Reinventing Biology

Respect for Life and the Creation of Knowledge

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11 Carnal Boundaries
The Commingling of Flesh in Theory and Practice

Stuart A. Newman

HUMAN FLESH IS on the cultural menu. Cannibalism as the last resort of ordinary people under duress has received sympathetic treatment in recent films that recount events that took place two decades[1] and a century and a half[2] ago. Cannibalism as the characterological organizing principle of a fictional mad genius was the hook of the Academy Award–winning best picture of 1991.[3] Persistent rumors about the ceremonial consumption of the livers and hearts of "class enemies," initially by zealots and then by ordinary villagers, in the Guangxi Autonomous Region of China during the Cultural Revolution of the late 1960s were kept under wraps for more than twenty years. The dissident journalist Liu Binyan, questioned about these stories in 1984, said that he had avoided writing about them "because the subject was so nasty." But the American public is now presumably ready: two nonfiction books on the Guangxi cannibalism incidents by the recently expatriated novelist Zheng Yi, although not yet available in English, have been widely discussed in the U.S. press by, among others, Liu Binyan himself.[4] And during the same period the emergence and trial of an individual in Milwaukee who had been eating or freezing portions of his murder victims' bodies played to a fascinated public and defined new outer limits of social pathology.[5]

How can we account for the recent interest in violation of one of the most fundamental of social taboos?[6] I suggest that cannibalism is a potent symbol of the erasure of traditionally conceived boundaries between different kinds of flesh. Such crossing of biological borders—previously the stuff of art and mythology—is, in the late twentieth century, increasingly a technological reality. This is evident in the recent profusion of research, medical, and commercial ventures involving transplantation of human embryonic tissues, human gene modification, and the production of "transgenic" animals.[7] The clash of this "carnal pragmatism" with traditional ideas of the mainstream culture inevitably fascinates and unsettles, providing a social context for entertainment technologies such as "morphing" (the computer-simulated transformation of one body into another seen in Arnold Schwarzenegger movies and Michael Jackson videos), the obsession in certain sectors of society with body building and cosmetic surgery, as well as the morbid interest in cannibalism.

The commingling of flesh is a central principle of animal existence, and its representation in the minds of humans in the form of metaphor and myth is a fountainhead of drives and taboos. Indeed, various senses of "commingling"—the mixing of the substance of one kind of individual with another, as in procreation, the transformation of the substance of one individual into that of another, as in pregnancy, and the incorporation of the substance of an individual into that of another, as in consumption, have been conflated in the conceptual frameworks of different cultures.[8] Functionally, animal procreation is only possible through the merging of cells produced by what are arguably the most biologically *distinct* members (i.e., the two sexes) of the most biologically *uniform* of populations (i.e., a species). Human sexual relations do not necessarily correspond to biologically defined roles, but all societies have sexual prohibitions (e.g., incest taboos) formulated in relation to the "facts of life" as they are understood. And the fact that women's bodies can grow babies makes the maintenance of carnal boundaries a qualitatively different issue for women than it is for men.

In Freud's view, the organization of the human psyche itself is initiated by the infant's recognition that its body and that of the mother are *not* confluent.[9] Freud's notion, as he acknowledged, is only a modern form of Plato's famous speculation in the *Symposium* that human love is based on a longing for a primeval state in which the lovers' bodies were a single entity. The special terror of cancer among all the ailments to which the human body is subject is related to its inversion of the ecstatic mixing of flesh. In this disease the body's own flesh produces an alien tissue that malignantly invades and may eventually suffocate its host.

Consumption of meat is the most common mode by which one individual's flesh is commingled with another's, and few if any cultures are without some restrictions in this area. Human flesh is, of course, subject to the most severe taboos, and when it has been eaten, the purpose almost invariably has been ceremonial rather than nutritive. Moreover, most if not all human groups have religious or aesthetic prohibitions against eating the flesh of certain kinds of animals, or concerning when or in what form animal flesh may be consumed. Maintenance of carnal boundaries thus appears to be a constant of human social organization and mental life, a point made repeatedly, on the basis of wide-ranging ethnographic evidence, by the anthropologist Claude Lévi-Strauss.[10]

Apart from procreation and diet, the mixing of the flesh of different individuals or species has traditionally been a strictly theoretical, rather than practical, possibility. And on a speculative plane the connotations of chimeras, organisms made up of mixtures of naturally occurring types, have not been always negative. The gods of ancient Egypt and India and the ancestral figures of Native American and Aboriginal Australian legends, for example, frequently partake of a combination of human and animal characteristics. Representations of human-animal hybrids in Mediterranean and Northern European pagan cultures could similarly convey positive values. However, with the rising domination of Judeo-Christian ideas in Europe, the specter of human-animal, or even purely human, chimeras became increasingly disquieting, as can be seen in medieval monster allegories such as *Beowulf* (ca. 1000), seventeenth-century werewolf hysteria,[11] and *Frankenstein* (1818).

The mixing of flesh and production of chimeras is no longer purely theoretical. Human organ transplantation began in the 1950s, first with kidneys, followed by livers (1963), hearts (1967), and lungs (1981).[12] By the late 1980s, transplantations of fetal tissue into adult brains and pancreases were being performed, with the goal of alleviating Parkinsonism and diabetes. More recently, attempts have even been made to cross species lines, with transplantations of baboon hearts and livers to human recipients.

In recent animal experiments, mixture of the flesh of different individuals and biological types has progressed even further, yielding chimeric "geeps" (animals formed by the jumbling together of cells from goat and sheep embryos)[13] and such curiosities as mice with four biological parents.[14] Most significant from the point of view of human biology is the new capacity to produce transgenic cells and animals, which originate in one individual or species but contain genes derived from another. If such alterations are made in "somatic" or body cells which are returned to the body of the cell donor, the individual thus reconstituted may thereby produce substances that he or she was previously incapable of making. This procedure has already been used by medical scientists as an experimental palliative for certain life-threatening human diseases. If the alterations are made in "germ line" or reproductive cells, then individual animals or humans will develop which are genetically chimeric in every cell of their bodies and can pass this condition to their progeny—and hence into their species' gene pool.

Beginning with organ transplantation forty years ago and continuing into the contemporary "brave new world" of gene manipulation, critics have raised ethical questions about the commercialization of body parts, the patenting of transplantable cells, and other means by which human tissues have been desacralized and introduced into the material culture. Simultaneously, the rise of militant ecological preservation and animal rights movements has challenged traditional attitudes concerning species integrity and value and the cultural implications of producing transgenic animals.

In what follows I will examine the historic bases of attitudes concerning the crossing of carnal boundaries in the Western societies in which the contemporary scientific culture originated and has achieved its most dominant form. I intend to demonstrate that the prevailing Judeo-Christian conceptual framework affected the development of scientific ideas concerning matter and flesh to such an extent that modern biology retains a profound but covert affinity with religious ideology. Furthermore, since the elements carried over from the earlier belief systems are generally unacknowledged by the scientific mainstream, so are those which have been discarded. I will attempt to show that powerful concepts that are useful in understanding the generation and maintenance of biological form and the nature of species differences have been suppressed as a quasi-mystical notion of genetic determinism (related, as I will show, to older religious ideas) became dominant.

Finally, the traditional religious and philosophical concepts of nature considered here carried specific ethical and moral implications which, to varying extents, continue to inform value systems of contemporary technological cultures. I will therefore explore how certain Western views of the relation between flesh and matter have promoted and other such views have provided a basis for resistance to increasing pressures to commodify tissues, trivialize species identity, and generally bring all flesh into the realm of commerce and manufacturing.

Kashruth and Eucharist

The ancient Hebrews, whose laws are one of the foundations of European-American moral codes, committed themselves to a set of precepts about the preparation and consumption of meat that embodied strict notions of boundaries between different forms of life. Indeed, Hebrew myth stated that the diet of humans before the Fall was vegetarian, as decreed by God in one of the earliest passages of the Bible (Gen. 1:29). In the interpretation of the anthropologist Jean Soler,[15] the fundamental difference between human and God is thus expressed by the difference in their foods. God's food is animal sacrifices, which serve as his "nourishment" according to the Bible, and that of humans is the edible plants. Only after the Flood, which humans brought upon themselves by their violence, was it permitted for them to eat meat: "Every moving thing that lives shall be food for you; as I gave you the green plants, I give you everything" (Gen. 9:3). Yet even then a distinction continued to be made between God's portion and that of humans, with the added injunction: "Only you shall not eat flesh with its life, that is, its blood" (Gen. 9:4). According to Soler,

> Blood becomes the signifier of the vital principle, so that it becomes possible to maintain the distance between man and God by expressing it in a different way with respect to food. Instead of the initial opposition between the eating of meat and the eating of plants, a distinction is henceforth made between flesh and blood. Once the blood (which is God's) is set apart, meat becomes desacralized—and permissible.[16]

This new dietary regime signifies a covenant between God and Noah's descendants, e.g., all human beings, but one that acquiesces to human corruption. The Lord says, after the Flood: "I will never again curse the ground because of man, for the imagination of man's heart is evil from his youth" (Gen. 8:21). Only when Moses appears is a third dietary regime instituted, and the purpose of this one is to make a distinction between the Hebrews and other peoples: "I am the Lord your God, who have separated you from the peoples. You shall therefore make a distinction between the clean beasts and the unclean; and between the unclean bird and the clean; you shall not make yourselves abominable by beast or by bird or by anything with which the ground teems, which I have set apart for you to hold unclean" (Lev. 20:20–25).

