3. Evolution: From Amoeba to Zebra

Evolution has proven to be the single most important theory explaining life's development. Understanding evolution at the cellular level has fostered the fields of molecular biology and genetic engineering, which provide tools for coaxing cells to develop in previously unattainable ways. In contrast, assembly of the first cell remains a deep mystery. Unlocking the *origin* of life will not only reveal how life first arose but could potentially unleash human intervention in all living processes. Francis Crick, co-discoverer of the structure of DNA, wrote that the origin of life is "almost a miracle, so many are the conditions which would have to be satisfied to get it going."[1]

CELLS AND ORGANISMS

The possibility of spontaneously forming the first cellular life from a macroscopic coalescence of molecules is generally agreed to be vanishingly small. An event of extremely low probability is possible but, even given an extremely long time, such an event remains unlikely. Just because an event is possible does not mean the event *will* happen. Terms such as "directed chance" and "biochemical predestination" have entered the scientific literature to imply that life was guided by the inherent properties of matter. The mechanism by which cells arose from inorganic precursors is sketchy but serves as a working model in the absence of a more compelling explanation.

1. Crick, *Life Itself,* 3.

The origin of cells is the key to understanding the origin of life. Cells are the smallest living units that can reproduce themselves from their own internal information. Virtually all cells use the same metabolic pathways, energy storage, protein replication, and genetic information system. The neurotransmitter acetyl choline is the same in organisms as diverse as plants, protozoa, and mammals. Humans share most of the same protein families with worms, flies, and plants. All these commonalities suggest a universal ancestor cell containing sufficient information to allow subsequent divergence into the three classes of living systems found on earth.

There is a tremendous amount of information in a cell. Each cell contains between 265 and 350 genes—estimated as the minimum genome size to code for sustainable, independent life. During the development of even the simplest organisms, these genes work in concert to specify organ and body structure. Organisms are constructed as integrated organs rather than as an assembly line with individual parts fitted together to make a machine. Consequently changes in one gene often have a global impact on the entire organism. Changes that are beneficial for one organ are often less beneficial for others. Evolutionary exploration through undirected random processes requires that many organisms will form and not survive before another organism arises that has an adaptive advantage.

THE FIRST LIVING ORGANISMS

Fossil and geochemical isotope evidence indicate life began on earth around 3.7 billion years ago. The development of life so soon after the earth's formation is remarkable because the early earth was heavily bombarded by meteor showers until about 3.8 billion years ago, leaving only 100 to 200 million years for life to develop. Calculations by some scientists suggest that the earliest cyanobacteria might have formed within as little as 10 million years after the earth became habitable.

Some of the best examples of these ancient fossils are stromatolites in Shark Bay, Australia. Produced by a build-up of cyanobacteria, these slow-growing micro-organisms form mat-like colonies. Ultimately, these die and form a thin, cement-like rock layer. The cyanobacteria migrate to the surface and reestablish the colony in a recurring process that eventually leads to large rock-like formations. Stromatolites flourished in the

early earth and dominate the fossil record deposits from about 600 million to 2.8 billion years. During this time, stromatolites produced oxygen even in the highly reducing environment thought to exist during earth's early development.

Significant effort has been expended to identify the first living organism. Extremophiles are touted as possibly the earliest life forms. Extremophiles are microbes that live in some of the harshest environments on earth: near undersea thermal vents; up to 3.5 km below the earth's surface in hot, pressurized environments; and in geothermal hot pools. Located in extreme environments, they seem ideally suited to the conditions of early earth and yet, buried by deep sea larval vents, or within the earth's crust, they would be in a relatively stable environment. The extreme environment ironically provides protection against other hazards such as the constant meteor bombardment during the Hadean era, volcanic eruptions, devastating ultraviolet radiation, and climatic changes. Many of these microbes live at temperatures of 80–110 °C and some even thrive at temperatures as high as 169 °C. Extremophiles have unusual biochemical modifications to stabilize the organism under extreme environments of heat, salt, acidity, and cold.

