

Essay 2:

Where did our scientific ideas about ourselves come from?

Theme: Science is a cultural system, but because it has a solitary goal – empirical accuracy – it self-corrects, and fares well when compared for its accuracy against other origin myths with additional, conflicting goals.

The beginnings of a new view of nature

The year 1543 is a good place to start, because far from being an entirely arbitrary year, it is the year that two crucially important works – paradigm-shifting works – were published. Europe was undergoing a rebirth or “renaissance” in art, looking to its classical ancient past for inspiration. The authority of the medieval Catholic Church had been coming under attack since a 34-year-old cleric named Martin Luther had expressed his outrage at its earthly workings in 1517, by posting 95 critical theses on the door of his church at Wittenburg. These radical ideas could be disseminated far more rapidly than ever before, since movable type had been in use for several decades, pioneered by a printer named Johannes Gutenberg.

Into this social and political context, an elderly Polish astronomer allowed his radical ideas to be published under his Latinized name Nicolaus Copernicus as he lay dying. Copernicus believed that the existing observational data on the solar system could be explained just as easily by a new approach, as it was by the age-old Greek system that held the earth to be constant and motionless and the celestial bodies to revolve around it.

His idea was *heliocentrism*, that the sun – not the earth – is the center of the solar system, and that all the planets except the moon revolve around it, rather than around the earth. This idea was radical, although much of his work – *On the Revolutions of the Celestial Spheres* – was not. Copernicus had made no new observations that proved his case (like, for example, Galileo’s observation of moons orbiting Jupiter, decades later). Rather, he pleaded his case as a theoretical consistency argument, showing that the available astronomical data could be explained in this new way at least as well as the old way. Like the old view, he believed that heavenly bodies moved in perfect circles (not in odd ellipses, as Kepler would later show), and that they were embedded in perfect solid spheres.

On the other hand, his idea implied that the heavens were considerably larger than they appeared, and that the earth was not their center. If true, it implied two things: first, received wisdom might be wrong; and second, humans might well occupy a peripheral spot in the earth and the heavens, and thus might not have been the focal point of the creation of the universe.



The same year, a Flemish physician called Andreas Vesalius published a different kind of work – highly empirical and deliberately provocative – *On the Fabric of the Human Body*. Where earlier medical treatises contained highly stylized representations of the human body, Vesalius illustrated his with brilliantly detailed and realistic renderings of the body, musculature, skeleton and organs. His radicalism was not so much in the implications of a theory, but in the methods of acquiring knowledge. How did Vesalius know how to draw the human body? Because he looked inside it, and saw for himself. And his message was: If you look inside the human yourself, this is what you’ll see. He called for physicians to learn anatomy by dissecting human corpses and seeing it first-hand for themselves.

Also unlike Copernicus, he boldly demonstrated that the received wisdom from ancient texts was indeed wrong in places. Where the ancient Roman physician Galen had made certain claims about the human body, Vesalius could demonstrate that the claim was based not on the structure of the human body, but on that of a pig, or horse, or monkey – because the human body differed from what the ancient text said. *All you had to do was look for yourself.*

The scientific revolution

The culmination of the 1543 works of Copernicus and Vesalius was a new approach to the natural world. From Copernicus we learned that new ideas might supersede old ones, and that the human species, and the earth, might not hold such glorified positions in the cosmos. From Vesalius we learned that empiricism was the most direct approach to gaining new knowledge. The empirical approach was the way to gain an accurate description of things; and it might be possible to establish such new knowledge in formalized and generalized ways.

Two such formalizers were the Italian astronomer/physicist Galileo Galilei (1564-1642) and the French mathematician/philosopher Rene Descartes (1596-1650). Among their many contributions, we learned from the former about regularities of motion; and from the latter, how to represent nature in two dimensions (“Cartesian coordinates”). Indeed Descartes formalized the new view of nature as nothing but matter and motion, categorically distinct from mind and spirit. Their contemporary, Francis Bacon (1564-1642), did not write any of Shakespeare’s plays (as rumor once had it), but did propagandize extensively for “the new philosophy” – science – which would bring a better life for all, if it were allowed to grow and flourish.

William Harvey (1578-1657) was the epitome of the new approach to the human body. He designed and conducted experiments to see whether the heart was really a heater for newly-created blood – as ancient wisdom (and contemporary thought) had it; or whether the heart is a pump, with the blood circulating through the body and returning after completing a cycle. Of course, he discovered the latter, setting off a new way of seeing the body – as a machine composed of functioning parts – and a new way of finding about how bodies work – biological experiment.

But the person who came to embody science was Isaac Newton (1642-1727) – mathematician, physicist, and mystic. Newton was a very undistinguished schoolchild until, as legend has it, an apple fell on his head and he got to wondering why things fall. Finding the mathematics of the day inadequate to the task, he invented his own “method of fluxions”, which we now know as calculus. In his *Principia* (1687), Newton set forth the fundamental laws of motion that are obeyed by all things in the

known universe; moreover, he described gravity mathematically, unifying and formalizing the process by which apples fall from trees and planets are kept in motion around the sun.

