of every other living being) is a desirable food source for these tiny life forms. Bacteria seek us as a source of autopoietic maintenance in their ancient struggle against thermodynamic equilibrium.

Perhaps we should take solace in the fact that the matter of our bodies returns upon death not to an inert state of matter but to the bacterial order undergirding the biosphere. "Don't you see," wrote Giordano Bruno, "that which was seed will get green herb, and herb will turn into ear and ear into bread. Bread will turn into nutrient liquid, which produces blood, from blood semen, embryo, men, corpse, Earth, rock, and mineral and thus matter will change its form ever and ever and is capable of taking any natural form."[2]

The wish to maintain one's youth, one's most attractive form, and ultimately one's very life is thwarted at the level of the animal body. But our individual defeat is a victory for the bacteria, which return the hydrogen-carbon compounds of our bodies to a living environment. Closer to life's original structures, bacteria do not live as we live, toward death. Banning an unfortunate accident, a mutation, or a gene-trading encounter with another bacterium, a single bacterial cell can "survive" essentially forever in its original form, as generation after generation of bacterial copies of itself are made by cell division.

We pluricellular creatures are each a disequilibrium structure of cells, as a bacterium is a disequilibrium structure of matter. Humanity as a species, even the entire kingdom of animals, has a far more fragile existence than theirs—just as their existence is more tenuous than that of nonliving matter.

THE METABOLICALLY GIFTED

Bacteria can swim like animals, photosynthesize like plants, and cause decay like fungi. One or another of these microbial geniuses can detect light, produce alcohol, waft hydrogen and fix nitrogen gas, ferment sugar to vinegar, convert sulfate ions or sulfur globules in salt water to hydrogen sulfide gas. They do all this and much more

not because they are "pathogens" or in service to clean our human environment but because their survival imperative led to their inventing every major kind of metabolic transformation on the planet.

The smallest of them have a diameter only a thousand times greater than a hydrogen atom. If there were such a thing as angels that could dance on the head of a pin, bacteria would be they. Ancient bacteria mastered nanotechnology. Already miniaturized, bacteria control specific molecules in ways of which human engineers can only dream. Far more complex than any computer or robot, the common bacterium perceives and swims toward its food. Choosing and approaching their destinations, bacteria propel themselves by flagella, corkscrew-shaped spinning protein filaments attached to living motors in the membranes of their cells. Complete with rings, tiny bearings, and rotors, they are called "proton motors" and spin at about 15,000 rpm. These proton motors move bacteria in the same way that "electric fan" outboard motors propel boats.

Rapidly reproducing, bacteria properly supplied with food and water double their cells in a half hour or faster. They have been and probably always will be the most important players in maintaining the biosphere. A single photosynthetic blue-green bacterium growing and dividing under ideal conditions could, in theory, produce all the oxygen now in the atmosphere in just a few months.

All other life forms depend on the workings of uncountable living, dying, and metabolizing bacteria. Our relations to the bacteria all around us factor into our health and well-being and that of our soil, food, and pets. As naked and simple as bacterial cells seem, they are continuously busy at the cellular and the planetary level. Varieties of bacteria exist that photosynthesize without ever releasing oxygen, yet they use carbon dioxide and hydrogen to produce all their cell parts. Others incorporate carbon dioxide and hydrogen from the air into body protein, converting their waste into methane gas. Still others turn sulfate to sulfide, or incorporate in-

ert nitrogen into their bodies. Only citizens of the bacterial kingdom are so metabolically gifted. When an animal (like the termite who produces methane) or a plant (like the starved bean who begins to supply itself with nitrogen from its roots) is discovered with such metabolic skills, it is because they have co-opted the bacterial bodies to their expertise. Such borrowing also applies to biotechnology performed by humans in white lab coats. We humans do not "invent" patentable microbes through genetic recombination; rather, we have learned to exploit and manipulate bacteria's ancient propensity to trade genes.

THE GENE TRADERS

Bacteria trade genes more frantically than a pit full of commodities traders on the floor of the Chicago Mercantile Exchange. The trading by bacteria of genetic information provides the basis for understanding new concepts of evolution.

Evolution is no linear family tree but change in the single, multidimensional being that has grown now to cover the entire surface of Earth. This planet-sized being, sensitive from the beginning, has become more expansive and self-reflexive as, for the past 3,000 million years, it has evolved away from thermodynamic equilibrium. Imagine that in a coffee house you brush up against a guy with green hair. In so doing, you acquire that part of his genetic endowment, along with perhaps a few more novel items. Not only can you now transmit the gene for green hair to your children, but you yourself leave the coffee shop with green hair. Bacteria indulge in this sort of casual, quick gene acquisition all the time. Bathing, they release their genes into the surrounding liquid. If the standard definition of species, a group of organisms that interbreed only among themselves, is applied to bacteria, then all bacteria belong worldwide to a single species. The Archean Earth was a promiscuous place of prodigious growth and rapid gene transfer that led, by and by, to the genetic restrictions of the Proterozoic protists, the larger composite beings presented in chapter 5.