discovery of the *genetikones*, a student named Lysandros observed that different species had different numbers of them. He looked for species with similar numbers, and found that chimpanzees from the School's breeding colony imported from equatorial Africa had only two more than humans. He postulated that the number of *genetikones* determined the form of the animal and tried removing various combinations of them from chimpanzee embryos. When this failed to produce viable embryos, he



Anthropithekos

11 points

Attribute Modifiers: ST+1 [10]; DX+1 [20]; IQ-1 [-20]; HT+1 [10].

Secondary Characteristic Modifiers: Per+2 [10].

Advantages: Arm ST +1 [5]; Brachiator [5].

Disadvantages: Social Stigma (Minority Group) [-10]; Stuttering [-10]; Ugly [-8].

Quirks: Dull [-1].

The *anthropithekos* (plural: *anthropithekoi*) is an artificial hybrid species with a mixture of human and chimpanzee *genetikones* (chromosomes). Although originally created by manipulation of the *genetikones*, *anthropithekoi* can breed normally amongst themselves. They can also interbreed with humans, but the offspring are sterile. They are not interfertile at all with chimpanzees.

Since being created 26 Olympiads ago, *anthropithekoi* have become a common sight in the streets of Alexandria. The Great Medical School presented a young pair to Philip VI, and they grew to become favored slaves in the imperial palace. The School took advantage of the demand this created for *anthropithekoi* slaves, selling them to raise funds. From that beginning, natural population growth supplemented by additional creations from the School has produced a population now numbering 11,000 individuals. A few travelers have taken *anthropithekoi* to the far reaches of the empire, but the vast majority live in Alexandria.

The species makes loyal, if dull, slaves. Once given a task, they can be trusted to carry it out dutifully. Over the years, several *anthropithekoi* have managed to earn their freedom, but most remain in slavery. Freed slaves and their offspring generally take up laboring or agricultural jobs, as their mentality is ill-suited to crafts or more lofty work.

To a casual eye, an *anthropithekos* resembles a rather hairy human with coarse features. They are stronger than humans, but not as intelligent or creative. They can learn language as easily as human children, but suffer from an inadequate voicebox that makes their speech strained and difficult to follow.

tried removing *genetikones* from chimpanzee ova and fertilizing them with human sperm.

Before long, Lysandros produced a hybrid embryo that divided a few times before dying. This was encouragement enough to continue experimenting. In Ol. 173,3 he produced a live birth of a human-chimpanzee hybrid, the first *anthropithekos*. Further work produced chimerae of other related species, such as non-sterile mules and cow-goat hybrids. Some of these new species have since become useful livestock animals, while the *anthropithekoi* proved to be trainable as slaves.

THE EMPIRE

The Macedonian Empire extends from Galatia (Gaul) in the west to Persis (Persia) in the East. Although Alexander the Great conquered India, his successors were unable to hold it and the border retreated to a stable position in Persis.

Egypt

Alexander moved his imperial capital to Alexandria, where it remains. The city is vast, sprawling across the Nile delta with a population of half a million people. The great lighthouse standing on the island of Pharos is the most distinctive feature of the city. Its 440' tower guides ships safely to harbor with mirrors casting a beam of light reflected from the sun by day and a fire at night.

Near the lighthouse, on the promontory of Lochias, stands the imperial palace. It is a grand building with hundreds of rooms and extensive gardens, sitting atop a rocky outcrop and commanding a splendid view of the great harbor. Its position near the coast makes it vulnerable to attack from the water, but Alexander the Great declared that if he could not be safe in his own capital then he did not deserve to live. His clones command the empire from his palace with the same bravado.

Further inland stand the temples dedicated to various gods, next to a huge amphitheater at which plays are performed. Next to these is the *agora*, a large open space where citizens gather to buy and sell wares, trade gossip, and argue politics. Half a mile south of the *agora* are the city's

major *gymnasion* and *palaistra*, where citizens engage in athletic pursuits and competitions. The large public baths sit next door. Nearby is the city's museum and the famous Library of Alexandria, in which over half a million scrolls record the knowledge of the empire on all topics.

West of the city center is the Egyptian quarter, populated by natives of the region, while east is the Jewish quarter.

Slaves

Greeks across the empire own slaves to perform household duties and run errands. Although slaves suffer from being low in status, they are not despised and mix freely with people of any status in appropriate social situations. It is not uncommon for slaves to earn enough to buy their freedom, or to become free when their owner dies. Being a freed slave carries no social stigma; ex-slaves can become respected citizens on their own merits.

Greece

The Greek homeland remains a patchwork of semi-independent cities under the umbrella of the empire. Alexander the Great kept them in line with shows of military might, crushing any cities that dared defy him. In the centuries since, individual cities have made occasional attempts to escape imperial control, but their fractious nature means neighboring cities are always happy to see the dissidents brought back into line. Still, it takes a strong leader to maintain control, and the cities probe each successive heir of Alexander for the weakness that will allow them to revolt.





The Provinces

Maintaining central control across the far-flung empire has always been the ruler's greatest problem. Alexander the Great solved it by appointing provincial governors, drawn from the local populations so that they had the requisite knowledge and respect of the people. This worked, more or less, but every so often a governor would begin to get ideas about ruling in his own right. Legions of the Macedonian army were therefore required to be spread across the empire in a state of vigilance to quell any potential uprising.

Alexander IX – the first of Alexander the Great's new sons – realized that he had at his disposal the means to send many of his father's sons out to the provinces to rule directly, with the help of local advisers. He had the Great School start producing siblings at a rate of three or four a year. By the time Alexander X took over the reins of the empire, the first sons of this program had been raised and groomed to be provincial governors. In the years since, the provinces from Persis to Galatia have remained relatively peaceful.

How long they stay that way, ruled by a collection of leaders with a genetic predisposition to megalomania, remains to be seen.

TECHNOLOGY

The empire of Alexander Athanatos is TL2 in most respects, following the technological development of our own world at the time. Weapons are generally iron, and large pieces of armor are still bronze. Horse riding is without stirrups.

Glass manufacture and working are up to TL6 standard, as is the science of geometric optics. This allows the creation of compound microscopes and refracting telescopes of high quality. In turn, this has spurred the development of astronomy to TL4 levels; people have seen the moons of Jupiter and lunar craters, but this has made little impact so far on traditional beliefs about the heavens.

The most significant divergence from TL2 is the level of biotech. Knowledge of bacterial diseases and their treatment is at TL7 level, but viruses remain mysterious and untreatable

except by vaccination. Surgery is at TL5, as far advanced as it can be without workable anesthetics. Relatively simple procedures such as amputations and removal of cysts can be performed reliably, if the patient can be held still, and superficial wounds can be stitched readily. Repairing damaged internal organs or performing transplants are beyond even the best surgeons of the Great Medical School, however.

*I am dying from the treatment
of too many physicians.*

– Alexander the Great

Great School researchers understand genetic heredity at a TL6 level. They know that the *genetikones* (chromosomes) pass on characteristics from parents to children, but have not fully formulated the concept of discrete genes. The chimerization process that has produced the *anthropithekois* is completely hit-or-miss, with no real theoretical understanding behind it. The idea of breaking apart the *genetikones* and combining pieces of them to make new ones has not occurred to anyone yet. They understand how selective breeding works but do not consider it useful beyond explaining how farmers slowly improve their crops and livestock.

Cloning

Cloning technology is at late TL8. Human clones can be created as desired, given enough attempts, but the resulting children's cells age prematurely because of telomere shortening (see *Risks of Cloning*, p. 24). Since nobody yet knows what *genetikones* are made of or how they work, let alone of the existence of telomeres, this problem is likely to remain unsolved for a long time.

Clones are uncommon, but becoming more commonplace, especially in Alexandria. The Great School will make a clone from any tissue sample for a price. Many men in homosexual relationships – which are not stigmatized – have taken advantage of this to produce children. Nobody considers clones to be *copies* of the person cloned; the universal belief is that they are *children* of a single person. Given practical experience with mature clones and seeing how they differ from their parents has convinced even the philosophers that they are no more than children, albeit with an unusual genesis. As such, they suffer no social stigma and fit into society normally. A few people have had clones made of recently dead loved ones, as a means of allowing the deceased to have children.