Science after Newton was quite simply different, and he became its epitome – both in good and bad senses. In the bad sense of the



modern view of the scientist, Newton was very competitive – he destroyed his perceived enemies and sought full and unshared credit for everything he worked on. Publicly he sounded magnanimous – “If I have seen further, it is because I have stood on the shoulders of giants,”

he said – but he held strong grudges against other scientists for daring to try and share the intellectual spotlight with him, and against the German mathematician Leibniz for inventing calculus independently. He was also an obsessive workaholic with consequent social and mental problems, and a lifelong bachelor with no known romantic interests.

In the good sense of the modern view of the scientist, however, Newton’s work defined the domain of science and framed its objectives. In the first place, it was now clear that there was a great deal the Bible had left out: math, the heliocentric solar system, gravity, and motion, just for starters. Clearly there was value in going beyond, or independently of, the Bible in a search for knowledge.

Second, Newton and his followers drew a distinction between proximate and ultimate cause. While the distinction had been acknowledged since ancient times, the new science brought the distinction to the foreground and made proximate cause the goal of science, demarcating it from theological speculations on ultimate or final causes. The philosophical implications of Newton’s unified physics were staggering, because they literally redefined the domain of God’s work.

If there were great generalizations to be discovered concerning the way in which light, or mass, or gravity worked, then God no longer needed to be invoked in every particular instance of light, or mass, or gravity. Rather, God could be seen as having devised these generalizations at the beginning of time, and then having let the universe run itself. This came to be known as the “mechanical philosophy” – the cosmos as a

great machine (an appropriate metaphor for the time, of course), running essentially like a great clock, built by God but no longer requiring His vigorous intervention.

Thus, God came to be seen as the Creator of the laws of matter and motion, which Newton had discovered. If God were a law-maker, and endowed humans with the intelligence to study the world, it followed that discovering the laws by which God set the world up was an admirable pursuit. And that became the object of science: to find underlying regularity in nature; specific instances or events were no longer as interesting or important as the underlying law established by God.

Thus, not only was God removed from immediate events, and His domain now restricted, but Nature itself thereby become less mysterious and more fundamentally knowable. It had a divinely-established order, set in motion by God. Indeed there was something fundamentally religious about studying Nature, for by coming to study the divine workings as they are manifest in the natural order, you can come to know the mind of God. The power of this view is retained even today. Compare, for example, President Clinton's words when the Human Genome Project announced the human DNA sequence in 1999: "Today we are learning the language in which God created life."

Biology, alas, lagged far behind physics and mathematics when it came to generalizations and laws. There seemed to be little you could learn from studying life that had the spiritual value of studying matter and motion, the fundamental constituents of the universe. Nevertheless, there were some profound changes occurring at this time in certain elements of our understanding of the human condition as well.

The decline of degeneration

For well over a thousand years medieval life had been governed by a view of human existence that was both static and pessimistic. It held that man had sinned in the Garden of Eden (and that it was woman's fault!) and as a result, had "fallen from grace" – so birth was painful, life was tough, and relief could only be expected through death – assuming you were a good Christian. Earth remained in a state of moral decay, reflected in material decay, and would only get better with the return of Christ. Moreover, it was tantamount to sacrilegious to try and improve your lot on earth; God wanted you to focus on the next world, not on this one.

This naturally encoded a justification for a stable social hierarchy – and the futility of aspirations to upward mobility that might upset that hierarchy. Life sucked, then you died.

And yet by the 17th and 18th centuries a different and more optimistic view was becoming disseminated. There were lands of great riches, resources, and opportunities, which could provide fortune for an ambitious sailor, merchant, or investor. Science was promoting the value of invention, and the Industrial Revolution was showing how creativity and hard work could change not only your life for the better, but everyone's life for the better. Maybe things weren't so bad after all!

Consequently the dour view of degeneration came to be replaced by a more optimistic view of social history as progress. Things could improve on earth, during your lifetime. You could live a better life than your parents had known. Maybe it wasn't life that sucked, but just the feudal political and economic system – and since you could see people getting freer and wealthier, maybe the purpose of history wasn't to have you look backward with remorse, but to look forward with anticipation.

What the new idea of social progress did was to get people thinking about earthly properties as being important, rather than passively accepting the world as it was passed down to you; and thinking about change as a fundamental part of human history. In other words, a new dynamic social universe was supplanting the old static order of things.

