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Nature, Progress and Stephen Jay Gould's Biopolitics

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Genetic manipulation promises to introduce biological novelties to the ecosphere, the dinner plate, and the schoolroom. Is there an appropriate Left response to such eventualities? From its earliest roots in the industrial revolution of the nineteenth century, the Left has generally been favorably disposed to technology, which has been seen as having the potential to liberate workers from drudgery and foster progressive changes in social relations. There is also a countervailing (though not necessarily antagonistic) Left tradition, beginning with Luddism and allied movements, of skepticism about promises held out by technological change, cognizant of the capacity of new technology to increase the power of hegemonic social groups over those less empowered. Additionally, the environmental and antinuclear and biological weapons movements of the twentieth century have contributed to Left theory the notion that there are consequences of technological activity that supersede class considerations. Global warming, nuclear winter, and pandemic infectious disease have the potential of doing away with us all, proletarian and bourgeois alike.

Now that, in the twenty-first century, we have technologies with the possibility of altering not just social relations and the physical environment and ecosphere, but organismal identities themselves, a whole new set of questions has been raised about their hazards and their political and even cultural implications. Like the earlier issues raised by environmental depredation and weapons proliferation, attitudes toward genetic engineering turn out to involve commitments beyond the standard Left/Right divide. In particular, where one stands on these questions depends on one's view of the relation of genes to biological traits, of the processes by which biological novelties have been generated in the past by human and nonhuman agency, of the privileged position (if any) occupied by the world as it exists outside human activity ("nature"), and of the relation of the natural to the artifactual. More specifically, it hinges on how one conceives of the process of organic evolution, the scientific field to which Stephen Jay Gould, a self-identified person of the Left, devoted himself and for which, during most of his life, he was the outstanding public representative.

An international social movement tied to resistance to economic globalization has emerged in opposition to genetic engineering of crops, animals, and humans. Much

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activity along these lines (which is far from homogeneous—most opponents of genetic manipulation of food sources have stayed away from the human manipulation issues) has been conducted by people and groups that see themselves as inheritors of Marxist thought in some loose sense. Nonetheless, opposition to genetically engineered organisms has met with indifference on the mainstream Left in the United States. *The Nation,* for example, has run as many articles viewing genetically engineered crops in a favorable light as the reverse, and its coverage of the prospect of cloning and genetic engineering of humans in columns, book reviews, and full-length articles has to be counted as generally accepting.

The resistance of the mainstream U.S. left (in contrast to much of its European counterpart) to signing on to the opposition to the "genetic future" may partly be attributed to the fact that this country's most prominent left-wing biologists, Gould and his Harvard colleague Richard Lewontin, have stayed on the sidelines, frequently expressing skepticism about perceived threats to the environment or the human species posed by genetic engineering and related technologies, and directing their criticisms (Gould 1985; Lewontin 2001) instead toward the occasional solecisms of leftist writers such as Jeremy Rifkin and Vandana Shiva who have raised these issues in forceful ways (e.g., Rifkin 1998; Shiva 1999).

Scientific data on the environmental and food chain impacts of the first large-scale introductions of genetically engineered crops are only now becoming available and the outcomes are not all benign (Quist and Chapela 2001; Alvarez-Morales 2002; Ortiz 2002; Nichols 2002). And while the consequences of human gene manipulation and cloning would primarily be social rather than ecological (Billings, Hubbard, and Newman 1999; Hubbard and Newman 2002; Fukuyama 2002), they might be expected to be matters of concern for critics of the bourgeois order who are also scientifically expert.

In this paper I focus on Gould, whose writings and public pronouncements on the new genetic technologies were remarkably rare despite the frequency of his public engagement on biologically related issues in literally hundreds of magazine articles, op-ed pieces, and television and radio interviews. When he did go on record about these issues it was to express the ordinary concerns of the liberal citizen, but not to endorse any notion that the ability to intervene in the genetic identity of humans and nonhuman organisms raised novel problems. For example, in a 1998 article in *Natural History* entitled "Above all do no harm," he advocates international agreements to ban chemical and biological weapons, and makes a strong pitch for what has come to be called the "precautionary principle" (Raffensperger and Tickner 1999). He states: "we should honor what might be called the 'negative morality' of restraint and consideration, a principle that wise people have always understood (as embodied in the golden rule) and dreamers have generally rejected, sometimes for human good but more often for the evil that arises when demagogues and zealots try to impose their 'true belief' upon all humanity, whatever the consequences" (1998, 82).

But in an aside, he quite specifically excludes from recommended bans the genetic technologies that give contemporary critics most pause, advocating leaving decisions on the circumstances under which humans could be cloned, for example, to regulatory bureaucracies such as those of the U.S. government.

