Topic II Lecture
[The Origin of Life and Its Development]
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Chance, Darwinian Natural Selection, and Why Theology Can't Do Without Them

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The scientific issue that poses perhaps the most and greatest problems for Catholic and other Christian theology and pastoral care has been the discovery of organic evolution. Did life arise naturally from non-life, or only by the direct action of God? Once life existed, did species and higher categories of organisms arise, change, and differentiate through natural processes, or by special creation? Did their adaptations evolve purely through the Darwinian process of mutation and natural selection, or by divinely-guided "intelligent design"? In particular, did human nature, intelligence, and free will come about through Darwinian evolution, or did God (and does God still) separately create each human soul and infuse it into a material body? Is the concept of a "soul" distinct from the body even tenable nowadays?

Today I will at least touch on all these interrelated issues, but mainly I want to emphasize one thing, namely the question of *mechanism*: how does evolution work, and what difference does it make theologically? Well, history shows that it makes a huge difference.

Along with uniformitarian geology, the idea of evolution itself – what Darwin called "descent with modification" – was in the air for several decades before Darwin published *On the Origin of Species* in 1859. Significantly, though, the theological opposition to these ideas came not necessarily from clerics with professional training in theology, and not mainly from a concern with biblical literalism. It came primarily from pious scientists themselves, especially in Britain, who were the very people studying the mechanisms of nature but who were anxious above all to preserve a role in nature for *purpose* (or teleology) and *divine providence* (Gillispie, 1951; Winsor, 2009). Darwin himself was convinced of the *fact* of *branching* evolution by the nested hierarchical pattern of taxonomic groups (Winsor, 2009). But he was also able to explain how the evolution of *adaptations* was *brought about* by the materialistic mechanism of natural selection working on inherited variations. That explanation eventually allowed the idea of evolution itself to prevail. And that was only the next logical step in what had been a long series of demonstrations of naturalistic mechanisms operating in the history of the world, steadily narrowing the space for providential acts by a "God of the Gaps". That "pushing back" of the realm of divine action has continued ever since.

Still today, a lot of people are comfortable with the idea of evolution only provided that they can stipulate that God guided it, or intelligently designed it, or at least helped it over the rough spots, like getting from non-life to life or from apes to humans. But the notion that starting with the Big Bang, God put evolution on autopilot … or as physicist Brian Swimme described it (*National Catholic Reporter*, Aug. 10, 2001, p. 5),

"Thirteen billion years ago, the universe began as hydrogen. Left entirely to itself the hydrogen became rosebushes, giraffes and humans" … well, that really bothers people.

Not only critics but even advocates of evolution have stumbled here. Pierre Teilhard de Chardin got in trouble with his Vatican superiors because his account of evolution called into question the doctrine of original sin. I've argued elsewhere that he might have answered his critics more effectively if he had paid attention to the nuts and bolts of Neo-Darwinian mechanisms, rather than just focusing on eschatology (Domning, 2010; GET NEW REF.). So here I want to give some attention to those mechanisms, and respond to some of the common concerns about them.

Chance and the Law of Selection

Perhaps the biggest bugaboo in this area is the role of *chance*. We say that genetic mutations, the raw material of evolution, are *random with respect to adaptation*, meaning that a mutation is no more likely to occur just because it would be useful to an organism. This is routinely misconstrued to mean that adaptive evolution itself is random, like a Boeing 747 suddenly assembling itself from the contents of a junkyard, as the creationists like to caricature it. But random mutations are *only* the raw material, like the clay of a potter. *Adaptation* is molded by the *anti-chance* factor of natural selection, which is the action of the physical and biotic environment confronting the newly-mutated organism with the brutal necessity of survival. The organisms that happen to have the genes that produce the best engineering, or the best behavioral strategies for survival and reproduction, will tend to leave the most offspring in future generations, and these favorable traits will tend gradually to become dominant in the species' gene pool.

Even if the overall outcome is acknowledged not to be *purely* the result of chance (because it involved natural selection as well), it is still hard for many people to believe that "mere" inanimate matter and impersonal natural forces could bring about complex adaptations without supernatural intervention. This "misunderestimation" of matter on the part of Christians is ironic, since it comes down to us through the heresy of Gnosticism, which has pagan rather than biblical roots; but there it is.