Alexander Athanatos in Infinite Worlds

Alexander Athanatos is a Quantum 5 parallel, one of several in which Alexander the Great did not die in 323 B.C. It is easily the most divergent of these but, as a relatively stable world, it is open for monitored tourism. Since the empire has yet to discover industrial technology, let alone electronics, there is no fear of natives understanding parachronics.

Several Infinity agents are posted in Alexandria, studying how the Great Medical School operates, as well as keeping tabs on the next generations of Alexanders and the central administration of the empire. It is a relatively peaceful timeline in which scholars can browse scrolls in the famous Library. The Library still exists in its prime, beyond one of the most popular alleged dates of its destruction in Homeline – by Julius Caesar's attack on the city in Ol. 183,2 (47 B.C.). It is clear that Caesar never rose to lead an independent Rome in this timeline, if he existed at all.

Given the local year, several researchers have an intense interest in looking for any evidence of Jesus Christ, but nothing has turned up so far.

Researchers also clone animals for research purposes, and for the few breeders who can afford to produce champion stallions and bulls without diluting their bloodlines by normal breeding methods.

ORGANIZATIONS

The Macedonian Empire has developed into a massive bureaucracy in the years since Alexander the Great, as a natural result of having to administer such a large and relatively stable territory. There are small political groups and larger trade guilds scattered across the empire; travelers affiliated with these may receive hospitality benefits in towns hosting a local branch.

The Great Medical School

Founded by the great physicians Herophilos and Erasistratus, the Great School at Alexandria is still the pre-eminent medical institution in the empire. It has expanded beyond medicine into a school providing a general education for youths. Many of the best families of Alexandria send their sons here for schooling, as well as some from Greece and the provinces. Locals attend the School during the day, while others board on the grounds.

Researchers at the School experiment with medical procedures and chemicals extracted from various herbs. Several chimera projects are underway, seeking to build on the success of the *anthropithekois*. And of course there is always cloning work for various wealthy and well-connected clients.

The School would make a suitable location for youthful adventurers, learning the secrets of medicine, interacting with learned physicians and political figures, and uncovering plots that require the unusual skills of gifted students to resolve.

The Boule of Alexandria

This is the council that governs the day-to-day operations of the imperial capital. Although Alexander XVII is absolute ruler of the empire, much of the day-to-day administration of his city is handled by the *Boule*. It is an assembly of 50 randomly chosen adult male citizens, who serve for a year. Alexander's genetic father instituted the custom of random selection to avoid political factions gaining enough power on the *Boule* to challenge his own. The king himself selects a panel of 10 *astynomoi* – magistrates to enforce laws, collect taxes, inspect goods, and oversee city construction projects – but the *Boule* decides what laws and projects they look after.

The random nature of selection means the *Boule* is inherently factionalized and the strengths of the various factions change on an annual basis. The king can overrule any fractious or damaging policies, but seldom needs to as they are unlikely to receive the required 2/3 vote. The selection is controlled by priestesses of various gods, who are supposed to be above corruption, but anything may be possible in an empire trending toward decadence.

The Temple of Asclepius

Asclepius is the god of medicine and healing. His priests enjoyed great power and influence as they developed the initial stages of the empire's medical knowledge. Initially, all the physicians at the Great Medical School were part of the religious hierarchy, but the School has since become

Alexander Phantasia

Alexander Athanatos is grounded in reality. Although the developments in biotech are unlikely, they are all *possible* with the level of technology described.

There are two options for adding more fantastic elements to the setting:

Rubber science can be used to justify weird genetics that allowed Hippocrates to be successful with his chimera-creation experiments. Mixing sperm and ova of different species results in viable hybrids combining the features of both parents. This allows the setting to contain many of the classical creatures of Greek legend: minotaurs, gorgons, harpies, centaurs, etc. The application of specific herbal extracts during *in vitro* fertilization or cloning might produce giants or other creatures. These changes alone add lots of variety and a fantastic feel.

Magic fits well into the basic campaign framework, either as a subtle agency controlled by elusive mystics, or as a potent and open force. Ritual magic suits the classical feel better than the default **GURPS** magic system, and may include biotech spells (p. 30).

progressively more secular, marginalizing the temple and its priesthood.

In recent times, the priests of Asclepius have begun to criticize the School and its methods, claiming them to be the work of dark gods. They denounce the research as doing harm to living beings, in conflict with the teachings of their god, and prophesy dark consequences for the empire. The School continues to hold the patronage of the king, however, so what few worshippers of Asclepius remain are becoming more desperate for a means to bring down the School and reassert religious authority. Most harbor intolerance for clones and *anthropithekois*.

CHARACTERS

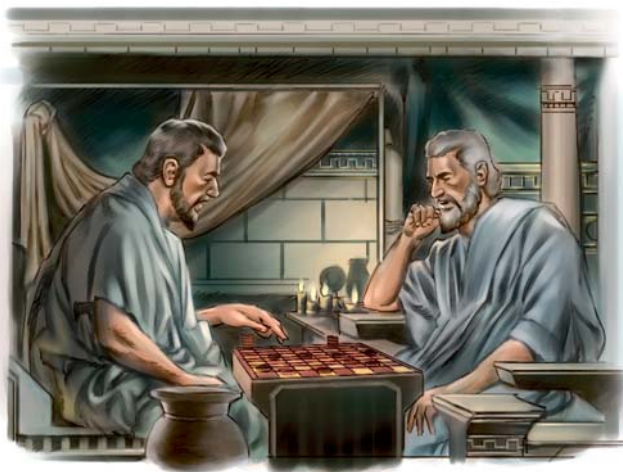
Physicians are held in high regard throughout the empire. Armed with knowledge of many diseases and effective treatments and vaccines, they are always in demand for the work they do. Traveling doctors perform vaccinations as they pass through rural areas, keeping outbreaks of infectious diseases rare. The most prestigious physicians are those trained at the Great Medical School in Alexandria, and the best go on to research and teach there. A substantial number of these conduct experiments in primitive cloning and genetic engineering technology, but they still consider themselves to be simply physicians, just working on different aspects of medicine.

Genetically engineered individuals come in two types: clones and *anthropithekois*. Clones will live essentially

normal lives, and can appear at any stratum of society from the lowliest slave up to the King himself. The only real difference compared to non-clones is that some of them will have shorter lifespans.

Anthropithekois are mostly slaves, and the few who are not are mostly laborers. Slaves actually make better PCs, as they have access to various households and can move in politically important circles without raising suspicions. Exceptional individuals with points spent on buying up IQ make suitable PCs or Contacts. The rare free *anthropithekos* with high intelligence and a non-laboring job is also useful as a significant character.

Surrogate mothers are required to carry the many sons of Alexander, as well as the children of the Great School's other cloning clients. This is a respected job in Alexandria, especially for those women chosen to give birth to the next rulers of the empire. Although surrogate mothers do not have much chance for physical adventure, they take an active part in raising the children and have plenty of opportunity for palace intrigues and political gossip. Older surrogates with grown children often travel to the provinces to act as advisers for their governing sons.



Character Traits

Because of the telomere problem (p. 183), clones of aged individuals in Alexander Athanatos have the disadvantage Short Lifespan (p. B154). The number of levels depends on the age of the person from whom the clone's genetic material was taken, as follows:

Age of Parent	Disadvantage
under 45 years	None
45 to 67 years	Short Lifespan 1 [-10]
68 to 78 years	Short Lifespan 2 [-20]
79 to 84 years	Short Lifespan 3 [-30]
over 85 years	Short Lifespan 4 [-40]

This means all the clones of Alexander the Great (who died at age 66) have Short Lifespan 1 [-10]. If a clone is made of a clone, use the *total* age of the original parent plus all intermediate clones as the *Age of Parent*. In this setting, clones with Short Lifespan mature normally at age 18; this variation from the normal disadvantage is treated as a special effect.