> (I should offer the proviso that, in making this general argument for moral restraint, I am speaking only of evident devils, or destructive technologies with no primary role in realms usually designated as human betterment: healing the sick, increasing agricultural yields, and so on. I am not talking about the more difficult, and common, problem of new technologies—cloning comes to mind as the current topic of greatest interest—with powerfully benevolent intended uses but also some pretty scary potential misuses in the wrong hands, or in the decent hands of people who have not pondered the unintended consequences of good deeds. Such technologies may be regulated, but surely should not be banned.) (Gould 1998, 78)

In another essay, Gould (1997a) analogizes heightened concerns (often voiced by critics of genetic engineering of crops) about the stability of evolved ecosystems against disruption by exotic species to the *Volkist* nationalism of Nazi-era ideologues, though he ultimately ends up taking a characteristically moderate position.

Gould's valiant efforts in the battle against the inappropriate application of biology to social policy, and against the pseudo science of evolution denial, are uncontested. Here I ask what it was about his views of the natural world that made him unresponsive to apprehensions about the new biotechnologies. It is reasonable, as a first approach, to entertain the idea that Gould's deep understanding of the evolutionary process justified this position. As is well known, Gould was highly skeptical of the notions of progress and ordained outcomes in evolution and genetic determination of human behavioral characteristics. These views, as we shall see, underpinned his views on genetic engineering and cloning. But important as his critiques were as counterforces to prevailing conservative doctrines, Gould was also not entirely immune to the ideologies of our time. Aspects of his evolutionary viewpoint may have blocked his receptiveness to the negative social and cultural implications of the new genetic technologies. Taken too far, Gould's views may provide a warrant for a *laissez-faire* attitude toward what gets introduced into the biosphere, and lead to underestimation of the damage that may be caused to humans and other species by genetic manipulation.

Turning Away from the Material

Critics of genetic engineering frequently appeal to notions of a natural order that may be disrupted if novel, human-manipulated organisms are introduced into the environment. In this regard they are drawing on ideas that are as old as, or older than, the Genesis creation myth, and which have been refracted across the millennia into numerous hierarchical and Romantic variants that still hold sway to some extent in the public consciousness. In the early twentieth century, ideas of this sort motivated environmentalism of the preservationist stamp associated with John Muir and Aldo Leopold and were held suspect by some Marxist critics who rightly detected in them aristocratic and nativist strains. Over time, however, as the integrity of the global environment has come under increasing attack by industrial and commercial activities, few on the political Left continued to define the anti-growth and— consumerist goals of radical environmentalism (particularly as applied to the industrial North) as antagonistic to a progressive social agenda. Indeed, they have become part and parcel of it (see, for example, Cuello Nieto and Durbin 1995; Levins 1996; Klein 1999; Czech 2000).

The health of the environment has been envisaged in terms of physical stability (no human-caused warming, melting, flooding), minimal accumulation of garbage and chemical pollutants, and conservation of biological species diversity. There is nothing in Gould's writings to suggest disagreement with these now standard *bien-pensant* concerns. The novel threats posed by genetic engineering, however, which have been suggested to include ecological disruption by substitution of faster growing engineered crops or animals for traditional cultivated or wild varieties, and uncontrolled (Krimsky and Wrubel 1996; Rissler and Mellon 1996) or deliberate (Lee 1999) replacement of natural by human-manipulated forms, did not, from the evidence of his writings and public comments, sufficiently conflict with Gould's conception of the natural order and its frailties to rise to a similar level of apprehension.

Evolutionary biology attempts to explicate the relationships of heredity to form and function, and to changes in these interconnections over time. Gould's entry into this field came after the neo-Darwinian synthesis of genetics, paleontology, and population biology had been firmly established by the generation of biologists that preceded him. The major tenets of this theory are that (1) evolution occurs by the enhanced reproductive success of "phenotypic" variants (that is, variants in some structural or functional attribute) within populations of organisms; (2) this "natural selection" occurs by means of competition between variant organisms for a common slice of the environment or "ecological niche," or by differential survival of variants when the environment undergoes change; (3) the only phenotypic changes that are reliably passed from generation to generation are those that are tied to changes in an organism's hereditary material or genes. Evolution is therefore reflected in change in the frequency of gene variants at the population level and, correspondingly, is pushed forward by random changes in the genes of individual organisms, which provide its raw material insofar as they are associated with phenotypic variants; (4) genetic changes of large phenotypic effect are almost always nonviable. Thus, evolution is nearly exclusively the result of the accumulation of genetic changes with incrementally small impact on the phenotype.

Gould was temperamentally inclined to cast a fresh eye on what was left unexplained by this paradigm by the intellectual influence of Thomas Kuhn's (1970) view of scientific revolution and, importantly, by his own political experiences as a student in the 1960s and his familial exposure to Marxist notions of the social determination of ideas. He also had a keen scientific capacity to detect patterns that did not fit into the reigning models (e.g., neo-Darwinism) though, as we will see, not always the theoretical means to come up with a coherent alternative.