Close examination of the dietary regime prescribed by Leviticus and Deuteronomy shows it to embody a theory of boundaries between living things that goes beyond issues of mere food. These laws have been considered in detail by the anthropologist Mary Douglas in *Purity and Danger* (1966)[17] and by Jean Soler in his 1973 article "The Semiotics of Food in the Bible." The following discussion is based in large part on their analyses.

It is clear that the concept of holiness from which the dietary laws flow is tied as well to nondietary prescriptions. As Douglas notes, "Hybrids and other confusions are abominated."[18] Leviticus states that "you shall not lie with any beast and defile yourself with it, neither shall any woman give herself to a beast to lie with it: it is perversion" (Lev. 18:23) and that "you shall not let your cattle breed with a different kind; you shall not sow your field with two kinds of seed; nor shall there come upon you a garment of cloth made of two kinds of stuff" (Lev. 19:19). Deuteronomy 22:11 contains its own version of the last proscription: "You shall not wear a mingled stuff, wool and linen together."

Both Douglas and Soler note that the conceptual framework of the Hebrews is continually referred back to the conditions that prevailed at the creation. The dietary laws themselves contain as a necessary (but not sufficient) condition that no flesh of carnivorous animals be eaten. And indeed, such animals were not included in the plan of the creation (Gen. 1:29–30). This is why hoofed animals, which have no means of seizing a prey, and cud-chewing animals are the only class of mammals from which the "clean" varieties are selected and birds of prey, such as the eagle, are specifically listed as "unclean." In Soler's interpretation, "Carnivorous animals are unclean. If man were to eat them he would be doubly unclean."[19] Along with this back reference to the earlier vegetarian regime of Paradise, the postdiluvian blood taboo is carried over into the new regime: "You may slaughter and eat flesh within any of your towns . . . as of the gazelle and as of the hart. Only you shall not eat the blood; you shall pour it out upon the earth like water" (Deut. 12:15–16). This is the condition for expiation of the "blood guilt" (Lev. 17:4) that attaches to anyone who kills a living being, the major prohibition of the Bible.

A further connection of the dietary regime to the plan of Creation is the stricture that animals to be eaten "shall conform fully to their class."[20] This echoes the prohibition against sacrificing to the Lord any animal with a "blemish" or "defect" (Lev. 22:21, Deut. 17:1). As Soler notes, "A fundamental trait of the Hebrews' mental structures is uncovered here. There are societies in which impaired creatures are considered divine."[21]

The relationship of cleanliness to the boundaries established at the creation is enforced by imposing a set of "ecological" precepts. In Genesis a division is made into three elements: the waters, the earth, and the firmament. Living creatures are brought forth in a specific relation to each of these elements: "Let the waters bring forth swarms of living creatures, and let birds fly above the earth across the firmament of the heavens" (Gen. 1:20); "Let the earth bring forth living creatures according to their kinds, cattle and creeping things and beasts of the earth according to their kinds" (Gen. 1:24).

The classification into creatures of the earth, water, and air is reiterated in the chapters of Leviticus and Deuteronomy that establish the dietary laws. "Any class of creatures which is not equipped for the right kind of locomotion in its element is contrary to holiness," Douglas writes.[22] Thus edible creatures from the water must have fins; those that do not move about (mollusks) and those that have legs and can walk (arthropods) are unclean. The qualifying trait for a bird is that it "flies in the air" (Deut. 4:17). Thus the ostrich is specifically prohibited, as are birds which spend most of their time in the water, such as the swan, the pelican, the heron, and all stilted birds. Moreover, "Every swarming thing that swarms upon the earth is an abomination; it shall not be eaten" (Lev. 11:41). The Hebrew word *shérec*, translated as "swarming" or "teeming,"[23] denotes appropriate locomotion for creatures of the water but not for those of the earth. So most insects are prohibited, but not all. Leviticus (11:21) permits as food insects such as grasshoppers and locusts, which have "legs above their feet, with which to leap on the earth."

Douglas and Soler consider the dietary laws of the Hebrews and the conceptual framework from which they derive as one example of the kinds of social-mental structures by which, Douglas writes, cultures "create unity in experience."[24] Although the specific items designated as significant and their relationships will vary among different cultures, Soler adds, "man knows that the food he ingests in order to live will become assimilated into his being, will become himself. There must be therefore, a relationship between the idea he has formed of specific items of food and the image he has of himself and his place in the universe."[25]

What goes for food must certainly also go for other commingling of tissues where this becomes feasible. Most relevant with regard to the structure of the Jewish dietary laws and the world view from which they flow is their pervasive influence (mainly through the authority of the Hebrew scriptures, Christianity's Old Testament) on the intellectual and moral development of European-American societies. For not only is a theory of biological boundaries and ecological order built into this perspective; these concepts are also closely tied to attitudes toward corruption and killing and the guilt that attaches to them and its expiation. These remain embedded (though perhaps to a diminishing extent) in contemporary culture, irrespective of how any of its biological notions may have been challenged by scientific activities.

Of course the view of nature embodied in the Hebrew scriptures is not the only ancient influence on contemporary notions of carnal boundaries. Christianity, from its inception, broke with a number of tenets of the Hebraic world view in a very decisive fashion. Soler, from his analysis of the Jewish dietary laws and the underlying conceptual structures, concludes that it is understandable that the Hebrews did not accept the divine nature of Jesus: "A God-man, or a God become man, was bound to offend their logic more than anything else."[26] Christ is the ultimate hybrid.

Christianity, in its mission to convert the Gentiles, drew a new line of demarcation. The new covenant sought to place all peoples and God to one side and the rest of Creation to the other side while simultaneously erasing the structures that separated the Hebrews from the other peoples. The New Testament is explicit about this. Mark (7:15) quotes Jesus as saying that "nothing that goes into a man from outside can defile him; no, it is the things that come out of him that defile a man" and goes on to comment: "Thus he declared all foods clean" (7:20). In Acts, Peter has a vision of a great sheet being lowered to the ground containing "creatures of every kind, whatever walks or crawls or flies." A voice says to him: "Rise, Peter, kill and eat." When Peter refuses, saying, "No Lord, no: I have never eaten anything profane or unclean," the voice replies, "It is not for you to call profane what God counts clean" (Acts 10:11–16). Later Paul instructs the Corinthians: "You may eat anything sold in the meat market without raising questions of conscience; for the earth is the Lord's and everything in it" (1 Corin. 10:25–26). And while the Hebrew scriptures assign guilt to the shedding of nonhuman as well as human blood and contain several passages condemning cruelty to animals, the New Testament is completely lacking in any such injunctions.

The Greco-Roman world in which Christianity first established itself was one in which human-animal hybrids were a commonplace of legends and gods were routinely assumed to take human form. This culture, unlike that of the Hebrews, was receptive to the concept of species blends and chimeras, especially a God-man. The unification of communicants with God in the Eucharist, an act of ritualistic consumption of the blood and body of Christ, represents the most extreme break possible with a Jewish moral order based on radical separation of the human from the divine, ritual extraction of blood from meat, and sanctification of living boundaries. But the Christian notion that humans, of all beings living on earth, have an immortal soul and are therefore the only creatures qualified for fusion with God initiated an alternative moral order which, while opening the way for glorification of human action (particularly in the service of religion), also fostered an alienation from, and reductive manipulation of, nature.

The hegemony of Christian thought during most of European history ensured the persistent influence of the Old Testament doctrine of genuine boundaries between life forms. However, the New Testament emphasis on the demarcation of humans from the rest of creation undercut the regulative role of this doctrine as a moral foundation and guide to right behavior. When an attack on the principle of species integrity was eventually mounted in the late nineteenth century by Darwinism, it beset an ancient framework of attitudes about the living world which, under the Christian regime, had already become rickety, its main pillar being a mystical notion of human uniqueness. And as this article of faith increasingly came into question in the present century, those elements of the traditional moral order grounded in respect for the inviolability of distinctions among living things began to dissolve.

Flesh and Matter in Pre-Enlightenment Europe

Partly because of its deliberate desanctification of biological boundaries, early Christianity had a tumultuous encounter with the question of the relation of living flesh to nonliving matter and in the process incorporated and rejected various views that had been inherited from non-Christian sources. The influential pagan idea that the earth itself is a benign female organism continually fell afoul of the patriarchal ideology of the Roman Catholic Church, which encouraged the persecution of animistic witches. It would nonetheless be invoked periodically by utopian and communitarian protestors against the alienation of land and resources from serfs and peasants. Polemicists such as Agrippa (1486–1535) and poets such as Spenser (1552–1599) and Milton (1608–1674) sought support in this idea for their resistance to the despoliation of nature caused by mining, which they likened to rape.[27]

In general, the Church fathers promulgated the Aristotelian notion that during the conception and development of all living beings the matter is provided by the female but remains inert without the animating principle supplied by the male. Manichaeanism, which flourished widely in Europe in the fourth century, took this notion further, asserting that spirit (identified with Good and the male principle) and matter (identified with Evil and the female principle) were substances that originally existed in radical opposition to one another. The mixture of the two substances in the contemporary world was held to be the basis of profound corruption and degradation, and the Manicheans promoted an ascetic ideal that included abstinence from sex, procreation, meat eating, and cultivation and harvesting. Although Manichaeanism was branded a heresy by the Church, its major precepts reemerged in the form of later Christian sects such as the Cathari of the twelfth and thirteenth centuries (also celibate and vegetarian), who went so far as to reject the doctrine of the Incarnation, i.e., that God could become flesh.