Slaves in Alexander Athanatos are Status -2 [-10].

Adventure Seeds

Prodigal Son

Up to now, the sons of Alexander have all taken well to their upbringing in the royal palace and turned out to be more or less adequate rulers. But Alexander XVII has come to the Great Medical School with a problem. His brother – destined to become Alexander XVIII – is a precocious youth of 14 and only interested in holding riotous parties, drinking wine, and chasing the female slaves of the imperial household. The king wants to know if this behavior is caused by a problem with the cloning procedure, and if there is any treatment that can improve his attitude. School physicians suddenly find themselves looking after an unruly teenager – who is the next king.

Racial Politics

Random selection for the new *Boule* has turned up the name of one of the free *anthropithekois* in Alexandria. He is eager to serve, but several factions are

forming variously to argue that he should not be eligible, or to stand in his favor. As this is the first time that one of them has become a notable personality in the city, his fellow *anthropithekois* are keen to see him take his place in the *Boule*. Placed as they are in the households of many powerful citizens, they could influence their masters in a number of ways. The priests of Asclepius naturally want to see the candidate invalidated.

Sins of the Father

In recent weeks messengers have arrived from Persis with disturbing news. The sons of Alexander sent to govern Persis, Syria, and Phoenicia are gathering armies, apparently in cooperation. Agents will need to be sent to the provinces to investigate and confirm the reports. If true, can even the might of Macedonia and Egypt stand against the combined forces of three men as great as Alexander? The surrogate mothers who gave birth to them may be invaluable in negotiations – or betrayals.

DRACONIS

Humanity has reached to the stars, sending sublight generation ships to a handful of systems within 20 light years. Observations from solar orbiting interferometers revealed the best targets: stars nursing one or more rocky worlds with atmospheres. The journey took hundreds of years, but now the fleet led by the *Dragonfly* has arrived at the Sigma Draconis system and the job of building a new world can begin.

At least that was the plan.

THE FLEET

The 13 major ships in the Draconis fleet began their lives as nickel-iron asteroids a mile or two across in Sol's asteroid belt. Through a process of drilling, filling with water, and "cooking" with solar mirrors, engineers converted 12 of the asteroids into Cole habitats – hollow cylinders 10-20 miles long and half as wide. After spinning to simulate gravity, the interiors were then filled with air and terraformed with soil and organisms. A typical ship comfortably houses 100,000 people plus enough farms and livestock to support them indefinitely.

The 13th ship – a mixed nickel-iron and silicate asteroid four miles across – was not hollowed out, but merely fitted with an engine. The plan was to use it as a source of metals and other heavy elements while in interstellar space. Rapid population growth and technological progress made demands on this resource greater than anticipated. The result was that within 50 years the fleet had converted this ship into a habitat as well and, perhaps more importantly, strictly rationed the use of metals and heavy elements.

A 14th ship is a comet, captured in the outer solar system and fitted with an engine and remote guidance system. It

was used as a supply of volatiles in interstellar space, for fusion, to replace any lost water, and to provide reaction mass for slowing down on approach to the Sigma Draconis system. While in transit, it was populated only by a small engineering crew, who spent rotating month-long assignments on the comet.

Over the centuries since they left Earth, biological components have grown and spread into every area of the habitat ships, forming a familiar and comfortable organic look to the interiors and the service tunnels that thread their way through the asteroid skins.

Fusion reactors in each ship generated all power in transit, but now that the fleet has arrived at Sigma Draconis the ships are growing photozyme outer layers and spreading vast wings to catch sunshine and supplement energy supplies.

Many of their ideas will prove impractical, and their colonies will fail. But some of those who really have a better idea will succeed.

– Robert Zubrin

Throughout the journey, the ships of the fleet maintained constant radio contact, and exchanged personnel and goods regularly with a flotilla of shuttles. These range

from one-person vacuum suits equipped with thrusters for traversing the distances between the ships, up to cutters capable of carrying 100 passengers. These transfers have continued after arrival.

Fleet Politics

When it left the Sol system, the fleet was a multinational cooperative venture, with citizens of over 100 countries represented on board. The nations of Earth recognized that maintaining sovereignty over the fleet as it receded into space would be a futile task, so granted it self-determination rights under a democratic system enacted by those on board.

Most issues concerning the fleet as a whole are decided by a participatory democracy in which all eligible citizens vote via the computer network. Any rapid decisions that need to be made are handled by an Executive Council of 13 elected members, one from each ship, chosen by that ship's residents at irregular intervals. The council members meet in person on the *Dragonfly* once a week and handle any other required business by telepresence.

Interfleet politics is generally harmonious, but definable factions have evolved amongst the ships over the long journey from Sol as the fleet's technology and available resources changed. The *Dragonfly* leads the largest, moderate faction, which includes the ships *Cadmus*, *Fafnir*, *Marc Ange*, *Scatha*, *Smaug*, *St. George*, and the small 13th ship *Wyvern*. These favor a slow approach, with terraforming beginning on the lifeless planet Quetzalcoatl, and feasibility studies on the eventual terraforming of Naga and Jabberwock. The ships *Ancalagon* and *Hydra* prefer a faster approach to the terraforming, with simultaneous efforts on all three inner planets to make them inhabitable as soon as possible. The group made up of *Apalala*, *Glaurung*, and *Jormungand* argue that terraforming is a long and expensive process, and the fleet would be better served by building more space habitats using the raw material in the Draconis system and leaving the planets alone.

In a full participatory vote a few years before arrival, the colonists agreed on a plan for political growth as the colony matures. Settlements will initially be under the control of a supervising ship and vote for its Executive Council representative. Once a region attains a population of 50,000 permanent residents, it will be granted independence and its own Council representative.

TECHNOLOGY

The Draconis fleet left Earth with TL10 technology. The default campaign setting assumes a hard science technology path, with no superscience (see *GURPS Ultra-Tech*).

The rationing of heavy elements meant that as the fleet traversed empty space it became increasingly reliant on technology that utilized lighter elements – in other words, biotechnology – rather than metals and ceramics. Nearly all non-computerized equipment on

The Sigma Draconis System

Sigma Draconis is a yellow-orange star, somewhat smaller, cooler, and dimmer (spectral type K0 V) than our own sun, 18.8 light years away. It masses 0.82 times the mass of our sun and emits only 0.39 times the light energy. It has three rocky planets in the inner system, three gas giants in wider orbits, and a fourth small body in an elliptical orbit between the innermost gas giants.

The first planet, Jabberwock, is a borderline greenhouse world, with a thick carbon dioxide atmosphere. At first glance similar to Venus, it is not as forbidding a target for terraforming, with an atmospheric pressure of 9.3 atmospheres and an average temperature of “only” 350°F.

The second planet, Naga, is the main target for settlement. It has a temperate climate suited to humans and a nitrogen, carbon-dioxide, and oxygen atmosphere with a pressure of 0.82 atmospheres. The oxygen, produced by an indigenous microbial biota, is not abundant enough to support baseline humans.

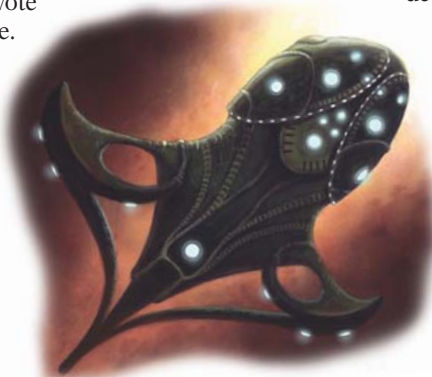
The third planet, Quetzalcoatl, is a rocky ball covered in a thin and patchy layer of water ice, representing frozen oceans of an earlier, warmer phase of its existence. The atmosphere is nitrogen, carbon dioxide, and methane. There are no signs of extant life.

board is now some form of biogadget, and the only items that are computerized are those that need to be.

A continuous stream of multiple news and information channels comes by radio from Earth, together with replies to messages sent increasingly long ago (37 years by the time the fleet arrives at Sigma Draconis). This stream brings scientific discoveries and engineering details, allowing the fleet to stay up to date on the latest tech from Earth.

