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WHEN I WAS A SCHOOLBOY, MY FRIEND and I used to amuse ourselves with fantasies about an imaginary chemical we called universal acid. I have no idea whether we invented it or inherited it, along with Spanish fly and saltpeter, as part of underground youth culture. Universal acid is a liquid so corrosive that it will eat through anything. The problem with universal acid, of course, is what to keep it in. It dissolves glass bottles and stainless-steel canisters as readily as it does paper bags. What would happen if somehow you came upon a dollop of universal acid? Would the entire planet eventually be destroyed? If not, what would be left? After everything had been transformed by its encounter with universal acid, what would the world look like?

Our speculations were a diverting joke; none of us expected to come in contact with such corrosive material. Yet in only a few years I would encounter something bearing as close a likeness to universal acid as anyone could wish. It was not a chemical but an idea – one that eats through virtually every traditional concept, leaving in its wake a revolutionized world view, with most of the old landmarks still recognizable but transformed in fundamental ways. It was the idea that Charles Darwin, in 1859, unleashed on an unsuspecting world. I was not the first to realize that I was dealing with dangerous stuff. From the moment of publication of The Origin of Species, Darwin's fundamental idea has inspired intense reactions, ranging from ferocious condemnation to ecstatic allegiance, sometimes tantamount to religious zeal.

Darwin's theory has been abused and misrepresented by friend and foe alike. It has been misappropriated to lend scientific respectability to appalling political and social doctrines. It has been pilloried in caricature by opponents, some of whom would have it compete in the schools with "creation science," a pathetic hodgepodge of pious pseudoscience. Almost no one is indifferent to Darwin, and no one should be. The Darwinian theory is a scientific theory, and a great one, but that is not all it is. The creationists who oppose it so bitterly are right about one thing: Darwin's dangerous idea cuts much deeper into the fabric of our most fundamental beliefs than many of its sophisticated apologists have yet admitted, even to themselves. Even today, more than a century after Darwin's death, many people still have not come to terms with its mind-boggling implications.

The Great Chain of Being

To APPRECIATE HOW DEEPLY DARWIN'S UNIVERSAL ACID has etched its way into the intellectual landscape, it may help to see how the world looked before Darwin

inverted it. A passage written by the English philosopher John Locke in his Essay Concerning Human Understanding, published in 1690, perfectly illustrates the conceptual blockade that was in place before the Darwinian revolution:

Let us suppose any parcel of Matter eternal, great or small, we shall find it, in it self, able to produce nothing.... Matter then, by its own Strength, cannot produce in it self so much as Motion: the motion it has, must also be from Eternity, or else be produced, and added to Matter by some other Being more powerful than Matter.... But let us suppose Motion eternal too; yet Matter, incogitative Matter and Motion, whatever changes it might produce of Figure and Bulk, could never produce Thought.... So that if we will suppose nothing first, or eternal; Matter can never begin to be: If we suppose bare Matter, without Motion, eternal; Motion can never begin to be: If we suppose only Matter and Motion first, or eternal; Thought can never begin to be.

The argument may seem strange and stilted to modern readers, but Locke himself thought he was just reminding people of something obvious: mind must come first, or at least it must be tied for first. And so it seemed to many brilliant and skeptical thinkers before Darwin. Behind their thinking lay a top-to-bottom view of things often described as a ladder, a tower or, in the memorable phrase of the American intellectual historian Arthur O. Lovejoy, a "great chain of being." Locke's argument invoked a particularly abstract version of the hierarchy, which I call the cosmic pyramid. This is what it looks like:

God

Mind

Design

Order

Chaos

Nothing

Everything finds its place somewhere in the pyramid – even blank nothingness, the ultimate foundation. Not all matter is ordered; some is in chaos; only some ordered matter is also designed; only some designed things have minds; and, of course, only one mind is God. What is the difference between order and design? As a first stab, I would say that order is mere regularity, mere pattern; design reflects Aristotle's telos, an exploitation of order for a purpose, as in a cleverly designed artifact. The solar system

exhibits stupendous order, but (apparently) it has no purpose – it is not for anything. An eye, in contrast, is for seeing. Before Darwin, the distinction was not always clearly marked, but Darwin suggested a division. Give me order and time, he said, and I will give you design – without the aid of mind….

