Dinosaur In a Haystack

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DIH 1. Happy Thoughts on a Sunny Day in New York City

On May 10, 1994, an annular eclipse occurred in parts of New England. In an annular eclipse, the moon is farther away from the earth than usual, and a "ring" (Latin, annulus) of sunlight remains around the moon at totality. Gould describes his anger with himself in not being able to travel to New Hampshire to see the best view, due to a prior commitment in New York City that day. New York would be exposed to a partial solar eclipse, which is not nearly as dramatic. His frustration turned to joy, however, as he walked the streets of Manhattan during the phenomenon. While it never became truly dark, the character of the light did change quite noticeably. Further, every small aperture, from a hole in an awning to gaps between leaves on sidewalk trees, produced an image of the crescent sun via the "pinhole camera" effect. New Yorkers, legendary for always being in a hurry, stopped along the sidewalks in large numbers to marvel at these effects. One of the most diverse groups of humanity on the planet came together to share a fascination and a smile with dozens of strangers. Gould, always the humanist, quickly became more taken with the reactions of his fellow New Yorkers than he would have been with a better view of the eclipse – and he was a big fan of eclipses. The first thing that people must have in order to appreciate science, he argues, is a curiosity about the natural world. Based on this, he concludes, science at the level of the common man is alive and well in the United States. He is also pleased to note that there are events that do not involve tragedy that can bring us together, across all sociological lines. Happy thoughts!

DIH 2. Dousing Diminutive Dennis's Debate (or DDDD = 2000)

Gould had more interest than most in the transitions of centuries and millennia. He offers no formal justification for this interest: he is not a numerologist, nor is he a believer in near-term "end times." [I speculate that it may stem from his self-identified goal of continuing his rewarding but no doubt exhausting monthly essay-writing "streak" through the end of the millennia, but no farther.] He begins this essay with the answers to some basic questions. First, "millennium" has two n's because it is a contraction of the Latin words *mille* (thousand) and *annum* (years); *annum* has two n's, so millennium does also. Second, he points out that the term technically refers a thousand-year period of time, rather than the transition between such periods. Moreover, the traditional (biblical) use of the term is as the *beginning* of a thousand year reign of Christ, culminating in the end of the world, rather than the end the group of years that all posses the same digit in the thousand's place.

Gould then proceeds to discuss the question of whether the 20th century ends on December 31, 1999 or December 31, 2000. Phrased another way, is the year 2000 the last year of the 20th century, or the first year of the 21st century? Gould's quick answer is that it is actually arbitrary. He gives us the history of the problem's origin, which is due to a sixth-century Monk named Dionysius Exiguus (literally "Dennis the Short"). Dennis was assigned the task of developing a formal Christian chronology by the Pope. In addition to a few technical errors, such as getting the date of Christ's birth wrong with respect to the Roman calendar by a few years, he made one big one that is the source of the problem at hand. Rather than defining the eighth day after Christ was born as the beginning of year zero, he chose it to be the beginning of year one. (He did this for B.C. numbers as well – the previous year was 1 BC, not 0 BC, so in numerical terms the date changed from –1 to +1 just after Jesus's birth.) This has given no end of headaches to Roman scholars, astronomers, and others over the years. It also leaves us with the logical position that if a century is to contain one hundred years, then the end of the first century must be 100 and not 99. This problem ripples through directly to today, although Gould tells us that Europeans did not really start struggling with the issue of what year the century ended until the 1699 – 1701 transition. The "common sense" position is that the centuries change at the "odometer moment." Gould's autistic son presented him an excellent rationale for this view: the first century simply had ninety-nine years instead of one hundred. Why not? Gould argues that both views are equally valid, because it is a human construction, rather than an external reality, that is involved.

If there is no correct answer to this debate, then can we learn anything? Gould answers yes: we can learn something about societies of the past in the arguments they used in each case. He argues that the "elites" (e.g., the presidents of the Ivy League colleges) have traditionally sided with the logical position of 00-to-01 as the correct moment. The "man on the street" generally prefers the view of 99-to-00 for the transition; Gould actually references the song "1999" by Prince in this category, in addition to references from earlier centuries.

DIH 3. The Celestial Mechanic and the Earthly Naturalist

This essay discusses the concept of determinism in nature through the perspectives of two great 18th century French scientists, Georges Buffon (1707-1778) and Pierre-Simon Laplace (1749-1827). Gould begins with Laplace, who survived and even thrived during the French Revolution, and contributed greatly to several fields of science and mathematics. One of his great accomplishments was to use Newtonian mechanics to solve a set of challenging problems in planetary and lunar orbits. (Laplace coined the term "celestial mechanics.") Careful analysis had shown that the influences of the planets on each other led to small but apparently accumulating perturbations in their orbits. If these continued to accumulate, the solar system would eventually become unstable. Additionally, these perturbations also implied that the solar system either could not be very old, or that some external force (perhaps God himself, according to Newton) must be employed from time to time to maintain stability. Laplace proved that these perturbations were actually oscillatory, rather than cumulative. No external forces were needed to maintain stability; the solar system was, therefore, deterministic in the absence of external events. He went further. He made the definitive argument, widely held until the flowering of chaos theory in the 1980's, that everything on earth was just as deterministic; there were just so very many more objects. In principle, Laplace argued, if we knew the exact position and velocity of every particle on earth at one instant, we could determine all future configurations as precisely as we could predict eclipses. (He recognized that such complete knowledge would never be obtained, and did some brilliant work in the young field of probability with this understanding in mind. Nonetheless, he remained convinced that the entire universe was fundamentally deterministic.)

Gould wrote this essay after acquiring a copy of Laplace's major work on astronomy for the public at large, *Exposition of the System of the World* (1796). This huge work is most famous today for a few pages at the end, which introduce the so-called nebular hypothesis. In these pages, Laplace postulated that the solar system was formed from a cloud ("nebula") of gas and dust that collapsed under its own gravity. This is interesting for two reasons. The first is that it is recognized as essentially true today. The second, and the basis for Gould's essay, is that this represents a historical, one-time-only event, the sort of thing that Laplace detested. Still, the solar system did presumably have to form somehow, and this approach led to a stable configuration. It addressed many observed facts: the planets all travel in the same direction about the sun; these orbits all lie close to the same plane; the planets all rotate in the same direction as they travel about the sun (he was unaware of Uranus, which does not); and all the moons rotate in the same direction as the planets. He developed this theory partially in response to the only other Newtonian-based model for the formation of the solar system in existence at the time, which belonged to Georges Buffon. In 1749, Buffon had proposed that a comet had struck the sun, and had ejected a large amount of mass that condensed to form the planets. This model could account for the first two observed facts discussed above, but Laplace noted that it predicts that some planets and moons should be retrograde (backwards-spinning or backwards-orbiting).

For his entire career, with this one famous exception, Laplace remained tuned to problems with closed, deterministic solutions; those where unique historical events that permanently changed the system played no role. Buffon, on the other hand, moved away from the deterministic realm of celestial mechanics to become a naturalist (hence the essay's title), which he considered to be primarily driven by the quirks of history. One of his major works, *History and Theory of Earth* (1749) [and the first volume of his 44-volume *Natural History* discussed in LSM 4], was expanded and published late in his life as *Epochs of Earth* (1778). It discusses seven directional periods that the earth has experienced. The first epoch is formation, via comet impact with the sun. Others include formation of the geology and life, culminating with humans. Laplace's works stay away from inference and anecdotal data wherever possible; Buffon's is filled with it. Laplace's universe is essentially independent of time; Buffon's is a collection of narrative stories, with beginnings, middles, and ends. Both forms are used and useful in scientific writing, and in Western thinking generally. [Gould's 1987 book Time's Arrow, Time's Cycle discusses other examples of these metaphors.] While acknowledging the importance of both, Gould adds that, as an evolutionist, he is more sympathetic to the narrative camp. He quotes the last paragraph of Darwin's *Origin of Species*, which also refers to both perspectives. It reads:

> There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

DIH 4. The Late Birth of a Flat Earth

As the title suggests, this essay refutes as myth the widely held view that most scholars after the fall of Rome and before the Renaissance believed that the earth was flat. Gould draws on the book *Inventing the Flat Earth* by historian J.B. Russell (1991) for the data.

There were two minor scholars whose work survives that argued for a flat earth between the years 250 AD and 450 AD. However, all of the giants – Venerable Bede, Roger Bacon, Thomas Aquinas, and others – all clearly assumed a spherical earth. Yes, Gould states, Columbus had to argue with the clerics of Ferdinand and Isabella, but the argument was not about whether he would sail off the edge of the world, as the tale is commonly told. It was over the actual size of the Earth, and thus the distance from Spain to Cathay (China) and India, which the clerics argued (correctly!) that Columbus had grossly underestimated. [Columbus died believing that he had reached Asia.]

So how and when did the idea that medieval scholars believed that the world was flat take hold? Russell argues that the first generalized claims to this effect took place in the early 19^{th} century, and became widespread in textbooks between 1860 and 1890. One of the main sources was John W. Draper, who wrote a best-selling book called *History of the Conflict Between Science and Religion*, first published in 1874. The other major source was Andrew Dickson White, co-founder of Cornell University and author of the book *History of the Warfare of Science with the Theology in Christendom* in 1896. Both wrote that the forces of knowledge and truth, including science, had been fighting against the dogmatism of Christian theocrats for thousands of years, and both used the (essentially false) flat earth argument as an example. The timing of these books is correlated with the response of western culture to Darwin's book on the theory of evolution (*Origin of Species*, 1859), in which heated debates between the two communities really did occur. Russell and Gould agree that this is not a coincidence.

Gould notes that for most of the past few millennia, science and religion have worked together far more than they have fought. The Church, for example, traditionally sponsored work in astronomy, in order to support such tasks as determining the correct date for Easter. Gould makes the point here and elsewhere [most notably LMC 14] that science and religion should have no inherent conflict because they work in different regimes: science in determining the nature of the universe, and religion in establishing our ethics and morals. Yes, he acknowledges, there have been historical turf wars, but for the most part the problem has been dogmatism, which has been and continues to be a problem for both science and religion.

DIH 5. The Monster's Human Nature

Gould discusses Mary Shelly's 1818 novel *Frankenstein*, and the moral lessons that have been falsely attributed to it starting with the Hollywood movie of the same name (1931). In the Hollywood version, the monster is evil because it was made with an "abnormal, criminal" brain. The implication is that nature, not nurture, is completely responsible for who we are; this was a commonly held view by the intellectuals at the time the movie was made [see ESD 28, for example]. The movie version also explicitly states that the story was a moral tale, warning against the use of science and technology by man to play God. The actual novel, however, differs completely in this respect. Mary Shelly's creative circle was strongly rationalist, and several members were atheists. The novel does not present the moral argument that is attributed to it by the movie. The monster himself is not born evil, but rather unformed: he has the capability for both evil and goodness, and is both intelligent and well spoken. He is, however, frighteningly ugly. The creator, Dr. Frankenstein, reacts with horror and disgust, and forces the creature to live as an outcast; it is this behavior, in the novel, that leads the monster to evil. Both nature and nurture play a part here, Gould states: the lack of nurturing by Victor Frankenstein and everyone else, and the fundamental nature of the rest of us that are inherently repulsed by gross deformities (which we can overcome). However, he cautions, we should not fall into the trap of assigning percentages to these two factors; the final product is a result of a much more complicated interaction between the two.

Gould also notes that the novel's preface begins with a reference to "the thoughts of Dr Darwin." This is not Charles Darwin, who was less than ten years old at the time, but rather to his grandfather, Erasmus Darwin. Erasmus had argued that the physical "substance" of electricity, rather than a non-physical or spiritual force, might be the essence of what we call life. Shelly drew on this as the mechanism for bringing the creature to life via a channeled lightening strike.

DIH 6. The Tooth and Claw Centennial

"Nature, red in tooth and claw" is a famous line from the also-famous (and very long) Victorian poem *In Memoriam*. Alfred, Lord Tennyson published it in 1850, some seventeen years after the death at age 22 of his dear friend Arthur Hallam. The phrase is widely quoted by evolutionary biologists and other scientists in support of Darwin's theory of evolution, although *Origin of Species* was not published until 1859. When Tennyson died, the November 1893 edition of the widely read British journal *The Nineteenth Century* published a series of tributes to him. The very first one is by the famous naturalist and Darwinian supporter, Thomas Henry Huxley. Gould takes the hundredth anniversary of Tennyson's death and Huxley's tribute as an opportunity to read the poem all the way through, and to offer his thoughts on the phrase, the poem, and the man.

Tennyson had studied science, among other things, at Trinity College at Cambridge, and made a lifelong effort to keep up with it – something rather unusual for a poet. Many of his poems reflect his understanding and appreciation of the sciences. Many of the verses in *In Memoriam* are assumed today to represent his Darwinian view of biology (which some argued was "in the air" even before Darwin published), as well as Lyell's geological views on steady, uniform processes. This is not the case, Gould tells us, based on his own reading and several professional books and reviews; he quotes extensively from the poem. Tennyson's work actually reflects the incorrect but mainstream scientific views of the day. Specifically, it reflects the view that natural history involved a series of creations, each with increasing excellence, mixed with periods of catastrophic extinction [see ELP 31]. The actual "tooth and claw" line is a reference to natural theology [HTHT 2, ELP 9], another discarded paradigm. (Natural theology argues, in part, that since God is good, all suffering in the world – including the loss of a loved one – must serve a purpose.) Some have read this poem as profoundly religious, others less so. Gould's view is that the poem simply reflects the psychology of one man's grieving over many years. Tennyson draws on science (among other things) for comfort, but in the end finds none; Gould has argued elsewhere that there is none to find [see LMC 14].

DIH 7. Sweetness and Light

The sixteenth and seventeenth centuries in Europe, which included the Renaissance and Newton, were an intellectual watershed in the West. Before this, the view was that modern people were inferior to their ancestors. During and after this period, the concept of progress took root, and the culture came to reflect the view that moderns could re-achieve, and perhaps even surpass, the wisdom and power of the Greeks and Romans. Individuals and examples of this extended transition period have filled many of Gould's essays. Here, he discusses some of the literary expressions and metaphors associated with the period as a whole.

Gould uses two main source documents for this essay: *On the Shoulders of Giants* (1965) by sociologist of science Robert K. Merton, and the writings of a famous satirist of the period, Jonathan Swift. The title of Merton's book is an example of how some intellectuals of the period (not just Newton, who is associated with the quote) approached the problem: "Yes, the ancients were giants; but at the same time, we do see farther than they do." Merton credits Francis Bacon, a decided "modern" in the battle between which generation was smarter, with "Bacon's paradox," although he does trace it back thousands of years. The paradox involves the concept of *ancient*, with the implied property of wisdom. On the one hand, the Greeks and Romans were born long before Bacon and us, so they are old while "we" are young. On the other hand, these ancestors functioned when the world itself was younger; so actually the more ancient ones are those who were born later. Also in the mix is the argument that Aristotle (as an example) was actually a young man when he made many of his key arguments. Gould offers no resolution to this paradox, and simply notes its use in the intellectual struggle between reverence for the wisdom of ancestors and the notion of progress.

