

# What Are We?

## The Social Construction of the Human Biological Self

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### Abstract

*This essay explores how the human biological self is socially constructed, and rejects various truisms that define our character. Rather than being stand-alone entities, the human biological self forms what biologists call “superorganisms” and what I call “poly-super-organisms.” Thus, along with prokaryotes (bacteria), viruses, and other entities, we are combined in an inseparable menagerie of species that is spread across multiple bodies. Biologists claim that only males and females are organisms. As described here, however, human sperm and eggs are equally entitled to that rank. Much about human reproduction is also socially constructed. For example, contrary to scientific wisdom, humans have always reproduced both sexually and asexually. Moreover, human life (the creation of a new organism) does not begin between conception and birth, and neither event creates new life. In addition, some cancer cells are organisms; they are contagious entities formed by asexual human reproduction. Finally, while science universally describes humans as being living entities, accumulating evidence makes clear that the life concept is failing. In fact, much that originates from human bodies does not fall under current biological or cultural classifications.*

*How we construct the human biological self has consequences for understanding our health, how we reproduce, and what we are. These social constructions greatly influence our views on abortion, stem-cell research, human cloning, and our post-human future. A more accurate construction of the human biological self will help us better navigate these contentious issues.*

*Society is a human product. Society is an objective reality. Man is a social product.*  
Berger and Luckmann

Charles Darwin transformed humankind from the singular divine creation described in Genesis to an integral member of the biological community. Since his great work *Origin*, Darwin’s basic insight has been so thoroughly

confirmed that Theodosius Dobzhansky titled his famous 1973 essay “Nothing in biology makes sense except in the light of evolution.” Still, much remains unresolved. As noted by the evolutionary biologist Ernst Mayr (1988: v), biology is plagued by conceptual confusion, a problem that extends to biology’s central notions of *organism* and *life*. The clarity of these

concepts has not improved since Mayr wrote his passage, however, and may have gotten worse. One reason is that accumulating evidence reveals these highly reified concepts correspond imperfectly to nature. Another is the mistaken belief that objective scientific knowledge alone is what determines the human biological self.

In their classic volume *The Social Construction of Reality* (1966), Peter L. Berger and Thomas Luckmann argued that individuals and groups socially construct perceptions of reality. Today, this view informs such diverse areas as race, gender, sexuality, and science. Karin Knorr Cetina (1981; 1999), for example, describes science as “epistemic cultures” that generate knowledge and send it downstream to the broader society. Latour and Woolgar (1979) and Latour (1987) add that this knowledge tends to flow in only one direction as science converts its transcriptions into “black-box” facts that non-scientists cannot assail.

In this essay, I describe how science and society socially construct *organism* and *life*. After reviewing scientific descriptions, I propose alternative interpretations to the human biological self and discuss their importance for understanding our health, how we reproduce, and what we are.

### **Biology, and What Biology Studies**

*Biology* is the study of life. Derived from the ancient Greek, the term itself only traces back to 1776 in Hanov's *Philosophiae naturalis ...* (Volume 3). The science of biology arose from natural history, a field that once investigated botany, zoology, geology, and more. Since Darwin, biology has become a sprawling and rapidly expanding research enterprise, one that more resembles clusters of sub-disciplines with fluid boundaries than a single field. In succinct terms, biology investigates the origin of the first living cells and all that has evolved from them.

Biology has not yet solved how life began. Oxford University evolutionary biologist Richard Dawkins (1976/89) speculates that life may have arisen from a self-replicating molecule he calls “the replicator.” Over millions of years, innumerable replications, and countless errors in duplication, this molecule perhaps formed a rich organic soup, and from it, the first living cells emerged. By applying probability theory to the chemistry of DNA and RNA, biologists have concluded that all current life forms originate

from single celled organisms without a nucleus — prokaryotes — that arose perhaps 3.5 billion years ago, cf. Woese (2002). For two billion years, prokaryotes — bacteria is a close synonym — were the earth's sole inhabitants. Over time, they originated sex and photosynthesis, significantly raised the earth's oxygen level, and formed the eukaryotic cell, which has a nucleus.

Most species the public knows — all the earth's animals, plants, and fungi — are “recently” arrived multi-cellular eukaryotes. Among them, vertebrates arose 600 million years ago, mammals 200 million years ago, flowering plants 140 million years ago, hominids within the past 7 million years, and modern human beings (*Homo sapiens sapiens*) a mere geological heartbeat of 195,000 years ago (McDougall et al., 2005). Single-celled eukaryotes like amoeba and paramecia are called Protists. To date, scientists have catalogued nearly 1.5 million contemporary species, but estimate that another 1.5 to 98.5 million remain undiscovered. Even so, present-day species may represent less than one percent of those that ever existed (Gould, 1996:65).

Among the first to catalog the earth's biology, Aristotle (384-322 BC) created a minimalist two-category scheme that only recognized animals and plants. It lasted for over 2,000 years, almost two centuries after the Dutch tradesman and scientist Anton van Leeuwenhoek (1632-1723) first discovered sperm and blood cells, and the prokaryotes (bacteria). Aristotle's scheme also outlived Swedish botanist Carolus Linnaeus (1707-1778) who laid the foundation for the modern biological nomenclature that classifies organisms by genus and species. Ernst Haeckel added a third biological kingdom in 1866 (Protista) and Herbert Copeland finally proposed a kingdom for bacteria in the early 1900s. It wasn't until 1959, however, that Robert Whittaker originated the first modern scheme. It consisted of five major groups, four kingdoms of eukaryotes — Animals, Plants, Fungi, Protista — and the prokaryotes, which he termed Monera, Figure 1. Interestingly, Aristotle's categories still survive in the public's widespread but outdated notions that all biological things are flora (botany) or fauna (zoology), and that all earthly things are animal, vegetable or mineral.

Figure 1. Phylogenetic Tree of Life Expressed as Five Kingdoms.

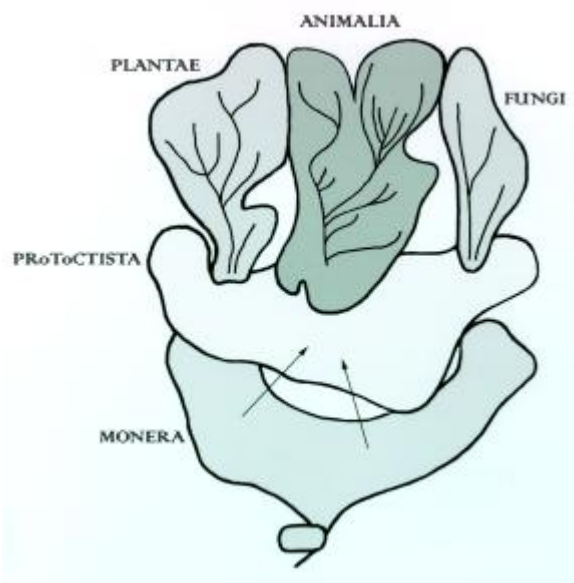


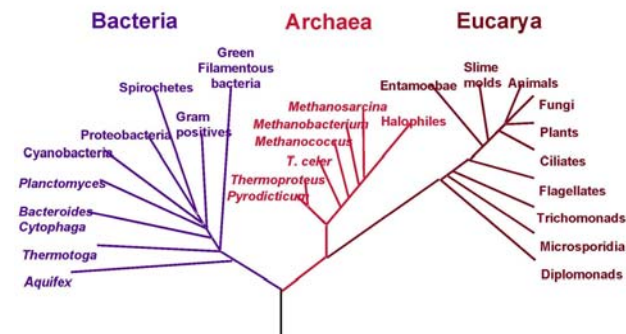
Image from:

<http://www.meta-library.net/media/5kingd.jpg>

Whittaker's five kingdoms were only a steppingstone to a radically different arrangement proposed by Carl Woese of the University of Illinois. It combined Whittaker's four eukaryotic kingdoms into one domain — Eukarya — and divided the prokaryotes into the two domains of Bacteria and Archaea, Figure 2. Bacteria and Archaea differ significantly; e.g., while both consist of single-celled organisms, the Archaea apparently cannot parasitize human beings. Woese's arrangement also innovatively proportions Figure 2 to reflect genetic variation. Based on molecular analysis, its line lengths estimate the genetic separation between groups and show that, in evolutionary terms, humans (animals) are rather closely related to yeast (fungi). As Dawkins (2004:555) quips, "When viewed through the 'eyes' of bacteria [prokaryotes], an *Amoeba* [a eukaryote] is scarcely distinguishable from a human [another eukaryote]." In an earlier seminal discovery, Nobel Laureate Joshua Lederberg and his student Norton Zinder (1952) had found that organisms pass genes to one another — and do so even across the three domains (Bacteria, Archaea, and Eukarya) — in lateral gene transfers (LGTs), Figure 3.

Figure 2. Phylogenetic Tree of Life Expressed as Three Domains.

Image from:



[http://en.wikipedia.org/wiki/Phylogenetic\\_tree](http://en.wikipedia.org/wiki/Phylogenetic_tree)

Figure 3. Phylogenetic Tree of Life Expressed as Three Domains with Lateral Gene Transfer.