Punctuated equilibrium—the fits and starts of the fossil record—was rightly elevated by Gould and his colleague Niles Eldridge to a phenomenon that required rethinking of the neo-Darwinian orthodoxy (Gould and Eldredge 1977). For more than a century paleontologists had been unearthing fossils with unprecedentedly novel characteristics from successive geological strata: paired limbs on land vertebrates, wings on insects. The standard neo-Darwinian view (deriving primarily from theoretical work of R. A. Fisher) was that sudden morphological change (saltation) cannot be characteristic of evolution since any substantially novel form would, with near certainty, be ill suited to its population's niche, or too much of a genetic rarity to be passed on to offspring. According to the evolutionary biologist Ernst Mayr, "The evidence, whether genetic, morphological, or functional, is so uniformly opposed to a saltationist origin of new structures that no choice is left but to search for explanations in terms of a gradual origin" (1976, 95). In the standard view, there must therefore be something incomplete about observations of morphological discontinuity—a consequence of preservational gaps in the fossil record.

A related phenomenon, taken up by Gould somewhat later, was the so-called Cambrian explosion—the finding that most, if not all, the major animal body plans burst forth in a relatively narrow span of time between 500 and 600 million years ago (Gould 1989). Here again, the evidence seemed to suggest relatively abrupt transitions had taken place, while the existing theory suggested that this was not possible. Both the punctuated equilibria of the fossil record and the so-called Cambrian big bang appealed to Gould's iconoclastic side.

Gould was attuned to the fact that thinkers of the nineteenth century dealt more productively with ideas of progressive change than did those of the twentieth. In his book *Time's Arrow, Time's Cycle* (Gould 1987), he explored the epistemological break made by the geologists James Hutton and Charles Lyell with respect to earlier views of the history of the earth. In Gould's account, the ultimate relinquishment by Lyell of an exclusively cyclical view of time, in which major geological transitions were part of a recurrent sequence, in favor of a concept of "deep time" in which history records a progression of unique events (recognizing that each is generated by perennial natural processes), was an intellectual landmark that set the stage for Darwin's theory of evolution. It is interesting to see how Gould characterizes this shift.

> At the one end of the dichotomy—I shall call it time's arrow—history is an irreversible sequence of unrepeatable events. Each moment occupies its own distinct position in a temporal series, and all moments, considered in proper sequence, tell a story of linked events moving in a direction . . . At the other end—I shall call it time's cycle—events have no meaning as distinct episodes with causal impact upon a contingent history. Fundamental states are immanent in time, always present and never changing. Apparent motions are parts of repeating cycles, and differences of the past will be realities of the future. Time has no direction (Gould 1987, 10–11)

As with many of Gould's formulations, an illuminating antinomy is presented, but little attempt is made to show the antagonistic forces in action. The work in which this passage appears is dedicated to the idea that these two categories of time may both operate within single formative episodes—regularities giving rise to a sequence of particularities. There is, however, virtually no description of the complex geological processes that Hutton and Lyell sought to explain. Rather, Gould attempts to grapple with the interplay of the recurrent and the contingent in geology by invoking a variety of religious narratives—the book of Ecclesiastes, ceiling sculptures of Norwich Cathedral, stained glass windows of Canterbury and Chartres, James Hampton's mid-twentieth-century masterpiece of "outsider art," *Throne of the Third Heaven of the Nations Millennium General Assembly*. Apart from their questionable metaphysics (and Gould's implicit assumption that conceptual frameworks are immune from distortion by their specific content), all these texts and artworks are formally similar in attempting to explicate such presumed singularities as the Creation, the Flood, the Virgin Birth, and the Second Coming, with the recurrent and timeless arbitrarily and mysteriously embedded in the unique. As Gould states:

> The same tension and multiplicity have pervaded our Western view of time. Something deep in our tradition requires, for intelligibility itself, both the arrow of historical uniqueness and the cycle of timeless immanence—and nature says yes to both. We see this tension in Burnet's frontispiece [Christ bestriding a circle of the Earth's recurrent stages in *The Sacred Theory of the Earth* (1691)], in Lyell's method for dating the Tertiary, and in Hampton's *Throne*. We find it etched into the iconography of any medieval cathedral of Europe, where the arrow of progressive history passes from Old Testament lore on the dark north side, to resurrection and future bliss on the sunlit south. Yet we also see the cycle within the arrow. A set of correspondences—like Burnet's globes and Hampton's symmetries—teaches us that each event of Christ's life replays an incident in the previous cycle of Old Testament history. We see, in short, Burnet's resolution of rolling wheels. Each moment of the replay is similar as a reflection of timeless principles, and different because time's wheel has moved forward. (Gould 1987, 200)

While some literary parallels may help enliven such an inquiry into time and process, interestingly, given Gould's avowed intellectual influences, there are no references to the writings of the nineteenth-century figures Marx and Engels, who also struggled with time's cycle and time's arrow, but in a more scientific fashion. The flavor of their method can be gleaned from the *Communist Manifesto*.