Bacon was a modernist; on the other side of the divide was Jonathan Swift, known today largely for *Gulliver's Travels*. His works were primarily satire of the times in which he lived, and are difficult to follow today because there are so many subtle references to specific people and events of those times. In 1704, he wrote a satire that is known today as "the battle of the books"; this refers to a war fantasy between books of "ancient" and modern (that is, 17th century) origin filed together on a library shelf. In the introduction to this work, Swift presents the famous (in literary circles) metaphor of the spider and the bee. The spider represents the moderns, and has constructed a mathematically sophisticated but fragile web out of his own being. The bee, representing the ancients, does not create a web but rather flits about nature collecting nectar. The spider charges that the bee creates nothing, only forages among the ideas of others. [This may refer to contemporary scholars of the ancients, rather than to the ancients themselves.] The bee retorts that the spider may indeed be producing original material, but much of it is toxic and most will end up as useless cobwebs. Further, the bee goes on, we fill our living spaces with honey and wax, which give mankind the gifts of sweetness and light (the latter via candles, and hence the essay's title), as opposed to dead flies and excrement.

Lastly, the bee takes for its domain a wide range of beautiful flowers, while the spider focuses almost entirely on the very small area of its web.

Gould is sympathetic to the bee's argument, in part because of the truth that yesterday's moderns are, if fortunate, tomorrow's ancients. He advocates a golden mean between the two, but expresses his disappointment that he cannot draw on "classic lines" from literature when teaching his classes, due to the fact that they are no longer commonly known.

DIH 8. In the Mind of the Beholder

This essay draws on three hot stories in the field of paleontology from 1993, the year that it was written. By the phrase "hot story," Gould is referring to items that appeared in such mainstream publications as the science section of the New York Times. What made each of them newsworthy is that so many scientists found the discoveries surprising; yet, in all three cases, Gould himself did not (although he did find them fascinating). Specifically, the three stories involve the duration of the Cambrian explosion, the dependence (or lack thereof) of insect diversity with flowering plants, and the evolution of our own species, *Homo sapiens*, from our presumed ancestor species, *Homo erectus*.

His stated motivation for writing this essay is to reiterate his theme that science is not a purely objective enterprise; if it were, all participants would see the world in the same way, and all would be surprised (or not surprised) together. The differences in individual reaction, he states, must be attributable to each scientist working from within his own worldview. This is not to say, he cautions, that there is no common external reality, or that it is "ok" for an educated person in today's world to believe that, for example, the sun goes around the earth. Nonetheless, a worldview is in the mind of the beholder, just as beauty (to a less constrained extent, of course) is in the eye of the beholder. [Unofficially, it is readily apparent that there is a degree of gloating going on, as each of these stories is consistent with *his* worldview, which includes punctuated equilibrium and contingency as dominant themes, as opposed to gradualism and progressive inevitability.]

The first story involves the discovery and dating of a volcanic ash layer in some beautifully preserved strata in Siberia from the very beginning of the Cambrian period, about 14 million years before the start of the Cambrian explosion [ELP 15] itself. (Volcanic ash can be accurately dated from the time it solidified via the radioactive decay of the naturally-occurring uranium in contains in trace amounts.) The end of the Cambrian explosion had been previously dated at about 530 million years, but the beginning was undetermined, and the standard estimate was some 30 million years earlier. The new data indicates that the duration of the explosion was only 5 or 6 million years long – 10 at the very most. The theme of much of the community, according to the press, was "intense surprise"; macroevolutionary change on this scale is supposed to be much slower than this. Gould, of course – opponent of universal gradualism and co-originator of the theory of punctuated equilibrium (PE) – had long suspected the relative abruptness of this event.

The second news story involves the incredible diversity of arthropods, and specifically insects, relative to all other types of animal life. Many reasons for this remarkable diversity have been proposed, and Gould suggests that there are likely degrees of truth in most of them. One of the dominant arguments, however, is that insects are so diverse because flowering plants are as well; the two groups evolved (and continue to evolve) together, in a process called "co-evolution." (Darwin wrote an entire book discussing the correlation of insect design to the enormous variety of orchids.) This certainly seems plausible, but is there *evidence* that insects – which originated in the Devonian period, some 325 million years ago – showed a marked increase in diversity when flowering plants (angiosperms) first appeared about 140 million years ago, or when the latter underwent own fantastic increase in diversity about 100 million years ago? Two of Gould's colleagues, Sepkoski (also his former graduate student) and Labandeira, carefully researched all scientific publications on fossil insects (a large fraction in Russian and Chinese journals), something that had apparently never been done before. What they found was that the number of insect families (the taxonomic genus above genus) quickly rose to almost modern levels by the beginning of the Carboniferous period (just after the Devonian). Although they later suffered a great setback during the great Permian extinction, as did almost all forms of life, they quickly diversified again afterwards. Further, there seems to be no correlation – at least at the level of family – between insect diversity and the coming of the flowering plants.

This was surprising to many scientists, as it went against Darwin's paradigm of the "tangled bank," his metaphor that argued that a change in one species or group ripples through the entire ecosystem, driving evolution. Gould had come to doubt this view, writing a professional paper in 1980 [*Clams and brachiopods – ships that pass in the night*, also discussed in TFS 30], arguing instead that organisms, while shaped by natural selection, were not really optimized by it (per PE again), and therefore did not always compete as intensely with each other as Darwin believed. Rather, he had argued, a random element – contingency – played a larger role in the formation of organisms than others had appreciated. [Gould's view is not that different groups do not interact at all; ESD 28, for example, discusses how many families of animals were wiped out when the Isthmus of Panama formed, allowing the intermixing of the formerly isolated North and South American fauna. (This event also led to the production of many new families as well.) He is instead arguing that the interaction between groups is not as large as was commonly believed.] In an epilogue, written two years later when this essay was being incorporated into his seventh collection, he notes that evidence for bees – today, universally associated with flowers – appear almost 100 million years before the appearance of angiosperms. The evidence is in the form of bee or wasp nests preserved inside petrified logs. Again, this was surprising to others, but "merely" fascinating to him.

The third story involves an ongoing debate on the origins of modern man, *Homo sapiens*. All professionals in the field agree that another, smaller-brained bipedal hominid species, *Homo erectus*, expanded its range beyond Africa about one million years ago [see TFS 12]. (Gould expands this to 1.6 million years ago, based on more recent discoveries, in the epilogue; also see LMC 10.) The community also universally supports the view that

H. erectus gave rise to *H. sapiens*. In a hypothesis called multiregionalism, some scientists argue that the dispersed *H. erectus* populations on different continents ("Java Man," "Peking Man," and others) evolved simultaneously but independently towards *H. sapiens*, albeit with some degree of interbreeding. Others argue for the "out-of-Africa" hypothesis, which proposes that *H. sapiens* evolved only once, in Africa, and then later moved to other continents in a second hominid wave about 100,000 years ago, eventually displacing the established *H. erectus* populations. Gould states that he is conceptually predisposed to support the out-of-Africa model, on the grounds that most new species arise in a localized region and then spread out. He offers rats and pigeons as examples, noting that no one suggests these species evolved independently, world-wide, from multiple ancestral populations. (The latter model is also, he notes, more consistent with PE.) However, the press, apparently representing the dominant scientific outlook (at that time), considered multiregionalism to be the "established" theory, and out-of-Africa to be the challenger. He speculates that this, too, reflects a "desire" on the part of many scientists to see human evolution, and in particular the development of our large brains, as specifically favored by natural selection (and thus, to a degree, inevitable), while he does not.

The news story from 1993 that he references was actually a blow to the out-of-Africa model; a significant flaw was discovered in an important computer model that was investigating the location of origin of the "mitochondrial Eve." (DNA from mitochondria, small organelles within all animal cells, is passed intact – other than mutations – from the mother to all offspring; the father contributes no part. Thus, it is far easier to trace human lineages using this DNA than that found in the nucleus.) "Molecular clock" studies of mitochondrial DNA had shown that the separation of *H. sapiens* from its ancestral stock occurred about 250,000 years ago, in Africa. The flaw involved the location (Africa), not the timing or the overall process. The error only allows that the method cannot determine where the event occurred, not that it happened somewhere other than in Africa; Gould notes that there is still a large and growing amount of evidence that Africa was, indeed, the source. [He elaborates on this in LMC 10.] In the epilogue, he adds that new findings on part of the Y-chromosome (passed only from father to son) indicate that our speciation occurred around 270,000 years ago; this compares well with the mitochondrial DNA evidence. The paper also estimates that this original population was comprised of about 7500 males.

DIH 9. Of Tongue Worms, Velvet Worms, and Water Bears

The Cambrian explosion has long been identified as a major event in natural history, and the focus of an important debate in Gould's career. The fossil record shows that all major extant phyla (loosely defined as those that include at least a few hundred living species) had their origins in this relatively brief period some 530 million years ago. The only exception is the Bryozoa, of which no fossil evidence to date has emerged to verify their existence prior the start of the next geologic period. The faction that Gould belonged to therefore argued that, with only a few possible exceptions, *no new phyla have appeared since the Cambrian explosion*. He writes:

> One might argue, without great exaggeration, that 530 million years of subsequent evolution has produced no more than a set of variations upon the themes established during this initial explosion – although some of these little fillips, including human consciousness and insect flight, had quite an impact upon the history of life!

Many scientists, including Darwin himself, did not and do not share Gould's view that the Cambrian explosion was distinct from "business as usual," and thus in need of its own explanation. Darwin argued that the apparent suddenness was probably an artifact of an imperfect fossil record. As time went by, additional evidence demolished this argument; however, those whose worldviews prefer a more stately and progressive view of evolution [Gould uses these sorts of terms regularly] fell back on other lines of reasoning to imply that the explosion was not a completely unique event. One tack uses the argument that the "explosion" still required 30-40 million years, and thus likely involves only a speeded-up version of an ongoing process. [Gould counters that the evidence discussed in the previous essay undermines this view, by limiting the duration of the event to "only" five million years.] Another, perhaps more important line of reasoning is that many of the so-called "minor phyla" – those with only a small number of living species – arose significantly later. If upheld, this view would establish that phylum-creation is an ongoing process, rather than a unique event.

Three phyla in particular are commonly referenced by supporters of this view as having relatively recent origins: Pentastomida (tongue worms), Onychophora (velvet worms), and Tardigrada (water bears). All three of these groups bear many important similarities to arthropods. Further, if one accepts the "increasing cone of diversity" paradigm in natural history [which Gould does not; see ELP 15], then the small number of living species in each of these phyla (less than one hundred in all three cases) is consistent with the notion that these phyla are all young, and thus have not had as much time to diversify as the more ancient phyla. This is plausible, Gould concedes, but is it true? This essay discusses evidence, some published in the year he wrote it, that all three phyla can now be dated back to the Cambrian period.

Velvet worms (onychophorans) superficially resemble caterpillars, and the 80 or so living species all live on land, which was uninhabited during the Cambrian period. The discovery in the early 20th century of one organism from the middle-Cambrian Burgess shale, *Aysheaia*, appeared to be in this phylum, but there was room for doubt. More recently, however, several other species of Onychophoran fossils have appeared in Cambrian strata, including the famous *Hallucigenia* [ELP 24]. While undoubtedly related to arthropods, it is now generally accepted that the branching between these groups took place long ago, and that this group does not represent a good example for the process of ongoing phylum creation.

Tardigrada, or water bears, are sub-millimeter-sized animals, most of which live in films of water on mosses and other vegetation. They are renowned for being able to go dormant in the absence of water and survive for decades in hostile conditions, then reanimate themselves when the water returns. They also resemble arthropods in several key ways. Prior to 1994, no fossil Tardigrada from any period had ever been found; but at a conference in that year, German paleontologists Walossek and Müller reported that they had made just such a discovery in pristine Cambrian strata in Siberia. Water bears are therefore also very likely products of the Cambrian explosion.

The third group, the Pentastomida or tongue worms, are all parasites, and almost all live in terrestrial vertebrates – which did not exist during the Cambrian period. Further, some genetic evidence had been reported that suggested that this phylum had diverged from crustaceans (one of the main groups of arthropods) between 350 and 225 million years ago, well after the Cambrian explosion. Finding fossil evidence of Pentastomida to contradict this evidence would seem impossible, for two reasons. First, they are all completely soft-bodied. Secondly, the degeneration of unneeded parts in parasites makes tracing their ancestry especially difficult; how would you recognize the fossil of a free-living Pentastomida if you found one? Yet this is exactly what happened – by the same group that found the fossil Tardigrada. This time, the data came from a Cambrian bed in Sweden, but with an unusual method of preservation – phosphatization [discussed again in LSM 21]. This fossilization process only works on very small organisms, by forming a hollow phosphate-based shell around soft-bodied creatures. This shell preserves exquisite detail, and can be exposed by dissolving the material in a weak acid to remove the background material. The details clearly indicate many features that are unique to living Pentastomida. What about the genetic evidence? Gould quotes from one of the papers, showing that the authors (in good faith) appear to have misinterpreted their data. Tongue worms appear to date back to the Cambrian explosion as well.

DIH 10. Cordelia's Dilemma

"Publication bias" was, when Gould wrote this, a small area of study about and within the field of science. Gould came to appreciate this fact when he stumbled on a 1988 paper written by Colin B. Begg and Jesse A. Berlin entitled "Publication bias: a problem in interpreting medical data." The thesis, as their title indicates, is that studies of drugs that yield significant medical effects are submitted, and accepted, more often for publication than studies of equal quality that do not show such effects. This is not, Gould tells us, an act of dishonesty, but merely a reflection of human nature. As humans, we like stories, and "nothing happened" makes a dull story. As such, publication bias appears in all fields of science, not only medicine. Gould notes that he first ran across this phenomenon while writing his book *The Mismeasure of Man*, which was on the subject of attempts by scientists to quantify intelligence and behavior, but often resulted in justifying racism and sexism.

Although a study showing that a drug is safe but not effective for a particular ailment may not be interesting (and therefore less likely to be published), at least the negative result is recognized. There is another kind of publication bias, Gould states: one in which the negative result is *not* recognized, but instead attributed to low-quality data, poor resolution, or a bad experimental design; *no* result, rather than a negative result. Gould offers a name for this phenomenon: "Cordelia's dilemma." Cordelia is the third daughter of King Lear in Shakespeare's play of that name. She is pressured by the king to join her two sisters in praising him excessively. As the only one of his daughters who truly loves him, she feels her only two options are to succumb and lie, or to remain faithful – by remaining silent. She chooses the latter, which the king misconstrues; rather than interpreting her silence as an act of faith and love, he takes it for what it *appears* to be: nothing. By analogy, Gould argues, Cordelia's dilemma in science is to interpret "no change over time" as "no data."