The anatomy of a "Pygmie"

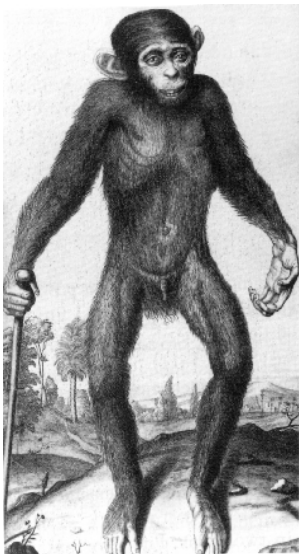
Travelogues from ancient times to the 18th century had mentioned remote races of people with one eye, or one leg, or no head; who hissed like snakes, or ate their children, or lived in caves. Sailors had been reporting the existence of bizarre, manlike beasts far away; but then they were known to be great exaggerators, and they also reported mermaids. Ships to the East Indies or Africa occasionally tried to bring an example of these apes home, but the ocean voyage and diet had never permitted it successfully. Finally in 1698 a young and ailing chimpanzee arrived in England from West Africa.

It died shortly thereafter, but became the subject of one of the most important scientific monographs of the age: Edward Tyson's (1699) *Orang-Outang, sive Homo sylvestris; or, The Anatomy of a Pygmie, compared with that of a Monkey, an Ape, and a Man*. Tyson was the

leading anatomist in England and provided not only a competent dissection, but the first clearly identifiable pictures of an ape (the ape in the title of his work actually refers to short-tailed monkeys, which were well-known).

Tyson made two crucial points in his monograph. The first is that, in tabulating the number of observable resemblances between the chimpanzee and a human, versus between the chimpanzee and a monkey, he could identify 48 anatomical resemblances to a human, but only 34 to a monkey. But of course it was not human, but an animal that looked more like a human than like anything else. The second crucial point was that its similarity to the human suggested physical continuity between the animals and ourselves. Certainly the resemblances between the human body and those of other animals had long been recognized, but this was something more: a creature more similar to a human than to anything else. It would no longer be possible to think of humans as distinct from all other forms of life – physically, at least.

The overwhelming structural similarity to the human form directly suggested to Tyson that it had been created to be functionally like a human as well. The bones and muscles of its legs were so similar to those of their human counterparts that Tyson could only imagine that it walked upright, as human do, and that it was made for doing so. And yet he had seen it walking, but it did so on all fours, using the knuckles of its hands. Perhaps, he reasoned, it was only doing that because it was sick. He resolved this paradox by having it drawn neither fully upright, nor knuckle-walking, but standing with the aid of a cane. This would encapsulate the symbolic position of the ape – nearly human physically, but not quite – an incomplete person, suggesting state or a time of subhumanity. Perhaps that is why the cane stuck with pictures of apes for about the next 150 years.



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Biblical fallibility, or at least incompleteness

Human origins had been rather simple to understand. God created the world in less than a week and near the end he created a man (“Adam” is Hebrew for “man”) and shortly thereafter took a rib and built a mate for him. There was speculation as to whether Adam had a navel or not – if so, then why, for he had no umbilicus; and if not, then he was oddly different from you and me. But by and large there seemed no compelling reason to question the Biblical narrative.

That situation changed in 1492. Clearly there were diverse and unfamiliar people out there, far away. How did they get there? The Bible didn’t say. Were they human, with souls and thus requiring salvation? The Bible didn’t say. If they were descended from Adam and Eve, how did they come to be as they are? The Bible didn’t say. And they must be descended from Adam and Eve, mustn’t they?

A papal decree in the early 1500s declared the inhabitants of the New World to be fully human, and lost after the Tower of Babel (in which people tried to build a tower to reach heaven, and God responded by destroying the tower and inflicting different languages upon the builders, thus confusing them so they could no longer cooperate).

A young rabbinical student in Amsterdam named Baruch Spinoza (1632-1677) posed a question to the scholars: If Moses wrote first five books of the Bible, as tradition holds, then how could he have written about his own death and burial in Chapter 34 of Deuteronomy, the fifth book of the Bible? Upon his subsequent excommunication from the Dutch Jewish community, Spinoza adopted the Latin name Benedictus (which, like Baruch, means “blessed”) and continued to study philosophy. Spinoza is credited with devising a fully rational philosophical system, in which the idea of God becomes virtually synonymous with His construction of the natural order. More importantly, however, Spinoza demands that the Bible be taken as an historical document – not as a document about history, but as a document situated within history. His work marks the beginning of the “higher criticism” of the Bible.

It is in this intellectual climate that a French Calvinist scholar and diplomat named Isaac de la Peyrère (1596-1676) published a book in 1655 that pales in significance and profundity next to Spinoza, but in fact was read by the young Spinoza, and had a considerable impact upon the

question of interest to us, human origins. La Peyrère's book was called *Pre-Adamites*, and raised the possibility that the Bible, being frequently vague, and occasionally self-contradictory, might be compatible with the idea that there were people around before Adam.

In particular, suggested La Peyrère, maybe the Bible is simply describing in Genesis the creation of the ancestors of the Hebrews; and maybe God created the ancestors of other peoples independently and earlier. The importance of La Peyrère's book may lie simply in the fact that it was publicly burned in Paris, and 36 refutations of it were published in the next few decades. Clearly it had touched a nerve.