> It is enough to mention the commercial crises that, by their periodical return, put the existence of the entire bourgeois society on its trial, each time more threateningly. In these crises, a great part not only of the existing products, but also of the previously created productive forces, are periodically destroyed. In these crises, there breaks out an epidemic that, in all earlier epochs, would have seemed an absurdity—the epidemic of overproduction. Society suddenly finds itself put back into a state of momentary barbarism; it appears as if a famine, a universal war of devastation, had cut off the supply of every means of subsistence; industry and commerce seem to be destroyed. And why? Because there is too much civilization, too much means of subsistence, too much industry, too much commerce. The productive forces at the disposal of society no longer tend to further the

> development of the conditions of bourgeois property; on the contrary, they have become too powerful for these conditions, by which they are fettered, and so soon as they overcome these fetters, they bring disorder into the whole of bourgeois society, endanger the existence of bourgeois property. The conditions of bourgeois society are too narrow to comprise the wealth created by them. (Marx and Engels 1848)

Or, more briefly, in the conclusion to Marx's *Eighteenth Brumaire*,

> the revolution is thorough-going. It is still passing through purgatory. It does its work methodically. By December 2 1851, it had completed one half of its preparatory work; it is now completing the other half. First it perfected the parliamentary power, in order to be able to overthrow it. Now that it has attained this, it perfects the executive power, reduces it to its purest expression, isolates it, sets it up against itself as the sole target, in order to concentrate all its forces of destruction against it. (Marx 1869)

Gould's descriptions of geological or biological upheavals contain almost nothing comparable to such dialectical examinations (compare the geological descriptions of the writer John McPhee [1998]). They are essentially homiletic treatments that acknowledge polarities without attempting concrete synthesis. Again and again, they appeal to religious or aesthetic props and bear little mark of the philosophy of qualitative transition pioneered by the two Germans a century and a half earlier. He rarely engages the actual material properties of what is being depicted; his analyses, both geological and biological, tend to be metaphorical rather than process-oriented or even mechanistic.

One of Gould's uncontested scientific contributions is as a founder of the modern confluence of evolutionary and developmental biology, known to its practitioners as "evo-devo." Motivated to account for the punctuated cadence of organismal evolution that he and Eldredge had discerned as a reality rather than an artifact, Gould reached back to the nineteenth century for developmental concepts that had been written out of the neo-Darwinian synthesis. These were concepts that dealt with embryogenesis—"ontogeny" in the old-fashioned terminology that he brought back into currency. Embryos develop in a directional fashion; material transformations turn one complex form into the next, much as Marx conceived of social organizations supplanting what went before by building upon and reorganizing earlier formations. Things can change abruptly during embryogenesis, and minor genetic or metabolic alterations during early development can have profound morphological consequences. Do such transitions in individual ontogeny have anything to do with the tempo and mode of "phylogeny"—the generation of different types of organisms in the history of life? The conventional wisdom denied it—individual development was "programmed," evolution was "random"—but Gould in his characteristically incisive fashion saw connections between the two.

Here too, however, he preferred to deal in metaphors rather than materialities. "Galton's polyhedron" was a model used by that nineteenth-century hereditarian to demonstrate that physical systems (including biological ones) need not, when incrementally perturbed, change in a continuous fashion. A sphere will roll along a surface by making incremental changes in its position of contact. A polyhedron, however, if prodded, will make a quantal change in its contact with the surface. This model became a perennial in Gould's writings (1986; 2001) and public presentations, usually standing in for actual biological examples. The spandrels of San Marco, the entry point into a famous critique of adaptationism by Gould and Lewontin (1979), are structural side effects of architectural necessities that later can be used for other purposes. Some speculations on possible biological examples of this phenomenon were proffered, but the specificity of the architectural example evidently compelled Gould as much or even more. He notably referred to the human chin and to human language as "spandrels."

When Gould did engage actual morphological transformations in biological systems, as he did when discussing land snails, the subject of his own empirical scientific research, the results were mixed with regard to his theoretical intentions. In his important first book, *Ontogeny and Phylogeny* (1977), he revivifed the older idea of *heterochrony*, changes in the relative timing of developmental processes that may distinguish evolutionarily related, but morphologically different, organisms. He devoted much of the 1977 work to arguing that heterochrony could account, in part, for large-scale evolutionary change ("macroevolution") and even to the discontinuities described by punctuated equilibrium. But the changes wrought by the presumed action of heterochrony on snail morphology are variations on a theme rather than quantum jumps (Gould 1977; 2002). Gould finally recognized that heterochrony by itself could not do the heavy lifting required for macroevolution, and the discussion of the possible relation between the two phenomena is only a page long in his theoretical magnum opus, *The Structure of Evolutionary Theory* (2002).

