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*Mary Frank,* Natural History, *1985*

# Revolutionary Biology

In science, it is said, the surest way to succeed is to attack the most respected thinker in your field. That rule seems to have been carried to its logical extreme over the past few years in the science of the history of life; a number of people have made impressive reputations by attacking none other than Charles Darwin. Of course, this senior colleague is not around to defend himself, but his intellectual offspring, the neo-Darwinians, continue fighting for his cause.

The resultant struggle pits the so-called gradualists—mainstream evolutionary thinkers, the sort found at almost any university—against the upstart punctuationists, such as the paleontologist Stephen Jay Gould, the geneticist Richard Lewontin, and Niles Eldredge, whose book on the subject, *Time Frames*, was published last year. The gradualists believe, as Darwin did, that nature rarely makes leaps—that the history of life is largely reducible to a series of micro-evolutionary steps. To account for major evolutionary changes, they point to the minor genetic changes seen in the wild and in the laboratory—the increased size of white rats over a dozen or so generations of selective breeding, for example. Such seemingly slight changes can, when accumulated over great lengths of time, amount to evolutionary overhauls and innovations—the advent, say, of new organs and appendages. The punctuationists, on the other hand, believe that evolution proceeds in fits and starts, that sudden and dramatic change occurs against the background of almost unimaginably long epochs of stasis. Indeed, Darwin was so far from getting the story right, they claim, that a new body of theory, outside the realm of current evolutionary biology, is in order.

Needless to say, the creationists, along with other species of antievolutionists, are enjoying the fight. They cheer with glee, expecting the challenger and the titleholder to bludgeon each other into insensibility, and thus nullify each other's influence. But no sooner do these outsiders appear than the two evolutionist enemies turn on them together. In that sense, it's a family fight. Like many family fights, though, it is often a bitter one.

Its outcome will determine how we see not only the history of life in general but the history of human life in particular. And the implications are more than abstract. If our species is in an epoch of stasis, then the current variation in the human world includes no examples of anything we might evolve into; the next step in the transformation of our species will be completely surprising and unpredictable, the outcome of a dramatic and sudden change. But if we are in the midst of a gradual and steady transformation, we are on the cutting edge of phylogenetic destiny; *we* are the raw materials of ongoing evolution—and, perhaps, can consciously shape that evolution.

Punctuationism, in its broadest contours, is scarcely new. At the turn of the nineteenth century, the French anatomist and paleontologist Georges Cuvier was documenting in unprecedented detail the fossil record of life. In the Paris Basin and elsewhere, he found remains of a striking number of extinct species: giant salamanders, reptiles with wings, elephants of a sort never seen—all, apparently, victims of natural disasters. The key forces in geology, he inferred, were such cataclysms as volcanic eruptions, earthquakes, drastic climatic changes, and major floods (the biblical one being the prototype); the face of the earth had been shaped by catastrophe. And this very much *needed* to be the case, for the sake of received doctrine; this model lent itself to the specter of repeated divine intervention.

Darwin, though born into Cuvier's world, fell under the influence of the British geologist Charles Lyell, who championed a different tradition, known as uniformitarianism. According to this view, the history of the earth could be explained by reference to processes still visibly at work. The erosion of a cliff by wind, the silting of sand into the bottom of a brook, the almost infinitely gradual destruction of rock by rain; these forces could be presumed to have operated always and could account for everything in the geological record.

Darwin embraced this outlook and carried it into the study of species. In the struggle for existence described by the British economist Thomas Malthus, and in the modification of form by plant and animal breeders, he saw processes that, if extended backward in time, could account for most transformations in the history of life. He cut from this cloth a uniformitarian biology, gave it the name natural selection, and never looked back.

Darwin did not know about genes, but these critical entities came to life scientifically in the early twentieth century, not long after his death. Being particulate, genes lent themselves to analysis by discrete, probabilistic mathematics. Models arose to account for both stability and change in populations, and these models, fused with data from genetics and paleontology, formed the basis of the "modern synthesis," which by the late 1940s was widely accepted. According to this view of evolution, the genes provide a continuous stream of raw material. Variation arising in the stream (resulting from either mutation or sexual recombination) is acted upon almost continuously by a selective process—namely, the different degrees of reproductive success that different genes enjoy. The result is gradual change in the basic characteristics of populations, with less adaptive traits disappearing as more adaptive traits appear. The neo-Darwinian mathematical laws of population genetics constituted a sophisticated, twentieth-century version of Darwinian uniformitarianism.