While treading the line between the organicist and dualist heresies to either side of it, the mainstream Church and its congregants struggled incessantly with the ambiguities of flesh and matter. In a 1989 essay,[28] Caroline Walker Bynum describes the vision of Christ received by Colette of Corbie, a fifteenth-century Franciscan reformer, as she prayed to the Virgin Mary: Christ appeared to Colette as a dish completely filled with "carved-up flesh like that of a child," while the voice of God warned her that it was human sin that minced his son into such tiny pieces. Bynum also writes about the cult of the eucharistic host of the late Middle Ages, involving miracles in which the bread of the eucharist turned into bloody flesh on the paten or in the recipient's mouth and related visions, such as that of the Viennese Beguine Agnes Blannbekin (died in 1315), who reported receiving Christ's foreskin in her mouth and finding it to taste as sweet as honey.[29] Around the same time theologians were debating whether, at the Second Coming, God would have to reassemble the same bits of matter that had before been animated by a particular soul.[30]

In these examples the transformation of matter into flesh and flesh into matter is always imbued with mystery and the supernatural. There is no implication, as there would be for later biological science, that the material commonality of all flesh represents the medium by which different kinds of beings could turn into one another in the normal course of things. Indeed, even the Devil could not change one kind of body into another. This was put quite explicitly in the influential late ninth-century Christian text known as the *Canon Episcopi*:

> Whoever therefore believes that anything can be made, or that any creature can be changed to better or worse or be transformed into another species or likeness, except by God himself who made everything and through whom all things were made, is beyond doubt an infidel.[31]

This doctrinal position, solidly grounded as it was in the Old Testament view that each living thing was created "according to its own kind," often ran up against the widespread medieval belief in werewolves, humans who involuntarily assumed the forms of animals, and in the presumed ability of witches to so transform themselves for specific evil purposes. Saint Augustine proffered a mystical explanation for these alleged phenomena, stating that such transformations affect neither the body nor the soul but a third part of the human called the *phantasticum*, a ghostlike double that is given a deceptive visible appearance by a demon. Saint Thomas Aquinas also invoked the Devil, who was said to be able to mold air around a body to make it appear transformed without being physically altered.[32]

Jean Bodin (1530–1596), a French lawyer and political philosopher, was an interesting transitional figure in these matters. Usually regarded as a proto-Enlightenment thinker for his advocacy of constitutional monarchy and religious toleration, he was also a misogynist who promoted the persecution of witches. His controversial views on werewolves anticipated, in certain ways, later "scientific" thinking on organismal boundaries. Bodin rejected the doctrine of the *Canon Episcopi*, holding that the commonality of humans and animals on the material plane made it reasonable that Satan could actually transform the body of one species into that of another. He used the analogies of men's ability to transform iron into steel and create hybrid plants to demonstrate that qualitative changes could be brought about in both nonliving and living materials by clever artifice. But since the real essence of the human being, according to Bodin, was not the physical form but rather the rational faculty, transformation into a werewolf (which was typically reported to occur without impairing reason) would leave the "true" human form unchanged.[33]

The line of thought initiated by Bodin was carried to its most extreme form in the following century by the French philosopher and mathematician René Descartes (1596–1650). Descartes was a pious Christian who combined his religious beliefs with the distinctively modern mode of philosophical and scientific thought which he is credited with founding. According to Descartes the animal body was essentially a machine, functioning according to mechanical laws like a clockwork or a highly perfected automaton. In the case of humans this machine was inhabited by an immortal soul, which, apart from commanding the voluntary motions, had no connection with the body's operations. Referring to animals, which he considered to lack a soul and therefore consciousness, Descartes stated: "I assume their body to be but a statue, an earthen machine formed intentionally by God to be as much as possible like us . . . "[34]

Descartes's views were clearly influenced by the great progress being made in the physical and engineering sciences by contemporaries such as Galileo and Kepler. In turn, they brought the study of the animal and the human bodies under a common scientific regime. Although the separate creation of the different species had yet to be questioned, the biological boundaries between them were being blurred. Indeed, as noted by the philosopher Hans Jonas, the concept of body as machine raised the question of why different species were created by God in the first place, "especially since mere complexity of arrangement does not create new quality and thus add something to the unrelieved sameness of the simple substratum that might enrich the spectrum of being."[35] In any case, the dissection of animals in order to advance knowledge of human anatomy gained impetus from the Cartesian theory. Moreover, the Christian theological division of the human and the divine to one side and the rest of creation to the other, which was integral to Descartes's model, actually relieved his adherents of qualms that might otherwise have stood in the way of their scientific activities. An account of experimenters working at the Jansenist seminary of Port-Royal in the late seventeenth century evokes the extremes of this mind-set:

> They administered beatings to dogs with perfect indifference, and made fun of those who pitied the creatures as if they felt pain. They said the animals were clocks; that the cries they emitted when struck were only the noise of a little spring that had been touched, but that the whole body was without feeling. They nailed poor animals up on boards by their four paws to vivisect them and see the circulation of the blood which was a great subject of conversation.[36]

The theoretical possibilities unleashed by the notion that living substance was just a variety of matter can be seen in the utopian writings of Descartes's contemporary, Francis Bacon (1561–1626). Bacon was the first great ideologue of modern science, touting its force in overcoming ancient superstition and its capacity to materially benefit society. Near the end of his life he began to set down his vision of human activity organized according to his progressive view of science in the uncompleted fragment known as *New Atlantis*.[37] In this work Bacon describes a scientific community organized very much along the lines of a modern research institute, a social entity that would in fact not be realized for another three centuries. In this institute, called Salomon's House, research is conducted on the physical and chemical sciences and mathematics as well as into the development of technologies, such as desalinization and the harnessing of wind power. But it is the vision of biological research presented by Bacon that most concerns us here.

Allowing himself free rein to speculate on the capacity of living materials to yield to scientific manipulation in a fashion well beyond anything found in the writings of the more mechanically minded Descartes, Bacon envisions botanical gardens in which the resident scientists practice

> all conclusions of grafting and inoculating, as well of wild-trees and fruit trees, which produceth many effects. And we make (by art) in the same orchards and gardens, trees and flowers to come earlier or later than their seasons; and to come up and bear more speedily than by their natural course they do. We make them also by art greater much than their nature; and their fruit greater and sweeter and of differing taste, smell, color, and figure, from their nature. And many of them we so order, as they become of medical use. We have also means to make divers plants rise by mixtures of earths without seeds; and likewise to make diverse new plants, differing from the vulgar; and to make one tree or plant turn into another.[38]

Salomon's House also has its own *Jurassic Park*-like facilities, but their uses go even further than those envisioned in the late twentieth-century novel, encompassing many of the touted prospects of modern transgenic biotechnology and its proposed application to human biology:

> We have also parks and inclosures of all sorts of beasts and birds, which we use not only for view or rareness but likewise for dissection and trials, that thereby we may take light what may be wrought upon the body of man. . . . By art likewise, we make them greater or taller than their kind is; and contrariwise dwarf them, and stay their growth: we make them more fruitful and bearing than their kind is; and contrariwise barren and not generative. Also we make them differ in color, shape, activity, many ways. . . . We find means to make commixtures and copulations of different kinds; which have produced many new kinds, and them not barren, as the general opinion is.[39]

The optimism of Bacon's utopian vision is exhibited in an overconfidence that exceeds that of most practioners of modern biotechnology, though perhaps not by much: "Neither do we do this by chance, but we know beforehand of what matter and commixture what kind of those creatures will arise."[40]

Carolyn Merchant, in *The Death of Nature*,[41] considers these passages in the *New Atlantis* to constitute an explicit rejection of respect for the natural world and the "beauty of existing organisms." And in a discussion of this work, Leonard Isaacs, who is more credulous than Merchant of Bacon's frequent avowals of religious and ethical sentiments, is nonetheless also troubled about the attitude toward nature implied by the goal of (in Bacon's words) the "effecting of all things possible." This program, according to Isaacs, constitutes "one of the most corrosive conceptions ever developed; and it has been eating away at the bedrock of religion for at least 3 centuries."[42] As the social ideology of modern science emerged, it was thus yoked to a technological imperative for which biological boundaries, whatever their significance in previous systems of thought, were just obstacles to be overcome.

Biological Types and the Chain of Being

Irrespective of the theories of Descartes and the speculations of Bacon, by the seventeenth century, flesh was still too solid to melt. Before the entry of evolutionary ideas into the mainstream of European thought, notions of the natural relationships between the various types of organisms were dominated by the concept of the *Scala Naturae*, or Great Chain of Being.[43] Taken over largely from the Greeks, this idea held that all natural entities, ranging from the inanimate through the animate, were unique and separate, occupying singular positions in sequences of forms of ascending complexity or perfection.

Perhaps the most widely diffused statement of this doctrine was that of the poet Alexander Pope, in his *Essay on Man* (1733):

> Vast chain of being! which from God began,
> Natures aethereal, human, angel, man,
> Beast, bird, fish, insect, what no eye can see,
> No glass can reach; from Infinite to thee,
> From thee to nothing.—On superior pow'rs
> Were we to press, inferior might on ours;
> Or in the full creation leave a void,
> Where, one step broken, the great scale's destroy'd;
> From Nature's chain whatever link you strike,
> Tenth, or ten thousandth, breaks the chain alike.

In its Platonic version, exemplified in Pope's verse, the discrete essences of the successive members of the chain were emphasized. The Aristotelian version, in contrast, stressed the principle of continuity and shading off of the properties of one class into those of the next. Scholars from medieval times on debated whether the perfection of the universe was manifested in the multiplicity and variety of things as they are normally encountered in the real world or whether qualitative gaps between types would represent imperfections and therefore must be a function of incomplete knowledge. However, in no case was the notion of the Chain of Being taken to imply that the created essences were actually transformable into one another.