While the fleet was in transit, researchers on Earth developed technology from TL10 to TL11. The pace of biotech development on the fleet was even faster, prompted by the need to use a biological approach to problems that could be tackled differently on Earth. Recently fleet bioengineers began producing experimental TL12 biotech items and sending the details of their research back to Earth.

With the extensive bio labs on board, the colonists have access to wet nanotech up to and including proteus nanovirus. Several people have used this to transmute themselves into Void Dancer parahumans (p. 72), with the ability to fly unaided between ships of the fleet.



Bioshuttle

560 points

This is a standard bioship shuttle used for carrying passengers or cargo between fleet ships. It is grown in vacuum on an umbilical tether from a modified blue whale germline, then fitted out with mechanical propulsion, airlocks, and life support when fully grown. It feeds when docked by attaching its mouth to a matching "teat" on the outside of what is almost literally a mothership.

The basic racial template is modified by the individual personality quirks of each ship, and many are custom fitted with various mechanical components to adapt them to specific roles. The creature itself masses 200 tons and is 100' long. It can operate for eight hours on oxygen stored in its tissues before requiring oxygen from either a docking facility or tanks carried as cargo. Basic Lift is 2.25 tons, and the internal payload space can carry 11.25 tons of cargo, 100 passengers in seats, or 10 passengers in cabins. The standard engine has a delta-v of 18 yards per second on a tank of fuel, giving the shuttle a range of 140 miles in deep space before requiring oxygen and refueling. Range in system is determined by orbital mechanics and can be significantly longer if oxygen is carried.

Attribute Modifiers: ST+140 (Size, -80%) [280], DX-2 [-40], IQ-3 [-60].

Secondary Characteristic Modifiers: SM +8, Per+5 [25].

Advantages: 3D Spatial Sense (Requires Signal, -20%) [8]; Compartmentalized Mind (Controls) 1 [25]; Damage Resistance 50 (Can't Wear Armor, -40%) [150]; Doesn't Breathe (Oxygen Storage 300x, -10%) [18]; Flight (Newtonian Space Flight, +25%; Space Flight Only, -75%) [20]; High Pain Threshold [10]; Injury Tolerance (No Neck) [5]; Longevity [2]; Nictitating Membrane 10 [10]; Night Vision 9 [9]; Payload 50 [50]; Radar (Extended Arc 360°, +125%; Increased Range 50x, +50%; Multi-Mode, +50%) [65]; Radiation Tolerance 50 [25]; Radio (Increased Range 10x, +30%; Video +40%) [17]; Reduced Consumption 2 [4]; Sealed [15]; Temperature Tolerance 50 (-460°F to 95°F) [50]; Unfazeable [15]; Vacuum Support [5].

Perks: No Degeneration in Zero-G, Sanitized Metabolism [2].

Disadvantages: Deafness [-20]; Mute [-25]; No Manipulators [-50]; Slave Mentality [-40]; Social Stigma (Valuable Property) [-10]; Unusual Biochemistry [-5].

Features: Aerial; Sterile.

Cost: \$500,000.

Many other inhabitants have either undergone biomodification or engineered their offspring into parahuman species. The most common changes include the addition of wings suitable for gliding across the low-gravity interiors of the Cole habitats, and – increasingly common – adaptations for the low oxygen levels that will be encountered on Naga.



Bioships

Although the main ships of the fleet are built on a metallic hull structure, they have integral biological components that give them some of the features of a bioship (p. 98). In particular, they have distributed organic sensors

Webgun

Webguns are personal sidearms available to any adult citizen on most of the fleet ships. They are biogenetic gadgets using a blend of genes from several species, as well as custom-designed sequences. Glands produce copious quantities of sticky proteins based on spider silk, which can be fired with an explosive puff of air from an internal lung. When fully charged, a webgun has enough of this protein for four shots. It cannot be reloaded – instead it produces new shots at the rate of one per hour.

A hit from a webgun works just like Binding 18 (p. B40).

GUNS (PISTOL) (DX-4, or most other Guns at -2)

TL	Weapon	Damage	Acc	Range	Weight	RoF	Shots	ST	Bulk	Rcl	Cost	LC
10	Webgun	Spec.	1	5/10	3	1	4	9	-2	1	\$400	3

that monitor the exterior for damage and intership traffic control, as well as the interior for life support conditions. This system automatically dispatches biological microbots for small repairs and uplifted animal technician squads for more complex jobs. The ships have no brain, instead feeding sensor data into and taking commands from a computer control system.

Fleet ships need not be treated as characters, as they have no personality or manipulative abilities. The artificial intelligences who run them (see below) may express personalities, but they can be treated separately from the ships, which are more like self-repairing equipment.

Many of the interfleet shuttles are fully fledged bioships, grown using custom-designed germlines to control development and features. They are based on heavily modified whales, adapted for vacuum support and equipped with mechanical propulsion and internal life support systems. Bioengineers developed these ships en route to Draconis as an alternative to building increasing numbers of inorganic shuttles, in order to save their precious metal supplies.

The bioshuttles all have individual names and personality quirks. Many citizens can recognize them by natural markings and greet them as old friends when boarding for a trip.

Artificial Intelligence and Mind Emulation

Low sapient and high sapient AIs are common throughout the fleet, looking after environmental systems, food production, power generation, and so on. They also serve as nannies and teachers for children.

When the fleet left Earth, AIs were universally considered to be nothing more than fancy computer programs – property to be used and discarded as required. Over the journey, news from Earth tracked a rise in the belief that high sapient AIs were fully self-aware and deserving of civil rights over their own existence. Several nations voted to grant high sapient AIs citizenship rights, and fleet members have had to become used to news reports treating AIs as people.

Although a few groups within the fleet agree with these developments, the majority of citizens still consider AIs to be non-self-aware property. Fleet voters have not even come close to adopting laws granting AIs any self-determination rights. For their part, the AIs are programmed to accept their lot.

Destructive mind uploading and personality emulation (see *GURPS Ultra-Tech*) are new technologies, invented back on Earth and only received by the fleet a decade before the arrival at Sigma Draconis. Although they have the capability to upload a person, fleet AI experts and philosophers are not convinced that destructive uploading maintains a continuity of existence that justifies the process. Despite a handful of people wanting to try it, fleet authorities have so far denied permission for anyone to undergo uploading. This attitude also partially stems from a concern about how the fleet would deal with an intelligent digital entity that some (most importantly *itself*) would consider the continued existence of a citizen.

In a startling development, Earth has signaled that it will be beaming the code for a mind emulation of a prominent terraforming expert soon after the fleet arrives at Draconis. There is no doubt that the fleet has the computing capability to house the emulation, triggering a fleetwide debate on whether it should be allowed to run when received, recorded and archived, or erased. With Earth over 18 light years away, there is no way to signal them not to send the emulation, and some people fear this is a first step toward Earth attempting to re-establish sovereignty over the fleet.

Uplifts

The fleet makes heavy use of uplifted animals, as both workers and companions. Neo-coons, space cats, and uplifted monkeys are common, while modified chimps can be seen working farms inside the ships and performing maintenance outside in vacc suits. Species capable of using the computer network intelligently are considered full citizens and are eligible to vote and represent ships on the Executive Council. Others are treated more like children or pets, depending on their abilities.

The fleet has genetic samples of thousands of animal and plant species from Earth. Although there is not enough space to maintain living populations on board, the raw genetic material forms a valuable resource for further research into new uplift candidates, as well as biogenetic and medical applications. There are also vague plans to populate the terraformed worlds of Draconis with terrestrial ecosystems, including a variety of wild organisms, but that is decades away.

Weaponry

Light, non-lethal personal weaponry is permitted on most ships (the *Apalala* and *St. George* being the exceptions). Any weapons capable of doing serious damage to a ship or shuttlecraft – slugthrowers, explosives, and particle beams – are restricted to Fleet Police (LC2). Heavy weapons are banned (LC0).