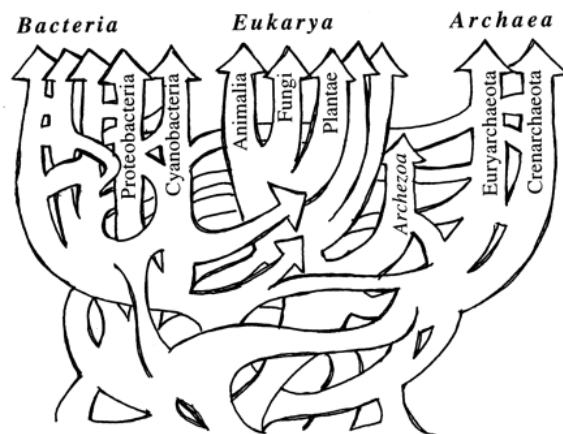


Image from:

<http://cas.bellarmine.edu/tietjen/Ecology/se2497604003.gif>

Figures 1-3 translate biology's above-described views to visual images. Originated by Darwin in *Origin*, graphs like these — termed *evolutionary trees*, *trees of life*, *phylogenetic trees*, or *cladograms* — convey information powerfully, but can also be powerfully deceptive (e.g., Gould, 1989). Thus, Dawkins (2004:135) recently comments:

We normally assume that we can draw a single evolutionary tree for a set of species. But ... different parts of DNA (and thus different parts of an organism) can have different trees. I think this poses an inherent problem with the very idea of species trees. ... Each DNA letter takes its own path through history. Each piece of DNA, and each aspect of an organism, can have a different evolutionary tree.

Dawkins' comment is one indication that the *organism* concept is failing; others follow.

### Organism

Organism: *An individual animal, plant, or single-celled life form.*

(Oxford English Dictionary, 2006)

Organism: *A living thing that has (or can develop) the ability to act or function independently.* (Princeton University, 2006)

*Biology lacks a central organism concept that unambiguously marks the distinction between organism and non-organism because the most important questions about organisms do not depend on this concept.* (Wilson, 2000)

*Organism* derives from the French *organisme* (1729) as related to a body that contains organs (Oxford English Dictionary, 2006). Although the term has no precise meaning, most definitions center on the characteristics of being a living, autonomous, biological entity that occupies a single body — like a human, dog, oak tree, or bacterium. More expansively, Mayr (1988:350) advises, "When using the word *organism*, [biologists] may have individuals in mind, or species, or higher taxa." Problematically and without explanation, however, biology and the public exclude from *organism* some entities that fit its definitions — such as gametes and HeLa cells.

### HeLas

In 1951, doctors at Johns Hopkins Hospital diagnosed Henrietta Lacks with cervical cancer; she died of the disease that same year. During her treatment, George Gey, the head of tissue culture research at Hopkins, sampled Ms. Lacks's malignant tissue in his search for a human cell line able to live indefinitely outside the body (Gey et al. 1952). Gey, who named these cells HeLa for He(nrietta)La(cks), was

magnificently successful. The cells he propagated did what few human cells had done before; they survived in laboratories, where they continue to live today. "Henrietta's cells were, and still are, some of the strongest cells known to science — they reproduce an entire generation every 24 hours" (Skloot, 2000). Gey's HeLa cells were immediately useful. They helped medical researchers identify the poliovirus strain that causes human illness and crucially aided Jonas Salk in the development of his vaccine. At the same time, Gey began sharing HeLa cells with colleagues across the globe. Some cells were even lifted into orbit by a space-shuttle aircraft, where they continued to multiply. Today, "the total daily worldwide production of HeLa cells must be measured in tons" (Dawkins, 2003:35).

Enthusiasm for Gey's triumph cooled, however, after Stanley Gartler in 1968 and Walter Nelson-Rees et al. (1974) announced their suspicion that HeLa cells, like laboratory weeds, had contaminated cell cultures across the globe. Initially greeted with skepticism (Gold, 1985), it turned out that nearly three decades of complex and costly experiments had been ruined. But ruined by what?

Ruined by what I am going to call *HeLas*, one could say.

But what are HeLas? They can't be Henrietta Lacks, who is dead; nor can they be another person. Even the most powerful rerogenetic technology cannot transform mutant differentiated HeLas into human clones. Calling HeLas *human cells*, *cancer cells*, a *cell line*, or just *cells* isn't better. These less specific terms conceal that HeLas have existed in total independence of Ms. Lacks for over 50 years, that HeLas occur in different strains with varying numbers of chromosomes (Bottomley et al., 1969), and that all HeLas differ from Ms. Lacks' normal cells, which had 46 chromosomes.

Significantly, the distinctive characteristics of HeLas once led Leigh Van Valen and Virginia Maiorana of the University of Chicago to propose that HeLas are a new species, *Helacyton gartleri*, in honor of the above mentioned Stanley Gartler. They write (1991:71):

Species originate in diverse ways. HeLa cells are the best known cultured cells of human origin. Here we propose, in all seriousness, that they have become a

separate species restricted to a particular environment (from Weasel, 2004).

While Van Valen and Maiorana's interpretation remains controversial in biology, it advances the notion that George Gey discovered an entirely new kind of organism — a HeLa organism — an autonomous, single-celled, eukaryotic creature produced by a multicellular human being, an entity that is human in origin but which is not a human being. Bernard Korzeniewski of the Institute of Molecular Biology astrobiologist (2001) extends this logic beyond HeLas to all cancer cells when writing:

Cancers are traditionally not regarded as biological individuals. From the cybernetic point of view, however, they are individuals. The act of tumorous transformation of a normal cell can be treated as breaking loose from the realization of the superior purpose of the entire organism and establishing another superior purpose, that is the reproduction of cancer cells.

There is more that suggests cancer cells are organisms. Science typically describes cancer as being a non-infectious disease (e.g., U.S. National Institutes of Health, National Cancer Institute, 2006). Yet HeLas are infectious. They contaminated cell cultures across the globe. Other cancer cells are also (weakly) contagious pathogens. That is why some cancer survivors are not allowed to donate blood (American Cancer Society, 2006) and why cancer cells can pass from donors to recipients in organ transplants (Barozzi et al., 2003). Metastatic cancer is also contagious in the definition-stretching sense that one colony (tumor) can establish new colonies at other body sites. Moreover, cancer is considerably more transmittable in some non-human species. In both Sticker's sarcoma (canine transmissible venereal tumor disease) Murgia et al. (2006) and Tasmanian devil facial tumor disease (Pearse and Swift, 2005), cancer infectiously passes from one host to another. A better-known example is feline leukemia, which is similarly transmissible. Despite this evidence, cancer is the only contagious cellular pathogen biology excludes from the category of organism.

Amherst College biologist Paul Ewald (2003:293, 296) offers a far-reaching summary and explanation for this state of affairs when he writes:

I expect that the common and highly damaging chronic diseases — atherosclerosis, diabetes, Alzheimer's disease, most cancers, and most fertility problems — will, in the next fifty years, be accepted as caused by infection.

The general opposition to infectious causation of cancer seems particularly ingrained. When considered on the basis of the actual evidence, this resistance is surprising, because medical researchers already accept infectious causes for about 15 to 20 percent of human cancers (up from less than 1 percent twenty-five years ago) and there are so few examples of human cancers for which infection can be ruled out (less than 5 percent).

This story doesn't end with George Gey, HeLas, and cancer cells, though it didn't begin with them, either. Long before Gey isolated HeLas, laboratories throughout the world had been propagating *cell lines* — non-human, single-celled eukaryotic entities — and scientists have been creating more ever since. So many more that we need multiple volumes to catalogue their human and non-human variety, cf. Koller et al. (2001).

Most essentially, HeLas and other cancer cells are about as self-sufficient (autonomous) as laboratory mice (Knorr Cetina, 1999, chapter 6), dairy cattle, domesticated sheep, and Chihuahuas, and just as able to pass on their genes. In sum, Van Valen and Maiorana have proposed that HeLas are a new species of organisms. To this I add that HeLas arose by a previously unheralded type of asexual reproduction. In it, somatic cells of human bodies produce single-celled organism offspring that differ in kind from their parents.

### **Sperm and Eggs (and sex)**

*Sex is best defined as the formation of an organism having genes from more than a single individual. Margulis and Schwartz (1998:14).*

*If you think you understand sex, you don't understand sex. Dawkins (2004:424)*

Gametes also fit biology's definition of *organism*. They, too, are excluded from this category. As living cells, sperm and eggs metabolize food and react to their environs. They derive their genes from the male and female bodies that produce them, reside within

these bodies for a time, and sometimes unite to form embryos. At issue is whether gametes act with sufficient autonomy to be considered organisms. They do not according to Robert P. George (2002:2) McCormick Professor of Jurisprudence at Princeton University and member of the President's Council on Bioethics who writes that spermatozoa and oocytes are "a part of the mother or of the father." They do, however, according to the Oxford English Dictionary; it defines *autonomy* as being "self-governing or independent."

Gametic autonomy is most obvious in species that reproduce by external fertilization. Staghorn coral, for example, set their sperm and eggs free in open water to find one another and to unite. The same occurs in the large brown algae *Fucus serratus*. Somewhat differently, the female tropical fish *Pseudotropheus zebra* releases eggs and takes them into her mouth for safety. When a male swims nearby and releases sperm, she sucks them up, which allows the gametes to locate each other and merge. Clearly, these gametes have agency; they act beyond the control of the bodies that created them.