La Peyrère's work had little of value for the modern scholar, except as having publicly called into question for the first time the literal truth of the traditional account of the creation of Adam. Oddly, La Peyrère's book would also be invoked as a precursor of a very different, and darker, idea – that the different races of people were the products of separate creative acts by God, and therefore had no common biological history and should be considered separate species – an idea called polygenism.

Monogenism

Taking La Peyrère's argument further than he did, one could envision different races being the products of separate creations. If so, then they were different in their very essences, and could not be considered members of the same species. This was an interpretation that was greeted with enthusiasm in the American South, prior to the Civil War; after all, if whites and blacks were not really brothers biologically, then slavery might have a scientific argument to justify it.

But the term "species" was beginning to take on a formal sense by 1700 – not two individuals that just looked similar, but rather, that were capable of interbreeding with each other. The implications for understanding the human species were profound. Clearly humans could interbreed, and were doing so all over the globe; European sailors had demonstrated that beyond reasonable doubt. By that very fact, they must be considered a single species, and if the units of God's creation were species, then all humans must have been the product of a single creative act.

The empirical evidence for monogenism swayed the bulk of the scientific community,

especially in Europe, by the mid-1700s. Polygenism would enjoy a vogue in America just before the Civil War, but except for brief flareups at Harvard (in the works of Louis Agassiz in the 1870s, and Ruggles Gates in the 1940s) was effectively dead.

Monogenism, however, carried with it an important implication. Accepting that humans comprised a single species and that that species had its origin in a single creative act, one must still be struck by the physical diversity in the human form over the earth. People looked different from one another; and if Adam and Eve were white, then Africans and Asians must have developed their divergent appearance over the course of human history. Therefore considerable physical change must be possible over the span of Biblical time.

The dispute between the monogenists and polygenists is worth considering, because the intellectual battle lines were drawn in somewhat different ways than seem familiar to us today. The monogenists held that the human species was a single natural entity, descended from an original single pair of people. They identified that couple as Adam and Eve, taking the Bible as literally true; and used that as an argument for the abolition of slavery. Thus they were Biblical literalists and social liberals.

But they were also obliged, by taking those positions, to accept the mutability of human form, and to develop explanations of how biological stocks could change through time. Thus, in addition to being Biblical literalists and social liberals, the monogenists were also the first evolutionists. Microevolutionists, to be sure – considering changes within species, rather than trans-specific change – but the first modern evolutionists nevertheless. The opposition, polygenism, held that different races were the products of separate creations, and had always been as they are; thus they clung to a static creationist view of human origins, invoked it odiously to support the institution of slavery, and rationalized it with a modern, liberal interpretation of the Bible.

Cause and Effect

Thinking about the universe as a machine – a powerful metaphor of the age – had another effect, in getting philosophers to think more rigorously about why things happen at all. History, for example, could be interpreted as "leading up to" the second coming of Christ. But little of history is thereby explained; if you

want to know why the Roman Empire fell, or why the Industrial Revolution occurred, interpreting it in terms of the second coming of Christ will not get you very far. Things happen for reasons in the immediate past, not in the distant future.

What's true for history is also true for physics. A billiard ball moves because of the one that just hit it, not because of the one it's going to hit. This is especially true if we adopt the Newtonian idea that the domain of science is the study of proximate cause. If there is an ultimate cause for the billiard ball moving – for example, the intention of billiards shooter – that is not the domain of physics and mechanics, but of psychology.

A Scottish philosopher named David Hume (1711-1776) examined the entire concept of cause and effect in scientific reasoning, and concluded that three things were needed to infer that A caused B with any degree of rigor. The first is some sort of physical contiguity of A and B, such as contact; the second is that A must precede B; and the third is the constant conjunction of the two, by which Hume meant a regular pattern in which the A and B occur together. Hume was obviously only interested in cause in the material world – the world of proximate cause, and matter and motion. His reasoning has dramatic consequences in biology, however.

- Why did the world come into existence on the first day? So that man would have a place to live on the sixth day.
- Why do animals have the features that they do? So that they would be able to survive where they live.
- Why is man gifted with the power of reason? So that when a difficulty arises, he can think his way through it.

Each of these questions contains a cause and an effect, but none satisfy Hume's criteria even remotely. Most acutely, they invert the necessary time relations between a cause and an effect: something on day 6 is the cause of something on day 1; human reason is there for its future use. This reasoning is *teleological* – or goal-directed. A bullet has a goal in its trajectory – the target at which it was fired; a fertilized egg has a goal – the maturity, reproduction and senescence of the organism. But does history have a goal? Do things happen today in order to unfold a plan for tomorrow? Or do things happen today because of what happened yesterday?

Hume would use the idea of causation to attack the popular liberal theology of his age,

which saw the hand of the Deity in forming the world and its beings, and in giving them goals and purposes for existing. But as Britain's most influential philosopher, he would set in motion the biggest doubts about the quality of these ideas as scientific explanations. Should not explanations about cause and effect in organic beings be framed in tangible, material, natural terms, as the rest of modern thought was clearly heading? And should not biological cause and effect be situated in history, with the past – not the future – causing the present?