In a world in which the boundaries between living things were supposed to be static, the transgression of these boundaries implied by the sudden appearance of biological novelties could be a source of public fascination. And given the right socioeconomic setting, such fascination could be genuinely disruptive. This was the case with the speculative episode known as "tulipomania," which brought Holland to the brink of bankruptcy in the early seventeenth century.[44] Tulips had been introduced into Western Europe from Turkey in the 1550s and became widely cultivated throughout the continent. Rare tulips, which exhibited variegated patterns unlike their parental strains, were particularly valued. At the peak of the speculative fever in the 1630s, individual bulbs sold for as much as several thousand florins. (For comparison, a thousand pounds of cheese sold for about 120 florins during the same period.) The sudden change in flower pattern seen in these tulips was known as "breaking." This phenomenon, which we now know to be caused by sporadic viral infection of the plants, was unpredictable and uncontrollable with seventeenth-century technology, making the often beautiful results a matter of mystery and luck. Hybridization, the technique responsible for most of the unusual varieties of tulips available today, requires raising the plants from seeds, which takes five to seven years for tulips. Such systematic manipulations could not have been undertaken without an understanding of the sexual nature of plants, which only became available with the publication of *De Sexu Plantarum Epistola* by the German botanist Rudolf Jakob Camerarius in 1694.

Although scientific plant breeding began in earnest in the eighteenth century, affording a more tractable experimental medium than animal breeding for testing the reality of the biological boundaries, the results of such studies had anything but a uniform effect on thinking about biological novelty and integrity. This can be seen in conflicting tendencies in the evolution of thought of two major figures of eighteenth-century biology, Carl Linnaeus (1707–1778) and George-Louis de Buffon (1707–1788).

Linnaeus, renowned for his system of classification of living organisms into branching family trees still in use today, was insistent in his early writings on the constancy and sharp delimitation of species from one another. In his *Fundamenta botanica* (1736) he stated: "Species are as numerous as there were created different forms in the beginning."[45] However, doubts about this proposition began to emerge several years later when he observed an abrupt morphological transformation in the plant *Linaria*:

> Nothing can be more wonderful than what has happened to our plant. The deformed offspring of a plant that used to produce flowers of an irregular form have now reverted to a regular form. This is not merely a variation with regard to the maternal genus, but an aberration in terms of the whole class; it provides an example unequaled in the whole of botany, which may now no longer be thought of in terms of the differences between flowers. What has happened is indeed no less wonderful than had a cow given birth to a calf with the head of a wolf.[46]

Since this *Linaria* was fertile and bred true, Linnaeus's notions of species integrity were shaken. He crossed out the words "*Natura non facit saltus*" (Nature does not make leaps) from his own copy of his *Philosophia botanica* (1751).[47] Further studies with interspecific hybrids led Linnaeus to the ultimately erroneous but intellectually courageous speculation that crossbreeding within a genus was a means for producing new species. In a 1764 letter he wrote: "We may assume that God made one thing before making two, two things before making four . . . first a single species from a genus, and then mixed the different genera so that a new species would form." The statement "*nullae species novae*" (no new species) was removed from the last edition of his major work, the *Systema Natura* (1766).[48]

By contrast, Buffon, in his early writings on the species question, dismissed the idea of sharp boundaries between types of organisms and rejected the Linnaean taxonomic scheme:

> Nature progresses by unknown gradations and consequently does not submit to our absolute divisions when passing by imperceptible nuances from one species to another and often from one genus to another. Inevitably there are a

> great number of doubtful species and intermediate specimens which one does not know where to place.[49]

To this way of thinking only individuals have a true existence, and a species is just a convention of human thought, a position explicitly stated by Buffon in the first volume of his major work *Histoire naturelle* (1749). But on the basis of evidence that he obtained himself and from correspondents during the following decade that whereas some distinct varieties of plants or animals could form fertile hybrids, others, like the donkey and the horse, produced sterile offspring, Buffon revised his views. The hybridization results appeared to provide proof for the objective reality of species as "the sole essences of Nature." A species, according to the thirteenth volume of *Histoire naturelle* (1765), was "a whole independent of number, independent of time; a whole always living, always the same; a whole which was counted as one among the works of the creation, and therefore constitutes a single unit of the creation."[50]

Just as different machines, e.g., clocks and water pumps, are built from similar parts and materials according to different plans, so could the different types of organisms have a common material basis. His eventual conclusion that species identities were discrete thus did not require Buffon, who was originally a physicist, to relinquish the eighteenth-century mechanistic world view in which he had been steeped. In reconciling his materialism with the idea of the separateness of species, Buffon proposed the radical concept of the "interior mold," a kind of three-dimensional template that determined the organizational properties of an organism's matter.

By this concept Buffon purported to solve one of the longest-standing controversies among natural philosophers: preformation versus epigenesis. The preformationists were advocates of the ancient idea that organisms successfully reproduced their kind by virtue of the presence of a miniature individual of the same type in either the sperm or the egg which enlarges but does not change its form during development. This doctrine had been criticized for numerous logical inconsistencies. One of the most compelling points was Buffon's own argument that since each "homunculus" would have to have a proportionately smaller one nested in its own germ cells for the production of the subsequent generation, the miniature being of the sixth generation would be smaller than the smallest possible atom.[51] The epigeneticists, led by the embryologist Caspar Friedrich Wolff (1733–1794), thought of organization, in contrast, as reemerging anew during embryonic development. One analogy that they used was the curdling of milk during the formation of cheese. Unlike the preformationists, however, Wolff and his followers had no notion of how such a process could be reproducible from generation to generation. In Buffon's view, this was the function and purpose of the interior mold.

This concept, of course, had to extend beyond the analogy of the sculptor's mold into which wax or plaster is poured, since this kind of template can only reproducibly render surface characteristics. Buffon recognized that embryonic development cannot be achieved by mere addition of molecules to surfaces. He therefore hypothesized the interior mold as "an intussusception that penetrates the mass,"[52] a hidden structure that organizes matter during embryonic development so as to produce a child in the image of its parents, and to provide "a general prototype in each species upon which all individuals are moulded."[53] Not being a philosophical idealist, he readily acknowledged that this prototype could be "altered or improved, depending on the circumstances, in the process of realization."[54]

Buffon's notion of the interior mold was not well received during his lifetime, partly because few scientific thinkers of the eighteenth century were willing to consider any view of matter other than the "corpuscular" theory then in fashion. This view attributed the qualities of materials much more to the properties of their irreducible atoms (which were completely hypothetical at that time) than to any interrelationships among these basic units. Buffon's great insight that complex molecular organization could be transmitted from one parcel of living matter to other parcels derived from it continued to be derided long after his death, most recently by the evolutionary biologist Ernst Mayr, who, as an unwavering proponent of "particulate" inheritance, considered the interior mold to be a Platonic idea.[55] The molecular biologist François Jacob, who was more appreciative of Buffon's notion, nonetheless considered its validity as a biological principle to be limited to the one-dimensional "mold" or template represented by the DNA molecule.[56] However, recent biological research has demonstrated that the egg and all the tissues subsequently derived from it contain "cytoskeletons," "nuclear scaffolds," and "extracellular matrices," all consisting of highly articulated three-dimensional networks of molecular fibers that are partitioned between daughter cells at each cell division, along with and in addition to the DNA. These findings underline the prescience of Buffon's concept of the interior mold.

Like staunch eighteenth-century citizens, Buffon couched his materialistic concepts of biological organization and Linnaeus his notion that new species could continually arise over time in terms of special creation. The implications of their insights pointed in a different direction, however. The embryologist Wolff, from his studies of birth defects in animals, was, like Linnaeus, impressed with the abruptness with which new forms could appear and with their subsequent stability.[57] In unpublished manuscripts he concluded that not every biological structure or species was a primordial product of nature which had received its existence directly from the hand of God. Like Buffon, he believed that the constancy of species and genera was derived from the specificity of a structured substance that reproduced itself, but he also entertained the possibility that external factors could modify this substance and cause hereditary changes.[58]

Thus, while the discreteness of biological boundaries had yet to be called into question, the possibility of their being breached in the normal course of events was raised by the new observations and the materialistic explanations offered for them. Among the boundaries increasingly characterized as permeable during the eighteenth century was the moral distinction between humans and nonhuman animals, the absoluteness of which had been a fundamental tenet of Christian dogma and Cartesian dualism. Alexander Pope, in addition to being a popularizer of the Chain of Being, was also a strong advocate of the humane treatment of animals and one of the earliest public opponents of scientific vivisection. Accordingly, he included mental faculties among the ascending chain of graded qualities in his *Essay on Man* and entertained the idea that animals, like humans, had immortal souls.[59] It is also significant, in light of the present discussion, that when Pope sought religious justification for the humane treatment of animals he invoked the authority of the Old Testament.[60]

During the next century the spiritual argument for the unity of creation would be replaced in the writings of philosophers and natural scientists by concepts such as "laws of form," "functional adaptation," and "community of descent." Debates about these ideas ultimately resolved into the Darwinian doctrine that biological boundaries exist not as a matter of principle but as a matter of contingency or historical accident. Since, as we shall see, the purported scientific foundation for this doctrine is debatable, it is of interest to examine the varying degrees to which this outcome was driven by evidence on one hand and by ideology on the other.

