CHAPTER 13

Gene Function

On Genomes

The Human Genome Project, which has revealed the DNA sequences of all the genes in a human cell, promises to revolutionize health care. From a biologist's viewpoint, however, even more exciting is the sequencing of genomes from many species. To obtain this information, researchers cut several copies of the same genome into many pieces, and then automated devices and computers sequence and overlap the pieces, deriving the continuous sequences of chromosomes. One way that researchers discover gene functions is by identifying similarities in databases of sequenced genes from other organisms.

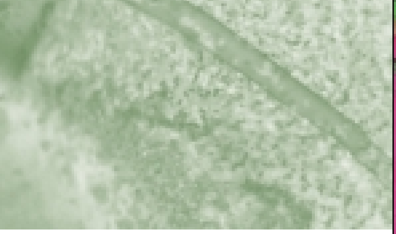
Several dozen species have already had their entire genetic selves laid bare, and the greatest lesson we've learned so far is how much we do not know. DNA sequences that have remained relatively unchanged over the ages among diverse species indicate much shared, if distant, ancestry. By comparing the genomes of species that lie at the boundaries of great evolutionary leaps, researchers can investigate the compelling questions posed below:

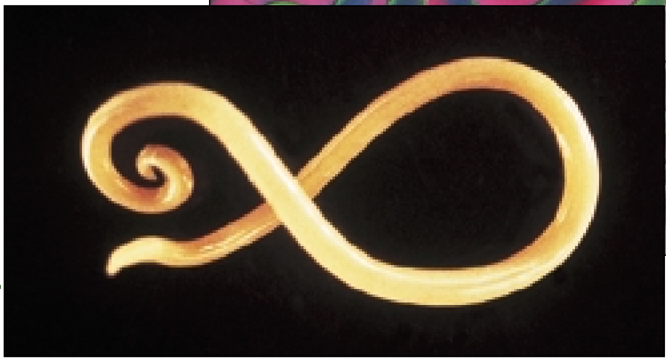
What is the Minimum Number of Genes Required for Life? The smallest cell known to be able to reproduce is the bacteria-like *Mycoplasma genitalium*. It infects cabbage, citrus fruit, corn, broccoli, honeybees, and spiders, and causes respiratory illness in chickens, pigs, cows, and humans. Researchers call its tiny genome the "near-minimal set of genes for independent life." Comparing *Mycoplasma* genes to those of other organisms offers an approximation of how this most micro of microorganisms uses what it's got:

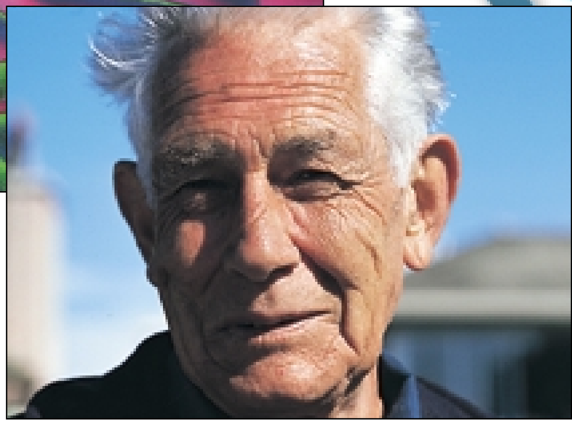
% of genome	Function
30	Maintaining its cell membrane
24	Expressing genes as proteins
22	Unknown: doesn't match any known gene
9	DNA replication
8	Obtaining energy
4.5	Evading immune attack by host cell
4	Making and recycling nucleic acids

(They add up to more than 100 percent because there is some overlap in function.) According to this genome, only 300 or so genes may be necessary for life.

What Are the Fundamental Distinctions Among the Three Domains of Life? Home for the Archaean *Methanococcus jannaschii* is the bottom of a 2,600-meter-tall "white smoker" chimney deep in the Pacific Ocean, at high temperature and pressure and without oxygen. Less than half of







DNA is at the heart of life, encoding the traits and characteristics of every plant, animal, and single-celled organism on earth.

M. jannaschii's 1,738 genes have known counterparts among other organisms. The cell surface, ion transport mechanisms, and metabolic enzymes are similar to those of bacteria, yet DNA replication and protein synthesis resemble these functions in eukaryotes. But *M. jannaschii* clearly also has its own way of conducting many of the activities of life.

How Does a Bacterium Work? In 1966, Francis Crick suggested that by identifying all the genes in an *E. coli.* cell, we would understand how it works. Crick's idea became reality in 1997, with the sequencing of the *E. coli* genome, but having the sequence was only a first step. In 1997, researchers knew the functions of only 2,000 of the 4,288 protein-encoding genes—more than half were a mystery.

What Is the Genetic Organization of the Simplest Eukaryote? The journal article unveiling the genome of *Saccharomyces cerevisiae,* entitled "Life with 6,000 Genes," was deceptive for this not-so-simple unicellular yeast. A third of its genes have counterparts among mammals, including those for more than 70 disease-causing genes in humans. Many of the yeast's genes are duplicated or clustered, similar to the organization in multicellular organisms.

Which Genes Are Necessary for Multicellular Existence, and Provide a Blueprint for an Animal? The genome of the transparent, 959-celled nematode worm *Caenorhabditis elegans* is packed with information on what it takes to be an animal. Thanks to researchers who, in the 1960s and 1970s, meticulously tracked the origin and final location of each cell and its progeny as the animal develops, much of the biology of the worm was already known before its 97 million DNA bases were revealed late in 1998. Its signaling pathways, cytoskeleton, immune system, DNA replication, and certain nerve-cell proteins are similar to ours! Comparisons to the yeast genome reveal requirements for multicellularity. Many of the worm's genes encode cell surface receptors for hormones, allowing cell-to-cell communication not seen in the much simpler yeast.

Which Genes Are Genes Distinct to Plants? *Arabidopsis thaliana* is the ideal model organism for plant biologists. Until the early 1980s, most species used for basic research were of agricultural value. But *Arabidopsis,* a member of the mustard family, offers such compelling advantages for research that it is the first flowering plant to have its genome sequenced. It has a short life cycle, produces abundant seeds, has a small genome, and has many mutants. Like *E. coli* and *C. elegans,* we already know much about its development, genetics, biochemistry, and anatomy and physiology.