About this time, too, what had formerly been called "natural philosophy" was coming to be labeled by another, newer term – "science".

The Great Chain of Being

The structure of the natural world was well-understood in medieval times. Just like the social world had a linear hierarchy, with the King at the top, and noblemen, knights, and peasants below, so too did the natural world have a linear hierarchy. Humans were obviously the pinnacle of creation, and things that were similar to humans were slightly below them, and so on, stretching down to lizards, fish, and insects. The hand of God gave the species of the world this pattern: species intergraded into one another to form a chain of perfection. It was obvious, it was simple, and it was affirmed by everyday experience.

Except that maybe it was not so obvious. A Swedish botanist-physician named Carl Linnaeus (1707-1778) set out to formalize the relations among animals, vegetables, and minerals, and published a small pamphlet in 1735 called *The System of Nature*. Linnaeus's "system" involved terse names and descriptions for each form of animal, with an even more obvious, if previously unheralded, structure: different species clustered into groups, and groups of groups clustered as well. Thus, lions and tigers, being similar to one another, could be seen as different species belonging to a common "order" (which he called *Ferae*) whose members had sharp teeth and claws. And this "order" was just one of several that could be clustered into a larger group of hairy, four-footed creatures that nursed their young, which he called a "class" – "Quadrupedia". And these in turn clustered with birds, amphibians, fish, insects, and worms into the Animal Kingdom.

The new pattern was even more obvious than the Great Chain of Being had been, and caught on nearly overnight in the academic

community. God Created, it was said, but Linnaeus Arranged. But these clusterings – which we would now call nested categories of equal rank – had an important consequence, in that they obscured the Great Chain of Being. Was there a sense in which falcons were really superior to sharks? Or deer were superior to falcons? Or camels were superior to deer? Or hyenas were superior to camels?

Was every species rankable in terms of their similarity to us? Or rather, could species more reasonably be aggregated into restricted groups based on their similarity to one another, and then into larger groups of more relaxed similarity?

What Linnaeus was doing here was applying a radical biological relativism to the natural world, tearing down the linear hierarchy of the Great Chain of Being, and replacing it with a hierarchy of a very different kind – one wherein all species are equal, but can simply be aggregated because of their pattern of resemblances. The reason we can call it biological relativism is that it parallels ideas that developed in other intellectual fields, about the equality of elements in a system for which non-equality had long been taken for granted. In fact, maybe the hereditary aristocratic hierarchies that had existed for centuries weren't so natural after all, and maybe life would be better without them. By the late 1700s, revolutions in America and then in France were promoting the radical relativistic idea that all citizens were equal before the law, and perhaps even that everyone was “created equal”.

Somewhat later, of course, anthropologists would come to appreciate that like citizens and species, cultures cannot be objectively ranked, except by narrow, arbitrary criteria – a position that they would call “cultural relativism”.

And Linnaeus emphasized the point by classifying the human species along with all other animals from the very beginning. By the 1758 edition of *The System of Nature*, humans were a single species (*Homo sapiens*), in contrast to a second species (of Linnaeus' imagination, unfortunately), *Homo troglodytes*; the genus *Homo* was one of four genera in the Order Primates (the others being monkeys, lemurs, and (mistakenly) bats; and the Order Primates was one of several orders within the Class Mammalia.

Buffon's Objection to the Nested Hierarchy

Linnaeus' general view of nature dominated the academic community almost immediately,

and the holdouts were few. One such holdout was a respected naturalist outside the university setting, a wealthy independent scholar who took the name of the town he owned, Buffon.

Count de Buffon (1707-1788) wrote his own summary of Nature, a work published over several decades, in 44 volumes, called *Natural History, General and Specific*. In it Buffon describes the different kinds of animals, and shows them with elaborate and beautiful woodcuts. His picture of the gibbon, for example, is the first in European literature.

His work was radical in its way. His theory of the earth had it formed by natural means, tens of thousands of years ago – far more than the theology faculty of the University of Paris would permit. They forced him in 1751 to retract some of his more heretical notions about earth history, naturalism, and “truth,” – showing how sensitive theologians were already becoming to the difficulties reconciling nature and scripture.

Unfazed, however, Buffon continued to publish thoughtful musings on natural history of varying degrees of radicalness. He argued explicitly for monogenism, against slavery, and for microevolution – and developed an esoteric theory of the effect of food and the conditions of life on a species' “internal mold” to account for it. For Buffon, the task of the scientist wasn't just to organize and name things, it was to explain their relationships; and Buffon saw classification as a sterile enterprise if it is unaccompanied by explanation.

He was especially troubled, however, by some of the implications he saw in the Linnaean classification. From comparative anatomy, it was clear that there was a strong correspondence among the bodies of different animals. One could, Buffon noted, convert the skeleton of a horse into that of a human with minimal effort.