Extremophiles demonstrate that life is not limited to the habitable zone of normal temperatures and pressure. Organisms living in the boiling streams in Yellowstone National park, highly acidic waste, and inside rocks deep under the earth's surface at high temperatures and pressures represent just a few of the amazing types of extremophiles found in some of earth's otherwise inhospitable places. At the same time, while extremophiles live in harsh conditions, few can tolerate a range of environmental conditions. For an extremophile to evolve into a comparable organism in a normal environment would require changes to occur in practically every protein, RNA, and ribosome. Gene sequencing places extremophiles among the lowest and shortest branches on the evolutionary tree of life. In contrast, temperate organisms appear to reside earlier in the evolutionary development of life and in the main roots of the tree of life. The evolution of the earliest living organism from an extremophile is advocated by some, but more researchers are looking for the first common organism from a surface organism in a more hospitable environment.

Fossil and geochemical records indicate that surface organisms that grow best in moderate temperatures appeared very shortly after the earth was able to support life. Once established, the first temperate organism would have had no predator and so would reproduce freely. Replication

would have been limited by a food supply, which may have driven the organism to the surface. In the transition to relatively cooler temperatures, mutant organisms might have been able to accommodate the required changes to their membranes and molecular machinery, eventually leading to the three biological domains of all life on earth; archaea, bacteria, and eukaryotes.

The fossil record and DNA mapping show remarkable parallels in support of a common ancestry, an ancestry from organisms that very quickly established themselves early in the earth's beginnings. The pathway by which the first members of each biological domain developed is obscure. DNA analyses and an accumulating fossil record provide hints as to the transition to the diversity of life both past and present.

The evolution of species rests on interpreting a fossil record that is anything but a seamless web from amoeba to zebra. The Cambrian epoch, about 600 million years ago, contains all the basic animal phyla, which suddenly appear in the fossil record like an explosion rather than as a gradual progression. Subsequent geological periods chronicle the emergence and disappearance of millions of species accompanied by enormous climatic and geographical changes. Although deleterious for some, ecological changes provided new opportunities for diversity, stimulating the creative development of new life forms.

The history of life written throughout the fossil record is one of massive species loss followed by differentiation within the surviving species. The fossil record is punctuated by the sudden emergence and sudden extinction of new species rather than a gradual evolution of species—a punctuated evolution with long periods of stasis followed by intervening periods of rapid change. Dramatic changes occur before natural selection refines the new organism, which suggests that while natural selection provides a powerful mechanism for sifting changes, other influences also operate. One potential influence that might operate in concert with natural selection is the local environment which is information-laden and provides specific conditions for organisms to adapt to.

EXTINCTION AND REBIRTH

Five particularly dramatic mass extinctions are apparent from the fossil record. The extinctions correlate with powerful ecological changes: exceptional volcanic activity, a cosmic radiation event, or the impact of an

asteroid or comet. The resulting dust clouds disrupted the atmosphere causing noontime darkness, plummeting temperatures, and the eventual death of many species.

The best known mass extinction occurred some 65 million years ago at the end of the Cretaceous period. Roughly two fifths of all marine animals disappeared and an even greater proportion of land animals. High iridium levels around 65 million years ago point to a massive iridium-rich meteor impacting the coast of Mexico and churning up huge dust clouds that obscured the sun. For cold-blooded animals the effect was lethal, putting an end to the dinosaurs that roamed the earth between 230 and 65 million years ago. Whereas the dinosaur age prevented the development of large mammals, their sudden loss offered new adaptations for mammals. For small, warm-blooded mammals the loss of large predators was a God-send, allowing their eventual evolution into modern Hominids.

One of the most celebrated species transitions is the origin of animals that fly. The fossilized bird *Archaeopteryx* has a body form very similar to that of a small dinosaur, teeth in the jaws, wings, and a long reinforced bony tail covered with feathers. Dinosaur fossils having remnants of feathers provide evidence that flight originated through a coincidence of body structure and covering that was adapted for a new type of motion. The cobbling together of features to allow a completely new development is characteristic of the messy way evolution proceeds with subsequent refinements over time.