Nineteenth-Century Theories of Biological Transformation

Flesh is matter, but the Newtonian concept of matter that continued to prevail throughout most of the nineteenth century could not account for the distinctive properties of flesh. In the classical picture, matter is inert. Although its motion is governed by mathematically precise laws, the outcome of this motion is entirely dependent on the initial preparation of the system—the arbitrarily given position and velocity of each particle. In order for the matter in a multicomponent system to become organized in a complex fashion, it would have to be "set up" in an appropriate way. That is why Descartes, Newton, and the other founders of the mechanistic world view could simultaneously be physical determinists and religious believers: God was in the initial conditions.

The German philosopher Immanuel Kant (1724–1804) was a critic of the notion that the existence of God could be derived from the design of the natural world. But he was equally dismissive of the hope that the principles upon which organisms were constructed could be derived from causal analysis based on physical science. In this regard he was affirming the independence of the laws of motion from the initial conditions, noted above. Kant argued that characterizing the functional relationships among parts of a complex structure such as a clock, a painting, or an organism was not the same as understanding the principle or purpose of its organization. While the purpose of a human-made artifact derives from the concept that led to its production, the "concept" behind a living thing cannot be discerned by scientific experimentation. Moreover, not only do organisms, like machines, exhibit a high degree of functional integration among their parts, but they are also self-generating and self-renewing; as Kant stated it, "every part is reciprocally purpose and means."[61] The principles behind the arrangement of matter in a living organism are even more opaque to causal analysis than those of machines.

Although science and religion were progressively diverging in the domains they sought to explain during the nineteenth century, they remained joined to one another by virtue of the recognition, epitomized in Kant's analysis, that organizational principle could not be derived from mechanism. And while progress in chemistry had undermined earlier beliefs that living matter consisted of elements other than those found in nonliving matter, for the generation of biologists that followed and were influenced by Kant (referred to as the "teleomechanist" school by the historian Timothy Lenoir),[62] the chemical mixtures that occurred in living tissues were organized in ways that were irreducibly different from anything in the inorganic realm.

Some of these scientists went beyond Kant's skepticism about arriving at conclusions about principles of organization from causal analysis and actually postulated the existence of vital principles or forces in living tissues. For example, the Swedish chemist Jöns J. Berzelius (1779–1848), writing about the "catalytic force" exhibited by certain biological molecules, indicated that this was not to be understood as "a capacity independent of the electrochemical relationships of matter" but rather as "a special sort of expression of those relationships . . . that remains hidden from us."[63] But if living materials are organized according to principles beyond our abilities to discern scientifically, then the different species or life forms also may be organized according to distinct suprascientific principles. Thus the materialist paradigm, now well established in physiological circles, could be maintained side by side and quite consistently with a firm belief in special creation.

The range of differing opinion on the principles upon which organisms were constructed and the stage at which the hand of God exerted its direct influence on organismal form can be seen in the debates between the "structural" or "transcendental" morphologists, who dominated on the Continent, and the "natural theologians," who held sway in Britain. Georges Cuvier (1769–1832), the French founder of paleontology and comparative anatomy, was a Christian believer who brought a holistic materialism to bear on the question of the separateness of creatures. The notion of a structural basis for biological uniqueness, which Buffon had proposed to underlie heredity and embryonic development, was generalized to the organismal level by Cuvier in his theory of the correlation of parts. He held that all the functions of an organism are interrelated by a "necessity equal to that of metaphysical or mathematical laws." He stated, moreover, that "if one of these functions were modified in a manner incomparable with the modification of the others, the creature could no longer continue to exist."[64]

Cuvier provided a set of examples that interestingly echoes the biological classification scheme underlying the dietary prohibitions of Leviticus:

> An animal that digests only flesh must be able to see its prey, follow it and tear it apart. Consequently, it must have a piercing eye, a keen sense of smell, a swift gait, agility and strength of leg and jaw. For this reason, cutting teeth for tearing through flesh are never found in the same species with a foot encased in horn that can only support the weight of the animal and cannot be used for grasping.[65]

His conclusion from such arguments was that abrupt discontinuities in the organization of the animal kingdom and gaps in the fossil record represented the absence of transitional forms that are, in fact, biologically impossible.

Cuvier was a strong opponent of the notion that the different types of organisms were derived from common ancestors by a process of "organic change," a theory proposed by his countryman Jean-Baptiste Lamarck (1744–1829) in his *Philosophie zoologique* (1809).[66] Indeed, Cuvier's ridicule of Lamarck's ideas and his caricature of the role of volition in the selection by organisms of their environments (the famous "giraffe" example) served to deny Lamarck his rightful place in the history of biology as the first systematic proponent of evolution.[67] Etienne Geoffroy Saint-Hilaire (1772–1844), Cuvier's colleague and fellow structural morphologist, believed that a single set of geometrical-topological "laws of form" were responsible for generating all animal types.[68] That led him to be more sympathetic to evolutionary ideas than was Cuvier. For while Cuvier was content to consider that the main branches of the animal kingdom and the various species within them had been separately created to occupy distinct functional niches, Geoffroy's emphasis on the common principles that underlay the generation of all animal types suggested that structure determined rather than reflected function (e.g., birds fly because they have wings, not the other way around). Moreover, it raised the question of why the laws of form had led to a variety of outcomes rather than a single type. In his later writings he proposed the idea that the environment, acting during embryogenesis, could modify "organized bodies," leading to new biological types.[69] However, Geoffroy was a religious conservative; while his laws of form might generate the occasional new type of organism as conditions changed, he believed that all living things conformed to a Unity of Plan that was unchanged since the time of creation.

Natural theology represented an alternative framework to transcendental morphology in accounting for the design of the living world. Like that doctrine, it was a blend of science and belief, albeit one that violated the Kantian precept of the impossibility of deriving knowledge of a creator from the nature of the "created." The commissioning by the Earl of Bridgewater, by a legacy upon his death in 1829, of a series of works "on the power, wisdom, and goodness of God, as manifested in the Creation" is representative of the flavor of the movement. Where natural theology most differed from transcendental morphology was in its emphasis on "adaptations," the suitability of biological structures for the functions they performed. Although Cuvier also stressed the interrelatedness of structure and function, his principle of the correlation of parts placed constraints on the possible activities that could be served by anatomical variation. Certainly the primacy given by Geoffroy and his successors to material properties of living systems and the concomitant rule-generated structures in determining biological function was bound to conflict with the natural theologians' view that the hand of God was manifested in even the smallest detail of each being's construction.

The nature of the debate between the structural morphologists and the natural theologians can be seen in the neurologist Sir Charles Bell's *Bridgewater Treatise* of 1833. At issue was the proposal by the structural morphologists that the *incus* (anvil) bone, one of the chain of three bones constituting the sound transmission system of the mammalian middle ear, was absent in birds because it had been "transformed" into the quadrate bone of the upper jaw joint. Bell's alternative account was that the bird has an articular structure in its upper jaw because it requires the extra mobility in order to catch insects. He comments:

> It is above all, surprising with what perverse ingenuity men seek to obscure the conception of a Divine Author, an intelligent, designing, and benevolent Being—rather clinging to the greatest absurdities, or imposing the cold and inanimate influence of the mere "elements," in a manner to extinguish all feelings of dependence in our minds, and all emotions of gratitude.[70]

Out of this tradition of natural theology came the British naturalist Charles Darwin (1809–1882) and his theory of evolution by natural selection. The central doctrine of this theory—that given the small morphological, physiological, or behavioral variations encountered in any natural population of a single kind of organism, the competition of marginally different individuals for limited resources has been sufficient to generate the entire array of biologically distinct types seen on the face of planet—is too familiar to require detailed discussion here. Because the mechanism that Darwin proposed for achieving organismal form and the interrelationships among parts in a living system is, on the face of it, so "unguided," the congruence between the structure of his theory and that of natural theology, while occasionally noted, is not considered by contemporary Darwinians to detract from the theory's scientific standing. Thus Ernst Mayr makes what he considers to be the "rather paradoxical claim" that much of the intellectual structure of the *Origin of Species* can be accounted for by the fact that the leading paleontologists and biologists of Darwin's day were natural theologians whose descriptions were filled with "what we would now call adaptations." He goes on to state that "when 'the hand of the creator' was replaced in the explanatory scheme by 'natural selection,' it permitted incorporating most of the natural theology literature on living organisms almost unchanged into evolutionary biology."[71]

While modern Darwinians thus concede the formal similarities between the "perfectionism" of natural selection and that of natural theology, the proposal that Darwin's mechanism of organismal change also shares some of the teleological assumptions of theistic metaphysics is much more controversial. Nevertheless, the historian of science John Cornell, studying Darwin's notebooks from the period in which he was formulating the theory of natural selection, concludes that

> the power he attributed to his new mechanism depended specifically on the assumption of a divine Being, intelligent like man but superior and utterly lawful. This assumption underlay both Darwin's idea of natural species' "perfect adaptation" and his stunning analogy of selective breeding to describe nature in terms of this mechanism.[72]

And the historian Robert J. Richards has inferred from Darwin's embryological writings that he believed that evolution was a progressive force,[73] leading to a situation in which (according to the last edition of the *Origin of Species*), "The inhabitants of each successive period in the world's history [are] higher in the scale of nature" than their predecesors.[74]

It should not be surprising that Darwin incorporated the theistic ideas of his cultural milieu into his biological theory. Given Kant's Newtonian judgment that knowledge of mechanism carried no implication concerning knowledge of organizational principle or "purpose," there were only two possible pathways to a more naturalistic understanding of the living world. One route was the incorporation of a dynamic conception of matter into biology, a conception that differed from the static view of matter of classical mechanics. If matter itself has "self-organizing" properties that can lead to the formation of structures relatively independently of the initial conditions of its preparation, then the goal-directedness of organismal physiology, development, even evolution could potentially find interpretations in the physical properties of biological materials.