In fact, Gould's backing off (frankly acknowledged in his final work) from his earlier, scientifically contrarian insights concerning the reality of abrupt evolutionary change and the stasis that separates such episodes, was due to his unwillingness to relinquish the conventional neo-Darwinian notion of strict genetic determination of the origination form and other aspects of overt biological character ("phenotype"). He was therefore forced to succumb to neo-Darwinian critiques of notions of abrupt morphological innovation just as other, nongenetic "efficient causes" of origination were coming into prominence in the field of evolutionary developmental biology that he did so much to establish. Recognition of Gould's embrace of genetic determinism in evolutionary theory (in contrast to his rejection of it in human behavior) takes us a great distance in explaining his stance toward biotechnology.

Stuck on the Gene

Gould is justly admired for his criticisms of "sociobiology," the attribution to genetic differences between human groups and individuals of class divisions, IQ inequalities, disparate social behaviors, and so forth. Many of these arguments can be found in his book *The Mismeasure of Man* (1981, rev. 1996), and to his writings with other members of the fluid Sociobiology Study Group (e.g., Bruce et al. 1979). Because we do not know to what extent and in what ways genetic and nongenetic influences contribute to complex characters in general, or even in any detailed way in specific cases, this area is ripe for ideologically influenced discourse. Hegemonic social groups have always taught that their pet conceptions of human nature and human variety are "natural," and genes are simply the currently fashionable surrogate for purported biological realities. Gould was quite clear about the deficiencies of applying this bankrupt model to socially embedded phenomena. The essential genetic homogeneity of the human species, and the changes in the fates of nations on historical rather than evolutionary timescales, provide sufficiently strong arguments to deflate the sociobiology of human difference. Gould performed an important cultural function in deconstructing the world-view represented by *The Bell Curve* (Herrnstein and Murray 1994) throughout his professional life and in numerous venues. Proposals of genetic contributions to human commonalities, such as language and altruism, while far from being solidly based (despite claims to the contrary [e.g., Pinker 2002]), are less ideologically fraught, and elicited less explicit opposition from Gould.

Significantly, however, when he turned from this work in the service of progressive ideology to discussions of evolutionary theory, Gould was as thoroughgoing a genetic determinist as any neo-Darwinian. (This should not be taken to suggest that Gould in any way supported the doctrines that individual genes are generally the targets of natural selection, that there are usually direct correspondences between genes and traits, or that all organismal features were naturally selected for their adaptive utility. He explicitly rejected all these oversimplifications.) Lewontin and Levins (2002), while declaring that Gould was "radical in his science," go on to say that "[n]one of Gould's arguments about the complexity of evolution overthrows Darwin. There are no new paradigms, but perfectly respectable 'normal science' that adds richness to Darwin's original scheme." Here they were undoubtedly referring to Gould's acceptance of the neo-Darwinian precept that evolutionary change is driven, on the whole, by natural selection of genetic variants with only small effects on an organism's phenotype.

Neo-Darwinism's genetic determinism finds narrow support in the recognition that "genes lie at the base of a causal cascade in the development of organisms" (Gould 2002, 634). As far as it goes, this statement is unexceptionable. Genes are the linear molecules inside an organism's cells that transmit information from one generation to the next about the array of RNA molecules and proteins the organism can produce. Hereditary differences between an organism and its offspring are typically associated with mutations—random, and essentially irreversible, alterations in the sequence of subunits of one or more genes ("typically," because certain types of more readily reversed chemical changes in genes, referred to as "epigenetic" or "paramutational," can also be transmitted across generational lines). The production of the forms of the bodies and organs of modern multicellular organisms—their ontogeny, or development—is pushed forward by Gould's "causal cascade," so that the products of sets of genes control the activity of other sets of genes, and cell and tissue form change in consequence. Genetic change may or may not lead to phenotypic change, but phenotypic change will not, in general, be inherited without genetic change.

But something is missing from this formulation. Proteins and RNAs, the biological molecules specified by genes, are not all there is to an organism. Cells contain water, salts, as well as other cell products like fats and polysaccharides. The collectivity of an organism's genes—its "genome"—therefore does not uniquely determine the physical forms the organism may assume. Organismal form arises from the molding and sculpting of collections of aggregated cells (tissues), and this depends on physical properties only partly influenced by the specific molecules, including the proteins (and genes) the cells contain. A simple but pertinent analogy is found in the various forms assumed by water. Liquid water can exhibit waves or vortices if subjected to certain kinds of mechanical disturbance, and can turn into ice or steam depending on the ambient temperature. All the while it has the same chemical identity: H_2O. Form is determined by more than mere composition.