DEATH, SUFFERING, AND GOD

The young Darwin is perhaps best thought of as a nominal Christian despite his early ambition to be a priest. Instead of joining the priesthood, he left to survey unknown lands on *HMS Beagle*. Over the following years he gradually discarded his Christian beliefs, in part because he was increasingly troubled by how a loving God could allow such brutality and death in the world. For Darwin, the irreconcilable difficulty was compounded by the loss of his favorite daughter, which left him angry and bitter at God. Ultimately Darwin became an agnostic.

How can God allow the loss of life caused by massive extinctions and the suffering arising from an evolutionary development of life? Developing a coherent religious framework that addresses the suffering and

the loss of life in evolutionary development involves weighty issues such as the nature of good and evil, free will, and atonement, but some insight can be gleaned from a careful analysis of the second chapter of Genesis.

People often equate the Garden of Eden with an idyllic environment in which there is neither suffering nor death. Genesis 2 portrays Eden as being harmonious but not necessarily having a distinctly different biology than exists on earth today. Hints suggest that the basic ecology is the same. In Genesis 2:20 ". . . the man gave names to all the livestock, the birds in the sky and all the wild animals." There is a distinction between livestock and wild animals. Presumably these are the same types of wild, carnivorous animals alive today which survive by preying on other animals.

If God used evolution as an integral part of creation, then death, pain, suffering, and natural disasters are a part of God's creation. The fossil and biological evidence points to recurring cycles of life and death from the first appearance of living organisms. The massive species loss that occurred 65 million years ago through an asteroid impact destroyed the dinosaurs and allowed mammals to diversify into higher animals. Some are willing to accept that the species cost in the "dinosaur project" is warranted by the benefit in evolutionary exploration that ultimately led to modern, sentient beings. Others stress that God, while permitting such processes, suffers in and with creation, sharing in the pain and loss. Although there is no definitive answer to the question of why suffering and death is part of creation, wrestling with the difficulties helps better understand good and evil.

Classically, the most persuasive argument is the "free-will defense" of evil. God creates a world capable of making itself by exploring both blind alleys and new forms. Pain, suffering, and death do not predominate in nature but are necessary consequences of a process of emerging harmony which inevitably discards old forms while developing better ones. Each step is a precarious move into new, unknown, territory. Periodic destruction of life, beauty, and order by creation is a corollary of a system capable of evolving through the exploration of all possibilities. An earth in which the constant movement of tectonic plates provides a protective mantle also allows earthquakes and volcanic eruptions to unleash tremendous energy. Dwellings subject to these forces may be severely damaged leading to loss of life, a problem exacerbated by people choosing to live in densely populated buildings rather than the sparse dwellings used by primitive humans. A creation having the potential to

unfold through exploration is a messy process, as most loving processes are.

Random mutation provides a supremely elegant and efficient mechanism for achieving an open, goal directed process. A world with opportunities for love, good, and free will requires an openness in which ill can occur through chance and through the choices of others. God is neither the author of evil nor directly responsible because the choices lie within creation and with created beings. Maneuverability is given for free action by intelligent beings without divine dictation. For example, the possibility of a particular natural evil such as pain allows compassion and individual expressions of sorrow, concern, and a desire to help alleviate pain. Such a process involves a cost but brings into existence states of great value: an appreciation of beauty, the possibility of moral choices, and rational understanding, for example.

Massive species loss and evolutionary development through blind chance may seem incompatible with a loving God, but the biblical picture is more complex. At the heart of Darwinian natural selection is reproduction, an essential component of God's plan for mankind as commanded in Genesis. The raising and caring of children, or any offspring, with love and nurturing is fully compatible with both evolutionary theory and theology.