We know that distinct kinds of nonliving matter assume preferred forms and patterns: liquids flow, taut strings vibrate as a whole and in discrete segments along their lengths, and soapy solutions form bubbles and foams. If, as I have suggested elsewhere,[75] there were analogous tendencies for primitive living tissues to assume preferred forms and patterns—hollow, multilayered, segmented, or jointed structures, for example—then the appearance of a particular set of body plans and organ forms over life's history would represent the inevitable emergence of stereotypical morphologies. A subset of these forms might meet with differential success under different circumstances—natural selection would still be possible—but the array of possible "types" would be intrinsic to fleshly matter and limited rather than open-ended.

Glimmerings of a dynamic view of matter were emerging in the early nineteenth century with the new science of thermodynamics, and our own century has seen sustained exploration of the forms and patterns generated by the dynamic behavior of fluids and of "excitable media." Geoffroy Saint-Hilaire's organismal "laws of form" were a prescient application of this view of matter to the living world.

The other pathway out of Kant's impasse, the one taken by Darwin and his followers, was to retain the classical view of matter and with it the formal structure of natural theology. Newtonian matter can be molded into any form or pattern, subject only to the constraints of the initial conditions, which are entirely arbitrary. Correspondingly, Darwinism makes no a priori statements about why organisms have the appearance and characteristics that they do. As the philosopher Thomas Nagel has noted, the theory of natural selection "explains the selection among those organic possibilities that have been generated, but it does not explain the possibilities themselves."[76]

Some of Darwin's most enthusiastic adherents, such as the Christian Darwinists Asa Gray (1810–1888) and George Frederick Wright (1838–1921), took comfort in the fact that Darwin's theory made no attempt to explain the origin of the variations preserved by natural selection, since, as Wright stated, it "left God's hands as free as could be desired for contrivances of whatever sort he pleased."[77] While the theistic metaphysical context from which Darwin's theory emerged was rapidly disavowed by most of his immediate successors, who emphasized the role of impersonal forces in the generation of biological types, it is difficult to avoid the conclusion that the Darwinian "mechanical" materialism that emerged as the scientific mainstream was a doctrine less threatening to the dominant social classes that espoused it than the alternative of a Geoffroyan "dynamical" materialism would have been. If fleshly matter was inexhaustibly malleable, there would be few limitations on the forms it could assume in the course of evolution. Whether through the workings of the hand of God or, as later became fashionable to believe, through "chance" coupled to "survival of the fittest," those who came out on top could well imagine themselves the products of a perfecting process. In contrast, if we all, humans and other species, were, in all our complexities, truly products of common natural forces, the biological world would have to be seen in more pluralistic terms and the human species would no longer be, in the words of Julian Huxley, one of the leading Darwinians of this century, "the highest form of life produced by the evolutionary process on this planet."[78]

In any case, the secular Darwinists, in order to render natural selection acceptably materialistic, needed to address Kant's precept that the organizing principle of a complex whole could not be derived from analysis of the functional interactions among its parts. But for the reasons already discussed, the solution to this problem could not appeal to the self-organizing properties of biological matter without undermining the Darwinian view of the external determination of the direction of evolutionary change. Specifically, the Darwinians needed an independent guiding force, analogous to the God of the natural theologians, to give form and reproducibility to the inert materials of their biological world. This force was soon provided by the theory of the isolation and continuity of the germ plasm proposed by August Weismann (1834–1914) and its eventual recasting into the scientifically questionable modern idea of the "genetic program."[79]

The Apotheosis of the Gene

According to standard accounts, Darwin's theory of evolution by natural selection was so intellectually compelling that it required only a plausible theory of inheritance to gain general acceptance among all but the most obstinate of the scientifically disposed. The "rediscovery" of Mendel's laws by several independent investigators around 1900 supposedly satisfied this requirement. There are certain historical distortions in this scenario; for example, Mendel's findings were never really "lost" to the scientific community,[80] and the nature of the mechanisms of heredity was never central to the most cogent scientific criticisms of Darwinism before or after 1900.[81] But more important, examination of the logic of both Darwin's and Mendel's contributions in light of present knowledge of the nature of biological stability and variation and of the mode and tempo of evolutionary change suggests that the neo-Darwinian "modern synthesis," as it became defined by the mid-twentieth century, incorporated uncritically held beliefs to an extent comparable to any of the earlier theories of nature discussed in this chapter.

In keeping with the requirement of his theory that biological organizing principles must reside in a medium independent of fleshly matter itself, Darwin put forward "the hypothesis of pangenesis" a decade after he first published the *Origin of Species*. This theory held that each cell in the body produced, and was represented by, invisible particles called "gemmules" which circulated freely throughout the system and accumulated in the reproductive organs. The mixing of the gemmules of two individuals would result in offspring that were in part similar to the parents and in part novel. Darwin, like most nineteenth-century biologists, also believed in the inheritance of acquired characteristics. He therefore proposed that the tissues of the body, upon being affected by "changed conditions" such as use and disuse, will "consequently throw off modified gemmules, which are transmitted with their newly acquired peculiarities to their offspring."[82]

In its proposal that vanishingly small, structurally unspecified particles could embody and regenerate specific living qualities, Darwin's theory verged on philosophical idealism. The idea that the traits of an organism could be "represented" in distinct and independent particles, which upon mixing would produce new versions of those same traits, is notably deficient in explanatory power. This is particularly evident when compared with the tentative attempts by Buffon and the members of the "teleomechanist" and "structural morphology" schools to conceptualize how the properties of "organized bodies" could be transmitted from generation to generation.

The fact that Darwin's theory of evolution could incorporate a virtually mystical notion of the transmission of biological qualities suggests that it lacked the specificity that might be expected from a purported explanation of organismic form and function. The substitution of Mendelism for pangenesis did little to correct this problem. Indeed, the version of Mendel's concept of inheritance that was incorporated into the Darwinian paradigm was much closer conceptually to pangenesis than to what Mendel in fact deduced from his studies of the transmission of traits in peas and hawkweeds.

Gregor Mendel (born 1822) entered the Augustinian monastery in Brno, Moravia, in 1843, and died there as abbot in 1884. As a Catholic monk he was steeped in Church doctrine and Aristotelian philosophy. Much of Mendel's success in classifying the qualities of plants and conceptualizing the regularities of their combination and transmission is attributable to his Scholastic intellectual background, according to the geneticist H. Kalmus.[83] Despite the efforts of the eminent population geneticist R. A. Fisher[84] and some later Darwinians to portray Mendel as a convert to evolutionism, Mendel's writings contain no evidence of affinity with this concept. Moreover, L. A. Callender has persuasively argued that Mendel was, rather, an adherent of the Linnaean version of the doctrine of special creation, discussed above, which left open the possibility that new forms could arise through hybridization.[85] Mendel's work with peas addressed the inheritance of alternative versions of the same characteristic within a given species (i.e., flower color, seed shape, or texture), while his studies of hawkweeds suggested that hybrids formed between preexisting species could exhibit some long-term stability. None of his results implied that major transformations between biological forms (that is, species and, ultimately, more divergent groups such as classes and phyla) could result from successive alterations in heritable determinants or "elements" (what we now call "genes"). But this, of course, would be a necessary condition if Mendel's factors were to provide the herditary basis for Darwin's doctrine that new biological types originated by sequences of gradual modifications.

The botanist Hugo de Vries (1848–1935) interpreted his own and Mendel's findings within a conceptual framework similar to that of Darwin's pangenesis, proposing that differences among individuals could be dissected into "unit characters," each with its own hereditary basis. For example, de Vries stated in his 1889 book, *Intracellular Pangenesis*: "If one considers the species characters in the light of the doctrine of descent, it then quickly appears that they are composed of separate more or less independent factors."[86] He saw no reason to change his opinion in 1900 after he became aware of Mendel's work.[87] But Mendel himself came to no such universal conclusions, even referring to the only law that he ever enunciated, that concerning the nature of the progeny of hybrids with two alternative characters, as the "Law Valid for *Pisum* (peas)." There is no implication that all traits, let alone all species, conform to this law. Moreover, in considering the class of features that were inherited in this fashion, Mendel wrote that "the distinguishing traits of two plants can, after all, be caused only by differences in the composition and grouping of the elements existing in dynamical interaction in their primordial cells."[88] Mendel's notion of how these "elements" affected the production of traits was therefore, from this limited evidence, a developmental one. That is, those factors of heredity which can exist in alternative states influenced the outcome of a generative process in a complex system rather than "representing" distinct traits, as they did for Darwin and for de Vries.

Eventually some biologists rejected the naive notion, embodied in Darwin's and de Vries's pangenesis theories, that each heritable characteristic is carried by an independent factor. For example, the Danish botanist Wilhelm Ludwig Johannsen (1857–1927) wrote in 1909:

> By no means have we the right to define the gene as a morphological structure in the sense of Darwin's gemmules or biophores or determinants or other speculative morphological concepts of that kind. Nor have we any right to conceive that each special gene (or a special kind of genes) corresponds to a particular phenotypic unit-character or (as morphologists like to say) a "trait" of the developed organism.[89]

Thomas Hunt Morgan, an embryologist turned geneticist and a central figure in the discovery that genes are parts of chromosomes, made the same point even more forcefully several years later:

> Failure to realize the importance of these two points, namely, that a single factor may have several effects, and that a single character may depend on many factors, has led to much confusion between factors and characters, and at times

> to the abuse of the term "unit-character." It cannot, therefore, be too strongly insisted upon that the real unit in heredity is the factor, while the character is the product of a number of genetic factors and of environmental conditions. . . . So much misunderstanding has arisen among geneticists themselves through the careless use of the term "unit character" that the term deserves the disrepute into which it is falling.[90]

Six decades of subsequent research have led to the generally accepted view that in functional terms, a gene constitutes nothing more than the cell's replicable record of the primary sequence of an RNA molecule, or indirectly, a protein. With the recognition that the molecules specified by genes can influence one another's synthesis and physiological activity, the modern view is seen to be in full accord with Mendel's notion of a "dynamical interaction" of elements causing the production of distinguishing traits.