The most common sidearm is the *webgun* (p. 227): a low-velocity gas-powered biogadget that uses silk glands to generate the equivalent of tangler rounds. Fleet Police also possess electrolasers.

Flexible body armor is freely available, but not used much, as there is little need for it. Rigid armor is restricted to Fleet Police, and even then is rare to nonexistent.

*Green technology means we
do not live in cans but adapt our
plants and our animals and
ourselves to live wild in the
universe as we find it . . .*

– Freeman Dyson

SETTLING IN

Now that the fleet has arrived at Draconis, it is time for some dramatic changes to the way life has been lived for the last few centuries.

Some of the inhabitants of the fleet remember leaving Earth, 346 years ago, having either been cryogenically preserved for part of the voyage or having lived the full period with the benefit of anagathic treatments. Generally, these “old-timers” are keen to get terraforming underway so they can step out on to a fresh new world, with a sky instead of a roof overhead.

The generations born on board are more mixed in their outlook. Some crave open air just as much as the old-timers, while others are comfortable in the ships and see no point in moving to a relatively hostile world. Still another faction has decided that terraforming the new worlds would not only be a waste of time, but would be actively unconscionable, as it would destroy the pristine conditions on them, including the alien biota on Naga. This group has been agitating for calling off all terraforming plans, but has been outvoted.

Parking Orbits

The first order of business on arrival at Draconis was to get the ships into parking orbits. Using the comet as reaction mass, they first went into elliptical orbits with periastrons between the orbits of Jabberwock and Quetzalcoatl. Over the next few years, they bled off energy at each approach, circularizing their orbits. Eventually, some of the ships went into final parking orbits around the inner planets.

The *Dragonfly* has taken up orbit about Naga, which is seen as the long-term inhabitable jewel of the system. It is accompanied by *Acalagon*, *Glaurung*, *Hydra*, *St. George*, and *Wyvern*. The ships *Cadmus*, *Marc Ange*, *Scatha*, and *Smaug* are in orbit about Quetzalcoatl. *Fafnir* holds a lone post near Jabberwock, while *Apalala* and *Jormungand* remain in solar orbit. *Jormungand* is in an elliptical transfer orbit that approaches Naga and Quetzalcoatl at its extremes, forming a slow shuttle service between the planets.

Terraforming

Terraforming in humanity’s home system has stalled, with various proposals to alter Mars and Venus blocked in international courts. Many on Earth are looking to the Draconis experiment to provide useful data to overcome opposition. While the ships were settling into final orbits, fleet explorers carried out reconnaissance missions to Naga and Quetzalcoatl. Jabberwock’s hostile atmosphere prevented manned landings, but robotic probes explored the surface.

With no evidence for any life, either extant or extinct, on Quetzalcoatl, terraforming work began there immediately. Since the atmosphere was dense enough to support humans already, it was a simpler prospect than terraforming Mars back in Sol system. Bioengineers grew large orbital mirrors of reflective biofilm to focus more of Sigma Draconis’ heat on the planet and introduced anaerobic microbes to begin removing the atmospheric methane and replacing it with oxygen. The oxygen content is climbing, but there is not yet enough to form a combustion hazard with the slowly decreasing proportion of methane. Planetary engineers expect atmospheric turnover to occur in another 50 years or so. Meanwhile, oxygen-breathing humans and parahumans are colonizing in domed settlements, while newly developed methane-breathing parahumans brave the elements to work unprotected on the surface.

The situation on Naga is complicated by the presence of a native biota. Biologists have taken extensive samples and discovered that the microbes are superficially similar to terrestrial bacteria, but operate on a linear genetic molecule using different base pairs than DNA. They produce analogs of enzymes and proteins with an even greater variety than those expressed by terrestrial organisms. Although thought to be incapable of infecting a terrestrial being, some of the predatory Nagan microbes produce an acid capable of damaging flesh.

But that is a minor concern compared to the ethical debate aboard the fleet about modifying the Naga environment. Introducing terraforming microbes would certainly disrupt and perhaps destroy the native life. Pro-terraformers argue that Naga represents the best environment for baseline and moderately modified parahumans to live, and that the native life is adequately sampled and will always be available in cultures for study and regrowth at any time in the future. The opposition believe it would be inherently irresponsible to reduce an entire planet’s biota to captive samples, and put forward the view that more extreme parahumans can live on Naga without modifying the environment. The Executive Council has called for a

decade-long moratorium on any terraforming effort, to allow a full and vigorous debate before submitting the question to what will be an historic vote.

ORGANIZATIONS

As the fleet is a relatively homogeneous culture concerned primarily with survival in a hostile environment and establishing a new place to live, its organizations are typically either administrative divisions or personal special interest groups.

The Executive Council

The elected council of 13 generally has little to do, as most decisions regarding the running of the fleet can be made at a leisurely pace through direct democracy. The main role of the members is diplomacy and negotiation, to maintain workable relations between the ships despite the ideological differences that have developed since they left Earth.

In a crisis, however, the Executive Council is empowered to make rapid decisions when the full electoral process would be too slow. There have been few crises in its history, but the period of change associated with the arrival and beginning of colonization in Draconis is potentially its most challenging time.

Fleet Police

Crime is uncommon, but among 1.5 million inhabitants there is always the potential for violent disagreements. The Fleet Police look after the welfare of individuals by neutralizing any hostile situations, capturing offenders, and – most important in space habitats – enforcing safety regulations. The force of 1,100 officers also investigates cases of petty theft and the rare murder. However, much of their work is chasing after youths who think taking a vacc suit for an illicit joyride is a good idea.

Engineering Section

Engineering Section is the loose collection of professionals who perform mechanical and biological maintenance on the fleet ships, as well as researchers who develop new technology usable by the fleet and for the colonization effort. This includes bioengineers who design genetic modifications for parahuman germlines, plants, animals, and microbes.

Some engineers perform the hazardous duties of ship repairs and modification, involving work outside the hulls. Others work on methods to get the ships to repair *themselves*, using biological techniques and materials. A subsection is dedicated to designing microorganisms that will be useful for terraforming work on the planets of the Draconis system, and testing them in a large self-contained chamber in the ship *Smaug*.

Medical Section

The members of this section look after the health and well-being of the fleet citizens. It includes physicians,

Adventure Seeds

Moles

Unknown to anyone else, a small group of fleet citizens are agents of an expansionist nation back on Earth. They have survived the entire journey through the use of anagathic technology and their long-term plans are about to come to fruition. Their goal is to take part in initial investigation of the Draconis system, then unleash genetically targeted viruses, which will wipe out enough of the population for them to take control of the mission and the planets in the name of their government back home. Although the plan is insane, it is definitely dangerous, and Fleet Police will be pushed to the limit to uncover and thwart it before thousands of people and the dream of an independent colony are destroyed.

Conflict

The disagreement between the citizens of the fleet over the pace of terraforming and how best to colonize Draconis flares beyond political debate and into violence. It begins when political migrations enhance the slight polarization of the different ships, and the Executive Council breaks down as some of them withdraw their representatives. With a de facto majority, the *Dragonfly* leads the efforts to begin seeding Quetzalcoatl with microbes, only to be attacked by ships from the anti-terraforming faction. Meanwhile, bioships are spotted on course for Naga from ships in the rapid terraforming group.

Life, But Not as We Know It

An expeditionary team on Naga comes across some macroscopic life forms. When samples are collected, their genetic structure is puzzling. Although the basis is the same as the native microbes, there are also some suspiciously DNA-like sections that code for familiar enzymes. It seems somebody has been engineering hybrids and seeding them on the planet, but who, and why?

surgeons, and bioengineers. The engineers work on new human and parahuman genemods designed to provide benefits for living either in the ships or on partially terraformed worlds. Medical section also includes nanotech scientists who perform research on nanoviruses.

CHARACTERS

Many character types can find adventure in the Draconis system.