Gould, of course, has a personal stake in this issue. Stasis, one of the key concepts of punctuated equilibrium, involves the identification of "no change" as, itself, important; in the famous phrase from the first paper he and Niles Eldredge wrote on PE in 1972, "stasis is data." Gould describes how his graduate advisor used certain statistical techniques to identify changes in 50 species of Devonian brachiopods over an extended period; not finding any, he did not publish, and in fact changed fields! In the operating paradigm of his advisor and almost everyone else in the profession, evolution is a continuous, ongoing process. Therefore, the absence of change (Cordelia's silence) was not an indication of something important, but simply "nothing." Gould tells us that, whether punctuated equilibrium holds up in the long run or not, he takes pride in motivating the community to look for stasis, and to recognize its theoretical importance.

Gould was motivated to write this essay, he tells us, by the contemporary (1992) publication of a study of stasis at the next higher taxonomic level – that of genus – by Ann Budd and Anthony Coates. PE refers only to the origin and continuity of species. When most or all of the species in that genus evolve in a similar direction, whether by abrupt punctuations or gradual and continuous phyletic gradualism, the community refers to this as a *trend*. Gould states that there are many trends in the fossil record, such as the increasing brain size of hominids over the past few million years [see ESD 22] and reduction in the number of toes on horses. [He notes in BFB 11 that the horse is actually a bad example. Also, in their original 1972 paper, Gould and Eldredge argue that trends in natural history can be explained in terms of both phyletic gradualism and punctuated equilibrium.] In an analogy to Cordelia's dilemma at the species level, a commonly unrecognized assumption is that all trends are *directional*; that is, gradual but continuous change toward "something." Budd and Coates examined species of the coral genus *Montastraea* (still important today) over the 80 million year span of the Cretaceous period. What they found was that, while species came and went, the attributes of the genus as a whole appeared to oscillate back and forth between certain limits; after 80 million years, species looked pretty much the same as they did at the beginning. Budd and Coates refer to this as "non-progressive evolution." Gould is delighted, primarily on the grounds that twenty years earlier this phenomenon would almost certainly not have been reported.

He is careful not to claim that there are no trends in most of natural history. Rather, it is that they are not as universal as was commonly believed; this should be recognized, he claims, if for no other reason than to better appreciate the importance of the "real" trends. [However, his 1996 book *Full House* – written a few years later – argues that progressive events and trends are actually quite rare in natural history.]

DIH 11. Lucy on the Earth in Stasis

A major portion of Gould's professional career was built upon the quasi-revolutionary view he developed regarding the nature of evolutionary change. He begins this essay by reiterating his view that one of the ways the human mind filters information is by trying to dichotomize it, sometimes inappropriately. Some of the most common divides we place on nature are "different versus same," "cumulative change versus cyclical change" [the subject of his 1987 book *Time's Arrow, Time's Cycle*], and – of special importance in this case – "change versus stability." For centuries in the west, during the Age of Kings, the prevailing view of the world was that it was static – or at least that it ought to be. In the field of what would become biology, creationism fit well into this larger paradigm held by society at large (or at least the ruling class, who either had the resources to study nature themselves, or could sponsor others). With the coming of the Enlightenment and then the industrial revolution, "change" was in the air, and it was perceived by the leading nations – in particular, England – as *progress*, and an inherently good thing. Gould often noted that Darwin and his argument for evolution (if not his mechanism of natural selection) benefited greatly from this social and political outlook.

However, Darwin's view of evolution (and, Gould argues, that of most Victorians) was one of gradual, steady change. But what if the pace of *change itself* changes? Gould argues that evolutionary change does not occur continuously, at least not all of the time, but rather tends to proceed in fits and starts. [An analogy from the field of physics is that, if creationism is an object at rest, and Darwin's view of evolution is motion at a constant velocity, then punctuated equilibrium is an evolutionary process that incorporates *acceleration*. Here, this term is used to include slowing down as well as speeding up, and specifically includes starting and stopping.] Much of the resistance that his model of evolutionary change has faced is not due to the fossil record (which speaks quite clearly on the subject, he states), but rather with the psychological barrier of sudden versus gradual transitions. He writes that his view does include constant rates of change, but he believes that "punctuational change writes nature's primary signature . . . ."

The inspiration for this essay came from the 1994 publication of the discovery of more fossils of *Australopithecus afarensis*, the species that includes the famous Lucy skeleton [TPT 11]. (The specimen takes its name, and this essay takes its title, from the Beatles song "Lucy in the Sky with Diamonds." The album it came from was a favorite at discoverer Donald Johanson's field site in Ethiopia in 1978.) The new finds strongly suggest that Lucy's species exhibited virtually no evolutionary change for at least 900,000 years, from 3.9 to 3.0 million years ago. Gould was "delighted" that the 1994 team (which included Johanson) interpreted the aggregate collection as an example of stasis. Most popular accounts, however (with a few noted exceptions), expressed *surprise* at this absence of change. The underlying message is that a million years ought to have been enough time for the species to have made at least some "progress." This conclusion, he continues, is surely based on the unarticulated (and almost certainly unrecognized) assumption that evolutionary change is continuous.

This perception also appears in two of the most frequent questions Gould is asked during his public presentations. The first is, "Where is human evolution going in the future?" The quick answer is, effectively, nowhere at the moment; the question falsely presumes that evolution is a gradual but continuous process. The second, related to the first, raises the issue of the role of civilization on human evolution. Specifically, does the practice of caring for the "weak" in society short-circuit the natural selection process, and therefore lead to the stagnation of our evolutionary progress? It does not, he replies. Modern humans appear to be in stasis; we are the same species we were ten thousand years ago, at the dawn of civilization, and for a hundred thousand or more years before that. He writes: "As the only evolutionary consequence I can imagine, such a cultural 'softening' of natural selection may slightly boost our genetic variability as a species, but I cannot regard such an increase as anything but neutral or favorable."

The fossil record [as of 1994] suggests that, during this 0.9 million year period, *A. afarensis* may have been the only living species of hominid. The species seems to disappear not long after this, but over the next several hundred thousand years, approximately seven new *Australopithecus* and *Homo* species abruptly appear. Gould references the "turnover-pulse hypothesis" of his colleague, Elisabeth Vrba, which postulates that a significant change in the environment – perhaps the initial formation of high-latitude glaciers – may be connected with this period of multiple punctuations. [He returns to the hominid fossil record in LMC 10.]

DIH 12. Dinosaur in a Haystack

In 1980, physical evidence was discovered that a large asteroid or comet had collided with the earth some 65 million years ago [HTHT 25]. The initial evidence came in the form of a thin layer of clay that was rich in iridium (rare on earth's surface but more plentiful elsewhere in the solar system). This layer of clay occurs at the boundary between the Cretaceous and Tertiary periods (abbreviated as the K-T boundary, with the "K" representing the Cretaceous period). This boundary also marks a major change in the fossil record, including the disappearance of the dinosaurs and many other plants and animals, on land and in the seas, as well. The discoverers of the iridium in this boundary layer, the father-son team of Luis and Walter Alvarez, immediately claimed that the timing was not a coincidence; that the impact was, in some way, *responsible* for the mass extinction. This turned out to be a very controversial claim; for 150 years, geologists and paleontologists had accepted that "apparent" mass extinctions in the fossil record were just that – false signatures of much more gradual, multi-million-year die-offs.

Gould recapitulates his argument that the originator of this uniformitarian perspective was the great Charles Lyell, who is often credited with turning geology into a science in the first half of the 19th century. As Gould discusses in ESD 18 and in the following essay, Lyell was confronted with a large quantity of "theories of the earth," all of which postulated one or more catastrophic events to explain the modern construction of the planet's surface. He and his colleagues responded by banishing all such violent cataclysms as both unnecessary (due to the relatively recent acceptance of deep time, and with it sufficient time for ordinary, observable processes to shape the earth) and counterproductive (due to their speculative and untestable assumptions). Gradual processes – to include the occasional earthquake, volcano, and flood, at the levels observed in historic times – should be exclusively assumed, he argued. The community should cease further theorizing, and instead concentrate on characterizing, dating, and matching up the earth's strata (a huge and vitally important undertaking, to be sure). Darwin strongly agreed with Lyell's gradualist view of both geology and paleontology, but differed with regard to the philosophical perspective of pure observation with no conceptual, theoretical framework in mind. Gould's office door displayed his "bumper sticker" view of the relationship of theory and observation, taken from the last sentence of the following paragraph that Darwin wrote to Henry Fawcett in a letter from 1861:

> About thirty years ago there was much talk that geologists ought only to observe and not theorize; and I well remember someone saying that at this rate a man might as well go into a gravel-pit and count the pebbles and describe the colors. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service!

In this passage, Darwin argues that it is essential to possess some sort of theoretical framework if one is to organize and "make sense of" the observations one makes. Gould extends this by claiming that it is impossible for humans *not* to hold or form at least a tentative model while studying a subject. However, he adds, these models can also *limit* what we observe, constraining us as well as assisting us. There exists a myth about science, he continues, that says practitioners modify or abandon their theories when confronted with data that refutes it. But this is not always true in practice. He writes:

> We say, in our mythology, that old theories die when new observations derail them. But too often – I would say usually – theories act as straitjackets to channel observations toward their support and to forestall potentially refuting data. Such theories cannot be rejected from within, for we will not conceptualize the disproving observations . . . . We escape by importing a new theory and by making the different kinds of observations that any novel outlook must suggest.

That is, he argues, new data by itself cannot overthrow an established theory. It can only be replaced when challenged by a different theory, one that makes different predictions. It is only in the context of two testable theories, he states, that we gain sufficient perspective from the results of our observations to modify or reject one of them. [Gould is very partial to this argument; he used it in his first paper on punctuated equilibrium, where he argued that the paradigm of phyletic gradualism prevented scientists from recognizing the phenomenon of stasis, even though many "observed" it.] Importantly, a new theory – even if it fails – often suggests new lines of research that can lead to unexpected findings.

By the time Gould wrote this essay in 1992, most members of the professional community had been convinced that a large impact did occur at the end of the Cretaceous. [A few continued to argue that the source of the iridium in the clay layer was volcanic in origin.] Doubt and debate remained, however, as to whether the impact directly resulted in a mass extinction, merely provided a final blow to a trend already well underway – or had no global effect on life at all. One of the most important arguments against the view that the impact was solely and directly responsible for the Cretaceous extinction was that many groups appeared to have vanished over a period of several million years, with many already extinct when the impact occurred. The primary evidence behind this argument was that their fossilized remains petered out many meters below the K-T boundary. However, a flaw in this model was identified by two of Gould's acquaintances, P. W. Signor and J. H. Lipps, and their quantitative analysis was published in 1982.

Most organisms, even those with hard parts such as shells or bones, are not preserved at all when they die. Some, however, such as clams, are much better represented in the fossil record than others, such as ammonites. (Ammonites are an extinct group of mollusks related to squids, but with a spiral shell. They disappeared at the end of the Cretaceous period.) When examining, say, a one hundred meter depth of fossilized sediments (representing, say, a million years of time) over an exposed outcrop, one might find only one ammonite for every few meters of sediment. The Signor-Lipps effect, as it is now known, simply states the date of extinction of a rarely-preserved organism is easy to underestimate, for the simple reason that the fossil found highest in the strata (and thus most recently alive) may not have been the last one that lived. Consider the following example, in which each meter of sediment represents (say) 10,000 years. Also consider that, on average, one ammonite fossil is found for every ten meters of strata. Third, for the moment, assume that the color and texture of the strata change markedly at a clearly-identifiable boundary, and that no ammonite fossils are found above this boundary. The "highest" (most recently deposited) ammonite fossil is found three meters below the boundary. Is it safe to conclude that ammonites became extinct 30,000 years before the boundary? It is not; the Signor-Lipps effect quantifies a sampling bias that can appear in rare species. That is, it is possible that the "apparent" petering out of many species over an extended time is actually an artifact of how uncommon they are in the fossil record.

This argument, of course, does not prove the hypothesis of abrupt, versus gradual, extinction. What it does do is *raise the question*; once asked, paleontologists can go out into the field to try to answer it. The obvious way to approach the problem is through "brute force": in this example, search a large swath of strata that lies in the first few meters below the boundary, looking for the proverbial needle in the haystack. Gould's point is that *no one would have bothered to do this* had the established, gradualist paradigm not been challenged by an *alternative paradigm*. Gould writes:

> So why wasn't the effort expended before? Paleontologists are an industrious lot; we have faults aplenty, but laziness in the field does not lie among them. . . . We didn't scrutinize every inch of sediment for the most basic of all scientific reasons. Life is short and the world is immense; you can't spend your career on a single cliff-face. The essence of science is intelligent sampling, not sitting in a single place and trying to get every last one. Under Darwinian gradualism, intelligent sampling followed the usual method of handful-from-the-haystack.

With two competing paradigms, tests can be constructed to choose between them. In the case of ammonites, Peter Ward (another colleague of Gould's) and others spent 15,000 man-hours looking through the pre-KT haystack for rare ammonites – and finally found some. In a book published in 1992, Ward writes (and Gould quotes): "Ammonites appeared to have been present for Armageddon after all."

Ammonites are important to professionals (and collectors), but dinosaurs capture everyone's imagination. It had been generally accepted that dinosaurs died out over an extended period of several million years. However, being terrestrial animals, whole dinosaur skeletons are preserved only under the rarest of circumstances, and thus may also be vulnerable to the Signor-Lipps effect. Yet another friend of Gould's, Peter Sheehan of the Milwaukee Public Museum, organized the volunteer-based "Dig-a-Dinosaur" program run by that institution to search for more plentiful bone fragments over a large area of the Hell Creek Formation in Montana and North Dakota. The strata were divided into three time-slices, and comparisons were made to see if the number of fragments decreased over time, which would suggest an extended decline; none was found. Gould quotes from the resulting 1991 publication:

> Because there is no significant change between the lower, middle, and upper thirds of the formation, we reject the hypothesis that the dinosaurian part of the ecosystem was deteriorating during the latest Cretaceous. These findings are consistent with an abrupt extinction scenario.

DIH 13. Jove's Thunderbolts

This essay fits closely with the previous one. Both discuss recently reported evidence supporting the view that a comet or asteroid impact with the earth some 65 million years ago directly led to the mass extinction at the end of the Cretaceous. Both also address the paleontological community's reluctance to accept, and in fact hostility towards, this view. The previous essay showed ammonites and dinosaurs, two major groups, did appear to be thriving up until the event after all. This essay focuses on the impact of the Shoemaker-Levy 9 comet with Jupiter, which demonstrated in spectacular fashion that a small impacting body can have a large-scale and long-lasting effect on a planet.