Another philosophical thread here that trips people up is the classic dichotomy between chance and necessity, or between chance and physical law. Natural selection does indeed have the qualities of a law: its action is evidently automatic, inevitable, and analyzable mathematically, and Darwin himself deduced it *a priori* from the observable facts of surplus reproduction, heritable variation, and finite resources. Presumably, selection would operate on any planet where life existed. But this law of natural selection is in no way inconsistent with the operation of chance factors. On the contrary: if there were no processes involved but anti-chance ones like natural selection and the gene regulation that repairs damage to DNA, evolution would grind to a halt as soon as it ran out of genetic variety to use in adapting to changing environments.

Some people turn this into an objection, arguing that natural selection can't be creative, because all it does is remove what's already there, decreasing genetic diversity. Now, we don't say that a sculptor like Michelangelo lacked creativity in carving his "Pietà", for example, just because all he did was knock pieces off of a rock. But rather than resembling stone-carving, where pieces are only removed from a block of marble, selection's operation on a population's gene pool is more like clay sculpture, where

material is constantly added as well as being removed. That new variety is supplied by mutation: *random* changes to the genetic material. As the Catholic theologian Sr. Elizabeth Johnson (1996: 8) sums it up succinctly: "Chance ... is not an alternative to law, but the very means whereby law is creative."

But it gets better. The field of *process ecology* is now expanding this classic understanding of Darwinian evolution by suggesting new ways of looking at this thing called "chance". As my friend Bob Ulanowicz has proposed, the role of chance in evolution doesn't need to be restricted to genetic mutations of the classic sort.

Now to give Darwin his due, let's remember that he did not have a particular mechanism of inheritance clearly in mind. Inheritance, for him, was basically a black box: the simple existence of heritable variations was a given for him, based on the long experience of animal and plant breeders, and this was all his theory required. What Darwin contributed was the idea of natural selection working on these heritable variations to produce "descent with modification". It was only long after Darwin's death, with the rediscovery of Mendel's principles of genetics after 1900, that a comprehensive, "Neo-Darwinian" synthesis of evolutionary theory could be made, which was done in the 1930s and '40s (Mayr & Provine, 1980). But Darwin's ignorance of genetics – that "black box" – turned out to be a great stroke of luck, because it rendered his conclusions very robust in the face of the growing understanding of how inheritance actually works. Basically, *any* kind of heritable change (whether single nucleotide substitutions, chromosomal rearrangements, or anything else) will do for Darwinian purposes, and serve as grist for the mill of natural selection.

What process ecology offers is just that: other ways besides damage to DNA in which heritable change can come about, and be exposed to selection. But this involves a bit of a paradigm shift in how we imagine life to have started in the first place.

Whence Life?

The usual idea is that life began with some simple self-replicating molecule – some primitive piece of genetic code, in effect – that came together by accident and was then improved by selection. That view has gene regulation operating almost from the beginning, preserving useful variations from errors in replication. However, an alternative view, propounded by the theoretical physicist Freeman Dyson (e.g., 2001), is precisely the opposite: that in the beginning was a complex population (a primordial soup, if you will) composed of a few hundred kinds of *non*-replicating molecules and characterized by error *tolerance* (after all, in the absence of replication there could be no erroneous replication). Dyson imagines these molecules as being confined in droplets and forming protocells, with replication evolving only later.

Now, Dyson is right to emphasize the inherent tension between replication and error-tolerance (that law-and-chance dichotomy, once again), and he focuses on the idea of *homeostasis* (which is the process of maintaining the status quo in a system by means of feedback cycles). The essence of life from the beginning, he says, was homeostasis based on that kind of complicated web of molecular structures. In other words, maybe metabolism and even ecology came before life itself! He also points out that *complex* homeostatic mechanisms (such as we see in natural ecosystems, free markets, and open societies) are more resilient than *simple* mechanisms of central control (like planned

economies, or the "selfish genes" of Richard Dawkins). And furthermore, he portrays the "replicator" molecules (nucleic acids like RNA and DNA) that evolve later as an "alien parasitic intrusion" and the locus of all "selfish" or competitive behavior (such as self-reproduction), as opposed to cooperative interactions. Dyson holds that "the history of life is counterpoint music, a two-part invention with two voices, the voice of the replicators attempting to impose their selfish purposes upon the whole network, and the voice of homeostasis, tending to maximize diversity of structure and flexibility of function" (Dyson, 2001: 151).