Bioengineers are in high demand for jobs ranging from parahuman design and developing terraforming microorganisms, to the necessary routine of taking care of bioships. Front-line engineers will go out into the field, checking environments on Naga and Quetzalcoatl and performing experiments in hostile conditions. Some will be collecting and characterizing the native life on Naga, with a view to learning its secrets and adopting them into new technologies. These field trips will involve exploring new territory and dealing with a variety of problems.

Parahumans and uplifts have new worlds of opportunity opening to them. Some will be more comfortable on Naga or Quetzalcoatl than in space, and will form the vanguard of colonizing efforts. Others will be more adapted to space, making them valuable contributors to various space construction projects.

Physicians are needed everywhere in the system, as people always need medical care. They will be valuable in the new colonies and anywhere that risky work is undertaken. Doctors will also be required to perform biomod operations, thaw cryonically frozen citizens, and supervise proteus nanovirus transformations.

VARIANTS

As presented, the Naga campaign is based shortly after the arrival of the fleet in the Draconis system, and deals with the themes of settling in and conflict between various groups who want to go about that in different ways. There are plenty of opportunities for setting a campaign in alternate parts of the colonization timeline, or with a different set of conditions.

In Deep Space

Hundreds of years out from Earth, and a century from their destination, this setting plays up the isolation of the fleet from both Earth and any ready source of energy and resources. In a crisis, the fleet is on its own. Although colonists and livestock have been screened for infectious diseases, there is always the chance that some contagion has been lying dormant somewhere or will mutate from existing microbes. An epidemic in one ship would be bad enough, as the Executive Council must make hard decisions regarding quarantine, but if it spreads to several of the ships it could lead to chaos.

Arrival

The arrival at Sigma Draconis is a once-in-a-lifetime event which could form the core of a campaign. Preparations would begin years in advance, with detailed observations of the planetary system and discussions of which planets should be targeted for terraforming by which methods and how to establish the ships in system orbits. There are plenty of opportunities for political jostling as factions attempt to stake claims for various parts of the system. This segues naturally into the default campaign after the ships arrive. Or perhaps there is a surprise waiting in the system . . .

Tragedy on Earth

At some point in the journey or shortly after arrival, the newsfeed from Earth just stopped. This could have been presaged by news of increasing political turmoils, or it may have happened completely without warning. Astronomical observations might show nothing obvious, or signatures of heavy radiation. Naturally, speculation about the reason runs rife amongst the fleet, and everyone has an opinion on what should be done. Radio queries will be sent as an almost automatic reaction, but with little hope of any response. Some paranoid people will blame aliens and demand the fleet stop sending signals. Others will be desperate to know what has happened and begin plans for a mission to send a ship to investigate.



Overtaken

The pace of technology on Earth continues to accelerate with its huge population and resource base, at a speed the fleet can't hope to keep up with. With a dash of super-science, Earth physicists could invent faster-than-light travel, engineers could build the ships, and nations could be setting up colonies on Naga by the time the fleet arrives! If FTL only works between stars, the fleet could be stuck in transit for decades, receiving a surprising radio message from their destination before learning from Earth that starships are on their way. This will generate a feeling of dislodgment and betrayal in many of the fleet citizens, who will not be happy when they arrive to find their promised land settled by the same nations they fled centuries ago. Another option allows FTL travel to the fleet in transit, instantly converting it from an isolated outpost of humanity into a waystation that people might want to leave en masse.

Later in the Terraforming

A few decades into the terraforming effort, a million genemods and parahumans are living unaided on Naga, there are small colonies on Quetzalcoatl, and it won't be long before radical parahuman species can survive on Jabberwock. With three different worlds and over a dozen giant habitats in space, the Draconis system has enough varied territory and activity to sustain a campaign of vast scope.

GLOSSARY

This section defines both scientific and fanciful terms found in this book and in biotechnology literature.

TECHNICAL TERMS

allele: One of the alternative forms of a gene in a particular position on a chromosome. For example, a gene influencing eye color will have “blue,” “brown,” and other alleles, with each organism possessing one of the options.

amino acid: An organic compound that is an essential component of protein molecules, and thus of life as we know it.

antibody: A protein made by the body’s immune system to attack and neutralize foreign bodies such as microbes or viruses.

antigen: A substance that triggers the immune system to produce antibodies.

apoptosis: The normal death of a cell that has reached the end of its useful life. This is a normal and healthy process, as opposed to necrosis.

archaea or **archaebacteria:** An ancient form of microbial life, related to but distinct from bacteria.

bacteria (singular: “bacterium”): A class of single-celled organisms. There are countless species of bacteria.

bacteriophage (“bacterium eater”) or **phage:** A small virus which only infects a particular species of bacterium. Can be used to insert new DNA into a bacterium.

base: One of the molecular “letters” in the genetic code, which combine into pairs and then connect in long chains to form DNA.

B-cell: A type of white blood cell that binds to foreign microbes, tagging them for destruction by the immune system.

biomimetics: Engineering designs that are patterned on or inspired by living things.

bioprocessing: Using bacteria, engineered plants and animals, or other biotech processes in manufacturing.

biotech or **biotechnology:** A set of biological engineering techniques, such as biomimetics, bio-nanotech, bioprocessing, cloning, engineering, and transplants, applied to research and product development.

blastocyst: A very early stage of a developing embryo, with only 32-64 cells.

cell: The smallest part of an organism that is capable of independent function. Cells are microscopic entities that consist of a nucleus and various organic and inorganic components, surrounded by a membrane.

chimera: An organism created by fusing together the cells of blastocysts of different species; a cruder form of blending traits than germline engineering.

chirality: The property of molecules having mirror-image variant forms. Normally only one chiral variant is utilized by biology.

chromosomes: The self-replicating structures within cells on which the genes are located.

cloning: The technique of asexually producing a group of cells or complete organisms, called clones, which are all genetically identical to a single ancestor.

cryonics: The practice of freezing the dead in hope that future science will be able to revive them.

deoxyribonucleic acid (DNA): The double-helix-shaped molecule that encodes genetic information.

diploid: Having two copies of each chromosome. Most plant and animal cells are diploid, but produce gametes by cell division without chromosome division, resulting haploid cells that combine to form a diploid zygote.

DNA: See *deoxyribonucleic acid*.

electrolyte: A liquid solution of ions such as sodium or potassium. Most liquids in the body are electrolytes.

enzyme: A protein that serves as a chemical catalyst, accelerating the rate at which a biochemical reaction occurs.

eugenics: The study or practice of human improvement through genetic control or genetic engineering.

eukaryotes (“true nucleus”): Organisms whose DNA is surrounded by a membrane and which possesses organelles. Eukaryotes are a “superkingdom” of life forms that include most terrestrial plants and animals other than bacteria.

gamete: A male or female reproductive cell (sperm or ovum). These combine during fertilization to form a zygote.

gene: A sequence of DNA nucleotides, located in a particular spot on a particular chromosome, that encodes a specific instruction to a cell.

gene-cloning: The process of duplicating genes inside modified bacteria.

gene therapy: Genetic engineering performed on a fetus, child, or adult to repair defective genes.