Shoemaker-Levy 9 had broken up into some 21 fragments in an earlier near-miss with Jupiter, and these pieces crashed into it sequentially over the period of July 16 – 22, 1994. This event had been anticipated for many months, and many earth-based telescopes and instruments were focused on it, as well as the Hubble Space Telescope and the Galileo spacecraft. Expectations were that the impacts would not be terribly impressive; the largest fragment was only a few kilometers across. However, the impacts produced huge explosions, and the marks left on the planet's surface were in some cases larger than the diameter of the earth. They were easily visible for weeks afterwards, and the measured temperatures in the affected areas took months to return to normal. These results viscerally, if not completely analytically, laid to rest another of the arguments against the Alvarez impact-based extinction model: that the effects of such an impact on earth would be relatively localized. Gould notes that the estimated diameter of the KT impact object is several times larger than the fragments that struck Jupiter.

Gould wrote this essay only a few days after the impacts occurred, and expresses a certain degree of vindication for his early support of Alvarez's theory. A fraction of the scientific community remained unconvinced that the impact associated with the global iridium layer was responsible for the cretaceous-tertiary mass extinction. [In retrospect, it appears that few of these had their minds changed by Shoemaker-Levy. It was, however, empirically reassuring to those who had come to accept this view.] Gould reiterates his opinion that there is another, more fundamental component to this resistance. Continuous, gradual change has been one of the most important underlying themes of the earth sciences for 150 years. Here he discusses why Charles Lyell, a lawyer by training, presented the "case" that catastrophic events should be completely excluded from the science of geology in his three-volume work *Principles of Geology* [see ESD 18, and the previous essay]. Forces that humans have observed in the past few thousand years, he argued, combined with vast amounts of time, can explain everything we observe today; allowing catastrophic speculation will "foster indolence and blunt the keen edge of curiosity." England's leading philosopher of science at the time, William Whewell, coined the terms "uniformitarian" and "catastrophist" in an important review of Volume II of Lyell's work in 1832. He did so to illustrate the essence of Lyell's perspective, and Lyell himself embraced this dichotomy. Whewell, however, noted in this review that the absence of exceptionally large catastrophic events in recorded history *did not preclude them*. But Lyell effectively "won his case," and geologists (as well as paleontologists) came to view all catastrophic proposals with a jaundiced eye. This served the purpose of discouraging ongoing baseless speculation, but led to an overreaction (Gould claims) when it came to Alvarez – who actually did have scientific evidence to support his proposed catastrophe.

There is another aspect to the philosophical (psychological?) discussion, he continues. The concept of uniform, steady change is consistent with a "comforting view of natural history" (Gould's phrase): steady progress toward inevitable results. The view that rare, catastrophic, and partially random events played a major role in the formation of our existence is disturbing to many people. William Glen, a geologist, historian of science, and colleague of Gould's, had written a book on how the theory of plate tectonics revolutionized geology. Glen later told Gould that he considered the K-T impact and resulting mass extinction to be far more revolutionary, from an intellectual perspective. In the end, plate tectonics fits under the uniformitarian conceptual umbrella, while an impact-induced extinction does not. Gould references Freud, who claimed that all great intellectual revolutions must alter some central concept about how humans view themselves [DIH 25, LMC 15]. Such an event implies that human existence was not dependent on the superiority of mammals to dinosaurs and progressive forces, but to a chance, catastrophic event.

DIH 14. Poe's Greatest Hit

Edgar Allan Poe, it turns out, wrote a book on nature. More accurately, his name appeared as the sole author on an inexpensive text on mollusks, although others did most of the work. This book, as it happens, was the only work he published that was reprinted during his lifetime. By this standard, it may be considered to be his most (and perhaps only) successful publication; hence the essay's title. A friend of Poe's named Thomas Wyatt, an actual expert on mollusks, produced large parts of it; other parts were copied and sometimes blatantly plagiarized from other sources. Poe's biographers, Gould tells us, uniformly describe it as shameless hackwork. Gould, who acquired a copy, agrees that Poe was no naturalist and did commit plagiarism, but states that the finished product is actually not that bad. In fact, he continues, it has a key feature that is standard practice today but was a true innovation in its time.

The text in question is entitled *The Conchologist's First Book*, and was first published in 1839. Gould researched the story behind it, with the following results. In 1838, a Professor Thomas Wyatt wrote an expensive book on mollusk shells ("sea shells"), with beautiful color plates. It did not sell well, and Wyatt was looking to produce a less expensive version with black and white plates (Gould tells us why later). The publisher was not interested in further eroding interest in the expensive version, and declined. So Wyatt, who new Poe through some unknown channel, paid him a lump sum of $50 to help him produce a new book. Poe wrote the preface and the introduction. Next came twelve plates of mollusk shells, all of which were directly stolen from a British book called *The Conchologist's Text-Book* by Captain Thomas Brown – as was a good part of Poe's introduction. The next section is a ten-page discussion of the parts of shells, and this was also plagiarized from Brown with some minor alterations. The main body of the work then follows: 120 pages of genus-by-genus description of each animal and its shell, and a list of all species within each genus. This section follows the structure of Wyatt's more expensive book, with the descriptions of the soft parts from the great French naturalist Cuvier [HTHT 7], and those of the shells from Wyatt's book. Captain Brown's work was easy to plagiarize because it was published in Scotland, and there were no enforceable international copyright laws at that time. Poe and Wyatt may or may not have thought they were behaving immorally, but some others certainly did. In later years, Poe expended some effort in a lawsuit against a journal that identified this plagiarism.

All of the preceding is true, but it is insufficient to explain what actually motivated the authors. Wyatt, it turns out, made a living on the lecture circuit, which at that time was any men's lodge, women's garden club, or book circle in any town that would have him. Speaking fees were low, and Wyatt would have made a significant fraction of his income from the sale of any printed materials that he brought with him – hence the need for an inexpensive book on his chosen subject. He could not use the plates from his own (expensive) book, as his publisher had denied him permission; but Captain Brown's book was readily available for "borrowing" plates and text. Why did Wyatt turn to Poe for assistance? Poe, it turns out, was fluent in French, the result of living in England for five years as a child and classically educated there. This allowed him to translate Cuvier's work on the soft parts of the mollusk, which Gould points out leads to the key innovation of this little book. "Conchology" is only the study of the *shells* of mollusks, which is how Linnaeus himself classified them. Wyatt's innovation, noted by Poe in the preface and introduction (and apparently missed by his biographers), is to describe the soft parts next to the hard parts. Thus, this is likely the first book on malacology (the study of mollusks) rather than pure conchology, although both terms are used in the book. Neither Captain Brown's book nor Wyatt's own expensive publication was structured in this way. Although the process by which the book was created was unsavory, and the integration between the animal and its shell rather minimal, Gould concludes that the result is definitely not "hack work."

Why did Wyatt not include his own name on the book? Perhaps, as Poe himself later suggested, it was an issue of name recognition; perhaps he knew plagiarism when he saw it, and wanted to protect his reputation; or perhaps it was just easier to tout the quality of a publication that did not bear his own name (no doubt he kept all proceeds for himself). The true reason or reasons appear to be lost to history.

DIH 15. The Invisible Woman

Women have historically faced the same types of discrimination in the sciences as they have in all other aspects of European and American life. Prior to the 1970s, Gould tells us, there were very few women scientists or professors in any field, including his own. In addition to the absence of official positions and salaries, they very rarely published, rendering even the most creative women metaphorically invisible.

One exception to this general rule during the Victorian era in England was a saccharine form of natural history book aimed at women and/or children (there appears to be little difference in style). All such books in this genre followed a certain format. One key element was the expression of the subject as a sign of God's goodness, his attention to detail, and his constant presence. Also implied was that all organisms were created either directly or indirectly for the benefit of God's greatest creation, Man. A third recurring theme in this culturally conservative era was the insistence that every creature (and, by implication, every person) had a place in the big scheme of things, and that it would be wrong to advocate any changes – including social changes – from God's plan.

Gould became interested in this genre as a historian of science, and wanted to gain insight into what these women were like. As an avid procurer of antiquarian books, he picked one called *The Conchologist's Companion*, 1834 edition, by Mary Roberts. He had not heard of the book or its author, but the subject was in his area of professional expertise. Not surprisingly, Gould learned nothing in the way of science from it, and he was mostly saddened by the thought of women burning with the need to learn and create being limited to writing such drivel.

Gould does, however, make a connection with one of the great essays by Edmund Burke: *Philosophical Inquiry into the Origin of Our Ideas of the Sublime and Beautiful*, first published in 1756. (In an extended footnote, he states that he had not read Burke's essay all the way through until preparing for this essay. It is forced opportunities such as this, he states, that keep him writing month after month.) Burke argues that the sublime is all things male, while the beautiful is all things female. "Sublime" refers to the concepts of wide-open spaces, stalking and killing prey, and danger, and is in essence about self-preservation. "Beautiful," on the other hand, incorporates the concepts of fragility, delicacy, bright colors, smoothness of shape, and is in essence about procreation. The importance of Burke's essay, Gould states, is that it captures the deep and profound sexism of the era, and we must know the roots of oppression in order to combat it effectively. He identifies several examples in Robert's book of what, in context, can be recognized as Burke's beautiful, and not a hint of sublime.

It proved very difficult for Gould to learn more about Mary Roberts, other than her dates of birth and death, the fact that she never married, and a list of the books she authored. This is consistent with the theme of metaphorical invisibility that these women experienced. But he did track down another of her books, this one of a different genre, called *The Progress of Creation*. As if to emphasize just how full of twists and turns the world is, Gould found himself actually angered by this book. It takes a hard line on creationism, including a literal interpretation of six days of 24 hours. By the time this book was published in 1846, this view had been completely rejected by the scientific community. She takes insulting shots at many of the leading (male) scientists of the time for expressing even the possibility that Noah's flood was only the latest in a series of catastrophes, and makes defiant claims for which there was contradictory evidence available at the time. This book was pure nonsense, Gould concludes – but it was sublime nonsense!

DIH 16. Left Snails and Right Minds

In this unusual essay, Gould discovers a mystery about snail documentation, but is unable to resolve it. The mystery does not directly involve nature, but rather the visual representation of snails in the plates of books before the mid-18th century.

Snail shells are one of the few macroscopic organic structures that do not exhibit bilateral symmetry; they are twisted. This twisting can take on one of two orientations, commonly referred to as dextral (right-handed) and sinistral (left-handed). Normal screw threads are dextral. Gould posits that one might expect the number of dextral and sinistral shells to be about the same, but this is not the case: almost all snail shells are dextral, although the occasional exception has been found in most species. However, the mystery of this essay is not why the fraction is other than 50-50 [or, although Gould does not raise this question, 100% – 0%]; the mystery is why virtually all books before about 1750 show snails as sinistral, while books after this date portray them in the more accurate dextral orientation. Gould, as a snail man, is sensitive to this issue because he has published papers where the photographic images have been printed with the negative turned over. This leads to dextral snails appearing sinistral (and vice versa), a source of low-level dishonor in his professional community. However, the figures he addresses here could not have been reversed like this, for they were all carved into wood or etched into copper. Since such etchings must be "mirror image" in all cases to make the print come out correctly, the next hypothesis might be that snail shells were a place where artisans could "skimp" and carve directly without anyone noticing. Gould considers this unlikely, since drawing backwards would have to be second nature to engraving professionals. He also considered and rejected the hypothesis that the advent of photography forced these artists to draw snails the normal orientation; there is a century between 1750 (when the snails appear dextral) and photography's introduction. Gould concludes that it must have been a formal convention of some sort, although why he has no idea what or why. He asks for help on this from his readers, and from antiquarian book dealers. In an epilogue, he thanks the many people who offered ideas, but reports that none to date had discovered the solution.

DIH 17. Dinomania

Gould was fascinated by dinosaurs in elementary school, while most of his classmates were not. After recapitulating some childhood slights regarding this discrepancy of values, he poses a question: why do these same creatures periodically capture the world's imagination in a fad-like way [a theme he also explored in BFB 6]? The specific motivation in writing this essay was the phenomenal success of Stephen Spielberg's movie *Jurassic Park*, based on the best-selling novel by Michael Crichton. [This essay originally appeared in the *New York Review of Books* on August 12, 1993, rather than his monthly column. Gould reviewed both Crichton's novel and the book *The Making of Jurassic Park* (about the movie) by Don Shay and Judy Duncan.] Gould expresses the hope that this round of dinomania is based on their recently-improved reputation, stemming from discoveries suggesting that, as a group, dinosaurs were not slow and stupid, and did not become extinct because they could not compete with mammals. Whether the seed of this feedback-driven enterprise was a brilliant marketing executive, or an innate reaction to our fascination with the "big, fierce, and extinct," he does not know.

He critiques the book and the movie, from the perspectives of both a professional scientist and a lifelong fan of dinosaur movies. He identifies certain factual errors: most of the dinosaurs that appear in both media lived during the Cretaceous and not the Jurassic, for example, and that most Velociraptors were smaller than the stars of the book and film. He generally liked the book, but was a bit disappointed with the movie (although he did love the dinosaur scenes themselves). He could easily identify several popular "trends" within the professional community, such as the views that dinosaurs were warm-blooded and lived in herds. He appreciated the mechanism of using ancient blood-sucking insects trapped in amber as a source of dinosaur DNA, although he then discusses at some length why this would not work in practice. He emphasizes that the proposed technique of filling in the genetic gaps with frog DNA is "their worst scientific blunder." He appreciated Crichton's use of chaos theory in the book (life is very complex, and will behave in unpredictable ways) as an explanation for how the dinosaurs get loose and wreak havoc. In the movie version, Gould is irritated that the chaos-theory-versed mathematician quickly defaults to the old chestnut about humans playing God as the source of the inevitable drama.

Gould closes with a discussion of the early scene in which the creator of the park entices a "big name" paleontologist to visit and recommend his facility. The scientist has no interest, until the entrepreneur offers to support his research for a few years if he agrees. Done! Gould notes that paleontologists, and researchers in natural history in general, have always depended on sponsors of one sort or another for money. Of course, most of these sponsors have been motivated by forces other than simple interest in the field of research. Museums suffer in a similar fashion, and depend to an ever larger extent on gift shops selling mostly useless stuff to pay the bills. Museum administrators build large movie screens and bring in exotic but scientifically limited displays, he says, hoping that people will walk by the "real" exhibits on the way. Gould expresses hope that the human need for authenticity – to see actual fossils, not replicas, or even animated models – will continue to draw people to museums.

DIH 18. Cabinet Museums: Alive, Alive, Oh!

The term "cabinet museum" refers to a Victorian-era style of exhibit hall that crams as many specimens as possible into glass display cases, with wooden drawers below to hold yet more specimens. This contrasts with the modern approach of exhibiting only a few key objects, with notes and sometimes-interactive features to optimize the educational aspect of the display. The Dublin Museum of Natural History, built in the 1850's, is one such cabinet museum. Gould visited this facility in 1971, as part of a research project on Irish Elks [see ESD 9], and hated the place. It was dark and decaying, with a century of grime. He returned to this facility in 1993, and found it to have been beautifully restored. In its cleaned and refurbished condition, it suddenly became apparent to Gould what the attraction was – one could spend hours in front of a single cabinet, and many like-minded people he knows of did in similar museums. He wrote this essay to congratulate the city of Dublin for restoring not only the exhibits, but also the entire building to its 19^{th}-century splendor. Newer exhibits can be found in adjacent buildings, but this one becomes a museum not only of the thousands of specimens, but also of a period in British history. Nearby is a statue of Molly Malone, a possibly-real 18^{th}-century seller of fresh cockles and mussels. A song about her, which includes the line "Alive, alive, oh!" (in the English translation, and referring to the freshness of the shellfish), is an unofficial anthem of Dublin.