But I see a problem here: If those first cells, as mere "error-tolerant tangles of nonreplicating molecules" (Dyson, 2001: 149), managed even to survive (that is, maintain their homeostasis) long enough to contribute to evolution, then any internal cooperation among their constituent molecules has to be seen as contributing to their homeostasis and survival. Given the alternatives of homeostasis or dissolution – maintaining the status quo, or failing to maintain it – we are already in a realm where natural selection can and must operate: cells unsuccessful at homeostasis will soon vanish. Moreover, promoting one's own survival is just as appropriately termed "selfish" as promoting one's own reproduction. So, given just the *persistence* of those protocells, this implies that natural selection, and "selfishness" of the most primordial sort, actually preceded the cells' reproduction, and thus preceded life itself as we customarily define it. In fact, this provides a ready explanation of how the "replicators" evolved in the first place: they simply allowed more effective preservation of whichever molecular combinations were better at homeostasis. So it seems to me that Dyson's characterization of the "replicators" as "alien parasitic intruders" is a bit unfair: they were a natural, indeed inevitable, improvement in the way the protocells did what they had already been doing, namely *persist*.

So, summing up to this point, it seems we have primitive metabolism, and probably a sloppy, imprecise form of reproduction – along with ecology, cooperation, competition, and natural selection: all of those things *already in place, before* there is even such a thing as a self-replicating molecule or cell that we would traditionally recognize as a living thing! Before the DNA world, or even the RNA world, many so-called "biological" processes were already up and running, and formed the milieu in which nucleic acids, and cells as we know them, evolved. To put this in just a few words, we might even say that life is a process, not a molecule!

In fact, Ulanowicz (2009: 61; italics original) traces this pattern all the way back to the generation of matter and antimatter themselves in the Big Bang: "The take-home message here", he says, "is that the enduring materials we perceive today are actually the endpoints of dynamical *configurations of processes*, asymmetries, and feedbacks of bygone eons." Matter, in other words, is just like life itself: a process, not a molecule.

Now I find this idea of life (let alone matter!) kind of mind-blowing: how could we have biology before life itself? How could the processes that *characterize* life today have actually *preceded* life, and *produced* life? But on second thought, isn't this what we should have expected: evolution as gradual change, one thing insensibly transmuting into another – in this case, inorganic chemistry leading into organic chemistry (which is simply the chemistry of carbon compounds), and organic chemistry leading into true biochemistry? Really, the only novelty here is thinking of organic chemistry in the absence of replicating cells, but having nonetheless an ecology, a metabolism, going on

within and among little droplets, perhaps little lipid-walled test tubes, if you will: maybe not so unthinkable after all.

But now we have to look more closely into these pre-biological processes that might have come to life; and here is where I think Ulanowicz's ideas are very helpful. In Chapter 4 of his book *A Third Window* (2009), for example, he talks about "autocatalytic loops" as being the basis of this evolutionary breakthrough. Now, what is an autocatalytic loop? Basically, it's a positive feedback loop – a relationship among two or more entities or processes that mutually interact to "egg each other on", so to speak, in whatever it is that they're doing. And of course it's not an idea that's original with Ulanowicz. For example, he quotes as a source the cyberneticist Gregory Bateson (1972: 404), who uses the term "causal circuit" for what Ulanowicz calls "autocatalytic loop": "In principle," says Bateson, "a causal circuit will generate a non-random response to a random event."

Now let's stop right here, because that quote brought me up short when I read it. "A non-random response to a random event": *that* has a familiar ring to it. That is an exact description of *natural selection*, which I described before as an anti-chance, or non-random, action of the environment on random events, namely mutations. Bateson and Ulanowicz are saying that positive feedback loops, causal circuits, or autocatalytic loops (whatever you want to call them) not only can but *will* generate Darwinian evolution!