The case for sperm autonomy is equally compelling in species that use internal fertilization, like humans. Biology once supposed that the females of all species upheld Western civilization's moral value of monogamy. Though he surely knew otherwise, "In almost all his voluminous writings, Charles Darwin [living during prudish Victorian times] assumed that females were monogamous and copulated with a single partner in each breeding attempt" (Birkhead 2000:13). This view prevailed until University of Liverpool biologist Geoff Parker, the father of sperm-competition theory, addressed the obvious fact that some females mate with multiple males in a reproductive cycle, leaving the male's sperm to compete for fertilization rights after the males have departed (Parker, 1970). The essential point Parker's logic highlights is that, in competition with each other, all sperm act autonomously, even the sperm of a single male. Each sperm mindlessly seeks to be the one among millions to survive by merging its genetic payload with an egg.

Sperm autonomy is often made necessary in species that use internal fertilization because female bodies act aggressively toward sperm. As William Eberhard of the Smithsonian Tropical Research Institute (1996) concludes, females

use dozens of physical and chemical mechanisms in attempting to favor the sperm of desirable males. By what is termed *postcopulatory sexual selection*, females can accept a male for copulation but reject him as a father by manipulating and rejecting his sperm. Eberhard speculates such selectivity may be the norm in nature.

Tim Birkhead, Professor of Behavioral Ecology at the University of Sheffield (2000: x), adds that "Recent research has provided dramatic demonstrations that reproduction occurs neither for the good of the species nor as a mutually beneficial interaction between males and females.... Sexual reproduction is anything but cooperative." In this context, his description of *traumatic insemination* provides a remarkable example of sperm autonomy (2000:144-5):

The common bedbug inseminates the female directly through her body wall. [She has no natural opening.] He does this by means of a sickle-shaped [knifelike] structure, the paramere.... During copulation, it flips outwards to pierce the female's body.... Only then does the penis ... start to transfer sperm ... The female has a spermalege ... into which the male injects his sperm ... [It is like] a bag of amoeba-like cells, whose job may be to destroy sperm. ... Those that escape ... continue their progress by swimming along ... to the ovary.

The most extreme form of traumatic insemination ... occurs in *Xylocoris*, a close relative of the bedbug. Here, insemination sometimes involves homosexual rape. Following insemination through the body wall, the rapist's sperm make their way to the [male] recipient's vas deferens and are used along with the male's own sperm the next time he inseminates a female.

Finally, let us consider the eggs of species that use internal fertilization. Admittedly, these eggs (and the oocytes they develop from) depend on the bodies that produce them more than sperm do. What critically determines their autonomy, however, is that these eggs are utterly selfish in their behavior. They take resources and protection from the bodies that create them but return no benefit whatsoever *to that body*, unlike white blood cells that destroy invading bacteria or red blood cells that deliver oxygen. In short, the eggs of females using internal fertilization are autonomous in the sense

they are exclusively self-interested, cellular, living beings — as is true of all gametes.

Trivializing sperm and eggs has been easy. Human adults are larger, more capable, more durable, longer-lived, and more intelligent. Gametes, in contrast, are invisibly small, fragile, short-lived, anonymously numerous, and often hidden away within bodies. Pithily describing our closest relative, Dawkins writes, “Chimpanzees compete via sperm proxies inside vaginas,” (2004:209). Still, because gametes act selfishly and uncooperatively — like the organisms they are — chimp sperm are no more a proxy for chimp adults than chimp adults are a proxy for chimp sperm. Size, capability, durability, longevity, and intelligence shouldn’t determine whether gametes are organisms — but historically they have.

Interpreting gametes as organisms has provocative implications. One is that our species actually consists of four *forms* of organisms\* — males, females, sperm, and eggs — not two — each with a different and stable genotype. Thus, with trivial exceptions, the somatic cells of our male and female bodies contain 46 chromosomes (23 pairs), but share only pairs. The remaining pair is the differentiating female XX and male XY-chromosomes. Sperm have only 23 (unpaired) chromosomes, some with an X and others with a Y. Finally, eggs (oocytes) start with 23 chromosome pairs (with two Xs), which are halved after a sperm penetrates the egg.

Oddly, science and society lack a word for the male and female forms that span the embryo-to-adult arc — the genetically constant entity that starts as an embryo and becomes a fetus, neonate, infant, child, and adult. To facilitate our discussion, I will coin the term *adult*. Thus, males and females are the adult human forms — from their first moment as embryos through adulthood — and sperm and eggs are our *gametic* forms.†

As a practical matter, our interpretation of *organism* affects how we view the origin of

\* Intersexed individuals raise this total above four cf. Fausto-Sterling (2000).

† This simplified discussion ignores intersexed humans, hermaphroditic organisms, species with more than two sexes, polar bodies, fungal plasmogamy, and genetic abnormalities such as trisomy, Turner syndrome, and cri du chat.

human life. As William Safire (2004) has observed, “...the resolutely pro-choice believe that [human] life begins at *birth*... [while the] resolutely pro-life believe that life begins at *conception*...” Neither view accurately reflects nature, however, if we give the phrase *to create a new life* its only sensible (non-metaphorical) meaning — that a new life is only created in the origination of an additional organism.

Thus, each oocyte (egg) a human female produces by oogenesis is an additional living organism, and consequently a new human life. So is each sperm a male makes by spermatogenesis. Adult bodies create these new human lives — autonomous gametes — by the millions. Only the tiniest fraction of them unite at conception in embryos. In this union, each embryo is a new adult, but it is not an additional organism. Instead, conception unites two unlike entities — the genomes of two gamete organisms — into a whole that, like an epoxy, irreversibly differs in kind from either precursor. Because conception reduces the total number of organisms from two gametes to one embryo, it creates no new — additional — life. Finally, leaving metaphors aside, the birth event also creates no additional organism, and thus no new human life.

To summarize, human sexual reproduction occurs as an alternation of forms in which males and females (adults) create sperm and eggs (gametes), and sperm and eggs merge to become a male or female (adult). These four forms are all alive, human organisms, and nothing can suspend their aliveness, humanness, and “organismness,” even momentarily. The clarity and simplicity of this interpretation contrasts, for example, with the view of physician, biochemistry PhD, University of Chicago professor, and former Chairman of the President’s Council on Bioethics Leon Kass (2002), who has written:

While the egg and sperm are alive as cells, something new and alive in a different sense comes into being with fertilization. ... Though there is some sense in which the lives of egg and sperm are continuous with the life of the new organism (or, in human terms, that the parents live on in the child-to-be [or child]), in the decisive sense there is a discontinuity, a new beginning, with fertilization. *After* fertilization, there is continuity of subsequent development, even

if the locus of the new living being alters with implantation (or birth).

Biologists can appear equally muddled. Seeming to imply that adult organisms directly create more adult organisms, Lynn Margulis and her son, science writer Dorion Sagan, declare, "When...a body made of cells grows another similar being...we speak of reproduction" (1995:24). This statement (which nicely describes gestation) contrasts with my alternative interpretation that in reproduction, human bodies do not "grow" additional human bodies — they create sperm and eggs. In another example of incorrectly described sexual reproduction, Columbia University Press' Columbia Encyclopedia (2000-2005) claims that:

Sexual reproduction occurs in ... all multicellular plants and animals. In ... all vertebrates it is the exclusive form of reproduction, except [for] ... parthenogenesis. Sexual reproduction ... produces a new cell (called a zygote), which develops into [!] a new organism.

Twice mistaken, this quotation implies that zygotes are not organisms the instant they are formed (more on this below). It also holds that humans do not reproduce **asexually**, a view that is uncontroversial in biology and just plain wrong. In fact, humans have always reproduced asexually; we do so frequently and "naturally" (and aside from vitro fertilization and laboratory cloning). Through the 14<sup>th</sup> day after fertilization, an embryo can spontaneously fragment into two cell clumps, and both clumps — each embryo — can continue to develop normally (Silver, 1997:63). That's how identical twins are formed. The first embryo is created sexually, by the fusion of genes from two gametes. This embryo — a human adult — develops into a small clump of cells that soon fragments into two clumps — two embryos. That is asexual human reproduction by definition and is how all identical twins occur. Monozygous twinning occurs worldwide at a steady rate of about 4 per 1,000 births (Wikipedia, 2006.)

I have tried to imagine how anyone could contend that humans do not reproduce asexually. It may arise from the logic of the following statements: Adult males and females are human organisms that produce sperm and eggs. Gametes, however, are mere cells — not organisms — and are only alive in a lesser cellular sense (recalling the quotation from Kass). As cells, gametes lack organismness,

and only serve adult bodies as proxies (recalling Dawkins). During conception, human gametes fuse to become embryos, which are not organisms immediately (recalling the Columbia Encyclopedia). Instead, embryos wait until they become fetuses — a time at least 14 days after fertilization — when their organismness emerges, as if by magic. At this point, the human adult (fetus) really is incapable of asexual reproduction (twinning).