DIH 19. Evolution by Walking

This essay celebrates the reopening of the fourth floor of one of Gould's favorite childhood and adult haunts, the American Museum of Natural History in New York. The two great halls that exhibit fossil and extant mammals were completely reorganized as well as refurbished. The organizing principle of the revised exhibits is the taxonomic model of cladistics, which focuses on the sequence of branching events in evolutionary history. This organizational structure is very important for what it does *not* do: emphasize perceived increases in complexity or progress (inevitably toward humans). This removal of humans from the center of the universe and the inevitable apex of natural history is a common theme in Gould's writing [DIH 25]. He is delighted to see this pedagogical institution present this perspective in such a visceral way: by walking down the main route through these halls, the visitor comes to primates – including humans – in the middle, not at the end.

The exhibit follows the six major branching events in mammalian history that cladistics emphasizes. The first is the synapsid opening, a hole in the skull behind the eye that separates early mammals from other groups of reptiles. [It is important to recognize that scientists use this feature simply as an identifier. It shows a common origin, but no claim is implied that this feature grants any particular evolutionary advantage or represents progress. Other branches continue to evolve.] The second event is the formation of the distinctive 3-boned mammalian ear. The third is the development of the placenta, where our group branches off from the order that includes the platypus. The fourth is the formation of a hole in one of the bones in the middle ear; primates branch off at this point. Fifth is the formation of the hoof, which occurred after primates came into existence. Sixth is a distinctive movement of the eye sockets near the nose, a feature which is shared by elephants and manatees (sea cows). This puts sea cows at the end of the hall of mammals, which delights Gould. He does, however, offer a word of caution: new iconographies can free us from old biases, but can introduce new ones. He notes that cladistics downplays unique traits formed by single lineages, such as the large teeth of saber-toothed tigers, and the bipedal gait of the genus *Homo*. It also downplays trends within groups that do not lead to further branchings, such as the reduction in the number of toes in the natural history of horses, or larger brains in one group of primates. Such events are important, he argues, even if de-emphasized by cladistics.

DIH 20. The Razumovsky Duet

The source of this essay is the dedication to an old book that Gould purchased. The book, written by Johann Gotthelf Fischer von Waldheim (1771 – 1853), was a minor but useful reference work on zoological classification for Russian academics. Gotthelf Fischer was born in Saxony (now Germany), and was involved in the activity that coordinated the naming of geological strata. He may have coined the term "paleontology." He spent the majority of his career in Moscow, as a professor and curator of the natural history museum there. Importantly, he was there when Napoleon arrived, and during the subsequent fire that destroyed some two-thirds of the city. This fire prevented Napoleon from feeding his troops and thus forced his disastrous retreat; but it was also a disaster for the city, including the natural history museum, which was destroyed.

This brings us to the dedication of Gotthelf Fischer's book, published in 1813; it is a plea for help (on behalf of his museum) to the Russian Minister of Public Instruction. This minister's name was Alexis Razumovsky; his brother, Gould discovered in his research, was Andrei Razumovsky. Andrei lived in Austria and was a great patron of the arts in general, and to Beethoven in particular. (Beethoven dedicated several of his works to his patron, including the famous "Razumovsky Quartets.") Gotthelf Fischer was not as successful with Andrei's brother Alexis, however. But over the next twenty or so years, Gotthelf Fischer did succeed in partially rebuilding the museum's collection. His success came not from wealthy patrons, but from his fellow scientists throughout Russia and the rest of Europe, who donated, traded, or sold books and specimens. The thesis of this essay is that scientists, for all their failings, are an international lot; they do not see the same borders as most people, even during extended periods of war.

DIH 21. Four Antelopes of the Apocalypse

The museum curator's lament is that often the most precious items in a collection are the surviving fragments of something that has been completely lost. In this case, the item in question is one of exactly four mounted specimens of *Hippotragus leucophaeus*, or the blaauwbock. The blaauwbock is a species of South African antelope that was first identified by a western observer in 1719, and became extinct in 1799. The coup de gras was a combination of hunting and habitat destruction via the introduction of sheep, but Gould notes that the animal had the hallmarks of a species on the brink of extinction anyway – a large animal with a small range. He was shown one of these mounted specimens on a private tour of a museum in Leiden, Holland; the other three are in other European museums. The curators in Holland are especially proud of their specimen, because it has been identified and confirmed (after some debate) as the holotype for the species. (According to the rules of biology, every species – extant or fossil – must have a single "best representative" or holotype in order to be an officially designated species. This is a big deal in the museum and life sciences communities.) Still, they are sad as well – only four mounted specimens and a handful of bones exist, and we have no knowledge of what the blaauwbock preferred to eat, what sounds it made, or how it behaved. All this information is lost forever.

DIH 22. Does the Stoneless Plum Instruct the Thinking Reed?

Luther Burbank (1849 – 1926), Gould begins, was the greatest plant breeder in American history. His horticultural inventions include the white blackberry, the Burbank potato, and the stoneless plum (an edible plum without a pit). He fell a bit short of his lifelong goal, the creation of a truly spineless cactus that would convert the American desert into rangeland for cattle. He was a bit of a showman, not unlike his contemporary Thomas Edison. Burbank's success was due to the incredible effort and sheer scale he put into creating his hybrids, and to his keen ability to detect slight variances in preferred directions. He was famous in his day, but only wrote a few articles. His longest, first published in a magazine in 1906 and then reprinted as a small book in 1907, is entitled *The Training of the Human Plant*. This book is the subject of Gould's essay.

Burbank, it turns out, believed in two distinct theories that are today recognized as false. The first is eugenics, the hodgepodge of beliefs that argues that the human race can and should be "improved" by selective breeding. The second is Lamarckism, a theory of evolution different from Darwin's, and known for its catchphrase "the inheritance of acquired characteristics." Burbank combined these two views together to form what Gould refers to as "liberal eugenics."

Most advocates of eugenics fall on the conservative end of the political spectrum, as it easily lends itself to the views that wealth and power are functions of birth and that government neither can nor should do very much to help the poor. To understand Burbank's view on breeding in people, Gould first explains his understanding of breeding in plants. In his book, Burbank argues that his success in breeding plants was the result of four processes: crossing, selection, cultivation, and persistence.

Crossing is the crossbreeding of many different strains of the subject organism in order to create variation. (One of the "liberal" aspects of Burbank's philosophy follows from this: we should welcome, not resist, the influx of different nationalities to America, as the mixing that will surely result will increase the variation within our national strain. Most supporters of eugenics were arguing that this would dilute or contaminate the purity of the English, or at least northern European, strains.) Selection is the unpleasant part, at least in the case of people: choosing a subset with the best features for reproduction, while preventing all others from doing so. In his plant breeding, Burbank would grow tens of thousands of plants, identify a few with the best traits, and uproot the rest – and repeat this process for years. These two processes – crossing and selection – are ultimately what led to Burbank's success, and both are fully consistent with Darwin's theory of natural selection.

The third and fourth processes, cultivation and persistence, are pure Lamarckian. Burbank misunderstood the causes of his breeding success. He believed he was creating genuinely new features in his plants, when in fact he was amplifying traits that were already present. His view was that many of the desired features in his selected plants were produced by his careful and loving *cultivation* of them, and by his *persistence* in maintaining this optimal environment over many generations (which helped these modifications to "stick"). This misunderstanding of nature did not, apparently, have an adverse impact on his ability to produce new agricultural products; but it did lead to his "liberal" perspective on eugenics. Less than optimal variations, he argued, do not need to be "weeded out" of the American gene pool (via death or forced sterilization). With proper and loving care over multiple generations, Burbank argued, these people would improve genetically via these Lamarckian processes, albeit at a slower rate. Burbank discusses and then rejects the use of such actions in humans on moral grounds: people are not plants.

Gould closes by quoting from Thomas Huxley's 1893 essay *Evolution and Ethics*, which directly addresses the "social Darwinist" arguments, and which Gould himself has discussed in several of his essays. Huxley himself quotes Pascal, who wrote that man is a fragile reed, but that he is also a thinking reed. This power of thought gives man the ability to create and define morality, and not simply to do what nature allows. Human consciousness allows us to create new rules to live by, which are separate from the laws of nature. Burbank was wrong about how new breeds are produced, Gould argues, but even if he had been right his efforts on eugenics would still have been wrong. We are, of course, constrained by natural law; but we should not try to base our ethics or morality on what we see, or believe we see, in nature.

DIH 23. The Smoking Gun of Eugenics

R. A. Fisher (1890 – 1962) was one of the giants in the field of evolutionary biology. His work in the early 20th century used pioneering statistical methods to show that Mendel's genetics was consistent with Darwin's natural selection, and was one of the key developments that led to the development of the modern evolutionary synthesis. Like other great men, he also blundered greatly on occasion. Gould describes the two most significant of these in this essay: his wholehearted support for eugenics, and his battle against those who argued that smoking caused cancer. The essay's title reflects these two subjects, and does not refer to a conclusive piece of evidence against eugenics.

Gould begins at the end, with Fisher's arguments against tobacco as a cause of lung cancer. Writing in the late 1950's and early 1960's, he acknowledges a correlation between smoking and cancer, but argues that correlation is not causation. Perhaps, he argues, cancer – or, more precisely, irritation caused by a precancerous lung condition – leads to smoking, as this (he argued) is a common response to all irritation. More likely, he continues, a predisposition to smoking and a predisposition to lung cancer are different results of the same (undiscovered) genetic trigger. As a community, he argued, scientists must be very careful about jumping on the tobacco-causes-cancer bandwagon, for three reasons. First, many people (including himself) enjoy smoking, so we need to be careful before disrupting society. Secondly, if science "cries wolf" and it turns out that there is not a causal relationship, science as a whole will be discredited. Third and last, he states, jumping to a conclusion will preclude further study, much of which is called for. With hindsight, Gould points out, we now know that Fisher was completely wrong. His arguments were reprehensible, in that his efforts did add delay government efforts to curb smoking. What was also reprehensible is that Fisher presented himself as an objective scientist seeking only the truth, when in fact he was so convinced of his position from the start that he actually became a paid consultant to the tobacco industry.

The other "embarrassing" view that Fisher held (at least to moderns who want to think highly of him) involves his arguments in support of eugenics. Gould is quick to point out that most geneticists of that period believed in some form of eugenics, and Fisher's was less malevolent than most. As with his position on smoking, the problem was not with his logic. It is, Gould states, with his willfully blind acceptance of a set of assumptions that he should have challenged. The only possible conclusion is that, again, his mind was closed despite numerous claims to the contrary. Gould quotes extensively from his magnum opus of 1930, *The Genetical Theory of Natural Selection*, of which more than a third refers to humans and advocates a form of eugenics.

Fisher argued that civilizations rise and inevitably fall, and that in all cases the reason for this fall is "the degeneration or depletion of the ruling classes." (Fisher was very British.) He emphasizes the latter: the upper classes simply do not produce as many offspring as the lower classes do. Rather than considering other causes for this phenomenon (marrying later, extended education, access to birth control, and even inbreeding in some cases), he simply *assumes* that there must be a genetic, inverse relationship between talent and fertility. Fisher strongly believed in a genetic basis for intelligence, behavior, and success, a position that Gould has opposed in many essays. Since the talented elites are required to keep the civilization running, their reproductive failure leads to cultural collapse.

However, members of the lower classes may occasionally be born gifted enough to be able to rise through the social ranks. Historically, such overachievers came from smaller families, which reinforced Fisher's belief in his genetic correlation hypothesis. Thus, men (always only men) who were able to make this rise probably had reduced fertility, and thus marrying into the upper classes would only be of limited assistance. (Fisher's brand of eugenics favored interbreeding of the ruling class with talented outsiders. This is consistent with "Fisher's fundamental theorem of natural selection," the centerpiece of his book, which states that the rate that evolution can take place within a population is directly proportional to the genetic variance within that population.) However, he notes, many of these men end up marrying rich heiresses, in order to obtain the funds necessary to continue their rise. But these women are, in general, the least fertile of all members of the upper class. This is because they come from lines with few siblings, and in particular no brothers – for if they had brothers, they would not be heiresses! Eugenics can help out, Fisher argued, by making the case that the state should provide financial assistance should to these talented underclassmen, so that they would not have to marry infertile heiresses. He made no political headway with his ideas, although he did do his part – in his mind – by raising six children. Nonetheless, all supporters of eugenics, Gould concludes, play into the hands of the social conservatives who favor blaming the victim and enjoy feeling self-righteous. Genetics should not be used to support a social hierarchy.

DIH 24. The Most Unkindest Cut of All

This is the only essay Gould wrote in which he explicitly discusses Nazi Germany and the Holocaust. He wrote it for the fiftieth anniversary of the Wannsee Protocol, which were written at the conference of that name that took place on January 20, 1942. It is here that Heydrich, with Eichmann taking notes, formally presented "the final solution to the Jewish question." Gould describes the document, which is readily available online. It begins by discussing previous attempts to "rid" the Reich of Jews, noting that success had been limited. It goes on to describe in some detail how the "final solution" would work: the forcible relocation of Jews to work camps, where many would no doubt perish. (This was a smokescreen, Gould reminds us; the intention was always extermination.)

Gould briefly discusses some of his childhood memories of the period. He acknowledges that he is not a poet, and furthermore spent those years as a child in Queens, so he has nothing to add to this widely known part of the Wannsee protocol. There are other parts, however, which are less well known. These parts are important for context, and are related to Gould's area of expertise: evolutionary theory. The Nazi mindset was that the problems facing the Aryan race – such as the trauma of the First World War and the humiliation and poverty of the peace that followed – were in large part the result of the mixing of their pure blood with Jews. Thus, "the Jewish question" involved not only what to do with "pure" Jews, but also with Reich citizens of mixed ancestry. (generally, half-Jewish meant Jewish, while quarter-Jewish did not; but there were exceptions at both ends.) The rationale behind this is, of course, is one of the Social Darwinist interpretations of Darwin's theory of natural selection. Gould came across the exact German phrase for "natural selection" while reading the Wannsee protocol, and was mortified that the most important concept in his intellectual life was explicitly, if incorrectly, used to justify the Holocaust. He takes the title of the essay from a line in Shakespeare's *Julius Caesar*, where Mark Antony refers to the stab wound made in the assassinated Caesar's cloak by his close friend Brutus.