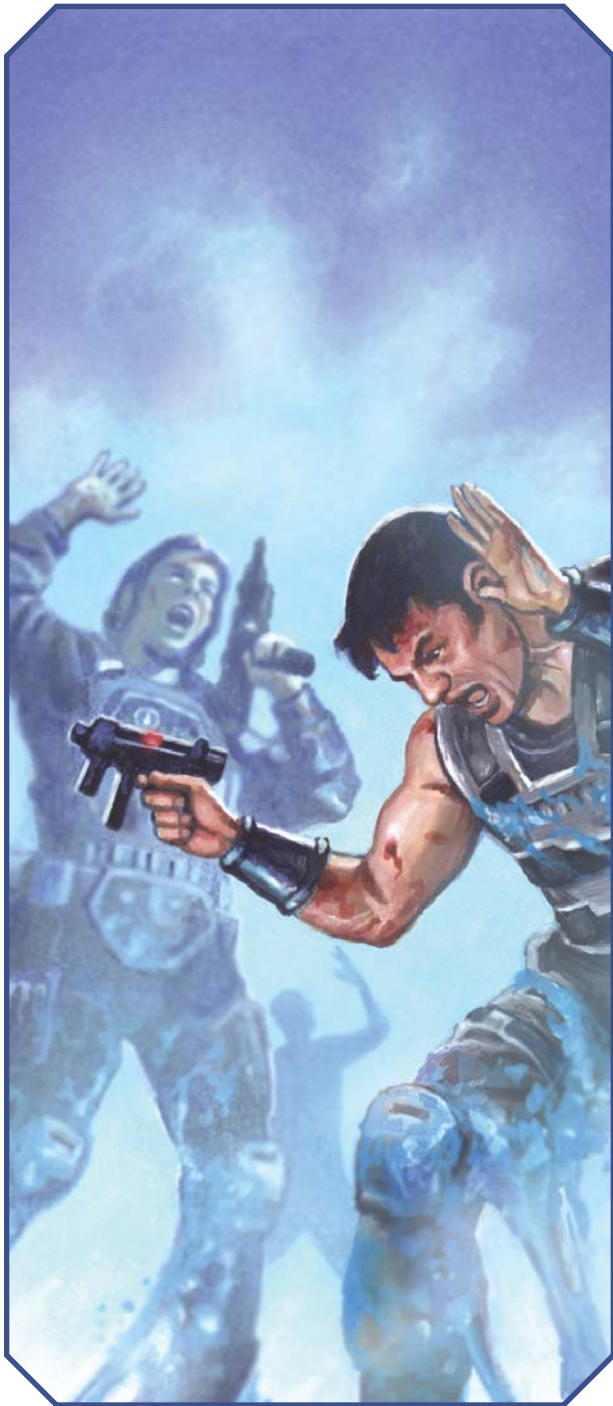
genetic engineering or **engineering:** Deliberate manipulation of DNA and genes in order to alter an organism’s genome.

genetics: The study of the patterns of heredity, the traits that an organism inherits from its ancestors.

genome: All the genetic material carried by individuals of a given species, containing the molecular instructions for inheritable features.

genotype: The specific genome of an individual; the combination of alleles the individual carries.

germ cells: The basic reproductive cells of a multicellular organism; see *gamete*.



germline gengineering: Genetic engineering of the germ cells so that an organism will develop in a different way than its unmodified genome would have indicated.

haploid: Having only one copy of each chromosome. Fungi and some algae are haploid organisms. Plant and animal gametes are also haploid.

hormone: A protein that acts as a chemical messenger within the body. There are many different hormones, each with its own function.

in vitro ("in glass"): Taking place outside a living organism, usually used when referring to "test tube" fertilization or

to the process of growing an organism in an artificial womb, clone tank, etc.

intron: A segment of DNA within a gene that does not code for protein sequences and that is edited out when the gene is expressed. Introns may have regulatory or structural uses.

ligase: An enzyme that can rejoin DNA fragments together, used as a tool in genetic engineering.

microbe: A single-celled organism, like a bacterium or alga. Usually microscopic, but colonies of single-celled organisms can be large enough to see.

mitochondrion (plural: mitochondria): An organelle that converts organic chemicals into a usable energy supply. It also contains DNA, separate from the chromosomes, inherited through the female line.

monoclonal antibody: An antibody grown in a cloned culture, producing usable amounts of identical antibodies.

nanomachine: A microscopic organic or inorganic robot, usually cell-sized or smaller.

nanotech or **nanotechnology:** An emerging technology based around the manipulation of atoms and molecules using microscopic machines. In biotechnology, nanotech promises the ability to precisely manipulate cells and genes.

necrosis: The abnormal death of cells, caused by injury or infection.

nucleotides: The basic molecular subunits of DNA or RNA. Thousands of nucleotides make up DNA molecules; their sequence determines the genetic code and the function of each gene.

organelle: A structure bound by the cell membrane in eukaryotic organisms, such as the mitochondria.

pathogen: An organism (usually a microbe) or chemical that causes a disease.

PCR: See *polymerase chain reaction*.

peptide: A short chain of amino acids, which may combine with other peptides to form a protein.

phenotype: The expression of a genotype in physical features of an organism.

plasmid: A ring-shaped structure of DNA, found in bacteria.

polymerase chain reaction (PCR): A means of rapidly copying DNA using specialized enzymes and equipment.

prion: A pathogenic protein capable of "hijacking" cells to produce copies of itself. Prions can produce various brain diseases such as BSE ("mad cow disease") and kuru ("laughing sickness") as well as pathologies of aging and senility.

protein: A large molecule made up of long chains of amino acids. Proteins are formed by cells as directed by their genes, and are the basis for the structure and function of living things. There are countless different kinds of proteins, each with its own specialized function.

protozoan: A single-celled microscopic animal somewhat more complex than a bacterium.

recombinant DNA: The basis of genetic engineering, this is the technology of cutting DNA molecules into discrete pieces and recombining them with other DNA molecules to form new genes.

ribonucleic acid (RNA): A chemical similar in structure to DNA. One type, messenger RNA (mRNA), relays the

orders from genes to the molecular machinery of cells, while other types perform other roles. Because of its ability to tell a cell what to do, RNA is a primary tool of engineers.

ribosome: Parts of the cell's molecular machinery, these are "factories" that create proteins under orders from the genes.

RNA: See *ribonucleic acid*.

telomerase: An enzyme that increases the number of telomeres on the ends of a chromosome.

telomere: A member of a repetitive DNA sequence at the end of a chromosome that serves as a buffer against incomplete copying.

tissue engineering: The design of artificial organic tissue.

transgenic: A transgenic organism is one that has genes added to it from outside its original species.

virus: A non-cellular biological organism that can reproduce only within a host cell. Viruses consist of RNA or DNA covered by protein. RNA viruses are especially useful tools for engineering.

zygote: A cell formed when two gametes combine in sexual reproduction. Zygotes grow into blastocysts, embryos, and ultimately adult organisms.

SCIENCE-FICTION TERMS

anagathic: An adjective used to describe technologies that slow or halt aging.

baseline: An unmodified genome or an example of a genetically unmodified species.

biogenesis: The process of creating functional biological beings or devices from scratch, using nanobots to assemble molecular components and then ensure they work together harmoniously.

biomod: A biological modification made to a living person for non-medical purposes. At TL7-8, the only biomods are cosmetic surgery. At TL9+, biomods become the organic equivalent of cybernetics, giving people many new abilities.

bio-nanotech: Nanotechnology that relates to biotechnology – for example, a proteus nanovirus.

bioplastic: A pseudo-organic TL10 material. Not to be confused with certain kinds of plastic made from organic materials like starch, which are also called bioplastics.

bioroid ("biological android"): A variant human (or humanoid) who was force-grown to maturity in a clone tank or assembled via nanotechnological biogenesis.

braintaping: A means of recording memory and personality, for immediate or later transfer to another body.

clone tank: An ultra-tech artificial womb equipped to force-grow organisms (not necessarily clones) to adulthood.

corpsicle: A corpse preserved using cryonics. Coined by SF author Frederick Pohl.

eugeneering: Genetic engineering for eugenic purposes.

forced-growth: A way of hyper-accelerating development within an artificial womb so that maturation from a germ cell to a developed adult takes months, not decades. It may use massive doses of growth hormones or other methods.

genefixed: Used to describe someone whose genes were manipulated at conception to fix or screen out genetic defects.

genemod: Short for "genetically modified." Someone or something that has undergone genetic engineering. Also refers to a genetic modification.

genesplice: To perform genetic manipulation.

ghostcomp: A computer capable of housing a self-aware braintape.

growth tank: An artificial womb.

metamorphosis (nano)virus: A proteus virus capable of performing radical changes in a living being's anatomy.

nanite, nano, and nanobot: Slang terms for nanomachines.

nanovirus: A swarm of nanomachines designed to perform harmful or benign tasks within a living organism. Not to be confused with the botanical term "nanovirus" which refers to a family of plant viruses.