The subtleties involved in relating genes to traits can be seen in the example of sickle cell disease, which is the classic case of an association of a gene mutation with impairment of health in humans. Persons who have this condition produce only mutated versions of a hemoglobin protein ("hemoglobin-S") in their red blood cells. The severity of the condition depends on the proportion of cells which are "sickled" and because of their shape may clog small blood vessels; severity therefore varies from asymptomatic in some individuals to life threatening in others. This variability exists because the degree to which the blood cells are made abnormal by the presence of hemoglobin-S is controlled by physiological factors quite independent of the hemoglobin gene; these factors differ from individual to individual and even vary in a given individual under different conditions.[91] Despite the ubiquity of such complexities, in the course of the development of the modern gene concept the warnings of Johannsen and Morgan have been often ignored.

The growing influence of Darwin's theory of natural selection required a formal disconnection between an organism's "plan" and its fleshly matter. Otherwise evolution of form (i.e., alterations of the plan) would be driven as much by the intrinsic propensities of such matter to generate certain structures as by transformations resulting from adaptation to changed conditions. To draw another example from sickle cell disease, one may look at a red blood cell as a partially deformable object which can take on a small number of different shapes depending on variations in its constituent molecules and in its local environment. Both genetic and environmental changes can induce a transformation from the standard biconcave disk shape of red blood cells to a sickle shape. Moreover, a given genetic change (i.e., mutation of hemoglobin to hemoglobin-S) can have the effect that a greater proportion of cells are sickled under standard conditions. But no plausible sequence of genetic changes can turn a red blood cell into a five-pointed star. Analogous constraints on the ability to generate form must have pertained to the multicellular parcels of matter that provided the raw material for the elaboration of the earliest plants and animals.[92] In other words, throughout the history of life on earth the relationship between genes and traits must inevitably have been mediated by what Geoffroy referred to as "laws of form."

However, as a result of the general acceptance of the Darwinian-Weismannian version of inheritance by the mid-twentieth century, the genome—an organism's collection of genes—came to be typically characterized as embodying or determining all of the organism's traits. Although the naive picture that each trait was "represented" by a particular gene or set of genes was no longer fully subscribed to, the notion of the presumed role of genes in determining all aspects of every biological feature and their collective autonomy in executing their functions was carried over from the pangenesis of Darwin and de Vries into the modern view. Thus the physicist Erwin Schrödinger, in his influential book, *What Is Life?* (1945), summarized the emerging consensus of many of his biologist colleagues and sounded the keynote for the new field of molecular biology when he wrote: "The chromosome structures are instrumental in bringing about the development they foreshadow. They are the law-code and executive power—or to use another simile, they are the architect's plan and builder's craft in one."[93] That this passage did not simply represent the musings of a nonspecialist prior to the discovery of the chemical nature of the gene is evident from a 1976 symposium paper by Max Delbrück, a founding figure of molecular biology. Under the wry but telling title "How Aristotle Discovered DNA," Delbrück stated: "It is my contention that Aristotle's principle of the unmoved mover [i.e., God] originated in his biological studies. . . . [U]nmoved mover perfectly describes DNA. DNA acts, creates form in development, and it does not change in the process."[94]

Therefore, while molecular biologists in their day-to-day work followed a Cartesian functionalist paradigm that permitted them very effectively to determine the manner in which the various molecules and cells of organisms were organized, some theorizers convinced themselves that they had also solved the problem posed by Kant of identifying the principle that guided this organization. This guiding principle was considered to be contained in the base sequences of DNA, a substance to which were attributed the powers of "self-reproduction" and the ability to "act" and "create."

The Modern Ideology of Flesh

The invention in the mid-twentieth century of the digital computer depended on developing a conceptual framework in which data and the programs to manipulate them were entirely separable from the machine itself. For such a machine, what it was actually made of (e.g., vacuum tubes, transistors, integrated circuits) had little bearing on the tasks it performed. This provided an apt metaphor for the presumed separation of instructions from material in what was becoming the standard description of biological systems. Thus the molecular biologists Alexander Rich and S. H. Kim wrote that "it is now widely known that the instructions for the assembly and organization of a living system are embodied in the DNA molecules contained within the living cell"[95] and the physicist Freeman Dyson, discussing the origins of life, declared: "Hardware processes information; software embodies information. These two components have their exact analogues in a living cell; protein is hardware and nucleic acid is software."[96]

What organisms are actually made of is entirely irrelevant from this viewpoint. The biologist Richard Dawkins is quite explicit about this in the following remarkable passage from his book *The Blind Watchmaker*:

> [Molecules of living things] are put together in much more complicated patterns than the molecules of nonliving things, and this putting together is done following programs, sets of instructions for how to develop, which the organisms carry around inside themselves. Maybe they do vibrate and throb and pulsate with "irritability," and glow with "living" warmth, but these properties all emerge *incidentally*. What lies at the heart of every living thing is not a fire, not warm breath, not a "spark of life." It is information, words, instructions. If you want a metaphor, don't think of fire and sparks and breath. Think instead of a billion discrete digital characters carved in tablets of crystal. If you want to understand life, don't think about vibrant, throbbing gels and oozes, think about information technology.[97] (Emphasis added.)

The philosopher Mary Midgley calls this mode of thinking about life "getting away from the organic." In her book *Science as Salvation* she notes that much speculative writing by male scientists during the twentieth century contains "quasi-scientific dreams and prophesies" involving visions of escape from the body coupled with "self-indulgent, uncontrolled power-fantasies."[98] An example is this fascinating statement from an article by Freeman Dyson:

> It is impossible to set any limit to the variety of physical forms that life may assume. . . . It is conceivable that in another 10^{10} years, life could evolve away from flesh and blood and become embodied in an interstellar black cloud . . . or in a sentient computer.[99]

The history of ideas developed in the present chapter provides a context for interpreting these denials of specificity to the material substratum of life, coupled with an exaggerated notion of human agency—what Midgley calls "predictions of the indefinitely increasing future glory of the human race, and perhaps its immortality."[100] One could infer, for example, that by opting so completely for a Hellenistic–New Testament concept of nature, with its de-emphasis on the reality and moral significance of biological boundaries, over the biologically pluralistic Hebraic–Old Testament concept, the Darwinian mainstream reinforced a cultural paradigm that valued power to transform the world over a respect for variety, balance, and limits. But the previous discussion also suggests that the Darwinian model to a significant degree represents a projection of scientifically unsubstantiated beliefs onto the natural world.

An alternative to the Darwinian-Weismannian view, referred to above,[101] attributes the bodily forms assumed by complex multicellular organisms to the intrinsic properties of the semisolid materials that constituted flesh at early stages of its evolution. The array of biological forms that populate the world are thus considered to be limited and stereotypical, not an open-ended set of structures whose particular characteristics depend mainly on the vagaries of extrinsically imposed functional adaptation. This alternative view is clearly closer to the "laws of form" perspective of Cuvier and Geoffroy than it is to the "descent with modification" paradigm of Darwin. In particular, by treating biological types as intrinsic to the matter from which organisms are made, the alternative view explicitly rejects the dualism inherent in Darwinism.

In these two views of the evolutionary process, which I will refer to as the "externalist" and "internalist" models, we can distinguish two very different notions of biological boundaries. In the externalist model, the organism is continually evolving into something different from itself. According to the philosopher Hans Jonas, for Darwinism "the emergence of forms falls wholly to the random play of aberrations from pattern, which as aberrations are by themselves indifferently 'freaks,' and on which the distinction between deformity and improvement is superimposed by entirely extraneous criteria." He continues:

> [I]f the gene system is the transmitter of heredity, stability—the condition of faithful transmission—is its essential virtue. Since [a mutation] is a mishap to the steering system of a future organism, it will result in something which from the point of view of the original pattern can only be termed a deformity. However "useful" it happens to be, as a deviation from the norm it is "pathological." As similar mishaps continue to befall the same gene system in succeeding generations, an accumulation of such deformities under the premium system of selection may result in a thoroughly novel and enriched pattern: but the "enrichment" would still be an excrescence on the original simplicity, a slipping of the discipline of form multiplied over and over again under the licensing of selection; and thus the high organization of any animal or of man would appear a gigantic monstrosity into which the original amoeba has grown through a long history of disease.[102]

For the externalist, transgression of biological boundaries is thus the never-ending evolutionary norm. In the internalist view, in contrast, almost all overt biological diversification occurs early on, when primitive organisms, because of the physical contribution to the determination of their forms, are to a certain extent mutually transformable. Through subsequent evolution the disparate kinds of organisms, by accumulating mechanisms which promote their capacity to develop "true to type" despite genetic mutation ("morphological stasis") and to maintain their phenotypic character in the face of changing conditions ("physiological homeostasis"), turn more and more into "themselves." According to the internalist view, then, the intensification of uniqueness, rather than the open-ended production of overt difference, may thus be the hallmark of organismal evolution once it has left its early, "physical" stage. This view implies, furthermore, that mixing and matching the biochemical capabilities of modern organisms by transgenic manipulations could be profoundly disruptive of species and individual identity and integrity in a fashion different from anything encountered during evolution.