And if it is once admitted that there are families of plants and animals, that the donkey is of the horse family, ... then one could equally say that man and ape have had a common origin like the horse and donkey.... The naturalists who establish so casually the families of plants and animals do not seem to have grasped sufficiently the full scope of these consequences, which would reduce the immediate products of creation to a number of individuals as small as one might wish. For ... if it were true that the donkey were but a degenerated horse – then there would be no limits to the power of nature. One would then not be wrong to suppose that she could have drawn with time, all other organized beings from a single being.

Buffon immediately goes on to reject the entire enterprise. In other words, he rejects Linnaean classification because to him it implies

macroevolution, which he knows cannot be true. The clustering of cats and dogs and bears into a single group must suggest, to him, the idea of common descent. Paradoxically, Linnaeus himself never drew that conclusion, and both men remained lifelong creationists, nevertheless despising one another.

Extinction

By the turn of the 19th century, another set of data demanded an explanation. The last known dodo, a large flightless bird found only on the island of Mauritius, had been seen in 1684. Had people (in this case, Dutch sailors) driven it to extinction?

If so, this created a theological problem. After all, the hand of God was evident in His works on earth, and one aspect of His bounty was to have populated the world with diverse forms of life that could be arranged into a Great Chain of Being. If almighty God made a chain, how could puny people destroy one of its links? If people could really make species disappear, and undermine God's plan of creation, wrote a prominent naturalist in 1690, that would constitute a "dismemb'ring of the universe" – clearly not something to be considered lightly!

Alas, no more dodos turned up. They did not seem to be hiding anywhere – not on Mauritius, nor in the remotest places people could think of. There were just no more dodos.

Apparently people could indeed make a species go extinct.

This observation settled in about the same time as another one came to light. The Industrial Revolution necessitated the construction of large factories, and building large factories necessitated the excavation of large holes for foundations. And excavating large holes turned up fossils.

Fossils had been known since the Renaissance, and their identity as formerly-living things had come gradually to be accepted. Suddenly it became clear that there indeed existed long ago a diverse fauna comprising animals similar to, but distinct from, any living species in the present. Extinction thus became an unavoidable fact of the history of life on earth. But how to make sense of it? What was God's plan for extinction?

Two French biologists tried to explain it in different ways. The first, Jean-Baptiste de Lamarck (1744-1829), had a surprisingly simple and elegant explanation. Lamarck argued that species have a natural fit to their environments,

but environments change. When such a change happens, the organism is faced with two options: either die, or change itself. He believed that they change according to their needs, and that the physical alterations they effect are stably passed on to their offspring – a theory that came to be known as *the inheritance of acquired characteristics*. Passing on the new body form to the next generation would result in the production of a new species, one slightly improved upon its parent, and thus one link higher up on the Great Chain of Being. Thus extinction was something of an illusion: new species succeeded older species, but were actually descended from them.

Lamarck can be credited with producing the first modern theory of macroevolution, the transformation of one species into another, or evolution above the species level.

Georges Cuvier (1769-1832) held a different view. He pointed out that the Great Chain of Being was passé, and by implication, any theory that presupposed it could not hold much water. Building on Linnaeus, he argued that there were 4 kinds of animals, built on entirely different body plans: vertebrates, "Articulata" (including insects), "Radiata" (including animals with radial symmetry), and mollusks – and that no amount of argument could permit them to be linearly ranked, for they were so different as to be non-comparable.

Instead, Cuvier looked to the patterns of geological history, in which layers of the earth appear to have distinct forms of life within them, and appear to have clear boundaries separating them from other ages, with other forms of life. This suggested not so much the transformation of species into new species as environments changed, but the wholesale replacement of diverse species alive at one time by a different set of species. Extinction, to Cuvier, was real, and when species died out, in some kind of catastrophe, new species were formed and took their place. Cuvier's theory came to be known as *catastrophism*, and although he forced the scholarly community to recognize extinction, he nevertheless declined to speculate as to where the new species came from.

But Cuvier was essentially the founder of modern vertebrate paleontology, and after Cuvier, one had to acknowledge that different species came into existence and passed out of existence at different times.

The Napoleonic Wars hindered communication between English and French scientists. In general the English were more

pious than the French, and were more preoccupied with trying to reconcile the data of biology (Lamarck had coined that term shortly after the turn of the 1800s) with Scripture. The French also tended toward grand theoretical syntheses, while the English were contemptuous of anything that couldn't be directly seen or measured. Consequently when Cuvier was translated into English, the translator introduced the idea that the most recent catastrophe was described in the Bible as Noah's flood, and this was not noticed for many decades. Moreover, it left the French with the best understanding of ancient life, but lacking the empirical basis in earth history to make proper sense of it.

The English, for their part, were busy observing, experimenting, and measuring – but lacked a coherent framework or even a philosophical approach for understanding it.