We've long known that Darwinian evolution emerges from a dialogue, so to speak, between a population of *organisms* and their environment: the organisms propose (by randomly mutating), the environment disposes (by non-randomly allowing only certain mutations to survive and spread), and the result is that the gene pool of the population changes over time (which is what we call evolution).

But now we're hearing it asserted that this business of "non-random responses to random events" is even more general than "organisms" – that it crops up "in principle" even in these "causal circuits" or "autocatalytic loops", which can be systems of simple chemical reactions, or even purely physical systems such as hurricanes (Ulanowicz, 2009: 130, 166). Ulanowicz (2009: 64-65) defines autocatalysis as "a particular form of positive feedback wherein the effect of every consecutive link in the feedback loop is positive." Each participant in the loop has at least a "propensity", or strong tendency, to facilitate the next member downstream. When process A increases in magnitude, most of the time B will also increase. B in turn tends to accelerate process C, and C tends to have the same effect on A. This setup is growth-enhancing by definition: positive feedback naturally leads to acceleration.

Now if B changes slightly, either to make it more sensitive to A or a stronger catalyst of C, this change will likely receive enhanced stimulus from A, leading to yet more growth or activity. Or, if B changes in the opposite direction, it will likely receive diminished support from A. Ulanowicz (2009: 68; italics original) argues that in this way, autocatalysis exerts "*selection* pressure upon its own ever-changing constituents." A random "mutation", if you will, in B is selected for or against according to the growth-enhancing or growth-diminishing effect of that "mutation" on the loop as a whole. And this selection arises entirely *within* the system; whereas Darwin thought of selection as something entirely external. But autocatalytic feedback, according to Ulanowicz, broadens our view of selection by importing the selecting environment, as it were, into the system (or alternatively, embedding the system into its environment).

This selection, in turn, gives autocatalysis what Ulanowicz (2009: 70-71) calls *centripetality*: the feedback loop tends to suck into itself more and more of the material and energy that sustain the loop. So, "any autocatalytic cycle becomes the center of a centripetal vortex, pulling as many resources as possible into its domain. Even in the absence of any spatial integument [any "skin" that encloses it], the autocatalytic loop itself defines the locus of this organic trait. That is, centripetality becomes a core element of a system's identity." To me, this implies that such an autocatalytic loop is inherently, first of all, a "self", with its own identity; and secondly, that it already exhibits what I've called "selfish behavior" in the broadest sense, namely self-perpetuation and self-enhancement by acquiring as many resources as possible (sucking them into its "centripetal vortex"). And all this, remember, is present and fully in action *before there is even anything we have called "life"*. We're just talking here, so far, about chemical reactions. If we have autocatalytic systems with individual identities, sucking up resources from their environment, then "selfishness" turns out to be an older and more general phenomenon than life itself!

There is one more element here that Ulanowicz (2009: 70) emphasizes, namely that systems differ in their *histories*, which can be partly *recorded* in their stable configurations. These can be configurations of molecules like DNA, but also stable configurations of processes. History recorded becomes *information*; in fact, it's the particularities of history that give an individual "self" its identity, in contrast to atoms or simple molecules that are indistinguishable from one another. And so we can glimpse how the "self" of a stable autocatalytic system, under selection both internal and external to itself, could eventually evolve a yet more stable and precisely reproducible way of recording information it has acquired the hard way about what works best in its environment. By evolving molecules such as RNA and DNA, which are records in the form of instruction manuals, the proto-cells could have done something analogous to what human societies did when they invented writing to record and facilitate what they needed to keep functioning. By the time the proto-cells did this, I think they had already crossed whatever we might define arbitrarily as the line between non-life and life.

Cooperation vs. Competition?

The next issue this brings us to is the dichotomy between these ideas "cooperation" and "competition", and the debate over the roles and relative importance of these in evolution. On the one hand, I, along with other Neo-Darwinians, have stressed the role of *competition* – as I did in my book with the late Monika Hellwig entitled *Original Selfishness* (2006). For example, on page 50 of that book, I wrote that

> the origins of cooperation and apparent altruism seem explainable in terms of selfishness, and selfishness may have been accompanied (and facilitated) by cooperation right from the beginning; but no one has managed (or, so far as I know, even tried) to explain the origins of selfishness itself in terms of altruism, or shown how cooperative units could persist in the absence of self-preserving behavior. Evolution is most plausibly viewed as following the same course as our individual development: we each started out in life totally self-centered, and only

> later learned to work and play well with others. Selfishness would thus appear to be the more primitive and fundamental condition, with altruism (if it arises at all) as its later-appearing derivative.