Only time will tell whether the internalist or externalist model better accounts for the facts of organic evolution. But can adherence to one or another of these paradigms possibly make a difference to our practical interaction with the natural world? After all, even in the Darwinian picture organisms are unique over any time scale in which human action can have any consequence. Indeed, the arch-Darwinist E. O. Wilson is one of the most eloquent scientific advocates of the preservation of the diversity of life. He argues that the expected generation of truly novel forms would be much too slow to compensate for any losses by extinction or ecological disturbances resulting from destructive policies with respect to the biosphere.[103]

But when Wilson's rationale for his valuation of diversity is examined closely, it is seen to embody a view of biological boundaries as disparaging as that implicitly held by the ecological despoilers whom he deplores. True to his practice of attributing all important organismal features to Darwinian processes, Wilson postulates that a long process of random genetic change, along with competition among individuals and groups, has produced humans with a set of "impulses and biased forms of learning loosely characterized as biophilia,"[104] by which he means a propensity to protect and cherish life in the particular array of forms that have co-evolved with us. Respect for nature is therefore in the genes. The world's flora and fauna, which, with Jonas, Wilson would have to admit are just so many Darwinian "freaks" and "monstrosities," are to be valued because they are *our* freaks and monstrosities.

But like many such "reified traits"—abstractions endowed with biological concreteness—Wilson's "biophilia" founders on the shoals of arbitrariness. As Stephen Jay Gould asks in his review of Wilson's *Diversity of Life,*

> Why should these valued features be deeper, more innate, more definitive of our nature, than our rapacity? Was it any less natural to kill all the moas of New Zealand, all the mammoths of North America? Surely for each biophile in the United States there are ten who would kill a deer for sheer sport, rather than for needed food; ten who will build the suburban shopping mall for each cry of "woodman, spare that tree."[105]

The sociologist Howard Kaye, in *The Social Meaning of Modern Biology*, places Wilson firmly within the tradition of natural theology in the attempt to biologize ethics and communal purpose.[106] Along with other critics he finds deep affinities between Wilson's view of the ideal society as a "social organism" and that of nineteenth-century pre-Darwinian social evolutionists. The philosophical dualism that connects Darwinism to natural theology also permeates Wilson's sense of the significance of biological boundaries, which, in this world view, must be seen as ultimately arbitrary, or at least extrinsically imposed. On one hand Wilson rhapsodizes that "[t]he flower in the crannied wall—it *is* a miracle. . . . Every kind of organism has reached this moment in time by threading one needle after another, throwing up brilliant artifices to survive and reproduce against impossible odds."[107] But on the other hand he approvingly quotes the entomologist Thomas Eisner:

> As a consequence of recent advances in genetic engineering, [a biological species] must be viewed . . . as a depository of genes that are potentially transferable. A species is not merely a hard-bound volume of the library of nature. It is also a loose-leaf book, whose individual pages, the genes, might be available for selective transfer and modification of other species.[108]

An ultimate celebration of genetic manipulation can be found in the following passage, reminiscent of Bacon's *New Atlantis*, in Dyson's *Disturbing the Universe*:

> Imagine a solar energy system based on green technology, after we have learned to read and write the language of DNA so that we can reprogram the growth and metabolism of a tree. All that is visible above ground is a valley filled with redwood trees, as quiet and shady as the Muir Woods below Mount Tamalpais in California. These trees do not grow as fast as natural redwoods. Instead of mainly synthesizing cellulose, their cells make pure alcohol or octane or whatever other chemical we find convenient. While their sap rises through one set of vessels, the fuel they synthesize flows downwards through another set of vessels in their roots. Underground, the roots form a living network of pipelines transporting fuel down the valley. The living pipelines connect at widely separated points to a nonliving pipeline that takes the fuel out of the valley to wherever it is needed. When we have mastered the technology of reprogramming trees, we shall be able to grow such plantations wherever there is land that can support natural forests.[109]

Such schemes must be considered overweening and dangerous fantasies, not only because of what might "go wrong" but also for the continued negative cultural impact of this Procrustean view of living beings.

The dualist conception of living organisms as program plus its execution, which has prevailed with the ascendancy of the Darwinian world view, has provided a notion of biological boundaries that corresponds perfectly with the requirements of modern commercial biotechnology in its drive to generate products such as experimental mice that contract cancer at high rates,[110] tomatoes that remain ripe-looking despite being weeks off the vine,[111] pigs that have leaner meat,[112] and, ultimately, children with enhanced athletic or social skills. Indeed, the molecular biologist and editor of *Science* magazine Daniel Koshland, Jr., contemplates the possibility that prenatal gene modification of humans could be perceived to meet future "needs" to design individuals "better at computers, better as musicians, better physically."[113] With the advent of human in vitro fertilization and embryo cloning, proposed applications of transgenic technology now threaten to bring human individuals into the realm of manufactured items.[114]

According to a report called *Patenting Life* by the U.S. Office of Technology Assessment, the nature of a species is "rooted in the identity of the genetic material carried by the species," although "how a species might be defined genetically is not yet apparent". It therefore follows that since mammals may contain 50,000 to 100,000 or more genes, "[w]hatever it is in the organization and coordination of activity between these genes that is fundamental to their identity as species, it is not likely to be disrupted by the simple insertion or manipulation of the small number of genes (fewer than 20) that transgenic animal research will involve for the forseeable future."[115]

These assertions are based on the erroneous assumption that there is a straightforward relationship between genetic difference and the "distance" between organisms in a typological sense.[116] Since biological boundaries are, in this view, historically contingent products of gradually accumulated genetic change, they can be slightly breached with only slight consequences. The government report on patenting life thus provides false reassurance to Congress and the public that the freaks and monstrosities almost certain to arise from transgenic research will be no different from the Darwinian garden variety that have supposedly spurred evolution on its way.

But as we have seen, there is an alternative to the scientific view on which this analysis is based. With roots, in Western culture, in the Hebrew creation myth, and with scientific branches represented by the thought of the naturalist Buffon, the morphologists Cuvier and Geoffroy, the embryologist K. E. von Baer (1792–1876), and in our own century the morphologist D'Arcy W. Thompson, the alternative view holds that the various types of organisms that populate the biosphere are the virtually inevitable formations of living matter, much as the elements of the periodic table are inevitable formations of subatomic particles. A consequence of this view is that as the different biological types began to emerge, evolution's effect would have been to sharpen rather than blur biological boundaries. In this nondualistic view, the properties of flesh define a range of organic possibilities to which any evolved genetic "programs" must necessarily conform.

I have argued in this chapter that biological dualism has emerged in European-American culture in concert with a value system that gives automatic preference to the drive to manipulate the living world over a more ancient stance—what William Wordsworth called "natural piety." But far from representing a scientific rejection of obsolete concepts of nature, the dualistic view of living beings, I have suggested, is at odds with reality. The public, which pays for and bears the consequences of technological change, has been sold a view of organisms as entities lacking in self-definition that are entirely malleable and programmable. But as we have seen, the acceptance of this view (among both scientists and the lay public) has often had less to do with scientific evidence than resonance with mythic and religious traditions embedded in the culture. Unearthing the multifarious intellectual pathways that have led to the currently dominant view has revealed that the culture contains, as well, alternative theories and traditions that could foster receptivity to a new respect for and scientific understanding of carnal limitations and biological uniqueness.

Notes

1. *Alive*, Touchstone Pictures; Frank Marshall, director; 1992.

2. *The Donner Party*, Steeplechase Films; Ric Burns, director; 1992.

3. *The Silence of the Lambs*, Orion Pictures; Jonathan Demme, director; 1991.

4. Barbara Rudolph, "Unspeakable Crimes," *Time*, January 18, 1993, p. 35; Liu Binyan, "An Unnatural Disaster," *New York Review of Books*, April 8, 1993, pp. 3–6.

5. Tom Mathews, "Secrets of a Serial Killer," *Newsweek*, February 3, 1992, pp. 44–49, 50–51.

6. I am assuming here that there is a continuity between a culture's socially sanctioned preoccupations and its "peculiar forms of pathology" (Christopher Lasch's term). This notion is developed, for example, in books by Michel Foucault (e.g., *Madness and Civilization*, R. Howard, trans., New York: Pantheon, 1965), Christopher Lasch (e.g., *The Culture of Narcissism*, New York: Warner Books, 1979), and Susan Bordo (e.g., *Unbearable Weight: Feminism, Western Culture, and the Body*, Berkeley: University of California Press, 1993).

7. See Andrew Kimbrell, *The Human Body Shop*, San Francisco: Harper Collins, 1993.

8. See, for example, Claude Lévi-Strauss, *The Raw and the Cooked*, J. and D. Weightman, trans., University of Chicago Press, 1969.

9. Sigmund Freud, *Beyond the Pleasure Principle*, J. Strachey, trans., New York: Liveright, 1928.

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18. Douglas, *Purity*, p. 53.

19. Soler, "Semiotics," p. 131.

20. Douglas, *Purity*, p. 55.

21. Soler, "Semiotics," pp. 132–133.

22. Douglas, *Purity*, p. 55.

23. Douglas, *Purity*, p. 56.

24. Douglas, *Purity*, p. 2.

25. Soler, "Semiotics," p. 126.

26. Soler, "Semiotics," p. 136.

27. Carolyn Merchant, *The Death of Nature: Women, Ecology and the Scientific Revolution*, San Francisco: Harper and Row, 1980.

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30. Bynum, "Female," p. 192.

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