Kinds, Essences and Change

DARWIN DID NOT SET OUT TO FIND AN ANTIDOTE TO Locke's conceptual paralysis or to pin down a grand cosmological alternative. His aim was slightly more modest: he wanted to explain the origin of species. The naturalists of his day had amassed mountains of facts about living things and had succeeded in systematizing those facts along several dimensions. Two great sources of wonder emerged from that work. First were all the discoveries about the impressive adaptations of organisms. Second was the recognition of the prolific diversity of living things: it had begun to dawn on people that literally millions of kinds of plants and animals inhabit the earth. Why were there so many? Even more striking were the patterns discernible within that diversity, particularly the huge gaps between many organisms. There were birds and mammals that swam like fish, but none with gills; there were dogs of many sizes and shapes, but no dogcats or dog- cows or feathered dogs. The patterns cried out for classification. Which principle of classification should count? The idea was not new; many versions of it had been seriously discussed since the time of the ancient Greeks. But there was a powerful Aristotelian bias against it: essences, after all, were unchanging; a thing could not change its essence, and new essences could not be born (except, of course, by God's command in episodes of Special Creation). In The Origin of Species he set out both to prove that modern species were revised descendants of earlier species – species had evolved – and to show how that "descent with modification" had taken place. The book presented an overwhelmingly persuasive case for the first thesis and a tantalizing case in favor of the second. Suddenly the burden of proof shifted to the skeptics:

Algorithmic Processes

DARWIN SUCCEEDED NOT ONLY BECAUSE HE DOCUMENTED his ideas exhaustively but also because he grounded them in a powerful theoretical framework. In modern terms, he had discovered the power of an algorithm. An algorithm is a formal process that can be counted on – logically – to yield a certain kind of result whenever it is "run" or instantiated. The idea that an algorithm is a foolproof and somehow "mechanical" procedure has been around for centuries, but it was the pioneering work of Alan M. Turing, Kurt Godel and Alonzo Church in the 1930s that

more or less fixed the current understanding of the term. Three key features of algorithms are important here:

1. Substrate neutrality: The power of the procedure is a result of its logical structure, not the materials that happen to be used in carrying it out. Long division works equally well with pencil or pen, paper or parchment, neon lights or skywriting, using any symbol system you like.

2. Underlying mindlessness: Although the overall design of the procedure may be brilliant, or may yield brilliant results, each constituent step is utterly simple. The recipe requires no wise decisions or delicate judgments on the part of the recipe reader.

3. Guaranteed results: Whatever it is an algorithm does, it always does it, provided the algorithm is executed with- out misstep. An algorithm is a foolproof recipe

Algorithms need not have anything to do with numbers. Consider the process of annealing a piece of steel. What could be more physical, less "computational," than that? The blacksmith repeatedly heats the steel and then lets it cool, and somehow in the process it becomes much stronger. How? Does the heat create special toughness atoms that coat the surface? Or does it suck out of the atmosphere subatomic glue that binds all the iron atoms together? No, nothing like that takes place. The right level of explanation is the algorithmic level: As the metal cools from its molten state, it begins to form a solid in many spots at the same time, creating crystals that grow together until the entire mass is solid. The first time that takes place, the arrangement of the individual crystal structures is less than optimal; they are weakly held together, with lots of internal stresses and strains. Heating the steel again – but not all the way to melting – partly breaks down those structures, so that, when next they cool, the broken-up bits adhere to the still-solid bit in a different arrangement. It can be mathematically proved that the rearrangements tend to form a progressively stronger total structure, provided the heating and cooling are done just right. To understand annealing in depth you have to learn the physics of all the forces operating at the atomic level. But the basic idea of how and why the process works can he lifted clear of those details and put in substrate-neutral terminology.