Natural Theology

When Charles Darwin was a student at Cambridge in the 1820s he was assigned works of natural theology, an English biology movement designed to demonstrate the hand of God in the study of Nature. How did they do this? By calling attention to the wonders of the natural world and challenging you to imagine how they could have come about in the absence of God.

This God, however, was not the God of the physicists, who set down mathematical laws at the beginning of time and then stepped aside; but rather, a busy craftsman, meticulously molding each species in a demonstration of both His love and bounty, and of His industry. Just as physicists could study the mind of God by inferring regularity in nature, biologists could study it by observing diversity. Imagine finding a watch in the street, went their most famous argument; its intricate complexity tells you that it was made by the hand of a clever craftsman, a watchmaker. Now look at the human eye or an orchid. Doesn't its intricate complexity speak as well of an intelligent designer – a benevolent celestial presence that made it come about?

But a series of devastating arguments were already known, having been formulated first by the skeptical philosopher David Hume. Consider the outline of the shape of your home state. Is it not complex? Aside from Utah, Wyoming, and Colorado, which are simple geometric figures, all the states are so complex that they are hard to draw accurately, and most are consequently instantly recognizable. And yet, they are not the

products of a heavenly state maker! They are the products of geological and political forces – complex forces, but understandable.

Thus, the appearance of a complex design doesn't necessarily imply a conscious designer behind it; the forces at work may be blind and undirected, but may be nevertheless understandable, and can produce a complex design as well.

A parallel argument was made by an economist named Adam Smith in his book *The Wealth of Nations* (1776). A complex, efficient economy, he argued, develops not through conscious controlled design, but spontaneously by the actions of people pursuing their individual interests. And such a system will tend to run as if guided by an "invisible hand," he wrote. Things apparently could come to exist without top-down creative control. And if economies could seem to exist as if made and regulated by an invisible hand, was it such a stretch to imagine organs and bodies being similar?

And what about the watch lying in the street because it didn't keep good time and was thrown there by a dissatisfied customer? If the existence of a lousy watch implies a lousy watchmaker, doesn't the existence of imperfections, such as degenerative disease, or baldness, or PMS, or birth defects, or acne, imply an incompetent Creator? Yet somehow natural theologians were not about to criticize the work of God, which showed that they were assuming His properties and existence, not deducing them.

Thus neither the observation of order and structure, nor the analogy to the attributes of a watch, are valid reasons to infer the wisdom or hand of God in operation. God might well exist, but He simply cannot be derived from the properties of living beings on earth. Those features could have arisen by purely natural means – which may be unknown, but are ultimately knowable – unlike the actions of God.

Uniformitarian Geology

Extrapolating backwards from the time of Jesus (4 BC? – 33 AD?), pious clerics had attempted to ascertain the time of Creation, given the fact that St. Luke's gospel provides the ancestry of Jesus back to Adam. In 1642, Bishop John Lightfoot calculated that God had been at work at 9 AM in 3928 BC creating the universe; and his calculation was revised in 1658 by Bishop James Ussher, who determined that momentous date actually to have been October 23, 4004 BC.

Buffon had speculated in the mid 1700s that the Earth was considerably older than the few thousand years the Bible suggests. But English empiricist science would come to make that even more likely, with the maturation of geology in the early 19th century. The key figure in that process was Charles Lyell (1797-1875), a Scottish geologist, who published a magisterial three-volume summary and synthesis of the field in the 1830s.

Lyell sought to reform geology by giving it a more empirically rigorous basis. We don't see miracles, reasoned Lyell, who was nevertheless a very pious churchman, and therefore we cannot invoke their effects in explaining earth history. As scientists we can only use the forces we know of, and can study, to explain the geological patterns we encounter.

That raised a serious problem for traditional Biblical chronology. After all, the processes we can see and measure, such as erosion – act extremely slowly. Glaciers move, and leave tracks of their movement, but they do so at a glacial pace. The erosion of coastlines by oceans, or riverbeds, can be measured, but invariably yields results showing very slow movement. Extrapolating backward, one can calculate that the processes that produced the effects we now see must have been going on for a very, very long time, far longer than the 6000 years allowed by the Biblical chronology.

Lyell's approach to geology came to be known as uniformitarianism, and subsumed three related ideas: (1) that the only types of process we can use to understand earth history are the ones we see in operation today; (2) that we can only invoke the magnitude of those processes that we see in operation today; and that (3) the earth was consequently very old, so old that it was hard to see when it began, and hard to project when it might end – it just cycled on, with minor perturbations, beyond the human grasp of time. The first idea precluded hypothetical catastrophic events, such as cometary impacts, from playing a major role in the explanation of earth history; the second precluded hypothetical events such as worldwide floods – floods were occasionally severe, but they were local, and not worldwide; and the third was the logical consequence of the first two.