Death too is part of the natural scheme of life. While death involves an inevitable loss, nature being "red in tooth and claw," the passing of one individual often provides life for another in the integrated web of life. Many of the biblical parables use the image of a seed being transformed to provide a crop for others to harvest. The image reiterates the cost often required in life. Jesus claimed that one of the highest virtues was to lay down one's life for others and provided the example himself that the world might know the full meaning of redemption.

Christian theology understands reality as an evolving creation in which creatures have the ability to change and become themselves. Science shows that the world operates as a package deal where the freedom of organisms to evolve into intellectual thinking beings comes with the potential for malevolent events. A more competent divine being could not create a universe in which there would be no disaster or disease. Such insight is the fruit of the integration model of science and religion.

Accommodating death, pain, and suffering with the possibility of free will provides an intellectual framework for understanding good and evil but offers little comfort in the face of personal tragedy. Young lives

snatched away through illness or disasters raise the question "why God?" Wisdom and patience develop in the face of such evil events through the slow and difficult exercise of understanding and experience. There is no fast-track through disturbing events, but a world having this structure provides the stage on which religion can offer answers to some of life's most difficult experiences.

NATURAL SELECTION

Natural selection is the gradual process through which biological traits become either more or less common in a population because of increased or decreased reproduction rates. Inherent within natural selection is feedback from the environment that results in refinement for subsequent generations. Through competition for limited resources, the better-adapted species are more likely to proliferate and eventually eliminate poorly adapted competitors. Darwin's theory of natural selection revolutionized biology by providing a uniquely effective, unifying explanation for the diversity of life.

The fossil record shows great stability over time followed by rapid change over relatively short periods, "punctuated evolution," in which a few entities rapidly displace earlier species. Physical separation of interbreeding populations can lead to genetic divergence between two daughter populations as mutations and genetic changes accrue. Large genetic changes more readily lead to a change in the gene pool of small populations, leading eventually to a new species. Competition with the parent generation can result in annihilation of either group depending on which trait better suits the prevailing conditions.

Natural selection leads to demonstrable changes in species. What is not demonstrated in this filtering process is a drive from simplicity to complexity, that is, complex, higher-order species and systems from simple precursors. Why, for example, did this natural process give rise to greater complexity rather than greater diversity of less developed organisms? If chance alone dictated the rearrangement of genes through genetic mutation, an increase in disorder would be expected, which would degrade the complexity of living organisms. Instead, a high level of order exists. Organisms became consistently more structured and efficient.

Living systems embody an extraordinary degree of complexity that seems difficult to explain as the result of a chance series of mutations.

And yet the evolution of life is usually compared to ascending a ladder of organization with man at the top. Chance events tend to dismantle rather than build complexity. Most random mutations are deleterious rather than beneficial, causing the organism to regress, rather than exhibit superior fitness. In humans the deleterious genomic mutation rate is estimated to be as high as three new deleterious mutations per individual. The progression of the universe toward increasing disorder is captured in the second law of thermodynamics. The more complex a system, the more prone the system is to degradation and malfunction—as attested to by anyone owning electronics! Complex systems are prone to failure because disordered states far outnumber ordered states.

Evolution very successfully exploits chance mutation and natural selection in pre-existing complex systems. What is not clear is whether evolutionary processes can create new systems through random mutation and natural selection or whether evolution builds on cues already existing in the environment. For example, in early bacterial studies examining the ability of E. coli to metabolize lactose, the structural gene that codes for the production of the enzyme galactosidase necessary to metabolize lactose was deleted. Initially, the bacteria did not grow as they could not metabolize lactose, but after a few days bacterial strains emerged that did metabolize lactose. The standard interpretation of this experiment is that the bacteria tinkered with another gene; a simple mutation was made to an existing enzyme that allowed the cleavage of the bond holding the two parts of lactose together. Where did the newly mutated gene come from? Strangely, the gene was already present in the bacteria, lying dormant without serving any function. In essence, the mutation relied on the organism's resourceful use of latent information, like rediscovering a previously read book in the bookshelf.