I have argued that we exist as four human forms — males, females, sperm, and eggs — which are all equally and uninterruptedly alive, human organisms. Humans reproduce both sexually and asexually. New human life (the creation of an additional organism) occurs by spermatogenesis, oogenesis, asexual embryo fragmentation (twinning), by cell division, as when HeLa-type cancer cells are formed, and perhaps in the formation of some conjoined twins and teratomas (cf. Silver 2006, 99-100, 156-159). Conception creates new adult males and females but actually reduces the number of living organisms from two gametes to one embryo. Thus, conception creates a new form, but does not create new human life. The birth event, a major transition in the life course of an adult, also creates no additional organism and no new human life. No human form — male, female, sperm, or egg — produces more of its own kind directly by sex (according to the definition heading this section offered by Margulis and Schwartz and also used by the President's Council on Bioethics, 2002:8).

### ***One-Organism Bodies — One-Body Organisms***

A variety of pre-scientific assumptions (social constructions) shape biology and the public's view of what an organism is. Resembling common wisdom or self-evident truth, these assumptions are nearly invisible, unassailable, and difficult to uncover in laboratory studies such as those Latour and Woolgar (1979) initiated. Let us next consider one that holds an organism consists of one — and only one — body, and conversely that each body is one organism. That is how most biologists and society view our human selves. As I see it, however, such bodies and organisms are uncommon in nature. Most living things are better interpreted as being superorganisms, polyorganisms, or poly-super-organisms.

### Superorganisms

Superorganism: *A collection or community of highly interdependent life-forms which behaves as if it were a single organism of a higher order.* Darling (2006).

William Morton Wheeler, an authority on eusocial (formerly social) insects, observed that an ant colony's sex cells reside only in the queen and drones. In 1911, he proposed that an entire ant colony is actually one organism — a superorganism — a single living entity comprised of many physically separate ant bodies that act collectively. Today, “The concept of superorganism is under dispute, as many biologists maintain that for a social unit to be considered an organism by itself, the individuals should be in permanent physical connection to each other...” (Wikipedia, 2006). For a defense of the superorganism concept, see Wilson and Sober (1989).

I speculate the lay public, if asked, would mostly agree that organisms need to remain physically connected. And this consensus — because agreements never occur randomly — is worth an explanation. Mine derives from the work of emeritus UCLA sociologist Harold Garfinkel who originated ethnomethodology, a field that investigates rules of social behavior that are ubiquitous, unconsciously learned, and made visible in “breaching experiments,” e.g., by reactions to people who purposefully face backwards in crowded elevators. My explanation extends Garfinkel's reasoning to rules we harbor about the behavior of things like inanimate objects and body parts. I call these rules *ethnoexpectations*, in Garfinkel's honor. Thus, gravity explains why apples fall, while ethnoexpectations explain why members of the public expect apples to fall, without their understanding Newton or Einstein.

We all have what I will term an *ethnoexpectation for physical integrity*, an expectation that the parts of organisms will remain physically connected. We gain this expectation as we encounter injured bodies, trees with broken branches, smashed cars, the human reactions to such events, and a sense of body boundaries. Minor rule violations like fingernail clippings or cut hair, raise no concern. Major violations, such as spilled blood and decapitation, evoke strong reactions. Thus, we all come to understand that the boundaries of bodies and organisms are coterminous. Through daily experience we learn that

unconnected bee bodies cannot be a single intact entity — the same way everyone learns to face forward in elevators. Counterintuitively, this nearly invisible process achieves what no educator could hope to duplicate — an improbable agreement on an esoteric issue without discussion. Because the ethnoexpectation for physical integrity develops in childhood, scientists are fully susceptible to it. As Brown University biologist Anne Fausto-Sterling observes (2000: ix), “Individual scientists are inclined to believe one or another claim about biology based in part on scientific evidence and in part on whether the claim confirms some aspect of life that seems personally familiar.”

Today the earth teems with insect superorganisms. Of the 950,000 known insect species (compared to 5,400 mammals; IUCN, 2006), a mere 2% are eusocial. Inordinately successful, half of all insect bodies exist within these species. Other superorganisms vary greatly and include slime molds, social amoebas, strawberry plants, and more. As Howard Bloom (1995:59) explains:

To you and me, a sponge is quite clearly a single clump... But that singularity is an illusion. Take a living sponge, run it through a sieve into a bucket, and the sponge breaks up into a muddy liquid that clouds the water... That cloud is a mob of self-sufficient cells ... But something inside the newly liberated sponge cell tells it, “You either live in a group or you cannot live at all.” The micro-beasts search frantically for their old companions ... Within a few hours, the water of your bucket grows clear. And sitting at the bottom is a complete, reconstituted sponge.

The most spectacular superorganism of all is the *Prokaryote*, which is my term for all the “bacteria” (prokaryotes) taken together. Numbering in the untold trillions of physically separate bodies, the Prokaryote blankets the earth; permeates the atmosphere; floats throughout every ocean, lake and river; and extends miles beneath the earth's 200 million square mile surface. Loosely spanning a 2-billion-cubic-mile space, the Prokaryote may constitute a third of the planet's biomass (Hart: 2004). Referring to the same entity in slightly different terms, Sonea and Mathieu (2001) observe, “The prokaryotes' constructive evolution resulted in the formation of a

worldwide web of genetic information, and a global bacterial superbiosystem (superorganism)" (but see Hanage et al., 2005). Detailing prokaryotic behavior, Waters and Bassler (2005) write:

Bacteria communicate with one another using chemical signal molecules. As in higher organisms, the information supplied by these molecules is critical for synchronizing the activities of large groups of cells. ... [In a] process termed quorum sensing, bacteria monitor the environment for other bacteria and alter [their] behavior on a population-wide scale in response to changes in the number and/or species present in a community. ... Quorum sensing confuses the distinction between prokaryotes and eukaryotes because it enables bacteria to act as multicellular organisms. ... [There is even] the intriguing possibility of prokaryote-eukaryote cross-communication.

Finally, Nobel Laureate Joshua Lederberg (2003) explains:

... [Prokaryotes] readily exchange genes within and between various species. They don't "speciate", or differentiate into genetically isolated organisms as we do. In fact, these bugs engage in "promiscuous lateral gene transfer," making the microbial world a kind of DNA-based worldwide web...

Before continuing, let me note that biology uses *superorganism* to describe three very different biological types. The first is a single entity spread over many bodies, like Wheeler's nest of ants. The second is formed by merging several individuals into one body — like lichens (described below). The third is a combination of the first two. As we proceed, I use *superorganism* for the first of these types, *polyorganism* for the second, and *poly-superorganism* for the third. Biology lacks comparable distinctions.

### **Polyorganisms**

*It's a very schizophrenic time. We have very unstable notions about the boundaries of the individual.* Sherry Turkle, professor of sociology at MIT, from Brin, (1998:82).

*Polyorganism* is my term for a body that is formed by the merger of several organisms, an arrangement that typically benefits all

participants and cannot be disassembled. Lichens, for example, are a fungus merged with an alga and/or a cyanobacterium. The fungus attaches to a tree or rock and stores water, and the alga or cyanobacterium produces food. The fungi seldom live independently in nature, though the alga and cyanobacterium do. Interestingly, the several organisms within the lichen reproduce separately and then re-form into one body.

Sex creates another variety of polyorganism (according to Margulis and Schwartz's above cited definition of sex). Sex does so by irreversibly merging a sperm with an egg to form an embryo. Some embryos arise from gametes of one species, as occurs in humans. Others result from the fusion of gametes of different species or types; termed *hybrids*, they include mules (from horse and donkey gametes), zorses (from horse and zebra gametes), and hybrid corn (from the gametes of two varieties of corn). Lynn Margulis' notion of the endosymbiotic creation of the eukaryotic cell is another example.

Chimeras are yet another type of polyorganism. A chimera is "An organism in which tissues of genetically different constitution co-exist as a result of grafting, mutation, or some other process" (Oxford English Dictionary). As the MedTerms Medical Dictionary (2006) informs:

Human chimeras were first discovered with the advent of blood typing when it was found that some people had more than one blood type. Most of them proved to be "blood chimeras" — non-identical twins who shared a blood supply in the uterus. ... About 8% of non-identical twin pairs are chimeras.

Other chimerical polyorganisms occur when two embryos merge in utero to form one body. Thus, the merger of human fraternal-twin embryos at an early stage of development creates an adult body with two complete genomes. Sometimes this process creates a body with the genitalia of both sexes. Late stage mergers produce conjoined twins. More expansively, Ainsworth (2003) notes "some researchers now think that most of us, if not all, are chimeras of one kind or another. Far from being pure-bred individuals composed of a single genetic cell line, our bodies are cellular mongrels, teeming with cells from our mothers, maybe even from grandparents and siblings"

Technological innovation has produced an explosion of human-made chimerical polyorganisms. Vintners form them by grafting the vine of one grape variety onto the rootstock of another, as do surgeons who transfer one person's heart or face to another's body. In xenotransplantation, surgeons move body parts across species, such as by inserting a pig's heart into a human body. More controversially, recent experiments have merged human skin cells with rabbit eggs to form multi-species chimerical polyorganisms (Mott, 2005). No end is in sight. The point is that, in nature and by human hands, several organisms are often irreversibly merged to form one body.