This position is backed up by a large body of evidence, from animal behavior and genetics, showing that cases of cooperation among organisms are well explained by the mathematical theories of kin selection and reciprocal altruism. "Kin selection" means cooperating with others, or doing things for others, in direct proportion to the closeness of your blood relationship to them: I'll do more for my son than I will for my nephew, or my third cousin. "Reciprocal altruism" just means doing things for others in expectation of a return: I'll scratch your back because you scratched mine yesterday, and you may do so again tomorrow, even if we're not related. These strategies can explain most, and maybe all, cases of cooperation among non-human species. So altruism among animals, it would seem, is only enlightened self-interest.

On the other hand, many writers have opposed this view, and wanted cooperation and mutualism to somehow be considered the foundational theme of evolution. As evidence, they cite observations such as symbiosis in general, in particular the origin of organelles of the eukaryotic cell by incorporation of symbiotic bacteria. Some even cite the affinities for each other that are displayed by subatomic particles, leading to the synthesis of atoms and molecules, and call that a rudimentary form of mutualism [REF.?].

But Ulanowicz (2009: 72) makes an important observation here that brings us back to autocatalytic loops, and in so doing points to a resolution of the problem:

> It is very difficult to overstate the importance of centripetality. It is a largely neglected, but absolutely essential attribute of living systems. Furthermore, centripetality is an agency proper to the loop as a whole. Although the accumulation of resources is accomplished at the compartmental level, the drive to increase such activity is strictly a consequence of the relational structure of the whole. As mentioned … in connection with Darwin's theory, a very important but unstated premise of his scenario is that participants strive to capture and accumulate resources. The conventional Darwinian narrative does not mention the origins of this drive, but we now see it as the deductive consequence of autocatalytic action.

So Ulanowicz (2009: 73) is explicitly asserting here that "competition is derivative by comparison" with the internal mutualism inherent in autocatalytic loops: "That is, whenever two or more autocatalytic loops draw from the same pool of resources, it is their autocatalytic centripetality that *induces competition* between them" (italics original). And further: "One should never lose sight of the fact that the autocatalytic scheme is predicated upon mutual beneficence or, more simply put, upon mutuality. … That competition derives from mutuality and not vice versa represents an important inversion in the ontology of actions" (Ulanowicz, 2009: 75).

Thus we find Ulanowicz doing what I had previously not observed, namely "managing to explain the origins of selfishness in terms of altruism", or at least

mutuality. But in doing so, rather than refuting my contention, I think he reconciles our diametrically-opposed positions. Bob and I have discussed this back and forth for the last couple of years, and I think we now agree on the following account of the situation.

What we have to recognize is that *different levels of organization* are involved. Ulanowicz is right that "competition derives from mutuality" – but from mutuality *at a lower level. Within* any given level, competition is causally prior, and can bring forth cooperation, which then in turn can spark competition at a third, still higher level. Cooperation emerges, secondarily, at each level as an effective strategy for competing. So, for example, the components A, B, and C of an autocatalytic loop form a mutualistic cooperative at level 1, and D, E, and F form a similar loop. But then, in a larger context (level 2), the loops ABC and DEF compete with each other for the same finite resources. Eventually, however, they may join, perhaps together with GHI and other loops, to form a super-loop, still at the same level 2. This super-loop, in turn, may compete with other super-loops at a still higher level of organization, level 3; and so on.

To take a concrete example: prokaryotic bacterial cells might unite symbiotically to form a eukaryotic organism, on the cellular level. Such eukaryotic cells might then compete, as separate organisms, until some of them combine to form a multicellular organism of which the eukaryotes are just the constituent cells. Multicellular organisms might then compete among themselves, and eventually combine to form a society or "superorganism", such as an ant colony, within which competition is suppressed in order to facilitate competition with other colonies. And so on.