An additional mutation is required in the gene responsible for signaling production of the newly modified enzyme. The likelihood that random chance is responsible for both the mutation in the enzyme and the signaling has been estimated to about 1 in 10^{18}, which is so small as to require about 100,000 years to achieve. For the changes to occur in the few days the experiment ran implies that spontaneous mutations are not independent events.

INTELLIGENT DESIGN

Living systems exhibit both complexity and design. Design is recognized when the event follows a *pattern* and when there is a small *probability* of an event occurring naturally. Much of the animosity toward evolution lies in the origin of design; is design a result of evolutionary refinement or a divinely guided process? A particularly frank analysis comes from the atheist Richard Dawkins who writes in *The Blind Watchmaker* that "We are entirely accustomed to the idea that complex elegance is an indicator of premeditated, crafted design. This is probably the most powerful reason for the belief, held by the vast majority of people that ever lived, in some kind of supernatural deity . . . ."[2]

Advocates of *intelligent* design focus on complex systems, such as an eye or the molecular motor that propels bacteria, and argue that these are irreducibly complex pieces of biological machinery whose removal leads to a complete loss of function. Take out the car battery and the car stops; remove one enzyme in the bacterial flagellum and no movement occurs. Intelligent design advocates argue that irreducible complexity is evidence of a grand designer, though the movement has worked hard to avoid the claim that the intelligent designer *must necessarily* be God.

Intelligent design, ID, was launched with Michael Behe's book *Darwin's Black Box*. The "black box" represents the smallest functional unit that Behe argues cannot come from earlier precursors through gradual adaptation.[3] Instead, an irreducibly complex component is suggested as evidence of a Grand Designer's handiwork. The response to intelligent design has been rather acrimonious and tended to alienate the very people that ID proponents hoped would consider divine guidance as a plausible explanation. The entire controversy underscores the point that people interpret the complexity differently; some see complexity as evidence of God's design while others, equally in awe, attribute complex systems to chance.

Scientists have responded to arguments for irreducible complexity with counter examples in which small, beneficial advances demonstrably improve an animal's survival. Over time, accruing numerous advances leads to a functional unit that might otherwise appear irreducibly complex. For example, parts of the molecular motor allow restricted motion in other organisms as a step on the way to a molecular motor.

2. Dawkins, *The Blind Watchmaker*, xvi.
3. Behe, *Darwin's Black Box*.

Over time, science has been incredibly fruitful at explaining complex systems of the type ID advocates have identified as requiring an intervention outside the normal bounds of science. As Dawkins says, design is most often interpreted to arise from the influence of an external agent, historically God. ID enthusiasts naturally seek evidence for God in creation because they typically operate from a theistic perspective in which God's influence is confirmed through personal experience; worship, prayer, and providence. Seeking evidence for God's handiwork through divine intervention seems to be fraught with difficulty with only scientific explanations standing the test of time. A more fruitful search for God's influence in creation seems to lie in explanations of meaning and interpretations of the significance of events.

EVOLUTION AND CREATION

Evolution is often presented as the inexorable progression of life to increasingly complex systems. Evolutionary processes explore new life forms through random mutation with beneficial accrual through natural selection. As yet no inherent principle has been identified that guarantees that evolution results in increasing complexity in the way that gravity guarantees that objects will always fall towards earth. Scientific analysis of the earth's history identifies an overall trend towards increased complexity, though whether this is because evolution is somehow weighted towards increased complexity, was just luck, or was divinely ordained remains unknown. Reflecting on this point, Darwin wrote in *On the Origin of Species*, "Probably in no one case could we precisely say why one species has been victorious over another in the great battle of life."

Of all the places in which science and religion intersect, none has caused as much dissension as the theory of evolution. Religious believers have evidence of God's existence through personal experience: divine guidance, answers to prayer, and spiritual experiences. Scientists have evidence from diverse fields that evolution provides the most comprehensive, unifying explanation for life on earth. The root difficulty lies in a perception that religion and evolution provide two different and incompatible explanations for the origin of life; either God created the world with people occupying a privileged position or life developed through a completely naturalistic process devoid of supernatural intervention.