To be sure, the modern synthesis had its dissenters. Richard Goldschmidt, a German geneticist, maintained that single-gene mutations could have huge consequences, occasionally producing "hopeful monsters"—offspring that differed immensely from their progenitors and that might, with a little luck, be well suited to their environment. Such quantum leaps, he believed, accounted for much of evolution. But Goldschmidt's ideas received considerable ridicule (skeptical colleagues conjured up visions of hopeful monsters hopelessly searching for mates), and the modern synthesis remained essentially unchallenged.

So things stood until the 1970s, when trends in population genetics, zoogeography, and especially paleontology converged to bring the hopeful monster back to life. Eldredge and Gould, among others, began to take more seriously some well-known facts of the fossil record. Species, it appeared, were remarkably stable for most of their time on Earth; change, seemingly sudden, occupied less than one percent of their history. The poverty of the record no longer seemed sufficient to explain the discontinuities, and a theory of punctuated equilibria—aeons of stability interrupted by phases of rapid transformation—was opposed to the traditional phyletic gradualism.

Meanwhile, discoveries in molecular biology showed that an organism's genetic text is largely redundant, raising doubts about the importance of single-gene mutations: If many genes were blessed with copies that could substitute for them in a pinch, wouldn't many genetic alterations be thus nullified? At the same time, it seemed that *some* "minor" mutations must be hugely consequential; greatly differing species—ourselves and chimpanzees, for example—were shown to differ in only a small proportion of their DNA. This finding offered some hope for Goldschmidt's hopeful monster. Mutations in only a few genes could theoretically cause a major transformation by altering one key process in organismal development. Simply extending the period of cerebral growth might tremendously enhance the intelligence of chimpanzees and move them dramatically in the direction of humans.

What emerged from all this was a dichotomous view of genetic mutations: many were effectively meaningless, it appeared, but a few were immensely influential—so powerful that they might in one fell swoop alter the course of an entire species' evolution. This suggested that selection takes place not so much within species as among them; new species are thrown up more or less randomly, and they become the raw material for selective extinction.

Support from biology was only the beginning; another boost followed from an unexpected quarter. Luis and Walter Alvarez, with others at the University of California at Berkeley, reported in 1979 that in rocks found at the boundary between the Cretaceous and Tertiary periods (the time of the disappearance of the dinosaurs) there was an unusual deposit of the metallic element iridium, likely to have come from a meteorite. They theorized that a large asteroid had struck the earth, putting up a vast climate-altering cloud of dust and thus causing mass extinctions of species throughout the world.

Cuvier's catastrophism had gotten a breath of life. As for the creationists, they had a field day with this obvious opportunity for divine intervention, and, from their point of view, the best was yet to come. In 1984, a study by David Raup and John Sepkoski, of the University of Chicago, proposed that the Cretaceous mass extinction was not unique—and that, moreover, such events were periodic, occurring every twenty-six million years. The idea of regular, random cullings of millions of years' worth of evolution was a boon to the punctuationists, who used it as an especially strong plank in the coffin they were building for neo-Darwinism.

Of course, the periodicity required an explanation: Why would meteor showers, or any other catastrophe, occur so regularly? Here John Donne's "trepidation of the spheares," the notion of earthly fortunes guided by the stars, experienced something of a revival. Astronomers wasted no time in providing suggestive scenarios: a slow bobbing up and down of the solar system through the plane of the galactic disk; a tenth planet that periodically unsettles a comet cloud hovering on the edge of the solar system; a similar effect from a supposed companion star to the sun whose nuclear fires had never ignited. The astronomers called this cool star Nemesis, but Gould urged them to consider a more dignified name: Siva, after the Hindu god—a reference to the star's paradoxical role as a simultaneously destructive and creative force throughout the history of life.

Nemesis, alas, was the better name. The whole concept of extinction periodicity began to wobble under a steady shower of criticism. Every one of the proposed astronomical causes has now been shown on astrophysical grounds to be quite implausible. And statistical scrutiny has revealed that, though there are indeed distinct peaks in the historical rate of extinction, they have not occurred at precisely regular intervals.

Meanwhile, reports of the death of neo-Darwinism have turned out to be greatly exaggerated. First, as its proponents point out, it has been clumsily caricatured. No one, beginning with Darwin himself, has proposed that evolution occurs at an unvarying rate. The literary pillars of the modern synthesis—classic texts written by the geneticist Ronald A. Fisher, the paleontologist George Gaylord Simpson, and the zoologist Ernst Mayr—have acknowledged from the start the possibility of rapid bursts of evolution following long periods of stasis.