The reason that individual, modern-day multicellular organisms do not exhibit the multifarious forms which might be expected from their material composition is that natural selection is particularly well suited to arriving at means for reinforcing the ontogeny of successful forms. Such genetic change over the course of evolution makes the means by which biological forms are generated more and more resistant to perturbation by the environment. This type of evolution—termed "canalizing" by C. H. Waddington (1942) and "stabilizing" by I. I. Schmalhausen (1949)—does not innovate form, but simply consolidates and preserves it. It is almost certainly the major source of evolutionary stasis, highlighted so vividly in Eldredge and Gould's punctuated equilibrium model.

What, then, is responsible for innovating or originating biological form? It is on this point that Gould's failure to break with the incrementalist orthodoxy of neo-Darwinism is crucial. From the earliest period of his professional life (Gould 1971), he was captivated by the proposal by D'Arcy W. Thompson (1942) that physical forces acting on the inherent physical properties of living matter organize cells and tissues, much as water or any soft material can be shaped and organized by its physical environment. Indeed, he spends thirty pages of *The Structure of Evolutionary Theory* discussing D'Arcy Thompson's decidedly nonmainstream ideas before concluding that, however interesting they may be, they cannot be correct because, first, organisms in general are not highly susceptible to molding by external forces and, second, there is no clear way, using standard neo-Darwinian mechanisms of genetic change of "small effect" followed by selection for improved reproductive success, for organismal structure to track and conform to the physical forces contemplated by D'Arcy Thompson.

But despite a fascination with these ideas that lasted more than three decades, Gould missed seeing their real usefulness because he neglected to engage the actual, material properties of the objects under consideration. These, in fact, are not modern-day organisms but organisms at much earlier stages of evolution. As noted above, stabilizing evolution results in genetic mechanisms and interactions that consolidate and reinforce the development of individual form. It is no wonder, then, that after hundreds of millions of years of such reinforcing changes, organisms generally resist direct shaping by their physical environments. Moreover, the profound complexity of genetic influences on form that arise during these long periods of evolution must lead to a situation in which genetic changes of "large effect" are bound to be pathological. Concerning modern-day organisms, then, the neo-Darwinians are largely correct.

Early organisms are a different story, however. Gould essentially acknowledges this when he writes in his book *Wonderful Life*:

> In the traditional Darwinian view, morphologies have histories that constrain their future, but genetic material does not "age." Differences in rates and patterns of change are responses to an unchanging material substrate (genes and their actions) to variation in the environment that reset the pressures of natural selection . . . But perhaps genetic systems do "age" in the sense of becoming "less forgiving of major restructuring" [Valentine 1977]. Perhaps modern organisms could not spawn a rapid array of fundamentally new designs, no matter what the ecological opportunity. (Gould 1989, 230)

Gould's use of the term "genes and their actions" to define the "material substrate" of evolving organisms indicates his genetic determinism. Had he expanded the collection of determining factors of morphological change to include the physical properties of biological cells and tissues, and the associated determinants pointed to by D'Arcy Thompson, he would have been able to bring in a category of cause that he clearly found compelling, and which can provide a source for the morphological leaps needed by the punctuated equilibrium model. (See Goodwin [1994], Kauffman [1995], and Müller and Newman [2003] for contemporary analyses in the spirit of D'Arcy Thompson.) Rapid generation of forms by physically based processes of "self-organization" in organisms with "youthful" genomes, followed by stabilizing natural selection, will yield organisms with "aged" genomes for which neo-Darwinian theory becomes valid (Newman and Müller 2000).

The phenomenon by which environmentally induced phenotypic change is eventually "assimilated" into the genetic repertoire by stabilizing selection was first proposed by J. Mark Baldwin in the late nineteenth century (Baldwin 1896) and has come to be called the "Baldwin effect." While the role of the Baldwin effect in the evolution of modern, genetically consolidated organisms is probably not great (Simpson 1953), early in the history of life it would have been much more efficacious. It is ironic that Gould, who was so insistent on deconstructing the notion of "uniformitarianism" which has been supposed to characterize Lyell's and Darwin's epistemological break (Gould 1987), failed to notice that the assumption of uniformity of formative influences over evolutionary time was unwarranted. Yet, it was this assumption that made the neo-Darwinist orthodoxy unreceptive to his insights on the tempo and mode of evolution.

Is Biology Arbitrary?

Gould chose the title *Wonderful Life* for his book on the Cambrian explosion, not only to express awe at the rapid proliferation of biological forms that emerged within a narrow time frame beginning about 543 million years ago, but in reference to Frank

Capra's 1946 film *It's a Wonderful Life*. In that film the main character is given the opportunity to see how the world around him would have turned out if he had not existed. Gould used the play on words as an emblem for his view that contingency plays a major role in the outcomes of natural processes and that the results are, to a great extent, arbitrary. In a famous passage from his book Gould proposes a thought experiment.