While there is no question that the Nazis misused scientific arguments for their own ends, the scientific community cannot be completely absolved, Gould closes. A few scientists at the time spoke out against this misuse of Darwin's theory, but most remained silent; some even defended it. William Jennings Bryan, a generation earlier, had certainly understood at a visceral level the attitude behind social Darwinism and eugenics [see BFB 28; his opposition to the theory of evolution was based on his false belief that these attitudes were, in fact, Darwin's theory]. Scientists must remain vigilant against this sort of misuse of science, he states, and be prepared to speak out. However, humility is also required, and scientists must acknowledge that science cannot address moral questions.

DIH 25. Can We Complete Darwin's Revolution?

This is one of Gould's definitive essays regarding his personal philosophy of life, man, evolution, and natural history. He begins with one of his favorite extended quotes from someone other than Charles Darwin. In the early 20^{th} century, Sigmund Freud wrote that the most important scientific revolutions were the ones that forced man to confront his limited importance: "Humanity has . . . had to endure . . . great outrages upon its naïve self-love." Two such revolutions stood out, in Freud's view. The first was the Copernican revolution, "when [humanity] realized that our earth was not the center of the universe, but only a speck in a world-system of a magnitude hardly conceivable." The other was the Darwinian revolution, which "robbed man of his particular privilege of having been specially created, and relegated him to descent from the animal world" – that is, as he notes in ESD 18, "[evolution] took away our status as paragons created in the image of God." (Freud's motivation for this line of thought was that, Gould notes, he believed his own work on the subconscious – undermining views of rational human thought – would constitute a third such revolution. Freud's work is not considered to be in this league today, although an accurate predictive theory of consciousness in purely biochemical terms might well achieve such status. Gould acknowledges that many true scientific revolutions, such as plate tectonics [ESD 20], do not significantly impact our views of man's place in nature, but suggests elsewhere that the discovery of "deep time" [HTHT 6] probably does.)

However, Gould's thesis is that there is a major step between the recognition of the revolutionary *premise* (a heliocentric solar system, an evolutionary origin of man) and the acceptance of its *implications* for the reduced status of man, in our own eyes. He refers to this intellectual demotion of humans as "pedestal smashing," and attempts to resist the implications – not the premises themselves – as "spin doctoring." The Copernican/

Galilean revolution, he argues, is complete in Freud's sense. It began when people accepted that the earth was not the center of the universe; it was completed when people came to accept the implication that there is apparently nothing particularly unique about it. Most people today are comfortable with the *concept* that life, perhaps even intelligent life, may exist elsewhere. On the other hand (he continues), Darwin's theory is not complete in this sense. Many people who understand and accept the premise of evolution as fact do *not* accept the pedestal-smashing implications that man is just another animal, albeit one with a large brain and unusual cognitive abilities. (He explicitly excludes creationists here. His argument involves the step between accepting "descent with modification" and of accepting the implications that man is not the end result of either a divine *or secular* process.) Gould summarizes his view of how we would all view ourselves in a post-Darwinian world without spin doctoring, and its significance to him:

> I like to summarize what I regard as the pedestal-smashing messages of Darwin's revolution in the following statement, which might be chanted several times a day, like a Hare Krishna mantra, to encourage penetration into the soul: Humans are not the end result of predictable evolutionary progress, but rather a fortuitous cosmic afterthought, a tiny little twig on the enormously arborescent bush of life, which, if replanted from seed, would almost surely not grow this twig again, or perhaps any twig with any property that we would care to call consciousness.

To support his argument that Darwin's revolution is not complete, and to illustrate some common misunderstandings, he turns to his personal choice for "a canonical media source for identifying the pulse of an educated culture": *The New York Times*. He calls out three items published in the previous twelve months in the "Science Times" section (two of which are letters to the editor). The first draws on the view that evolution works to benefit species as a whole, which would in turn imply the existence of a higher-level controlling force or principle. Specifically, a reader argues that sexual reproduction evolved because it offers significant advantages to *species* that employ it. Gould disagrees:

> Natural selection may lead to benefits for species, but these 'higher' advantages can only arise as sequelae or side consequences of natural selection's causal mechanism: differential reproductive success of individuals. . . . Warm and fuzzy ideas about direct action for the good of species represent a classical strategy in spin doctoring, one that has precluded proper understanding of natural selection for more than a century. . . . Darwin's mechanism works through the differential reproductive success of individuals who, by fortuitous possession of features rendering them more successful in changing local environments, leave more surviving offspring. Benefits accrue thereby to species in the same paradoxical and indirect sense that Adam Smith's economic theory of laissez faire may lead to an ordered economy by freeing individuals to struggle for personal profit alone – no accident in overlap, because Darwin partly derived his theory of natural selection as a creative intellectual transfer from Smith's ideas.

Darwin's theory, like Adam Smith's in economics, involves only a metaphorical "unseen hand" and not a real one [see ELP 9]. As evidence that sexual selective forces in particular work for the benefit of individuals rather than species, Gould offers several illustrations, one of which is the peacock's tail. This structure offers no advantage to the species as a whole, and in fact may work to limit its longevity. Its sole functions are to impress females and discourage rival males, and thereby gain an individual advantage over other members *of its own species*.

[While expressing direct support for Darwin's view of natural selection, which is fully consistent with that of the modern evolutionary synthesis, this argument appears to differ from Gould's own quasi-revolutionary departure from this orthodoxy. Gould's final work, *The Structure of Evolutionary Theory*, argues that evolution operates at a hierarchy of levels, one of which is, in practice, the species. His "out" comes from his extension of the term "Darwinian individual" from a single organism to include certain types of aggregates that meet five distinct criteria. He discusses this concept explicitly in these essays only rarely, but it is at the heart of the next one – DIH 26.]

The second "Science Times" exchange subtly draws on the false notion that evolution exhibits sensible directionality. The article itself suggested that, had the asteroid that struck the earth at the end of the Cretaceous period not impacted sulfur-rich rocks, "dinosaurs might well have survived the impact, thereby changing the course of evolution." Another letter to the editor challenged this particular choice of words. The submitter wrote: "Actually, it was the demise of the dinosaurs that changed the course of evolution. Had the dinosaurs not been wiped out, evolution would have continued on the same path it had been following for at least 150 million years." Gould criticizes both, arguing that both sides tacitly (and, no doubt, subconsciously) assume that *evolution follows paths* in one direction or another. This may appear to be a small point, but it is not; such a view implies a determinism, effectively a *destiny*, in natural history that (Gould argues) is not present. There are no paths for evolution to follow.

The third example involves the assumption of continuous evolutionary change, which in turn involves the spin-doctoring notion of evolutionary *progress*. Under the title "Evolution of Humans May Be Faltering," the *Times* reporter (William K. Stevens) quotes scientists who note that modern man is anatomically indistinguishable from our ancestors of 100,000 years ago, well before Cro-Magnons made paintings in caves. As an advocate for punctuated equilibrium and its concept of stasis, Gould found nothing objectionable in the descriptive part of the article. His emphasis is instead on the implied "performance problem." Stevens begins his article this way: "Natural evolutionary forces are losing much of their power to shape the human species, scientists say, and the realization is raising tantalizing questions about where humanity will go from here. Is human evolution ending, ushering in a long maturity in which *Homo sapiens* persists pretty much unchanged?" Gould counters:

> Most species are stable during most of their geological duration. . . . I can only conclude that the spin doctored view of life's history conceives of evolution within species as a continuous flux of improvement and adaptation. We are

> particularly prone to expect such a result for our own species. After all, we evolved from small-brained ancestors, and we have achieved our exalted status by cranial enlargement. Shouldn't this process, as intrinsic, be continued during our period of maximal spread and success? Therefore, if we have truly stabilized, isn't something funny going on, and mustn't that something be an imposition of our cultural discoveries upon our biological estate? No, no, a thousand times no. Our stability is orthodox – at least in a fully revolutionary Darwinism with smashed pedestals.

While he views humans as a small, fortuitous twig on a big bush, he does recognize and celebrate the uniqueness of our ability to contemplate that bush and everything else. The smashing of these pedestals should not demoralize us, he argues; the truth sets us free, although it may force us to seek comfort and solace elsewhere. [He returns to the theme of Darwin's unfinished revolution in LMC 15.]

DIH 26. A Humongous Fungus Among Us

In 1992, when Gould wrote this essay, a story appeared in *The New York Times* with the headline "Thirty Acre Fungus Called World's Largest Organism." (The technical paper behind it appeared in the journal *Nature* on the same day.) The newspaper, of course, focused on the size, weight, and age of this gigantic fungus, which is comprised mostly of a large but thin matrix of connected threads within the soil, surfacing in a few places to form clumps of mushrooms. Large fungal mats were previously known to science, so the scientific aspect of importance was not in the size; rather, it was on the methodology used to determine that the mat was indeed one organism and not several. Comparisons of the genome from samples over the site were consistent with the single-organism view, and it was known that different mats of the same species did not "merge" into one another but established distinct boundaries. However, since one mushroom can produce millions of spores, an alternative possibility is that the fungal mat was the result of many interbreeding siblings that had spread out over a large area. An additional genetic test was required to determine whether the mat was an individual or a group. To prove the former, the authors showed that the genetic variability within the fungus was relatively high. This is important because one of the results of extensive inbreeding is a marked reduction in genetic diversity; high variability thus indicates a single organism.

Gould's next step is to question the definition of "individual" in cases such as this type of fungus, as well as grasses that send up many blades from underground runners. He references another paper from the 1970's that posits that aphids are analogous to grass in this respect. [Gould discussed a related paper by the same author, Dan Janzen, in a much earlier essay, ESD 11.] A female aphid will produce thousands of female offspring from unfertilized eggs, all genetic clones of her and each other. Thus, in the perspective of this paper, a colony of such aphids is really a single organism, just like grass only without the physical connecting threads. (The female aphid eventually produces some males, and sexual reproduction occurs.) Perhaps the definition of "individual" is not as clear-cut as it might appear [also see TFS 4 & 5].

What might a better definition of the term "individual" involve, biologically speaking? This question brings Gould to the real point of this essay. In Darwin's view, an individual is the structure that is the focal point for the forces of natural selection. There are five required criteria in this view: the individual have a definite temporal start and stop points (birth and death); it must remain genetically stable for the time in between; it must be able to reproduce; and these offspring "must be produced by a principle of inheritance that makes children resemble parents, with the possibility of some differences." Interestingly, bamboo colonies, groups of aphids, and fungal mats also meet these criteria, and in this sense may be identified as individuals. Furthermore, genes themselves may exhibit such behavior [HTHT 13], and (he argues) species can as well. [Gould does not elaborate on this here, but it is an essential theme of his professional papers, and of his final work *The Structure of Evolutionary Theory*. This view only works under the paradigm of punctuated equilibrium. In this view, a species comes into existence relatively abruptly (in a punctuation), and later becomes extinct. Importantly, during the extended period between these events, the organism is in *stasis*, as opposed to the modern synthesis view of gradual but continuous phyletic change. In the punctuated equilibrium (PE) paradigm, "speciation" is analogous to reproduction, and the "offspring" are both similar to, and different from, the ancestral stock.] Thus, in this view, genes and species may both be considered "evolutionary individuals" and susceptible to Darwinian-like selection processes. Gould writes:

> Natural selection can work simultaneously at several levels of a genealogical hierarchy – on genes and cell lineages "below" organisms, and on populations and species "above" organisms. All these levels produce legitimate Darwinian individuals – and this hierarchical definition gives us the large, inclusive, and proper biological meaning of the term *individual*.

In his own view, Gould is not replacing Darwinism and natural selection in the PE paradigm; he is extending it to include a hierarchy of levels, and broadening the definition of an evolutionary "individual."

DIH 27. Speaking of Snails and Scales

Gould never uses the word "emergence" in this essay, but it is the underlying theme. As he discusses in TFS 25, emergence or holism is the view that new rules or laws come into play as one examines a composite structure, such as an organism or a population, as opposed to simply extrapolating the rules that apply to the components. The latter view, reductionism, allows for some very powerful simplifications if it can be applied successfully – as it can in many cases in mathematics, physics, and elsewhere. In this essay, he discusses two examples where the reductionist view proves inadequate.

He begins with his favorite "bumper sticker" definition of *Homo sapiens*: we are storytellers. This description captures several attributes of our uniqueness in one phrase: we have language, we are social, and we make mental models of the world around us in a characteristic way. Our nature leads us to view natural history, as well as human history, in terms of linear "stories" with a beginning, a middle, and an end. This helps us make sense of an overwhelmingly complex world. However, we can fall into the trap of oversimplifying in this way. This is partially due to the rather limited number of storylines in the human repertoire, which can force us to shoehorn reality into one of a finite number of established channels. (He refers us to his concept of "literary bias," introduced in BFB 16.) Gould acknowledges that it is in our nature to do explain the world in terms of stories, and we never will – nor should – stop trying to do so. However, he offers, it pays to be aware of the common storylines we draw on, as this helps us to identify our biases, or preferred modes of thought. (It also helps to increase our repertoire of stories.) One common storyline in Western culture for the past few centuries is that of *progress*, involving changes from small to large, simple to complex, and primitive to advanced; the word "evolve" itself implies this [ESD 3, IHL 18]. (Gould has discussed in several of these essays how this storyline has been misapplied to evolution, with *Homo sapiens* as the end of the story.) Here, he presents two examples that illustrate his point that a simple system or structure is not always a primitive version of a more complex one. Both involve the Caribbean island of Curacao; the first involves the local Creole language, and the second the land snails that Gould did his early research on.

The majority of the island's inhabitants are mostly the descendents of African slaves. When these ancestors arrived, they spoke a plethora of languages that were mutually unintelligible. As has been well-documented in similar cases, people in such circumstances begin to communicate with each other through a "pidgin" which is not native to any of them. Pidgins have no grammar to speak of. However, and remarkably rapidly – often in a single generation – the pidgin proto-language evolves into a Creole, which is a true language with a characteristic but simple grammar. This occurred on Curacao, leading to a unique Creole language called *papiamentu*. Most of the words are clearly related to the Dutch and Portuguese languages of the former slaveholders, but the grammar is unlike either of them. This is where the concept of progress falsely appears: for centuries, linguists thought of Creole languages as primitive forms of our own. That is, scholars believed that human language "progressed" over time from meaningful grunts, through pidgin and Creole-like forms, into modern Indo-European and other languages. What more recent studies have shown is that the grammars of these Creole languages resemble *each other* far more than they resemble, say, the language of the local ruling class. Gould references the famous linguist Noam Chomsky, who argues that these grammars reflect a universal, evolutionarily-developed human grammatical structure. The point, Gould tells us, is that Creole languages are not an "in-between" state reflecting partial progress toward our own language, but instead something else; something different.