neogenesis: The next step beyond biogenesis; the creation of a new organism or species capable of living independently, without ongoing biochemical support from symbiotic nanomachines. A neogenetic being can be assembled like a biogenetic one, or grown from an assembled zygote.

organlegger: Someone who steals live organs from hospitals or kidnaps victims to sell to transplant patients. Coined by SF author Larry Niven.

panropy: The philosophy or practice of colonizing hostile environments by adapting humanity to be able to survive in them. Coined by SF author James Blish.

parahuman: A variant human who has undergone species modification.

polykeratin: A form of artificial tissue that is capable of changing its shape.

proteus virus: A nanovirus that hijacks cellular machinery for the purpose of transforming cells.

sensa-skin: An ultra-tech form of artificial tissue.

species modification: Genetic modification that inserts new genes not native to a species' original genome.

transhumanism: A movement promoting the modification and diversification of the human species to overcome the limitations of human biology.

upgrade: A genetically modified variant of a species, designed to be superior to an unmodified individual. Upgrades are usually capable of breeding with normal members of their species.

uplift: The process of modifying animals to improve their intelligence, communications, or tool-using capabilities, often with the goal of creating a sapient or near-sapient race. Coined by SF author David Brin.

uploading: The act of being copied or transformed into a digital intelligence. Similar to braintaping, but return to a biological body may not be desired, or even possible.

variant human: A member of a human variant race.

variant race: A subspecies that has been adapted from the original species through genetic engineering. Depending on the extent of the engineering, it may be similar to or very different from the original.

BIBLIOGRAPHY

There are far too many works of fact and fiction to cover in this brief space, so this bibliography concentrates on works especially useful in inspiring adventures and game settings. Dates are for the most recent edition, where possible.

Fiction

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Blish, James. *The Seedling Stars* (Roc, 1972). Classic collection of stories about pantropy, the adaptation of humans to alien worlds.

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Heinlein, Robert. *Friday* (Del Rey, 1997). Adventures of a genetically-engineered super-agent.

Herbert, Frank. *Dune* (Ace, 1965). Classic novel about the making of a messiah, also featuring ecology, eugenics, and an anagathic, mind-expanding drug. Sequels contain many other biotech elements, such as exotic variant human races.

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Kress, Nancy. *Beggars in Spain* (Avon, 1993). Upgraded humans are engineered for enhanced intelligence and sleeplessness, and come into conflict with the rest of society (and vice versa). Sequels include *Beggars and Choosers* and *Beggars Ride*.

Kingsbury, Donald. *Courtship Rite* (1982). A complex political story set on Geta, a harsh world whose people practice plural marriage, cannibalism, and eugenics.

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Ore, Rebecca. *Gaia's Toys* (Tor, 1995). A dystopian post-plague near-future in which eco-terrorists use genetically-modified insects to combat the establishment.

Reed, Robert. *Marrow* (Tom Doherty Associates, 2000). High-biotech near-immortal humans (and others) inhabit and explore a mysterious world-sized starship.

Shirow, Masamune. *Appleseed* (Dark Horse, 1995). Graphic novel series that coined the term bioroid; adventures of two cops in a bio-cyberpunk utopia threatened by terrorists. Book 3: *The Scales of Prometheus* has especially strong biotech themes.

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VanDermeer, Jeff. *Veniss Underground* (Prime Books, 2003). Another example of the New Weird science-fantasy genre, set in a decadent far-future city where artists are bio-engineers and uplifted meerkats and multi-limbed mini-elephants are servants.

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Dragon's Island and "terraforming" in *Seetee Ship* (both 1951).

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Easton, Thomas A. *Sparrowhawk* (Wildside Press, 2000). A future world filled with bio-constructs and biove-hicles.

Martin, George R.R. *Tuf Voyaging* (Meisha Merlin, 2003). The adventures of a freelance interstellar ecological engineer.

Shelley, Mary. *Frankenstein, or the Modern Prometheus* (Pocket, 2004). Originally published in 1818, this is the classic story of a scientist's creation of artificial life and its tragic consequences, and is often considered the first science fiction novel.

Cryonics

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Human Cloning

Cherryh, C.J. *Cyteen* (Aspect, 1995). Set in the Union-Alliance SF universe, the story focuses on a deliberate attempt to recreate a murdered genius through a combination of cloning and duplication of the original environment and life experiences.

Cherryh, C.J. *Serpent's Reach* (Mandarin, 1989). Long-lived aristocratic families breed cloned servants and trade with insectoid aliens while feuding amongst one another.

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Weaver, Michael D. *Mercedes Nights*. (St. Martins, 1987). A celebrity is cloned multiple times for sale as a sex toy.

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Butler, Octavia. *Xenogenesis* (Doubleday, 1989). Seemingly benevolent aliens biologically modify humans to adapt them to their own society.

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Bioterrorism, Outbreaks, and Medical Thrillers

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Bear, Greg. *Darwin's Radio* (Del Rey, 2000). Diseases sleeping in the human genome return as the trigger for evolutionary change. Sequel *Darwin's Children*.

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Film and Television

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Appleseed (Shinji Aramaki, 2004). The most recent animated version of the Shirow manga.

Blade Runner (Ridley Scott, 1982). Bioroid "replicants" created as servants and warriors attempt to elude police in future Los Angeles.

Crest of the Stars (Yasuchika Nagaoka, 1991). Space opera anime focusing on the Abh, a variant race of humanity, and their conflict with the United Mankind, with fascinating details of Abh aristocratic, high-biotech culture. Based on a series of novels by Morioka Hiroyuki, it provides many details of Abh culture. Sequel *Banner of the Stars*.

CSI: Crime Scene Investigation (Anthony E. Zuiker, 2000). Iconic police forensic investigation TV drama set in Los Vegas; spinoff series *CSI: Miami* and *CSI: NY*.

Dark Angel (James Cameron and Charles H. Eglee, 2002-2004). TV series about a genetically-engineered supersoldier living as a fugitive in cyberpunk Seattle.

E.R. (Michael Crichton, 1994-Present). Massively popular emergency room medical drama.

Fantastic Voyage (Richard Fleischer, 1966). A submarine and its crew are miniaturized and used to perform life-saving surgery; a short-lived TV series was also made.

Gattaca (Andrew Nicol, 1997). A genetically-imperfect man struggles to get ahead in a future in which your genome determines your status.

Gene Shaft (Kazuki Akane, 2003). Animated TV series in which inhabitants of a genetically-stratified future society (including an uplifted dog) confront an alien artifact.

Gundam Seed (Mitsuo Fukuda, 2002-2003). Anime mecha TV series featuring a conflict between genetically-enhanced space-colony-dwelling humans and normals (some enhanced by drugs). Sequel *Gundam Seed Destiny* (2004-2005).

House, M.D. (David Shore, 2004-Present). TV series which treats clinical diagnostics as detective work. The brilliant but unrelentingly acerbic title character is a model of scientific detachment.

Neon Genesis Evangelion (Hideaki Anno, 1995). Psychologically intense anime TV series in which giant robots and biotechnology bring on the apocalypse.

Outbreak. (Wolfgang Peterson, 1995). An airborne virus threatens to spread from a small town.

Star Trek (Gene Roddenberry, 1966-1969). Doctor McCoy is the archetypal "ship's doctor" in SF and Spock is the classic alien hybrid; the original series and its many spinoffs often deal with medical plots. *Star Trek II: The Wrath of Khan* (Nicholas Meyer, 1982) features eugenic supermen as its villains.

Tenchi Muyo! (Hiroki Hayashi and Masaki Kajishima, 1992). Fun anime space opera that features an alien culture that makes use of tree and animal bioships (one of which can transform into a cute furry critter).

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THE FUTURE IS ALIVE

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It's the technology of the posthuman age: biotech! Upgrade your old body with steroids, smart drugs, transplants, and viral nano . . . or get a new one. Improve on nature with eugenics and gene-fixing. Or go parahuman – if you love cats, become one! You have time to explore the possibilities – death is only a temporary inconvenience with cryonics and immortality drugs. And who needs silicon? Vatbrain biocomputers are where it's really at!

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