More important, what seems sudden to a geologist can seem an aeon to a geneticist. In the best-documented sequence of fossils supporting punctuationism—the excellent series of mollusks extracted from Lake Turkana, in northern Kenya, by Peter G. Williamson, of Harvard's Museum of Comparative Zoology—"revolutionary" change appears to have taken five thousand to fifty thousand years, an average of twenty thousand generations, if living relatives of the snails in question are any indication. As J. S. Jones, of University College, in London, has pointed out in the pages of *Nature*, this is the approximate equivalent of a thousand years in a fruit fly breeding experiment, six thousand in a mouse experiment, or forty thousand in a dog experiment—enough time in each case for radical morphological and behavioral evolution. (Witness the clear difference between, say, Chihuahuas and Saint Bernards, varieties that have diverged through artificial selection lasting only a few thousand years.) Williamson's African snails require nothing for their "sudden" speciation other than ordinary Darwinian selection.

In almost any given population of organisms, there is ample inherited variation to provide the basis for change that is fast enough to seem sudden to a fossil expert yet slow enough to seem gradual to a geneticist. Even such thresholds as the loss of limbs or an increase in the number of vertebrae can result from an accumulation of minor mutations. (In the case of vertebrae, for example, the middle section of a bone can gradually become thinner until it is, in effect, the bridge between two distinct, larger bones that now merit the label vertebrae.) What's more, long epochs of stasis in the fossil record may conceal evolution that is not reflected in fossilized parts.

And those epochs of stasis—probably many—that *are* real can be explained by "stabilizing selection" (as many punctuationists realize). Consider a population whose environment is changing rapidly. The changes may mean that a genetic ensemble dramatically different from the present one would be hugely more adaptive, yet the population may not evolve in that direction. Because of the incremental nature of evolutionary change, the population can reach this "ideal" ensemble only by passing through intermediate ensembles that are themselves maladaptive. So the organism is hemmed in at a less than optimal point on the adaptive landscape. Hence, there occur long periods of evolutionary stasis even amidst radical environmental change. All told, nothing in the evidence submitted by the punctuationists requires reaching outside the modern synthesis.

Which leaves us with the puzzle of why its demise has been so firmly pronounced. In the 1840s and 1850s, while Darwin was dawdling (it's really the right word) over the preparation of his great work on evolution, Karl Marx, under Georg Friedrich Hegel's influence, was developing a dialectical philosophy of social change. The beliefs of both Marx and Hegel can be viewed as a historical version of Cuvier's catastrophism; like Cuvier, they postulated long periods of relative calm punctuated by marked and rather rapid phases of change—political revolutions, in Marx's particular brand of dialectic. Some modern critics of neo-Darwinism—such as Lewontin and his Harvard colleague, Richard Levins—see a key role for Hegelian dialectics in biology; punctuated equilibria fit naturally into their worldview. So it is not surprising that they would consistently underestimate the flexibility and growth of the modern synthesis. Their contributions, when placed squarely outside the synthesis, seem more revolutionary, and more newsworthy, than they might if placed within it, where they belong.

There are other reasons why some scientists might find the theory of punctuated equilibria more congenial than that of gradualism. Gradualism raises the specter of eugenics: If we are subject to a continuing process of Darwinian evolution, hadn't we better take some charge of it lest it carry us in an undesirable direction? Certain answers to this question—those of the social Darwinists in the late nineteenth century, the American eugenicists of the early twentieth century, and the Nazis, for example—have produced among the most awful political outcomes of modern times. It would certainly be simpler to believe that there is no ongoing evolution to change the direction of; that all genetically based human variation in strength, intelligence, sexuality, disease susceptibility, parental behavior, body size, and so on, bears no relation to long-term evolution; that there is no sense in which some people are vestiges of the past and others prototypes of the future.

Unfortunately, such considerations cannot justify the choice of a theory of how evolution works. Besides, even if it were legitimate to infer *is* from *ought*, we couldn't do so in this case, because in a sense the theory of punctuated equilibria is tainted by association with eugenics, too. After all, even assuming the punctuationists are right about the nature of evolution, the question remains: Are we now in a period of stasis or in the midst of a revolution—a period of change that invites intervention no less than ongoing, gradual evolution? We don't know and, unless the human fossil record fills out considerably, we can't know. Further, given the rate of contemporary societal change, cultural transformations will almost surely determine the human fate before any biological ones—even the twenty-thousand-generation "revolutions" envisioned by the punctuationists—can take effect. If we create a culture that favors human decency, phylogeny will take care of itself. ●

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