In the second example, Gould recounts his early professional research in the field of land snails on the very same island of Curacao, and is quite autobiographical. The genus *Cerion* is very diverse and widely distributed throughout the Caribbean, but only a single species exists on this island. He discusses how two previous research efforts had come to opposite conclusions about the distribution of variations within this population on Curacao. One study concluded that there were distinct *regional* differences; the other concluded that all of the variations were due to the immediate local conditions (elevation, type of soil, amount of rain, and so on) but were not regional. In the late 1960's and early 1970's, a young Stephen Jay Gould sought to resolve this issue with the technique of multivariate analysis, recently made feasible by the advent of affordable computing [see TFS 11]. Multivariate analysis is simply the technique of comparing many different physical variables (in this case, measured snail shell dimensions) against each other and to look for patterns and relationships. Gould was successful, in that he was able to identify certain features that did indeed vary regionally, and others that varied by local condition; that is, he found that both previous studies were partially correct. However, he states, his original motivation was to hone his multivariable analysis skills on the relatively simple case of Curacao, and then move on to the vastly more complex case of the Bahamas, where there were many species and vastly more variety. In this, he was not successful, in that he was not able to extrapolate his technique. Curacao was *not* merely a simplified version of the Bahamas, when it came to varieties of Cerion; the interactions of the Bahaman species with each other led to emergent patterns that could not be ignored.

He closes by noting that his most recent trip to Curacao, and his motivation for writing this essay, was to help celebrate the 70th birthday of Benoit Mandelbrot, one of the founders of fractal geometry. One of the classic examples of this field is that the length of a coastline (traditionally England's) is a function of the scale at which you measure it. If you measure at the scale of a grain of sand, the coastline may be almost infinite; the larger the minimum size of the one considers, the smaller will be the sum of the pieces. That is, the scale matters; "large" is not always a big "small," and "complex" is not always a former, identifiable "simple." The essay's title probably refers to his story-telling approach regarding snails and fractals, but "speaking" could refer to his discussion of languages.

DIH 28. Hooking Leviathan by Its Past

There were a series of exciting fossil whale discoveries in the 1980's and 1990's, which Gould discusses here. The record that we have, as a result of these discoveries, clearly shows a series of discrete steps between land-dwelling ancestors and marine descendents, and allows us some insight into how the "intermediate" animals functioned. Rather than presenting the tale in terms of natural history – the oldest animals to the most recent – Gould tells it in the chronological order in which the discoveries were made. He acknowledges doing so because it makes a more rewarding "tweak" to the creationist community. Creationists have long wielded the cetaceans (whales and dolphins) as a weapon against the concept of evolution. They argued that it would not be possible for a half-terrestrial, half-marine organism to survive under any imaginable circumstances. Not only had no intermediate cetacean forms been discovered in the fossil record, they continued, none ever could be. Gould clearly savors this unambiguous victory.

Before he discusses fossils, Gould notes that he always found the "impossible transition" argument rather curious: otters are basically terrestrial animals that do very well in water, while sea lions are clearly marine animals that can and do move adequately on land. Further, seals propel themselves with feet, not a tail fluke, and modern whales have vestiges of hips. He also notes that other extended transitions of the same magnitude have been well-documented, such as two of the jaw bones in reptiles becoming ear bones in mammals [ELP 6], the transition of the lobe-fin fish's swimming paddle to a tetrapod's walking limb [ELP 4], and of course archaeopteryx and Lucy [TPT 11]. There are there are actually three different orders of mammals, he notes, in which some or all members have made the land-to-sea transition. There are the Carnivores, which include dogs, cats, and bears, but also seals, sea lions, and walruses; the manatees and their kin, which are related to elephants; and the cetaceans, which are descendants of an extinct order of mammals called mesonychids (or their close relatives). Mesonychids were relatively large, predatory animals related to modern even-toed undulates such as antelopes; imagine a wolf with hooves. Nonetheless, he acknowledges that the transition between walking legs and a ropey tail to no legs and a large fluke is a massive change that easily lends itself to question, if not ridicule. But the fossil record finally provided some hard data. Gould presents the story of discovery in four parts, with a fifth added in an epilogue.

Case One, as Gould refers to it, is the discovery of *Pakicetus*, the oldest whale (so far), found in Pakistan in 1983. Only the skull was found, but numerous features identify it as an early whale. The teeth closely resemble those of mesonychids, as expected. One important intermediate feature is that the ear still worked as in terrestrial animals, via an ear hole; additional analysis in 1993 confirmed that the pad of fat in the jaw, which conducts sound to the inner ear in modern whales, was not present. A second important transitional feature is that the sinuses contained air, rather than blood as in all modern whales, making deep diving impossible; this is consistent with the discovery of *Pakicetus* in shallow sediments associated with the mouth of a river. The creature lived in the middle Eocene period, about 52 million years ago. While exciting to scientists, the absence of tail and/or hind leg fossils precludes it from dousing creationist arguments.

Case Two is the discovery of the rear legs of a previously known whale, *Basilosaurus*. This early whale lived between about 47 and 42 million years ago, and so is considerably younger than *Pakicetus*. In 1990, a team successfully joined bones from many individuals to form a composite leg, including femur, tibia, fibula, kneecap, and toe bones. Evidence indicates that the leg did "stick out" through the side of the whale, but was only a foot or two long – a small fraction of a 50-foot animal. While once again fascinating, the legs could serve no function on land (or probably even in water), and therefore do not meet the "transitional" criteria that Gould is seeking. Those with open minds see such artifacts and remnants as evidence that evolution occurs [see, for example, TPT 1]; but to a modern creationist, it means no more than free-floating hip remnants in modern whales.

Case Three is the discovery in 1993 of a whale called *Indocetus*, of intermediate age between *Pakicetus* and *Basilosaurus*. It contains fragments of the hips and legs that indicate that the rear limbs were large enough to support the animal on land; however, their fragmentary nature precludes them from supporting a claim of victory.

Case Four, in Gould's words, is "the smoking gun." The January 14, 1994 issue of the journal *Science* contained a description of a very well preserved fossil of a new genus, which the authors named *Ambulocetus*, and would have weighed about 600 pounds in life. It was found in the same Pakistani sediments as *Pakicetus*, but about 120 meters higher, and therefore slightly younger. Its rear feet were, in the words of the authors, "enormous," and each toe terminates in a small hoof. It did not have a tail fluke, but rather a terrestrial mammal's long, thin tail. The rear vertebrae show that it propelled itself through the water with powerful up-and-down strokes of the rear portion of its spine, much like a tiger running (rear legs together). This is consistent with the animal's origins as a terrestrial predator, and offers insight into why whales today undulate their spine up and down for propulsion, rather than the side-to-side technique employed by fish. The authors recognize that the up-down swimming motion of cetaceans thus developed *before* the tail fluke, and apparently employed the animals legs (in some fashion) for propulsion instead. *Ambulocetus* could also clearly move on land, although its front legs were shorter than its rear. It is the very creature, Gould states, that creationists argued could not exist.

Gould wrote this essay shortly after the *Science* article on *Ambulocetus* appeared. Three months later, too late for the essay, another discovery was reported; Gould includes a discussion of it as an epilogue. Case Five, in this convention, is a smaller, 10-foot whale called *Rodhocetus*. It lived about 46.5 million years ago, and is about 3 million years younger than *Ambulocetus* (Case Four, the smoking gun), and about the same age as *Indocetus* (Case Three). Although the tail is not preserved, the spinal column between the head and pelvis is complete, along with the pelvis itself and a few leg bones. Several features identify *Rodhocetus* as another beautifully intermediate creature. The vertebral spines near the neck are long, as is the case with terrestrial animals where strong muscles are required to hold up the head. However, the neck vertebrae themselves are shortened, a feature which limits head turning but supports more efficient motion through the water. The lumbar vertebrae are still directly connected to the hipbones, which is required for supporting its weight on land. However, these vertebrae are fused (for strength) in terrestrial animals, but unfused in *Rodhocetus*, as in modern cetaceans. This allows for a much smoother and more powerful stroke when swimming. The rear leg itself is much larger than *Basilosaurus*, but considerably smaller than *Ambulocetus*. Thus, it is possible that *Rodhocetus* spent some time on land, but it is by no means certain. Finally, it was found in deep-water ocean sediments, indicating that it could dive more deeply than older proto-whales.

DIH 29. A Special Fondness for Beetles

Natural theology [ELP 9] was a mainstream form of creationism that began in the era of Robert Boyle [LMC 15], a 17th-century colleague of Newton, and formalized by William Paley in 1802. Its two tenants are that the *existence* of God can be inferred from His Creation, which shows intelligent design (and continues to exist in certain pseudo-intellectual circles), and that His *goodness* can be inferred from it as well [HTHT 2 discusses the drawbacks of this second premise]. In the 20th century, well after the scientific community had abandoned natural theology, a story has it that one or more theologians asked the great biologist J. B. S. Haldane (1892 – 1964) a question that presumed this view. What, the question went, can we conclude as to the nature of the Creator from a study of His creation? The answer Haldane gave, which Gould tells us is the single most famous one-liner in evolutionary biology, is: "An inordinate fondness for beetles." With his fascination of human story telling and modes of processing information, Gould spends the first part of this essay discussing his efforts to track down the actual quote and its true context.

He tells us that he has been keeping a file on this quote for ten years, but it was a heated exchange of letters to the editor in a British journals *Nature* and *The Linnean* that prompted this essay. It began with an article that, in passing, referenced the questioning theologian as being the famous scholar, Benjamin Jowett; this is unlikely, as he died the year after Haldane was born. In the firestorm that followed, several pieces of information were elicited from people who knew Haldane. It turns out that he used the phrase often in speeches and lectures, but never identified the theologian (perhaps there was none). Haldane himself did not write the quote down. One on-the-record response from the exchange of letters states that he did, in fact, say "an inordinate fondness for beetles." The one contemporary mention of the quote actually has him saying that the Creator, if he exists, must have "a special preference for beetles" – not quite the same. A third reference, also from the letter, adds that Haldane sometimes said "a special preference for stars and beetles." Gould draws the essay's title as a compromise between these last two versions. His reason for going on about this topic is that it illustrates three common ways in which humans change stories to embellish them. The first refers to who actually said it; often such a quote may be attributed to someone more important or famous. (This quote has been attributed to Thomas Huxley on occasion.) Haldane himself was famous enough to not require this, but it may explain the use of Benjamin Jowett as his foil in one version. The second is, what were the circumstances? The story always works best if it was an impromptu response to a hostile remark. Finally, what were the exact words? Often the actual response is not witty enough to satisfy the story, and must be embellished. Such is human nature, not only in the area of fiction but also in what is supposed to be history.

The essay then changes direction, turning to discuss the question of how much fondness the Creator – literally or metaphorically – really *does* have for beetles. One survey of the data at the time found that 1.82 million species of animals and plants (but not fungi or unicellular organisms) had been named and described in the literature. Of this total, about a quarter are, in fact beetles, while well over half are insects of one form or another; this would seem to make the point. However, Gould continues that these figures may only the tip of the iceberg. While the discovery of a new vertebrate is a rare event, this is not the case with arthropods. What, then, is the actual number of species of beetle on earth? The estimates vary widely, but a common estimate is 30 million species. This particular estimate is based on a combination of assumptions and fieldwork performed by Terry Erwin, an American entomologist. In the early 1980's, he took examples of 19 different species of rain-forest tree, fogged them with insecticide, and collected everything that fell out in fine nets. He then made a series of assumptions, such as how many beetles were unique to that one species of tree. He established his estimate by multiplying his findings by the number of different species of tree in tropical rain forests. Others used his raw data but varied the assumptions that followed, and came up with a range of estimates that span more than an order of magnitude. There is still much we do not know about the current state of life on earth; but in any case, the point remains that there are a lot of beetles out there. [Gould never does write an essay on Haldane's role in evolutionary theory, but he does discuss another aspect of his life in LSM 20.]

DIH 30. If Kings Can Be Hermits, Then We Are All Monkeys' Uncles

Since Darwin, biologists organize the living world in terms of line of descent, or genealogical proximity – what Darwin called "propinquity" – rather than by functional similarity. For example, whales are grouped with mammals due to their anatomy, rather than with fish. As the taxonomic field of cladistics came to replace the more traditional techniques of phenetics in the 1990s (when Gould wrote this), branching order – that is, genealogy – came to dominate biology to an even larger degree. Traditionally, lobe-finned fish such as lungfish were grouped more closely with ray-finned fish (such as trout and tuna) than they were with other vertebrates such as mammals. However, it was known that modern lungfishes and all terrestrial vertebrates – including mammals – shared a common ancestor more recently than that shared by lungfish and ray-finned fish. Technically, then – according to cladistics, which groups exclusively by propinquity – lungfish are more closely related to cows than they are to trout. [In 1981, Gould expressed some dismay at this view of lungfish – see HTHT 28 – but clearly by the time this essay was written in 1992, he had come around.] Gould states that it was the advent of practical gene sequencing, along with powerful and affordable computing power, that allowed scientists to use genes themselves to determine branching order.

One main class of the arthropod phylum, which contains everything from insects to horseshoe crabs, is the Crustacea. The crustaceans include crabs, lobsters, and shrimp, but also a number of smaller groups. One of these is the Anomura, which includes about 800 species of what are commonly called hermit crabs. Hermit crabs, which are not technically crabs at all and more closely related to shrimp, typically live in the discarded snail shells. Their bodies have adapted to this mode of life in several ways. The abdomen is tapered, and actually curves in one direction or the other in order to better fit into the curled shells; it is also soft (that is, not mineralized). They typically have only two large pairs of legs, which project forward, to be of use while the body is inside the shell; the other pairs of legs are small and hold the hermit crab inside the shell.

On the other end of the size spectrum are king crabs, which live in arctic waters and typically grows to width of feet and a weight of ten pounds. King crabs certainly look like crabs: they have a wide, flattened, mineralized carapace ("shell"), the abdomen is small and tucked under body, and it has several pairs of sturdy walking legs. It moves like a crab and lives the lifestyle of a crab. However, it appears to be a close relative of the hermit crab by propinquity. There are four lines of evidence to support this conclusion. The first is certain detailed parts of king crab anatomy, which differ from true crabs and instead resemble the Anomura. The second is a very close similarity in the larval stages of king crabs and hermit crabs. The third is the existence of a number of "intermediate" species, such as free-living crustaceans with asymmetrical extended abdomens and re-calcified shells (Gould gives several examples). This suggests that only a few genes control whether the carapace is long and round like a lobster or wide and flattened like a crab; whether the carapace is mineralized or not; and whether certain legs grow long or short. Crustaceans seem able to change back and forth within these modes relatively easily. This lends credibility to the notion that, despite the large functional differences between kings and hermits, they could be close relatives. The fourth and final line of evidence comes, of course, from the DNA. A paper written by C. W. Cunningham, et al and published in 1992, which prompted Gould to write this essay, looked at the DNA of many of these crustaceans. It concludes that king crabs and hermit crabs are, in fact, very closely related, sharing a common ancestor 13-25 million years ago; Gould discusses the paper in some detail.