> I call this experiment "replaying life's tape." You press the rewind button and, making sure you thoroughly erase everything that actually happened, go back to any time and place in the past—say, to the seas of the Burgess Shale. Then let the tape run again and see if the repetition looks at all like the original. But suppose the experimental versions all yield sensible results strikingly different from the actual history of life? What could we then say about the predictability of self-conscious intelligence? or of mammals? or of vertebrates? or simply of multicellular persistence for 600 million difficult years? (1989, 48, 50)

He opts for the view that running life's tape again will almost always lead to disparate outcomes.

> I believe that . . . any replay of the tape would lead evolution down a pathway radically different from the road actually taken. But the consequent differences in outcome do not imply that evolution is senseless, and without meaningful pattern; the divergent route of the replay would be just as interpretable, just as explainable *after* the fact, as the actual world. But the diversity of actual itineraries does demonstrate that eventual results cannot be predicted from the outset. Each step proceeds for cause, but no finale can be specified at the start, and none would ever occur a second time in the same way, because any pathway proceeds through thousands of improbable stages. Alter any early event, ever so slightly and without apparent importance at the time, and evolution cascades into a radically different channel. (51)

Gould sees this as a paradigm for all the "historical sciences," which may hope to explain things after the fact but which are not equipped to make meaningful statements about future developments. It is unclear where this leaves his occasional (though sometimes vacillating [see Gould 2002]) identification with the Marxist world-view which, notwithstanding crude claims by some adherents of positive knowledge of the future, has, at its best, yielded useful projections of historical trends.

It is easy to see how Gould's reluctance to address in a critical fashion strictly genetic accounts of the origination and generation of biological form led him to the conclusion that biology is essentially arbitrary. Gene mutations change phenotypes (if at all) in directions that are random with regard to any adaptive advantage. Gene variants increase in frequency if they have such advantages relative to changed environments, but environmental change itself has no inherent directionality over the long term, although asteroids or other sudden changes in the external world can, of course, clear the way for mass extinction and replacement by survivors. In this picture there are, however, no directional biases arising from inherent properties of evolving organisms that guide their morphological change ("orthogenesis").

A world in which the types of organisms and the forms they assume are arbitrary, highly contingent, and destined never to reappear if the "tape" were run again, is quite different from one in which organismal forms are inevitable emanations of the natural world. What Stuart Kauffman asserts about the origin of life from nonliving matter applies equally well to the origin of multicellular life from single cells: "If life were bound to arise, not as an incalculably improbable accident, but as an expected fulfillment of the natural order, then we truly are at home in the universe" (Kauffman 1995, 20). The notion that there is a "naturalness" to the biological order is hardly an uncomplicated one (see Newman 1995; Lee 1999). It is the basis for varieties of radical, but also of spiritual, environmentalism, as noted above. The question, here, though, is the narrower one of the extent to which organisms are arbitrarily constructed, according to current scientific understanding.

Gould was typical among neo-Darwinists (which he clearly was, despite his many important expansions and elaborations of the paradigm) in taking the view that evolving organisms change in a purely opportunistic fashion which, despite acknowledged "constraints" that promote or disallow certain directions of change, yield forms that have little inevitability. The philosopher Hans Jonas characterized the neo-Darwinian paradigm in the following way.

> [T]he 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 . . . 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. (Jonas 1966, 51)

It is unsurprising that such a view of life could foster indifference to genetic alterations—"we" (i.e., the biotechnology companies, which have essentially unrestricted warrant to implement these technologies) are only doing what nature has done before us, "nature" here being implicitly understood to be Jonas's global generator of pathologies.

Matter Matters

Biology, in fact, is not arbitrary. Acknowledging this, however, requires an evolutionary theory more comprehensive than neo-Darwinism. Organismal forms are complex, but animal "body plans" are stereotypical, and essentially all of them (about thirty-five) appear to have arisen during the Cambrian explosion more than half a billion years ago. (Perhaps one additional body plan has emerged since that time.) As we have seen, early evolution of bodies and organs was driven, in part, by the profusion of morphologies that physical processes could generate acting on the "plastic" medium of living tissues prior to genetic rigidification. The result of this was a copious, but limited and stereotypical, range of forms. (Recall the waves and vortices in agitated water.) The forms of the earliest organisms (surprisingly, from the perspective of the neo-Darwinian orthodoxy of "random" evolution) are predictable from the physics of soft, chemically active materials: they are two- or three-layered, solid or hollow, segmented or unsegmented, crenellated or smooth, tissue masses (Newman and Müller 2000; Müller and Newman 2003). These forms, which originated more than 600 million years ago are, in fact, also those of the embryos of modern-day organisms.