Another example: a group of people form a cooperative tribe, which competes with a neighboring tribe. Then those two tribes form an alliance to fight the tribe across the river. And so on up the scale. What we have in this cooperation-competition dialectic, in other words, is a chicken-and-egg problem. Depending on where in the hierarchy of levels of organization we look, we might find that either cooperation or competition is "primary", either is "derivative". Which one is *ultimately, ontologically* primary seems to be a question not for biology but for chemistry, at least, and probably for particle physics, if not metaphysics – because both cooperation and competition were already present and deeply rooted long before the origin of "life". Among living things, *both* cooperation and competition are part of God's "very good" creation.

"Intelligent Design"?

Now, once cosmic evolution and chemical evolution have produced feedback systems with even the most rudimentary capacity for self-perpetuation and replication, then Darwinian evolution is off and running: the envelopes of diversity and complexity are bound to be stretched as long as such systems survive. According to Ulanowicz (2009: 76-77), autocatalytic mutualism has an inherent direction, tending to propagate itself and become more prevalent, and uniformly supporting "the growth and continued existence of all members." It tends to generate ever-higher levels of organization, newly emergent qualities, and true novelty. Selection, even within an autocatalytic cycle, can be truly *creative*.

So, given life, and mutation and natural selection, Neo-Darwinian theory predicts the diversification and complexification of that life with no inherent limit. And indeed we find that complex adaptations of all sorts, from the biochemical to the anatomical and

behavioral, have appeared – not just once, but over and over again: similar eyes in a human and an octopus; similar wings in birds, bats, and bugs; similar societies in termites and naked mole rats. It seems like every halfway-decent engineering design has been used by evolution, not just once but multiple times – just as we'd expect from an intelligent engineer.

So it's not a surprise that many people down through history have concluded that the complex adaptations of living things to their environments are just that: the detailed designs of an intelligent designer. And since about 1984, we have in this country a well-publicized school of thought known as Intelligent Design (ID), with vocal advocates such as Michael Behe and William Dembski, who claim to prove scientifically that Darwinian mutation and selection are inadequate to have produced the diversity of life we see today. Although they avoid religious language and distance themselves from the biblical literalists who espouse special creation, in practice they adopt many of the same arguments as the creationists. Because they are also intentionally vague about the extent to which they accept evolution itself, ID has a certain attraction to theists who don't want to deny evolution but do think they have to leave room for God to do something useful.

I'm afraid this even includes folks at the top of the Roman Catholic hierarchy (Horn and Wiedenhofer, 2008; cf. Domning, 2008). Following the publication of Darwin's theory in 1859 (when they were still smarting from the Galileo affair more than two centuries before), Catholic authorities treated it with circumspection, not formally condemning evolution but making clear their strong reservations about biblical interpretation, a materialistic origin of humans, and its implications regarding the Fall of Adam, original sin, monogenism, and the theology of salvation (Artigas et al., 2006). Grudging acceptance of evolution came slowly, notably with statements by Popes Pius XII (1950) and John Paul II (1996). Yet, at the top of the hierarchy there is still interest in some form of ID as an alternative to strict Darwinian naturalism. Meanwhile, they seem to ignore the growing literature of Catholic evolutionary theology. This situation is unfortunate and unnecessary, given recent theological advances made in the light of evolution.

So, while special creation in general is not presently an issue for the Catholic Church, there remains in some quarters an uneasiness with the well-founded scientific conclusion that natural selection, acting on random mutations, suffices to explain the evolution of today's organisms, including humans with their intellect and free will. The ancient Christian tradition of defining humans as "creatures composed of body and soul" has forced the question of when (or if) in human evolution, as well as in embryological development, the individual soul was "infused" directly by God into each human body. This putative event is the critical remaining stumbling block in reconciling scientific conclusions about human evolution with Catholic teaching, which infers a direct divine intervention (effectively, a form of ID) in the transformation of "lower" animals into humans.

I don't have time in this talk to discuss ID in detail; it's been exhaustively analyzed and refuted in several recent books. I just want to point out the fundamental intellectual flaw that lies at the bottom of it. The overwhelming consensus of philosophers and scientists in relevant fields is that ID is outmoded science – just the old God-of-the-gaps "argument from design" expressed in modern jargon. This argument is basically a failure of imagination: "If *I* can't imagine, *right now*, how something could

have evolved through natural selection, then God must have done it!" Hence, ID is the opposite of science: when the explaining gets tough, ID gives up, and appeals to the supernatural.