While readers may not be impressed with the difference in the functional versus genealogical relationship between these marine invertebrates, Gould states, they may care about the relationship of man to chimpanzees and gorillas. The latter two species of primate are grouped into the family Pongidae [or were, when Gould wrote this], with humans in the separate family Hominidae. Functionally, this makes sense, as gorillas and chimps are both knuckle-walkers, have fur over most of their bodies, and possess similar-sized brains. Until recently, he states, it was believed that the genetic information supported this relationship as well [see HTHT 28]. However, newer evidence employing the genetic tools discussed above now suggests that chimps and humans retained a common ancestor well after the gorillas had branched off. That is, if this evidence holds up, we must conclude that chimps are more closely related to humans than they are to gorillas. [Chimpanzees, Gorillas, and Orangutans are now all placed in the family Hominidae.]

Gould makes a short but important point in this essay about the testability of the theory of evolution. Some creationists have made the charge, he tells us, that evolution cannot be tested and therefore cannot be a science. While this has always been a nonsensical argument, he points out that modern genetics does in fact prove the "decent with modification" aspect of evolutionary theory in spades. The ability to easily sequence DNA appeared more than a century after *Origin of Species*. The common coding language of DNA for all living things, coupled with a remarkably close correlation between genetic similarity and the organizational structure of Linnaeus, are greatly under-appreciated facts that could have destroyed, but in fact overwhelmingly support, the theory of evolution. He continues this theme in the next essay.

DIH 31. Magnolias from Moscow

In one of several autobiographical moments in this essay, Gould tells us that he finally visited his fiftieth state – Idaho – in his fiftieth year. He accepted an invitation to speak at the University of Idaho in Moscow, he acknowledges, partly because it rounded out his "collection." He also discusses how much he appreciates small academic outposts that are off the beaten path; researchers there spend much more time talking to members of other departments, something that rarely happens at Harvard due to intense over-commitment. The comparative rareness of visitors, such as himself, also leads to an exceptionally warm reception from his hosts. One of the ways in which the faculty expressed their gratitude with his visit was to drive him two hours northeast to a fossil lakebed discovered twenty years earlier in the tiny town of Clarkia.

Francis Keinbaum discovered the Clarkia lakebed in 1971, while using a bulldozer to create a skimobile racetrack on his land. The lake formed about 20 million years ago, during the Miocene period, and lasted about a thousand years. The sediments that filled it in are about 100 feet thick. While these sediments contain occasional insects and many microfossils, the most spectacular finds here are the leaves. When the waterlogged rock is split (with a kitchen knife!), leaves that look no different from the day they fell appear at each bedding plane. Most are green, but many possess autumnal colors. Within a few minutes, the leaves dry to a black film and blow away. The excellent preservation is due to three factors: the leaves fell directly into the lake rather than being transported by some mechanism; the lack of oxygen in the ancient lake, which prevented their decomposition; and that the ground remained waterlogged and oxygen-free for the entire 20-million period. The preservation is so good that cellular structure and leaf chemistry can be examined. One of the most exciting aspects of these fossil leaves is that DNA can be extracted from the chloroplasts (although not, so far, the nuclei, which are not as well preserved). Before the sequencing of these fossils, the oldest DNA ever extracted was from a 13,000-year-old sloth; this discovery pushed that date back by three orders of magnitude. Comparisons of the large DNA fragments with their modern equivalents provide direct evidence of an important genetic principle: changes in the genome occur far more commonly in those parts that do not code for anything, or are redundant [see ELP 28]. This property had been inferred from studies of modern DNA, but this was the first case that demonstrated it explicitly.

When Keinbaum first saw these leaves in the layers he dug up, he recognized that they were not like any leaves that lived in Idaho today. He contacted the closest scientific community (at the university in Moscow). It was quickly determined that two of the most common leaves belonged to magnolias and cypress trees. These are warm-climate trees that exist today only in the southern Appalachians of the US, and in parts of Asia. Scientists had known that the Miocene was much warmer than today, but the evidence of a detailed warm-weather ecosystem from that era in Idaho was a remarkable find.

Gould makes a few more points in closing. DNA sequencing adds important knowledge, he says, but it is an *augmentation* to old-fashioned fossil collection and museum curation, not a replacement for them. He encourages his paleontological colleagues to not be so self-deprecating about this. He also expands upon the counter to the creationist argument that evolution makes no predictions and therefore cannot be tested. First, it does make predictions, he states; if one found human remains in previously unexplored Miocene deposits, it would damage at least parts of the theory of evolution. Second, the fact that genetics leads to a structure of life that is so close to that worked out by studies of macroscopic forms (fossil and extant) is one of the strongest pieces of evidence that life evolves.

DIH 32. The First Unmasking of Nature

Gould begins by gently spoofing his own ability to produce an analogy under almost any circumstances. He shows images of the two sides of a 50-Kroner note from Sweden, which shows King Gustav III (reigned 1771 – 1792) on one side and Carl von Linne ("Linnaeus," 1707 – 1778) on the other. Besides this connection via the mint, both are involved in a story of a disguise within a disguise. In King Gustav's case, he was the subject of an opera by Verdi that involved a masquerade ball. For many years after the opera was written, due to politics, Gustav could not be identified by name – so the location of the story was moved to Boston, where the King was transformed into a Governor. Hence Gustav was masked twice in Verdi's tale: first by the character donning a costume to attend the ball, and secondly by change in the nationality of the character himself. As for Linnaeus, he is credited by Gould as the man who removed one of the two metaphorical masks that had prevented people from correctly understanding biology. (Darwin, in this analogy, would later remove the other.)

Thomas Henry Huxley wrote that all sciences proceed through three stages. The first of these, which he refers to as *Natural History*, involves raw data collection with no theoretical construct at all. Gould argues here [as he does elsewhere – see DIH 12, in particular] that this is actually impossible – some sort of model must be in play, or the data cannot even be gathered. (He also reiterates his argument that science does not move in a straight line as Huxley suggests here, but rather in fits and false starts. However, this structure serves his immediate purpose, so he continues.) Huxley's second step is *Natural Philosophy*, which uses various empirical methods to group the data, but still has no theoretical underpinning. Finally, Huxley's final stage of science development is *Physical Science*, which incorporates a theoretical construct to "make sense" of the organized data, in terms of cause and effect. Huxley was clearly writing about the transformation of biology into a true science in the 19^{th} century, with his compatriot Darwin as the bridge to the third stage. The source of the transition from the first to the second stage, according to Huxley, was Linnaeus. Gould concurs.

Linnaeus grouped organisms by their common physical characteristics, rather than by their function or behavior. For example, as mentioned in DIH 30, he grouped whales with mammals instead of fish. He is credited with being the first to use the "species" in all cases as the fundamental unit of biology. He also invented an important taxonomic nomenclature: the use of single words for the identification of genus and species, formalized in the tenth edition of his *Systema Naturae* in 1758. This seemingly minor naming scheme turns out to be critically important for organizing life hierarchically, much as Arabic (vs. Roman) numerals greatly assist in algebra. However, Linnaeus was no evolutionist – perhaps not a surprise considering that he worked a century before Charles Darwin published *Origin of Species*. He was a strict creationist, and his worldview was that he had glimpsed part of God's thought process in his taxonomic structure. [Gould discusses how Linnaeus developed a taxonomy that fits evolutionary theory so well without being an evolutionist in IHL 21, and problems that arise when this structure is applied to inappropriate subjects such as rocks and minerals in the same essay and in LMC 4.]

Linnaeus, Gould states, did not simply collect and organize raw data in a theory-free environment as Huxley suggests. Linnaeus not only had to create a theoretical framework to hang his data on, he had to remove other models that impeded a better understanding (thus partially "unmasking nature"). These models typically involved the view that nature was created specifically for humans. One model that Linnaeus displaced belonged to Ulysse Aldrovandi, who grouped animals by such characteristics as size, utility to man, and supposed possession of human-like qualities (such as wisdom, e.g. the owl). Another, by Conrad Gesner, was based on the Great Chain of Being, the anthropomorphic paradigm that placed man just below angles. [In LSM 9, Gould also addresses the efforts of Buffon.] Linnaeus was arrogant (Gould tells us), and mistaken about the source of the similarity in his groupings, but he did consider his organizing taxonomy to belong to God rather than Man. His recognition and codification of the structure of life in its own terms was a necessary step, without which Darwin's second unmasking of nature – descent with modification – would not have been possible.

DIH 33. Ordering Nature by Budding and Full-Breasted Sexuality

Linnaeus was successful in grouping animals by closeness of their relationships with other animals [see the previous essay]. However, plants proved to be more difficult to organize in this way. What he did instead, starting in the 1730's, was to group plants based on the male and female parts of their flowers. Most flowers have one pistil (female) and a distinct number of stamens (male). Linnaeus binned plant life into 24 classes, most based on the number of stamens. Some unusual classes consisted of species with male and female flowers on different individual plants. One class was reserved for all plants that have no flowers or seeds at all, but reproduce via other mechanisms such as spores. The problem with this approach, as Linnaeus himself recognized, is that it tends to group plant species that are not very closely related to each other. However, he could find no better principle, and this approach served two very important functions: it was easy to teach, and it was easy to use.

Another member of the Enlightenment that swept Europe in the 18th century was Erasmus Darwin (1731 – 1802), grandfather of Charles Darwin. Erasmus was a well-to-do physician, thinker, and poet, and a member of the progressive movement of his day. In 1789, he wrote a 238-page document entitled *The Loves of the Plants*. In iambic pentameter (!), Erasmus poetically describes each of Linnaeus's 24 plant classes. Since flowers are part of the plant's reproductive system, Darwin uses metaphors relating the pistils to women and the stamens to men, often in the form of stories related to current events or to classical literature or mythology. Gould presents over a dozen examples of Erasmus's highly ornamented prose. For example, of the Iris, in the class of Triandria (one female pistol and three male stamens), he writes:

> The freckled *Iris* owns a fiercer flame,
> And three unjealous husbands wed the dame.

The descriptions were likely intended to help students or other readers learn and remember the Linnaean classes; Erasmus notes that he was paid to write it. The metaphors themselves do not, however, produce any additional scientific insight [one of the points of the next essay]. On the other hand, they do allow Darwin a forum to present his views on evolution (in the pre-natural selection sense), progress, and his rather liberal (for the time) view of human sexuality. Drawing on an article by Janet Browne, Gould notes that the sexism inherent in the culture is apparent in Darwin's writing. As a great user of metaphors himself, it is with mixed feelings that Gould pans Erasmus's use of them; but he cannot help but be fundamentally opposed to analogies between human feelings or behaviors and the natural world.

While Erasmus Darwin was relatively liberal, the motivator of his book – Linnaeus – was decidedly conservative, especially about sexual matters. Yet, Linnaeus himself coined the term "mammal" for the class of animals that includes humans. Why did he, Gould asks, identify the group in terms of such a sexually charged body part? He was the first to do so in this way. Clearly it had to do with the unique manner in which mammalian mothers feed their offspring; but in such a male-dominated world, why emphasize this uniquely feminine capability? Londa Schiebinger, another scholar whose work Gould references in this essay, makes the case that Linnaeus wanted to emphasize his view that humans were part of the animal world, and not a separate creation (or even taxonomic kingdom) as some of his opponents argued. He assigned humans the genus-species identifier *Homo sapiens*, with the simple, albeit ambiguous, descriptor: "Know thyself."

DIH 34. Four Metaphors in Three Generations

Gould loved metaphors, as well as words and word origins. He begins with a few etymological anecdotes from a trip he took to Greece. He discovered that one of the words he and Niles Eldridge used to describe their theory of punctuated equilibrium – *stasis*, referring to a period of stability – is used to identify bus stops in Athens. Another is the word *metaphor* itself, which appears on moving vans and luggage carriers; there it moves literal objects, rather than concepts, from one place to another. After this amusing introduction, he turns to the body of the essay. He references four metaphors used by Erasmus Darwin in his 1789 work *The Loves of the Plants* [see the previous essay], and follows this with four metaphors from Charles Darwin's 1859 *Origin of Species*. Since Erasmus is Charles's grandfather, the essay's title becomes apparent.

Metaphors are a powerful tool for conveying ideas. Like any conceptual tool, they can impede intellectual understanding as easily as it can assist it. Metaphors can be misleading as well as insightful; they can also be ineffective as well as useful. Gould charges that Erasmus's metaphors are of the ineffective variety. They are long and flowery (no pun intended), but do not enlighten the reader scientifically, or provide any additional insight into the subject. To be fair, it was not his intent to do so; he was simply trying to illustrate Linnaeus's taxonomic structure in an artistic and entertaining way. Charles has a much more difficult task: to convey a different way of thinking about nature. He employed metaphors to clarify his new and unorthodox viewpoint. Gould greatly prefers these metaphors, on the grounds that they effectively illuminate Charles's vision.

The four metaphors from Erasmus's *The Loves of the Plants* that Gould chooses are as follows. The first relates sequential fertilization in one type of flower to a noted 17^{th}-century Frenchwoman, famous for her many liaisons. The second involves Impatiens, a plant with an "explosive" seed dispersal mechanism. Erasmus relates this plant to the Greek tale of Medea, who violently threw her children to the ground (before slaying them, which as Gould points out, would seem to render the metaphor inappropriate). The third describes plants that disperse their seeds by wind in terms of Montgolfier's recently-invented hot-air balloon. The fourth suggests a connection between seeds that can "hitch a ride" on floating detritus and thus travel great distances, even across oceans, to the story of baby Moses, sent down the river in a reed basket.

Gould chooses the following four metaphors from Charles's *Origin of Species* as his personal favorites. [Gould does not mention it here, but much of his career involved challenging numbers two and four below. Despite his earlier point that metaphors can be misleading, he does not raise this issue here; his point in this case is how effective they are in explaining Charles's ideas to an audience that was unfamiliar with them.] The first focuses on the widely held view at the time that nature's "balance" reflected the benevolence of a loving God, whose creation is intended largely for human benefit. Charles writes of the falsity of this view, arguing that we forget – or choose not to see – that "the face of nature bright with gladness" actually masks the reality that all animals survive by feeding on other living things, often other animals. He goes on to argue that nature is devoid of intrinsic purpose, and what we perceive as balance and order in nature is only a side consequence of individual struggle. The second metaphor Gould chooses is "the wedge of progress," which conveys the view that the driving force of evolution in a crowded world is perennial competition. [ELP 21 discusses this metaphor in detail, as well as Gould's alternative perspective.] The third is "the tree of life," which presents a view of how living things are related to each other. This metaphor greatly predates Darwin (and in fact appears in the Bible), but Charles adds a time-dependent element: he relates living and dead branches to living and extinct lineages. The fourth selection is not really a metaphor; rather, it is an analogy, the one that gives Darwin's theory of evolution its essential identifier. In chapter 4 of *Origin of Species*, he proposes that "natural selection" is analogous to artificial selection, which breeders have used on dogs and pigeons for hundreds or thousands of years. [Darwin is making his case that macroevolution is microevolution plus "deep time." Elsewhere – most notably in *The Structure of Evolutionary Theory* (2002) – Gould disagrees, arguing that the two are separate, albeit connected, processes. Perhaps appropriately, however, Gould states his belief that evolution at higher hierarchical tiers is *analogous* to natural selection at the level of the individual organism.]