### ***Poly-Super-Organisms***

*Poly-super-organism* is my term for a superorganism that is combined with a polyorganism. Poly-super-organisms are biological individuals formed from multiple bodies and multiple species. Common in nature, poly-super-organisms include acacia ants and trees (acacias). As ants, acacia ants are superorganisms in their own right. The trees are members of the legume family, which includes peas and mimosas; most grow in Central America, southern Africa, and Australia. The trees I refer to — swollen thorn acacia — have large hollow thorns. Various ant species live in these thorns and only eat a substance the trees exude. In turn, the ants defend the trees from invading vines, mammalian herbivores, and insects. As Willmer and Stone (1997) note, the "... plants can manipulate the insects to do what they want." The trees even release a chemical that keeps the ants from attacking pollinating bees. The trees and ants have irrevocably fused in many combinations — many bodies of different species inseparably united — which makes them poly-super-organisms.

Termites form another poly-super-organism with bacteria, fungi, and protozoans. Termites, unable to digest cellulose, the major part of their diet, only survive by bringing microorganisms into their guts to convert cellulose into digestible sugars.

A far more remarkable poly-super-organism exists — and it is us. As Louisiana State Medical School (2002/2006) website once informed:

[Human] bodies are like mobile warm-blooded coral reefs, rich in microbial biodiversity and home to vast numbers of

bacterial cells. Indeed, [bacterial cells are much smaller than human cells and] it has been estimated that there are [ten times] more bacterial cells ( $10^{14}$ ) associated with the average human body than there are human ones (only  $10^{13}$ )! This normal bacterial flora lives on the external body surfaces and in the gut.

Humans are microbe free at conception. We start becoming poly-super-organisms at birth or before when prokaryotes begin invading us in waves (Favier et al. 2002). In time, perhaps 1000 species of bacteria come to live within us, most in the mouth, small intestine, colon, and on our skin. A square centimeter of an adult's epidermis holds an average of 100,000 bacteria; five times more reside in our armpits. These prokaryotes are not simply foreign invaders. Some are benign. Others, essential to our survival, break down otherwise undigestible plant polysaccharides (fiber) in our digestive tracts; boost our immune systems; produce the vitamins thiamine, pyroxidine, and K; and ward off illness by out-competing their harmful prokaryote cousins (Brody, 2006). Thus, Gill et al. (2006) conclude, "Humans are [poly-] superorganisms whose metabolism represents an amalgamation of microbial and human attributes."

We are just beginning to unravel our profound relationship with the Prokaryote. The adult human body, for example, contains 100-fold more prokaryotic genes than human genes (Xu and Gordon 2003), which occur in different blends in different people. It is possible that these varying prokaryotic blends affect our health (cf. Carmichael, 2006; Henig, 2006). Scientists, for example, have proposed seeding children with prokaryotes to ward off illness (Haslam, 2000). Similarly, the biopharmaceutical firm Oragenics received FDA approval for a clinical trial in which dentists rub patients' teeth with genetically modified bacteria. The company's goal is to replace native bacteria that produce acid with others that do not, thereby ending cavities for life (Pollack, 2004).

More spectacularly, Washington University distinguished professor of molecular biology Jeffery Gordon and his team have found that the intestinal blood vessels of postnatal mice develop improperly in the absence of particular gut bacteria. They write, "By showing that indigenous microbes play a key role in the postnatal development of host niches they

occupy [e.g., the intestine], our findings illustrate the importance of the coevolution of animals and their microbial partners....” (Stappenbeck et al., 2002). Gordon’s team has also found that in mice bacteria help regulate fat storage and weight (Bäckhed et al., 2004). Because humans and mice are genetically similar (about 90% of our genes overlap), future research may expect to identify comparable prokaryote-human relations.

Human bodies are just as tightly linked to viruses. Thomas Spencer of Texas A&M University and his team, for example, have found that in some mammals (and perhaps in humans) successful reproduction may require the activity of retroviruses (Chatterjee, 2006). Margulis (1998:64) adds that:

Viruses today spread genes among bacteria and humans and other cells, as they always have. Like bacterial symbionts, viruses are sources of evolutionary variation.... We can no more be cured of our viruses than we can be relieved of our brains’ frontal lobes: we are our viruses.

All the genes in human cells are not human. Recent research has found that about 8% of “our” genes originally came retroviruses (Scientific American, 2006), and others came from the Prokaryote (Ponting, 2001). Parallel research finds that the Prokaryote has also infused its genes into other living and extinct species, cf. Hall et al. (2005).

Our bodies additionally house a zoo of fungi, worms, protozoa, and other biological entities, and *lacking* them may make us ill. In his Hygiene Hypothesis, D. B. Strachan (1989) proposed that bodies can be too “clean” — having had too little exposed to parasites — which increases our susceptibility to asthma, allergies, diabetes, eczema, and autoimmune diseases like rheumatoid arthritis, cf. Pesola et al. (2005). Colitis, for example, may result from our hair-trigger autoimmune systems pouncing on bodies that lack a parasite target. In fact, recent clinical trials show helminthic therapy — infecting patients with parasitic worms — can ameliorate colitis and Crohn’s disease (Summers et al., 2005).

In *War of the Worlds*, H. G. Wells depicts microorganisms as humankind’s ultimate protector, our unseen shield against an invincible armada of Martian spaceships. Jared Diamond, professor of Geography and

Physiology at UCLA, sees a sobering real-life parallel in *Guns, Germs, and Steel* (1997). Diamond argues that animal pathogens like smallpox and measles (the latter genetically resembles canine distemper) jumped to human bodies during early animal domestication in Eurasia. These diseases afflicted Europeans hideously, but after becoming endemic, their lethality somewhat waned. When Europeans brought “their” germs to the New World, however, these microbes attacked the native population with unmitigated virulence. Less dramatically but similarly, the Prokaryote still besets tourists who drink untreated water in foreign countries. Perhaps the first to address these issues broadly, Joshua Lederberg (2000) notes, “We should think of each host and its parasites as a [poly-] superorganism with the respective genomes yoked into a chimera of sorts.” For better and worse, we are one with the “zoo” within us.

Accumulating evidence is making clear that biological entities are more complex than the *organism* concept allows. With *organism* failing, *life* — the most reified of all concepts — is similarly vulnerable.

### The Boundaries of Life

*A frozen embryo is neither alive nor dead, but rather in a third, entirely different state.*

Lee Silver, Princeton University biologist (1997:94).

*We define life to be self-reproduction with error correction. Note that a single human being does not satisfy this sufficient condition... [but] a male-female pair would ...*

John Barrow, Cambridge University mathematician, and Frank Tipler, Tulane University mathematician (1986:215).

*Machines are honorary living things.*

Richard Dawkins, Oxford University evolutionary biologist (1986:10).

*I think computer viruses should count as life.*

Stephen Hawking, Cambridge University physicist (1994).

In 1974, the noted astronomer Carl Sagan wrote in an *Encyclopedia Britannica* essay, “There is no generally accepted definition of life.” This hasn’t changed, though few have tried to

explain why. Science journalist Steven Levy, a rare exception, eloquently concludes in *Artificial Life* (1992:7) that “part of the difficulty arises from culture’s refusal to yield the province of life to the realm of science.” Yet science doesn’t need permission to explain life; science would if it could.

Three theories — Vitalism, Mechanism, and the qualitatively different Autopoiesis theory — attempt to explain life. In simple terms, Vitalism views life as a miraculous force that pours into (human) vessels like a liquid, and pours out at death. Religion and the public mostly accept Vitalism, despite its narrow focus on human life and total lack of empirical confirmation. In contrast, biology favors Mechanism, the post-Cartesian view that sees living things — specifically cells and organisms — as exceptionally complex machines that operate solely by principles knowable by science, cf. Weber (2006) and Torley (2006). Admittedly, many of these principles remain undiscovered.

In a rare moment, Vitalism and Mechanism agree that life characterizes material things, but that life is not a property of matter itself. The point is obvious on reflection, otherwise atoms, electrons, and quarks could be considered to be alive. As Margulis and Sagan (1995:23) remark, “DNA is an unquestionably important molecule for life on Earth, but the molecule itself is not alive.” Consider an analogy that nicely contrasts Vitalism with Mechanism. It relates life in organisms to functioning in cars. Vitalism would contend that cars function because a vital force flows into them at their inception and flows out at their demise. Alternatively, Mechanism would hold that a car’s parts — wheels, engines, spark plugs, and fuel — cannot function separately. Rather, functioning only emerges when a car’s parts are properly arranged.

Functioning in cars is a good analogy to how biology views life. Both are emergent properties; the whole exceeds the sum of its components. Thus, life only emerges in cells upon the correct assembly of such parts as their cytoskeleton, mitochondria, Golgi apparatus, water, and DNA. Life similarly emerges in whole organisms, like people, bees, mushrooms, and bacteria, but not in their parts like hearts, brains, wings, or rhizomes.<sup>‡</sup> Life could also potentially

<sup>‡</sup> Biologists sometimes describe tissues, organs, and other body parts as being alive. When doing so, they subtly change the term’s

emerge in exobiological (off-planet) agents, and in artificial forms.