The "evolution" of the chemical elements provides an analogy from still another natural system. This "evolution," of course, did not take place by natural selection, but by aggregation of subatomic particles as the universe cooled after the cosmic Big Bang. Where and when any specific element took form was based on various contingencies, but the physical laws that govern how many electrons, protons, and neutrons can coexist in a single entity and in what arrangement (i.e., quantum mechanics) determine that only 110 or so elemental atoms are possible, with no intermediate types. The emergence of the chemical elements (codified in the Periodic Table) is thus an authentic example of punctuated equilibrium. Insofar as organic evolution is similarly orthogenic at its early stages (as suggested above), it also conforms to this pattern.

Such an expanded view of evolutionary processes treats organisms as material entities rather than, as the genetic determinants would have it, mere expressions of their genetic content. It acknowledges as well that over time genetic processes can evolve in such a way as to insinuate themselves into the generation of characteristics, including aspects of behavior and individuality. But in Gould's thought, the determinants of patterns of behavior, particularly human behavior, are considered to be entirely distinct from the (genetic) determinants of outward form.

Gould's downplaying of the role of genetics in human individuality and behavior, coupled with the assumption that biological species identity is determined only by the genes, led him to a paradoxical blindness to the social dimensions of the prospect of human genetic manipulation and cloning. In an essay written shortly after the report of the cloning by scientists of a sheep, he wrote:

> We regard cloning, or the production of two (or more) genetically identical creatures, as eerie beyond all concept of natural order, at least for mammals and other complex animals. Dolly the sheep, the first mammal cloned from the adult cell of a single parent [*sic*] . . . has shocked the world beyond any merely intellectual reason—primarily by raising for so many people . . . our deepest worries about the distinctiveness of our own personhood . . . May I suggest . . . that all these fears are misplaced, for these questions have a clear answer, known to all human societies

> throughout history. Identical twins are clones . . . [y]et we know, and have always known, that human identical twins—whatever their quirky similarities in behavioral details, as well as physical appearance—become utterly distinct individuals. (Gould 1997, 15–6)

But what this comparison with twins ignores is that twins are genetically unprecedented individuals who happen to be born at the same time. A clone, in contrast, is a person produced from a genetic prototype (not a "parent" in the biological sense), something that has never been possible in previous human history. The social novelty of producing people asexually, the potential psychological impact on the clone of having been produced according to a preexisting template, questions about who bears responsibility for a laboratory product in human form with no well-defined parents (biologically or socially), and the motivations for cloning—commercial, eugenic, and otherwise—are all ignored by Gould in his zeal to minimize the role of genes in human individuality. In reality, however, the "genetic" aspect is the *only* similarity between twins and clones. Gould's dismissal of concerns about cloning simply because identical twins are genetic clones turns him into a genetic determinist *malgré lui*.

Conclusion

Gould was criticized throughout his career by those (e.g., Dawkins 1986; Dennett 1995; Pinker 2002) whom he called "Darwinian fundamentalists" (Gould 1997c) for not adhering closely enough to the neo-Darwinian orthodoxy. But while he could marshal a persuasive case for broadening neo-Darwinian theory to include constraining factors, so that phylogenetic change was not attributed solely to adaptive scenarios (Gould 2002), as we have seen he continued to hold on to orthodox notions of causation in ontogeny. This led him to over- and underestimate the role of genes and their interactions in the determination of form and behavior, respectively. A more nuanced view would treat both form and behavior as outcomes of an interplay between genetic and nongenetic determinants, with the relative contributions of each potentially changing over the course of evolution, and with genetic change often acting to stabilize, rather than originate, phenotypic change. Epigenetic origination of form (particularly early in multicellular evolution) and of behavior (retained to a high degree in the human and some other lineages) introduces an orthogenic component into ontogeny and phylogeny not provided by change solely at the genetic level (Newman and Müller 2000; Müller and Newman 2003).

But putting genes in their proper place as supporting players in the evolution of form and function (Newman 2002; Moss 2002) does not imply that altering genes in highly evolved organisms is innocuous. A bit player who forgets his lines can ruin a play, and a set of interacting genes, even with merely stabilizing functions can, if perturbed, derail the organism's development, composition, or functional integrity. This is the basis of the brief against genetic manipulation and the reason that the burden of proof on safety and (in the case of proposed application to humans) the social impact should reside with the proponents of the technology. But it is a view that neo-Darwinism, for which the natural state of things is the world of pathology laid out by Jonas, rather than the world of the familiar invoked by Kauffman, cannot accommodate. And indeed, few critics of genetic manipulation have come from within the neo-Darwinist ranks. In Gould's case, his failure to move beyond this determinist science in a fundamental way kept him, notwithstanding his scientific imagination and political progressivism, from assessing the pitfalls of genetic technology in a truly dialectical fashion.

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