For example, metallurgical annealing has inspired a general problem-solving technique in computer science known as simulated annealing, a way of getting a computer programs to build, disassemble and rebuild a data structure (such as another program) over and over, blindly groping toward a better – sometimes even an optimal – version. Similarly, Darwin's ideas about the powers of natural selection can be lifted out of their home base in biology. Darwin himself had few inklings about the microscopic processes

of genetic inheritance (and those turned out to be wrong). Because of substrate neutrality, however, his basic insights have floated like a cork on the waves of subsequent research and controversy, from Mendel to molecular biology.

Universal Acid, Redux

HERE, THEN IS DARWIN'S DANGEROUS IDEA: The algorithmic level is the level that best accounts for the speed of the antelope, the wing of the eagle, the shape of the orchid, the diversity of species and all the other occasions for wonder in the world of nature. Incredible as it may seem, the entire biosphere is the outcome of nothing but a cascade of algorithmic processes feeding on chance. Who designed the cascade? Nobody. It is itself the outcorne of a blind algorithmic process. As Darwin himself put it, in a letter to the British geologist Charles Lyell shortly after the publication of Oriqin: "I would give absolutely nothing for the theory of Natural Selection, if it requires miraculous additions at any one stage of descent.... If I were convinced that I required such additions to the theory of natural selection, I would reject it as rubbish."

The idea of evolution by algorithm is still controversial. Like universal acid, Darwin's idea quickly began to eat its way out of its original container. If the redesign of organisms could be a mindless, algorithmic process of evolution, why could that process itself not be the product of evolution, and so forth, all the way down the cosmic pyramid? And if mindless evolution could account for the breathtakingly clever artifacts of the biosphere, how could the products of our own minds be exempt from an evolutionary explanation? Darwin's idea thus also threatened to spread all the way up the cosmic pyramid , dissolving the illusion of human authorship, our own divine spark of creativity and understanding. In response, anxious thinkers have waged a number of failed campaigns to contain Darwin's idea within some acceptably safe, partial revolution. Cede some or all of modern biology to Darwin, perhaps, but hold the line there. Keep Darwinian thinking out of cosmology, out of psychology, out of human culture, out of ethics, politics and religion! (Among those who favor holding the line within biology itself, Stephen Jay Gould has offered several post-Darwinian counterrevolutions.) The forces of containment have won many battles and, to their credit, have exposed and discredited rnany flawed applications of Darwin's idea. But new, improved waves of Darwinian thinking keep coming.

In Darwin's conception, the vertical dimension of the cosmic pyramid becomes the measure of how much design has gone into items at a given level. Minds still end up near the top, but only because they are among the most advanced effects (to date) of the creative process – not, as in the old version, its cause or source. And the products of human minds, namely, human artifacts, must count as more designed still. That might

seem counterintuitive at first; surely a paper clip is a trivial product of design compared with any living thing, however rudimentary. But imagine yourself walking along an apparently deserted beach on an alien planet. Which discovery would excite you more: a clam, or a clam rake?

Cranes and Skyhooks

NOW IMAGINE ALL THE LIFTING THAT MUST HAVE BEEN needed to create the magnificent organisms and (other) artifacts in the upper reaches of the cosmic pyramid. Vast distances must have been traversed since the dawn of life and the earliest, simplest self-replicating entities. Darwin has offered an account of the crudest, most rudimentary, stupidest imaginable lifting process: natural selection. By taking the smallest possible steps, the process can gradually, over eons, traverse those huge distances. Could it really have happened that way'. Can Darwin's mindlessly mechanical algorithms really get all the way to here (the world of wonders we all inhabit) from there (the world of chaos or utter undesignedness) in only a few billion years? Or did the process need a leg up now and then, if only at the very beginning, from some sort of "mind first" force or power or process? In short, does evolution need a skyhook ?