Setting the search for *life* in historic context, Margulis and Sagan (1995:39-40) write:

Before the exploits of Bruno and Galileo, Descartes and Newton, and Darwin, everything had been alive, except for the natural magic trick of death; now in the scientific-mechanistic world everything was inanimate, dead, except for the scientific puzzle of life.

In fact, life never completely puzzled biologists. They have long known that human individuals, dogs, and trees are alive, and that rocks, clouds, and corpses are not. The great surprise came when scientists and others tried using their resident wisdom to define *life* and couldn’t. Nothing, it seems, separates what we know is alive from what we know is not. This is the intractable problem haunting Mechanism: No trait universally corresponds to life’s emergence, not replication/reproduction, metabolism (specifically catabolism), cellularity, growth, reaction to stimuli, complexity, evolution, or pattern maintenance.

Exemplifying this problem, individual cells and multicellular organisms express life differently. Cells, for example, catabolize food — they convert food to energy. Multicellular organisms don’t, however, beyond the catabolism that occurs in their cells. In other words, multicellular organisms have a catabolism only in the sense that a heart has a catabolism, or the Prokaryote, or the whole earth. In the same vein, biologists cannot specify which cell parts are essential for life to emerge. Thus, our red blood cells (erythrocytes) are said to be alive even though they cannot reproduce, and have no nucleus, mitochondria, or DNA. Such problems leave biology puzzled but undaunted, setting Margulis and Sagan to

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denotation to mean “a tissue or organ that is composed of living cells.” Thus, biologists don’t explain how a “living” whole heart differs from a “living” half heart, or expect “living” hearts to reproduce offspring, or say life is an emergent phenomenon in hearts. Moreover, if hearts are alive, by implication, tumors — as distinct from the cells in tumors — must also be alive. Finally, Margulis and Sagan, for example, don’t include the terms *tissue* and *organ* in the index to *What Is Life?* (1995).

conclude their volume *What Is Life?* by optimistically writing, "...we can ask with curiosity but can answer only tentatively and with humility the question of what life is, hoping, with you, that the search continues" (1995:199).

Trouble is, there's nothing to search for. *Life* isn't like missing-link fossils or the hit sites of asteroids. *Life* is a social construction. It is whatever we say it is. The reason biology cannot define *life* satisfactorily — scientifically — is that the *alive*, *dead*, and *inanimate* categories correspond imperfectly to nature. They no more meaningfully group the entities that biology studies than did the pre-scientific trichotomy of *animal*, *vegetable*, and *mineral*. I will explain this statement in detail below, but let us first dispense with the third theory, Autopoiesis.

Chilean biologist Humberto Maturana (1969) and his student Francisco Varela (1980, 1987) originated Autopoiesis, a Mechanistic theory of a different sort. Rather than explaining life, per se, Autopoiesis describes complex systems that are self-organizing, emergent, and hierarchical. As such, Autopoiesis theory counterintuitively groups living cells and organisms together with hurricanes, the Great Red Spot on Jupiter, and more. Thus, Maturana (1981) writes:

[Autopoietic] systems, as unities, are networks of production of components that (1) recursively, through their interactions, generate and realize the network that produces them; and (2) constitute in the space in which they exist, the boundaries of this network as components that participate in the realization of the network... a living system is an autopoietic system in physical space.

Autopoiesis theory is incomplete, reliant on undiscovered mathematics, and abstruse — but it doesn't require the *alive*, *dead*, or *inanimate* categories.

### ***Alive, Dead, Inanimate***

*Life: The property which constitutes the essential difference between a living animal or plant, or a living portion of organic tissue, and dead or non-living matter.* Oxford English Dictionary (2006).

*Biology is the "science of life"... It examines organisms on several levels... One of the most difficult definitions in biology is "What is life?"* New York Public Library, (1995).

Princeton University's WordNet 2.1 (2006) identifies fourteen different senses of the word *life*.

Historically, the *life* concept worked well enough. Few cared about the most obvious anomaly that our fingernails and hair continue to grow after we die. Twentieth-century technology created other anomalies, however, as life-support machines started keeping brain- and heart-dead individuals alive. Less noticed was that our life theories Vitalism, Mechanism, and Autopoiesis explain only two categories — entities that are and are not alive (or an emergent complex system) — while the public and biology use the three categories of *alive*, *dead*, and *inanimate*.

To facilitate our discussion, I am going to call the *alive*, *dead*, and *inanimate* categories *the ADI sets*. Taken together, they resemble a pie cut into three fat wedges, each bordering the others. Some entities straddle the set boundaries, e.g., a brain-dead person (between *alive* and *dead*), a decomposing corpse (between *dead* and *inanimate*), and a biological virus (between *alive* and *inanimate*). As is currently understood, an entity can only belong to one set at any time, but can transition between sets given the proper circumstance.

Oddly, no term describes the ADI sets taken together, i.e. a word comparable to *dog* as related to *poodle* and *pug*. While most sets are nested, e.g., poodles and pugs are dogs; dogs and cats are mammals; mammals and fish are vertebrates, etc. — the ADI sets are not. This linguistic gap is peculiar. More peculiar is that both biology and the public think the ADI sets are exhaustive — that all material things are *alive*, *dead*, or *inanimate*. They aren't, however, as the following examples illustrate.

Imagine a hospital operating room where transplant surgeons hold a failing heart they just removed from a potential recipient. The

surgeons are also keeping a donor's good heart packed in ice. Following biology's logic, neither heart is alive because neither is a cell or a complete organism. These hearts cannot be dead, however, because they were never alive. Calling them inanimate makes even less sense. Note that if a whole heart could be alive, the same must hold true for half a heart, a tenth of a brain, or a pound of flesh — which makes no sense to current understanding.

Transplant surgeons solve this problem pragmatically by calling a good heart *viable*, a bad heart *not viable*, and a soon-to-be heart recipient *alive*. By this asymmetrical reasoning, a man without a heart has a different status than a heart without a man. But why? Dentists similarly call good teeth *viable* and others *not viable*. Lee Silver (1997:93-4) identifies the same issue from different evidence, noting that frozen human embryos aren't alive or dead (or inanimate), but instead they exist in a state of suspended animation.

Freshly picked apples, potatoes, and lettuce pose a similar anomaly. This produce cannot be alive because none is a whole organism or single cell. Nor can it be inanimate or dead because it can all reproduce: The potatoes have eyes that can grow into new plants. The apples contain seeds that can become trees (unless we think seeds are organisms in their own right). Finally, many lettuce cells are totipotent (totally potent) and can develop into a complete organism (as can some cells in all plants). In sum, we often call produce fresh, rotten, or spoiled but hardly ever call it alive, dead, or inanimate.

The Russian scientist V. I. Vernadsky additionally noted that, except for igneous rocks, most near-surface matter on earth once resided within living organisms, including sedimentary rock, hydrocarbon fuels, diamonds, water, soil, and atmospheric gases. Thus, from his vantage, the *inanimate* set inappropriately lumps together dissimilar entities, some that were once alive and others that never were.

Finally, highlighting a non-scientific example, Mormons apparently think the *dead* set combines "regular" dead entities with dead people who can choose their religion posthumously. As the *New York Times* reports (April 11, 2004:27):

The Church of Jesus Christ of Latter-day Saints has long collected names

from...records...for posthumous baptisms.... Church members stand in to be baptized in the names of the deceased non-Mormons, a ritual the church says is required for them to reach heaven. The practice is primarily intended for the ancestors of Mormons, but many others are included, since the church believes that a person's ability to choose a religion continues after death. Non-Mormon faiths have objected to the baptisms.

One might imagine the ADI sets could be made exhaustive by appending to them the just reviewed categories of *viable*, *not viable*, *suspended animation*, *fresh*, *rotten*, *spoiled*, *inanimate never alive*, *inanimate previously alive*, *regular dead*, and *dead but able to choose a religion*. We could additionally append categories from the quotations that head this section (*honorary life* and *self-reproduction with error correction*). Finally, we could add categories for replicating entities biology excludes from the alive set, i.e.: mitochondria, plasmids, transposons, satellite DNA, prions, crystals, and biological and computer viruses. It wouldn't help. Nothing can make the *life* concept fully correspond to nature

### **Life and the Levels of Biological Organization**

James Lovelock, an excellent if unconventional scientist, once challenged biology's claim that life only occurs in organisms and cells (biology's levels-of-life claim). Arguing that life emerges above the level of organism, he wrote "Gaia is the superorganism composed of all life tightly coupled with the air, the oceans, and the surface rocks" (1979/1995: x). More expansively, biophysicist and Director of UCLA's Program on Medicine, Technology and Society, Gregory Stock writes "...the thin planetary patina of humanity and its creations is truly a living entity. It is a 'superorganism' — a community of organisms so fully tied together that it is a single living being. [This superorganism includes all the] other nonhuman elements and structures that are part of the human enterprise" (1993:20).