Suddenly the age of the earth was opened up, and geology had some breathing room. Species had time to live, to develop, to die out; and geological processes had a rock-solid empirical foundation. Lyell's work would have a major impression upon the young Charles

Darwin, sailing around the world in the HMS Beagle as it was being published.

Adam's world

This still left one thorny problem for anyone interested in incorporating humans into the history of life on earth. The earth seemed to be old, and displayed a succession of faunas: dinosaurs at one stage; saber-tooth tigers and mammoths at another. Where did humans fit in? There was certainly no evidence to suggest that they lived among the dinosaurs. Humans were clearly geologically very recent, and dinosaurs very ancient.

Natural theologians coyly reconciled earth history and human history by interpreting the formation of the animals by God as recorded in Genesis to be specifically the formation of modern animals. What the Bible relates, they reasoned, is the creation of the modern world, prepared by God for Adam and Eve in Eden, loaded up with the animals and plants that we see now. Prior to that was an archaic world, a pre-modern world, filled with the remote and unfamiliar creatures of paleontology.

This, however, was beginning to have problems as well. All over Europe, ancient remains of extinct mammals were becoming known; and were inferred to have been part of the pre-modern world, before the Garden of Eden. Yet just as ancient geologically as these mammals were chipped rock tools, known as eoliths, or "dawn stones". Since humans were, and remain, the only species known to sharpen the edges of rocks to make cutting tools out of them, it followed that these tools were made by some form of primitive people. Were they "pre-adamites" or modern people in a modern world since the Garden of Eden?

Many scientists favored the latter view, since it removed the teleological reasoning implied by seeing a modern world created as simply a planned pre-condition for the appearance of humans. One could instead see the history of life intertwining with the history of humans, as ancient life unfolded into modern life, and archaic humans into modern humans. It could be seen as a history, a development, an evolution.

Charles Lyell, however, wasn't among those scientists. Although he was the champion of uniformitarianism, and had settled the issue on the age of the earth, he was conservative enough theologically not to be able to imagine tool-making human beings living alongside extinct

forms of life. The evidence, he felt, was just insufficient to settle such a crucial issue. In the 1850s, a series of careful archaeological excavations showed incontrovertibly that Lyell's position was no longer tenable. The tools were now being found with the bones of extinct animals, alongside them, scattered among them, and in clear association with them. Some form of human had lived and chipped stone tools on a pre-modern earth, long before Adam and Eve and the Garden of Eden on the modern earth.

Lyell himself reluctantly acknowledged it was true.

Human evolution

The early evolutionary theory of Lamarck was highly speculative and very bold. Lamarck not only applied his theory of acquired characteristics and evolution "up the great chain" to animals, but he explicitly recognized that it might apply to humans as well. Clearly the most similar animals to humans were the apes; could we imagine such a transition from ape to person? Lamarck had written that indeed we could, in his *Zoological Philosophy* (1809):

If some race of four-handed animals, especially one of the most perfect of them, were to lose, by force of circumstance or some other cause, the habit of climbing trees and grasping the branches with its feet in order to hold on to them, and if the individuals of this race were forced for a series of generations to use their feet only for walking and to give up using their feet like hands, there is no doubt ... that these four-handed animals would at length be transformed into two-handed and that the thumbs on their feet would cease to be separated from the other digits.

Furthermore, if they ... were impelled by the desire to command a large and distant view, and hence tried to stand upright, and continually adopted that habit from generation to generation, there is again no doubt that their feet would gradually acquire a shape suitable for supporting them in an erect posture. Lastly, if these same animals were to give up using their jaws as weapons for biting, tearing or grasping, or as scissors for cutting and feeding on plants, and if they were to

use them only for chewing; there is again no doubt that ... their snout would shorten more and more, and that finally it would be entirely erased so that their incisor teeth became vertical.

Lamarck's ideas never caught on among the scientific establishment in England. But among the literate lay public, there was certainly interest in the problem of the transformation of species.

One member of the literate lay public was a Scottish publisher named Robert Chambers (1802-1871). He spoke and corresponded with many scientists, and read widely, and in 1844 he anonymously published a book essentially espousing Lamarck's ideas, called *Vestiges of the Natural History of Creation*. Chambers' ideas were crude and far more mystical than academic biologists would tolerate, however. He saw life as a continual progression, and not only had humans ascending from apes, but Europeans ascending from non-white peoples as well. The work was heretical, racist, and not very well-informed biologically.

And yet there was something compelling about the idea of species changing, and all life being somehow connected. *Vestiges* went through 11 editions and sold 24,000 copies in its first ten years, 1844-1854. (By contrast *The Origin of Species* would go through 6 editions and sell only 9,500 in its first ten years, 1859-1869.)

Vestiges was scorned widely by scientists throughout its publication history, although it was widely read. Its author was vilified for his ignorance and for his heresy by the experts. If the author's identity had become known, it would have made him a laughingstock and destroyed his career. So if anyone else out there was harboring similar ideas about the transformation of one species into another, or "the development hypothesis" (as it was known), he would do well to keep them to himself.

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