skyhook. orig. Aeronaut. An imaginary contrivance for attachment to the sky; an imaginary means of suspension in the sky. –Oxford English Dictionary

The first use of the term noted by the OED dates from 1915, when an airplane pilot, commanded to remain aloft for an hour beyond the planned landing, replied, "Submitted: that this machine is not fitted with skyhooks." Skyhooks would be wonderful things to have: miraculous lifters, unsupported and insupportable, great for hauling unwieldy objects out of difficult circumstances and speeding up all sorts of construction projects. Sad to say, though, there are no skyhooks.

But there are cranes. Anyone who is, like me, a lifelong spectator at construction sites surely has noticed with some satisfaction that it sometimes takes a small crane to set up a big crane. And it must have occurred to many other on- lookers that, in principle, the big crane could be used to build a still more spectacular crane. In principle (if not in real-world construction projects), there is no limit to the cascade of cranes that could be organized to accomplish some mighty end. In the Darwinian context cranes are natural evolutionary sub-processes or features that speed up the basic, slow pace of natural selection. Cranes are expensive; they have to be designed and built from everyday parts already on hand; and they need to be erected on a firm base of existing ground. Once built, however, they are excellent lifters; they do their job in an honest, non-question-

begging fashion; and they have the decided advantage of being real. For more than a century skeptics have been trying to find a proof that Darwin's idea just cannot work, at least not all the way. Time and again they have come up with truly fascinating challenges: leaps and gaps and other marvels that do seem, at first, to need skyhooks. But then along have come the cranes – discovered, in many cases, by the very skeptics who were hoping to find a skyhook

Sex

ONE EXTREMELY POWERFUL CRANE, MOST EVOLUTIONARY theorists agree, is sex. Species that reproduce sexually can move through the universe of possible, non-lethal designs – which might be called design space – much more rapidly than organisms that reproduce asexually. That cannot be the raison d'etre of sex, however. Evolution cannot see far down the road; anything it builds must have an immediate payoff to counterbalance the cost. Some other, short-term benefit must have maintained the positive selection pressure required to make sexual reproduction an offer few species could refuse. Another crane, one that was created to be a crane, is genetic engineering. Genetic engineers – people who engage in recombinant-DNA tinkering – can now take huge leaps through design space, creating organisms that would never have evolved by "ordinary" means. That is no miracle – provided the genetic engineers themselves (and the artifacts they use in their trade) are wholly the products of earlier, slower evolutionary processes. In The Descent of Man Darwin made it clear that the cranes of evolution reach all the way up to the throne of mind. That idea was too revolutionary for many people – and it remains so, even among some of evolution's best friends. Alfred Russell Wallace, whom Darwin acknowledged as co-discoverer of the principle of evolution, never quite got the point.

Why couldn't the most important thing of all be something that arose from unimportant things? Darwin's inversion suggests that varieties of excellence, worth and purpose can emerge, bubbling up out of "mindless, purposeless forces." People ache to believe that human beings are vastly different from all other species – and they are right. We are different. We are the only species that has access to an extra mode for preserving and communicating design: culture. (Other species have some capacity to transmit information "behaviorally" as well as genetically, but they have not developed culture to the takeoff point that our species has.) People have language, the primary medium of culture, and language has opened up new regions of design space that only we are privy to. In a few short millennia – a mere instant in biological time – we have already launched our new exploration vehicles to transform not only the planet but the very process of design development that created us.