Unimpressed, biology gives Gaia very short shrift. In Dawkins' words, "Gaia falsely focuses attention on planetary life as a single unit" (1998:224). More pointedly, Lovelock laments, "The French Nobel laureate Jacques Monod, in his book *Chance and Necessity*, castigated holistic thinkers like me as 'very stupid people' ... Until this year, it was near impossible for a

scientist anywhere to publish a paper on Gaia, unless to disprove or disparage it" (1979/1995: ix-x). Lovelock's critics have been somewhat muted as the term *Earth Science* has replaced Gaia in the scientific community. Whatever it is called, Gaia dovetails nicely with the ideas of a worldwide network of lateral-gene-transferring bacteria, the Prokaryote, and poly-super-organisms. The essential point is that biology has never explained why life cannot (but autopoiesis can) occur above the level of individual organisms.

The next example also contests biology's levels-of-life claim, but in a different way. In most species, "bugs" start their complex life cycles as eggs and hatch into larvae — e.g., moth eggs hatch into caterpillars — that spin cocoons. Within its cocoon, a larva becomes a pupa. It, in turn, undergoes metamorphosis and is transformed to an adult insect. Thus, from NewScientist.com (2006):

Question: When an insect is changing inside its cocoon, and has turned to slush, is it alive? In what way is it alive?

Answer #1. In many metamorphosing insects, the majority of the cells in the pupa turn to mush, but there are clusters of cells that remain intact. These cells feed on the mush, divide, and go on to develop the legs, eyes, wings, antennae and so on that we see in adult insects.

Martin Harris, Australia.

Answer #2. An insect undergoing metamorphosis is alive regardless of what state its body may be in. ... An insect, or other organism, could not be dead at one stage of its development and alive at a following stage, because the death of an organism is always irreversible. The death of a multicellular organism such as an insect must be defined separately at different levels of organization: the intact body; the organs and tissues; and finally, the individual cells.

Aydin Orstan, Carnegie Museum of Natural History.

According to this account, a metamorphosing organism can devolve into cannibalistic cells — the organism disappears but doesn't die — that reconstitute themselves into a very different looking entity that is still the original organism! The questions this example

raises are, "What level of biological organization stays alive during metamorphosis?" and "How does this jibe with biology's levels-of-life claim?" The statement that "the death of an organism is always irreversible" is also of interest. It exemplifies one of biology's socially constructed transition rules (described below) that govern how entities supposedly move between the ADI sets.

A further challenge to biology's levels-of-life claim arises in laboratories that grow biological entities that are more than cells but less than organisms. Wikipedia (2006) describes an early event in this currently unfolding drama, noting:

On January 17, 1912, Nobel prize-winning physician Dr. Alexis Carrel placed a part of a chicken's embryo heart in a nutrient medium in a glass flask of his own design. Every forty-eight hours the tissue doubled in size and was transferred to a new flask. Twenty years later, it was still growing.

From the humble beginning described above, a growing enterprise is learning to engineer and culture biological tissue. Balesh and Vacanti (2006) describe this technology's medical value, noting, "Once confined to the realm of science fiction, the creation of replacement human body parts has become reality. ... The greatest success in the field thus far has been in the realm of skin tissue engineering. ... Still in its infancy, tissue engineering holds great promise for the future of transplant medicine." In fact, much has already been accomplished, e.g., Scientific Sessions (2006). Companies such as Organogenesis and Fibrogen are currently working to culture human tissues that will replace "deceased" bones, hearts, skin, livers, nerves and more. Instead of transplanting organs, the future sees laboratories engineering replacement tissues for insertion into failing human bodies.

Other researchers seek to culture meat in laboratories. Thus, Edelman et al. (2005:659) comment, "Although meat has enjoyed sustained popularity as a foodstuff, consumers have expressed growing concern over some consequences of meat consumption ... including nutrition-related diseases, food borne illnesses, resource use and pollution, and use of farm animals. ... The techniques required to produce [cultured meat] are not beyond imagination." The nonprofit research organization New Harvest, in supporting these

ambitions, asserts that lab-grown (factory) meat is as natural as bread, cheese, yogurt, and wine.

Even more exotic research hopes to put a subset of human tissues onto a chip. "It starts out like any silicon chip ... but this is no microprocessor designed for a computer. Instead, there are miniscule chambers filled with human cells: liver cells, lung cells, fat cells, all connected by tiny cannels. A nutrient fluid is pumped through the channels, flowing from one chamber to another just as blood flows from organ to organ in the body. ... The idea is to create ... brainless mini-bodies that will be ideal for studying diseases and testing drugs" (Orwant, 2006).

Oron Catts and Ionat Zurr describe themselves as artists. Working at the University of Western Australia, they have used bioreactors to create what they call *tissue sculptures of semi-living objects*. One is a cultured-tissue frog steak. Another is a miniature leather-like jacket grown from immortalized cell lines (a mix of human and mouse cells). Putting their work and my illustrations in context, they (2006) write that the *extended body* consists of "cells and tissues that are living and growing outside of the organisms from which they originated. ... The biomass of disassociated living cells and tissues is in the thousands of tons. These fragments do not fall under current biological or cultural classifications."

Other tissues described above also exist beyond current biological and cultural classifications. Like HeLas, these tissues are able to survive as laboratory mice, dairy cattle, domesticated sheep, and Chihuahuas. Thus, broadly summarizing this discussion, semi-alive objects, humans on a chip, engineered tissue, metamorphosing insects, the Prokaryote, poly-super-organisms, and Gaia all dispute biology's claim that life only emerges in cells and organisms.

### **ADI-Set Transitions**

Let us explore a final challenge to the concept of *life* by examining our expectations for how entities transition between the alive, dead, and inanimate sets. I will term these dynamics *set transitions*, and call the six potential moves between the three ADI sets *transition events*. I will also call the principles that govern these events *transition rules*.

Starting with alive-to-dead transition events — how living things become dead things —

biology has invented these rules: Only living things can die. Living organisms must die. And, living things have a natural lifespan (that technology can extend). We typically think all living things follow this alive-to-dead trajectory. Thus, Wikipedia, reflecting public perceptions, informs that "Lifespan is one of the most important parameters of any living organism (Organism, 2006)."

In fact, nature violates all these rules. For example, Silver writes (1997:29)

At the completion of cell division, there are two 'daughter cells,' each containing its own copy of the complete genetic material that was present in the original 'parent' cell (*which ceases to exist*). [Emphasis in the original].

Silver's quotation, which expresses biology's standard view, implies that almost half the organisms alive today will never die. Thus, because the overwhelming majority of living organisms are prokaryotes, it follows that nearly half the prokaryotes will divide, cease to exist, and thereby escape death. The same fate awaits HeLas and other immortal replicators. For different reasons, a few "lucky" sperm and eggs never die either. Instead, they simply "disappear" by forming embryos.

Silver's quotation also implies that fission resets a cell's age clock, thus transforming a day-old parent into two daughter cells, each that is zero-hours-old. But is this possible? I am aware of no parallel to this interpretation. For example, halving a week-old hamburger doesn't make the two halves "fresh." Interestingly and in addition, separating the umbilical attachment of a birthmother and child, leaves the mother's age clock unchanged, but arbitrarily resets the child's clock to zero (in fact, the child is about nine months old). Finally, separating conjoined twins resets the time clock of neither twin.

Consider a last example. In 2,000, Vreeland et al. report finding prokaryotes that had been embedded in salt crystals for a quarter-billion years. Amazingly, when taken to a laboratory, these cells began to divide! By Silver's interpretation, Vreeland's prokaryotes were 250-million year old parents before cell division and became zero-hours-old daughters the instant afterwards. Really?

Let us bring some order to this confusion. Counterintuitively, the age-of-cells issue hinges on whether fission is interpreted as being

reproduction or growth — and there is no fully satisfactory resolution to this issue. In the context of multicellular plants, Dawkins (1989/1976:43) writes:

Many plants propagate vegetatively by sending out suckers. In this case, we might prefer to speak of *growth* rather than of reproduction ... there is rather little distinction between growth and non-sexual reproduction anyway, since both occur by simple mitotic cell division. Sometimes the plants produced by vegetative reproduction become detached from the 'parent'. In other cases, for instance elm trees, the connecting sucker remain intact. In fact, an entire elm wood might be regarded as a single individual.

If fission is reproduction, one prokaryote divides to become two "new" cells, and each lives for the usually short time it takes for the cell to either die or divide. If cell division is growth, however, fission "extends" one prokaryote into two bodies, thus making every living prokaryote (and the Prokaryote) an outgrowth of the first prokaryote, and about 3.5 billion years old! No empirical evidence can decide this issue.

One lesson these examples suggest is that biology uses different rules to describe how different entities transition from the alive to the dead set, i.e. human individuals must die, but prokaryotes, HeLas, and gametes need never die if they divide or merge. Another is that we (using Cesium clocks) measure time objectively, but that the age of entities is socially constructed. Finally, these examples help us see that *reproduction* and *growth* are also socially constructed concepts and not objective scientific knowledge.

In the second group of transition events, dead things become inanimate, as when a corpse decomposes. Biology typically describes these transitions vaguely or poorly, if at all. Unexplained, for example, is how a living carrot transitions to dead as we eat it, and how the carrot parts we don't incorporate become inanimate. Moreover, anomalously and reminiscent of Vernadsky, biology holds that the residual organic molecules (yet another category we could append to the ADI sets) of very early bacteria (biomarkers) have never fully transitioned to inanimate, even over eons. Interestingly, the term *organic* has a special status in discussions about the ADI sets, namely

that *organic* is often used to fudge the distinction between dead and inanimate entities.