In contrast, evolutionary biology, like all natural science, keeps looking for *natural* explanations of natural phenomena, and refuses on principle ever to resort to supernatural explanations, because these are inherently untestable. This basic principle of scientific procedure is known as *methodological naturalism*. It's just a rule of procedure, without which the search for knowledge would be immediately short-circuited. It's not an assertion that the supernatural doesn't exist; that would be *metaphysical naturalism*. Certainly there are evolutionists (like Richard Dawkins) who embrace metaphysical naturalism, but in doing so they are going outside the boundaries of science and entering the domain of metaphysics, just as much as the special creationists are.

This distinction between methodological and metaphysical naturalism is one that the ID advocates and the biblical creationists both refuse to make, because they see it as a slippery slope to total materialism. But in fact, many philosophers and scientists, including myself, don't find it slippery at all. What we do find is that Darwin's idea of natural selection is impressively good at explaining our data about living things, in testable ways: it hasn't let us down yet.

Theological Implications

This brings us, finally, to the implications that all this has for theology and pastoral care, and why I say theology can't do without chance and natural selection. Many recent theological advances have been made in the light of the scientific understanding of life's evolution, which theologian John Haught rightly views as "Darwin's great gift to theology". In the past half-century, evolution has become a fruitful source of theological reflection, beginning with the work of Pierre Teilhard de Chardin and continued by a growing number of other writers. This school of thought, called evolutionary theology, deserves to be more widely applied in Catholic and all Christian ministry – because it can deepen appreciation for the majesty of God's creation, the power of natural agencies in bringing it about, the nature and limits of God's action in the world, and the value that God places on this created world, including ourselves. In fact, evolutionary theology is uniquely suited to be a *Christian* theology, because it is so deeply *incarnational*: it underlines like no other the importance of this material creation – of which God thought highly enough to become a physical part of it.

More specifically, we can draw the following six conclusions from what I've been saying:

1. Even though living cells have not yet been assembled from simple chemicals in the lab, we can already visualize ways in which this might very well have happened spontaneously in nature (and what I've just outlined is certainly not the only possible scenario that has been proposed). So science today is clearly pointing in the direction of demonstrating that **life did in fact arise spontaneously out of non-life, on this planet and probably on many others, without *direct* supernatural intervention.**

2. Neo-Darwinian theory has proven so effective at explaining the adaptations of living things by mutation and natural selection that **science today finds no need for any**

"intelligent design" or "special creation" of species or higher categories of life, including humans.

3. This applies all the way up to the highest grades of evolution we have achieved: the attainment of human intellect and free will, which have traditionally been considered attributes of a separately-created, immortal "soul". With the various aspects of intelligence (including the capacity for rational choice) increasingly being explained by neuroscience as evolved activities of the physical brain, **there no longer seems to be a need to postulate a "soul" of the traditional sort to account for the observable features of human personalities. As for the unobservable attribute of immortality of the individual personality, that seems to me best explained theologically by the action of God's grace at the point where our material development leaves off: namely, death.**

4. Competition and cooperation have both been part of the dynamic of life from its beginning, or even before. In various circumstances, both can be survival strategies favored by natural selection. On any given organizational level, however, competition is causally prior and tends to lead to cooperation, which in turn leads to more competition, between larger entities at a higher level. **Therefore, both competition and cooperation must be seen as parts of God's "good" creation and of the creative process itself.**

5. Natural selection enforces "selfish" behavior on all living things. This is most obvious in competitive interactions, but it's also true in cooperative ones, which almost always are manifestations of enlightened self-interest. **While this amoral "selfishness" is necessary for self-preservation and self-reproduction, it inevitably sets the stage for immoral behavior on the part of moral agents, once these have evolved**. This *original selfishness* is what our tradition has called "original sin" (Domning and Hellwig, 2006; Domning and Wimmer, 2008).