Crane-Making Cranes

HUMAN CULTURE IS NOT JUST A CRANE MADE UP OF CRANES; it is a crane-making crane, so powerful that its effects can swamp many (but not all) of the earlier genetic pressures and processes that created it and still coexist with it. What kind of evolutionary revolution took place to set us apart so decisively from all other products of the genetic revolution? The explanation, I think, parallels the wonderful story told by the biologist Lynn Margulis of the University of Massachusetts at Amherst, about the revolution that paved the way for all complex life. Once upon a time, Margulis says, the only organisms on earth were cells without nuclei, the prokaryotes. They were simple, solitary forms of life, destined for nothing fancier than drifting around in an energy-rich soup and reproducing themselves. Then, one day, some prokaryotes were invaded by parasites. But the invaders turned out to be beneficial; they joined forces with their hosts, creating a revolutionary new kind of entity, a eukaryotic cell. That partnership opened up the vast space of possibilities known as multicellular life. A few billion years passed. Then one fine day another invasion began. A single species of multicellular organism, a kind of ape-like primate, had developed a variety of structures and capacities that happened to make the organism particularly well suited for the invaders. In fact, the primate hosts had created the invaders as well, in much the way spiders create webs and birds create nests. In a twinkling – in less than 100,000 years – the invaders transformed the apes who were their unwitting hosts into something altogether new: witting hosts, who, thanks to their huge stock of new- fangled invaders, could imagine the heretofore unimaginable, leaping through design space as nothing had ever done before.

Following the evolutionary biologist Richard Dawkins of the University of Oxford, I call the invaders memes. The radically new kind of entity created when a particular kind of animal is properly furnished (or infested) with memes is what is commonly called a person. Roughly speaking, memes are ideas – specifically, the kind of complex ideas that form themselves into distinct memorable units, such as: arch; wheel; wearing clothes; vendetta; right triangle; alphabet; calendar; the Odyssey; calculus; chess; perspective drawing; evolution by natural selection; Impressionism; "Greensleeves"; deconstruction.

In Dawkins's conception, memes represent units of cultural transmission analogous to the genes of biological evolution. Like genes, memes are replicators, subject to much the same principles of evolution as genes are. Their fate is determined by whether copies and copies of copies of them persist and multiply, and that depends on the selective forces that act directly on the various physical vehicles that embody them. Some thinkers have proposed that there could be a science of meme evolution – memetics –

strongly parallel to genetics. Others consider the proposal absurd. Whatever views people have, There can be no returning to pre-Darwinian innocence. Some people hate the very idea of explaining culture in evolutionary terms. I think they are making a big mistake. They want to believe that the human way of life is radically different from that of all other living things – and so it is. But they also want to understand that difference as the result of a miracle, a gift from God, a skyhook, not a crane. Why? Why should people flinch from carrying Darwin's idea through to its logical conclusion? The answer, I think, is fear. They are afraid that the idea will not just explain but will explain away the minds and purposes and meanings that everyone holds dear; that the universal acid will pass through their most cherished monuments, dissolving them into an unrecognizable and unlovable puddle of scientific destruction.

I can sympathize with such concerns. But the damage, if damage it is, is already done. Even if Darwin's idea came to be rejected by science – utterly discredited and replaced by some vastly more powerful (and currently unimaginable) vision – it would still have irremediably demolished everything that came before it. Simply by making design without mind conceivable, Darwin rendered Locke's argument, and the thinking behind it, as obsolete as the quill. Whatever we hold precious, we cannot protect it from our curiosity, because being who we are, one of the things we deem precious is the truth. Our love of truth is surely a central element in the meaning we find in our lives. In any case, the idea that we might preserve meaning by kidding ourselves is a more pessimistic, more nihilistic idea than I for one can stomach. If that were the best that could be done, I would conclude that nothing mattered after all.

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Questions on Darwin's Dangerous Idea

1. Why does Dennett suggest Darwin's idea is a 'universal acid'.

2. What did the 'great chain of being' or 'cosmic pyramid' explain to people of Locke's era?

3. What features do algorithms possess? Does Darwin's idea contain those features?

4. What does Darwin's dangerous idea do to the cosmic pyramid? What does it have to say about 'design'?

5. In the Darwinian vocabulary, what are 'cranes'?

6. List three cranes.

7. What is the 'crane-making crane'? Explain the concept of memes. Come up with three of your own memes?