In the third group of transition events, inanimate things become alive. The most significant issue concerning these transitions is whether humans will ever transform inanimate matter into living, humanly intelligent entities in laboratories. University of California, Berkeley philosopher John Searle rejects this possibility ardently. Even physicist Roger Penrose and science writer/editor Martin Gardner (1987) have argued that humankind will never create (artificial) life with human intelligence. Science fiction writers have long imagined more, however. Isaac Asimov in his novels and Arnold Schwarzenegger's terminator movies, for example, both anticipate the creation of sentient robots. Science didn't much respect Sci-Fi's vision until University of Michigan graduate student Christopher Langton, influenced by John von Neumann, organized the first-ever conference on artificial life (AL) in 1987. Recognizing that life is not a characteristic of matter, AL researchers have concluded that: Life is a process. The life process isn't bound to flesh necessarily. And, all processes can be emulated within a computer. Embracing these premises, J. Doyne Farmer and Alletta d'A Belin (1992:815) at the second AL conference in 1990 predicted that:

"Within fifty to a hundred years a new class of organisms is likely to emerge. These organisms will be artificial in the sense that they will originally be designed by humans. However, they will reproduce, and will evolve into something other than their original form...The advent of artificial life will be the most significant historical event since the emergence of human beings."

Where will AL and related research lead? Inventor Ray Kurzweil (2005) optimistically predicts humans and machines will soon merge and achieve new intellectual heights together. Jaron Lanier (2003) and others dissent. Most pessimistically, Carnegie-Mellon University roboticist Hans Moravec (1988, 1999) concludes that our more capable "mind children" (robots) will compete for our ecological niche and will replace us.

Other research expands this discussion. Cello et al. (2002), for example, created a precursor to an inanimate-to-alive transition by reconstructing a poliovirus in a laboratory from scratch (viruses are not alive). Since then, other

researchers have re-created other viruses in laboratories, including the one that caused the 1918 flu pandemic. More directly related to the issue at hand, two international workshops have recently addressed how science might soon create living artificial cells (Rasmussen et al., 2004). In fact, much research is now directed to fulfilling Farmer and d'A Belin's prophecy that we will soon create artificial organisms that fit within the *life* category. Science is on the threshold of being massively able to create inanimate-to-alive transitions.

Science pays little attention to the three remaining ADI-set transitions — dead to alive (e.g., resurrection, cryogenesis), alive to inanimate (e.g., God turning Lot's wife to a pillar of salt), and inanimate to dead (no examples) — so we'll skip them.

### Conclusion

*In the twentieth century, we went as far as we could to uncover and describe the components of complex systems. Our quest to understand more has hit a glass ceiling because we do not yet know how to fit the pieces together.* Albert-László Barabási (2003:225), Notre Dame University, professor of physics.

*... One of my points about philosophers of science, they have zero understanding of science. That's my experience. I know of no leading scientist in the world who pays the slightest attention to the philosophy of science.* Lewis Wolpert (Winter 2007), University College London, professor of Biology.

In 2002, Professor of law at Princeton University and member of the President's Council on Bioethics, Robert P. George argued that "Public policy should protect embryonic human beings...." and all forms of human cloning should be banned. In justifying these policy statements, he described the human biological self in these terms:

Plainly, the gametes whose union brings into existence the embryo are not whole or distinct organisms. They are functionally (and not merely genetically) identifiable as *parts* [emphasis in the original] of the male or female (potential) parents. ... Each has only half the genetic material needed to guide the development of an immature

human being toward full maturity. They are destined either to combine with an oocyte or spermatozoon to generate a new and distinct organism, or simply die. Even when fertilization occurs, they do not survive....

Because gametes lack survivability and genetic completeness, Professor George argues they are "functionally identifiable" parts of the bodies that produce them, not organisms. He — and science — make this claim even though the characteristics of survivability and genetic completeness are unrelated to definitions of *organism*. Moreover, in his argument, Professor George fails to mention that the "natural" process of embryo fragmentation (twinning) has been producing human clones for millions of years. To this, techno-critic Jeremy Rifkin adds that "It's a horrendous crime to make a Xerox of someone." If taken literally, however, his statement would make a criminal out of every woman within whom identical twins originate.

On March 6, 2006, Governor Mike Rounds signed into law South Dakota Women's Health and Human Life Protection Act (HB 1215). The bill's preamble includes the statement that:

The Legislature accepts and concurs with the conclusion of the South Dakota Task Force to Study Abortion, based upon written materials, scientific studies, and testimony of witnesses presented to the task force, that life begins at the time of conception ...

The South Dakota Legislature didn't explain what sort of life begins at conception and didn't acknowledge that *conception*, *pregnancy*, and the time at which pregnancy begins are socially constructed. As Silver informs in *Remaking Eden* (1997:61), "In a certain sense, a woman cannot be pregnant during the first week following ovulation. There may be an embryo inside, but it is separate and not dependent upon her for its development ... [Women who use an IUD for birth control] may have newly formed embryos inside them multiple times each year, even though they never become pregnant." Silver adds that contrary to common wisdom a human embryo doesn't begin its existence as a single cell formed from a sperm and egg. Instead, "the chromosomes in the ... [sperm and egg] duplicate themselves separately, and then copies from each come together inside the actual nuclei formed *after* the first cell division. It is within each of the two nuclei present in the two-cell embryo that a complete set of forty-six human chromosomes

commingle for the first time" (p. 45). Thus, when used as a "morning after pill," RU-486 (Mifegyne) acts as a contraceptive not as an abortifacient.

Silver's construction of the human biological self provoked a firestorm, but mostly for ideas I haven't yet described. In particular, his *Remaking Eden* laid bare to public awareness the potential of genetic engineering (GE) to prevent illness, enhance intelligence, heighten athletic ability, make bodies more beautiful, and increase life span. GE even might transfer into humans the genes of other species so that some day we glow in the dark like jellyfish, smell with the sensitivity of dogs, or emit electrical shocks like the South American knifefish known as the electric eel. Silver even argues that GE might transform the human race into separate species that he calls the Gen(et)icRich and the GenPoor — with enormous social consequence.

In response to GE's potential and making the claim that humans have a naturalness that needs preservation, The President's Council on Bioethics in "Beyond therapy" (2003) wrote:

If there are essential reasons to be concerned about these activities [genetic engineering] and where they may lead us, we sense that it may have something to do with challenges to what is naturally human, what is humanly dignified, or to attitudes that show proper respect for what is naturally and dignifiedly human....

To guide the proper use of biotechnical power, we need something in addition to a generalized appreciation for nature's gifts. We would need also a particular regard and respect for the special gift that is our own given nature. For only if there is a *human* "givenness," or a given humanness, that is also good and worth respecting, either as we find it or as it could be perfected *without ceasing to be itself*, will the "given" serve as a *positive* guide for choosing what to alter and what to leave alone.

The President's Council didn't attempt the daunting task of defining humankind's essential core, which doesn't require that a human being have arms, a human heart, the ability to speak, emotions, intelligence, or consciousness. Francis Fukuyama, a member of the Council, did attempt this task, however. In *Our Post-Human Future* (2002), he writes that after "we strip all of a person's contingent and accidental

characteristics away, there remains some essential human quality underneath that is worth of a certain minimal level of respect — call it Factor X" (p149). Silver, in *Challenging Nature* (2006:96), retorts that Fukuyama's Factor X is "nothing other than the traditional Christian conceptualization of a human soul," which is another way of saying that Silver disagrees with Fukuyama's way of constructing the human biological self.

#### What are we?

Humankind once dreamed the earth centered the heavens and we were granted dominion over the living things that move upon the earth. Today, we imagine a world of one-body organisms and one-organism bodies. Nature little resembles these myths. Human bodies are not all human. We are inextricably meshed in poly-super-organisms, a menagerie of species spread across multiple bodies. Like lichens, we are composed of different organisms that reproduce separately and later re-form into poly-super-organisms. Humankind doesn't own "its" genes, and "our" genes are not alone in creating our bodies. Humans are not just males and females; we are also sperm and egg organisms. We reproduce both sexually and asexually. Cancer is a contagious disease. The *life* and *organism* concepts are failing.

Humankind faces a post-human future. During this century, we will use genetic engineering and other technologies to become what we have never been before. A rapid and accelerating pace of change will alter us as we create new living organisms, machines with human intelligence, and humans with machine parts and genetically enhanced bodies. I believe we will better understand our selves and this future by more accurately constructing the human biological self.

In April 2007, Jane Peterson and Lu Wang of America's National Human Genome Research Institute organized a National Institutes of Health sponsored meeting to discuss the creation of the Human Microbiome Project (Singer, 2007). This project hopes to record the genomes of all microbes living throughout the human body. Among questions it would address are how an individual's personal microbial "signature" relates to health and disease, and whether humans really are symbiotic creatures who would die

without the prokaryotes and other species within us. "At the end of the day, we'll end up with another perspective on the evolution of our species, our human-microbial selves," says microbiologist Jeffrey Gordon.

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