6. All of this together is important for theology because it gives us something that traditional Christian theology otherwise lacks: a necessary and sufficient explanation of *evil*. We no longer take the Garden of Eden as literal history. What replaces (or rather supplements) it is the much grander story of evolution. This story begins all the way back at the Big Bang, with particles being formed and coming together and breaking apart according to physical laws as well as chance. Complex molecules organized themselves by chance into autocatalytic systems. Within those systems, natural selection began to favor and preserve certain interactions and the molecular arrangements that promoted them, while other arrangements broke down. The successful arrangements evolved into the first living cells, and these cells developed new molecules to preserve information that had proven useful for the cells' own survival and replication. Now everything speeded up: **chance mutations in that information could be acted on further by selection. Most of these mutations were misfortunes, along with all the other kinds of accidents, injuries, and death that we call "physical evil".** But some of those random breakages and copying mistakes happened to be useful. Life diversified into every available environment and form and way of making a living. The endless creativity of the evolutionary process was now on display: a dialogue between chance and law, between mutations and the demands of the environment, with countless solutions to countless problems tried and tested. Sooner or later, something like us was bound to happen: **living things that could see and judge and act on their surroundings, and make choices, for better or worse. These creatures were necessarily selfish, like all**

their ancestors, so some of their choices were also selfish and injurious to others – and so "moral evil" also came into the world.

The point is that *all of this is of a piece* – a coherent whole, a single creative act by a single Creator. The astrophysicist Neil deGrasse Tyson points out that the elements -- hydrogen, oxygen, and so forth – occur in the human body in much the same proportions as they do in the universe as a whole. "If we were made of an isotope of bismuth," he says, "you'd have an argument that we're something unique in the cosmos, because that would be a really rare thing to be made of. But we're not. We're made of the commonest ingredients. And that gives me a sense of belonging to the universe, a sense of participation" (Tyson, 2012).

Furthermore, this creation was "very good" in its intent and in its overall result, even though it *necessarily* entailed physical and moral evil. The stuff of the universe is inherently breakable; *we* are inherently breakable; so brokenness is inseparable from our existence, not just metaphorically but tangibly. God could not have made a living, growing material universe in any other way. In fact, some of the breakage was an essential ingredient in the creative process: without those copying errors we call genetic mutations, there could not have been the selection and evolution that led to us. As the poet William Blake wrote in another context (*A Vision of the Last Judgment*), "to be an error, and to be cast out, is a part of God's design." Likewise, John Milton's Adam was delighted to find that God was able to bring good even out of evil (*Paradise Lost*, book 12, lines 469-476).

As you can see, this train of thought leads to far-reaching theological conclusions about the nature of the Creator and the creative process, about evil, theodicy, and "original sin", and about what we mean by salvation in Christ. We'll pursue these implications in our next conference this coming fall. But for now, we can start to see why the scientific understanding of life's evolution is valuable for our faith, and why Jack Haught calls it "Darwin's great gift to theology".

When we look back along that road we've traveled in the evolutionary sciences, back to early-19th-century Britain, we see a consistent pattern in the interaction of those sciences with religion – specifically, with devotion to the idea of divine providence and purpose. As the historian Charles Coulston Gillispie (1951: 226-227) described it, "The trouble was not that progressives themselves rejected the idea of purposeful design, but that their opponents instinctively felt that eliminating providential direction would lead in that direction. … [I]n the nineteenth century … orthodox natural theology was more interested in control than design. … They feared that if God's role as an immediate, if occasional, adjuster of the material world was whittled away, He would also be displaced as a governor of its inhabitants."

Over the two centuries since then, that image of a Providence demonstrably micromanaged by a controlling designer God has receded – and that's a good thing for our theology. We have gotten more and more used to the idea of a God who allows the world complete autonomy in the operation of natural laws, and yet cares deeply about this world and has definite opinions about our behavior. This would have seemed paradoxical two centuries ago. But by now, most of us have given up the idea that empirical science could prove (or disprove) the existence of God. That leaves theology free to contemplate all the intriguing things science implies about what God must and must not be like (if there is a God). It's true that a "minimalist", or metaphysically

materialist, view of Neo-Darwinism can undermine faith. But the broader view laid out here can be the basis – not a proof, but part of the foundation – for a more robust theology.

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