Natural selection provides an explanation of life's development while at the same time highlighting the improbability, and unpredictability, of sentient beings coming into existence. Divine guidance of life's development through an evolutionary process, theistic evolution, is an alternative theory to explain the emergence of sentient life. How this might occur is a mystery because a purely physical weighting would be both detectable and natural in the sense of being explained within the framework of science. How an infinite, non-physical God interacts with a finite creation is a perplexing issue at the forefront of science and religion. At a minimum God's causal interaction must be different from the normal physical causality.

A relationship between God and people requires the presence of causal relations between the physical entity of each individual and a divine, intangible being. For this relationship, an interrelated cause and effect must exist between God and people and between God and the physical universe. God must be able to communicate with thoughts in the brains of conscious individuals and upon the prior processes that brought sentient beings into existence. A personal creator God requires that the laws of nature are not fully deterministic but are influenced by God's intentions.

The creation story in Genesis 1 embraces both divine creation and evolutionary processes. Verse 24 indicates that God used natural process; "Let the land produce living creatures . . ." and immediately in the following verse "God made wild animals." The Bible sees no contradiction with these two statements. Apparently God unleashed a process capable of generating creatures through an exploration of the potential inherent in the world, resulting in creatures that could reproduce themselves. God brings into being a fruitful universe in which animals have the potential to develop into creatures of even greater form.

> And God said, "Let the land produce living creatures according to their kinds: the livestock, the creatures that move along the ground, and the wild animals, each according to its kind. And it was so. God made the wild animals according to their kinds, the livestock according to their kinds, and all the creatures that move along the ground according to their kinds."[4]

The vanishingly small chance of life's origin has often been explained by believers as the providential workings of a process initiated by

4. Gen 1:24–25

an omnipotent God. The emergence of life from a seed is a theme woven throughout the Bible that might parallel divine guidance of natural processes to bring forth life. If God has worked to bring creation into being through purely natural processes, then definitive evidence of divine intervention is likely beyond scientific detection. The best "evidence" of divine guidance might be for a process by which random events captured and enhanced evolutionary advances over time, a process believers could view as providential. Certainly the idea of spiritual direction bringing life to fruition has a long history in Christian theology. Historically, God's omnipotence was argued to be better demonstrated in divine creation of each species in turn and only later was divine activity thought to be greater through an evolving process resulting in each separate species.

The chronological development of each species is recorded in fossils laid down over time. Plants and animals whose skeletons become compressed in sandy sediment create a book whose pages are read by sequentially dating each individual layer. Reading from the lowest layer to the topmost provides a history of how the book of life has influenced the characters over time. Although some pages appear missing, a remarkably consistent and comprehensive history emerges. Recent fossil additions fill in gaps rather than causing huge upheavals to the basic ideas of evolution. Evolutionary trees trace the development from one common ancestor with a gradual divergence through the main plant and animal classes to individual species. The power of this model lies in understanding differences between animals in different parts of the tree. Why do bats fly differently than birds and why do they "nest" in the mammalian branch of the evolutionary tree rather than with the birds? Comparison of the bat's bone structure in the wing indicates a closer similarity to flying rodents, much more like an extended gossamer paw, than the bone structure of a bird.

Genetic comparisons strengthen confidence in the veracity of evolutionary trees. Each parent provides genetic information to the offspring in the evolutionary tree. Comparing genes between related animals unravels a who-dunnit mystery identifying which animal passed what genes to whom. Following this trail, with the help of hundreds of scientist-sleuths, allows an evolutionary tree to be planted. The fact that both the gene tree and the fossil record are virtually identical only serves to confirm early speculation that animals and plants evolved over time through common ancestors.

The biological description of evolutionary development is not as neat as the equations of physics, but the explanatory laws are equally powerful. For example, keen naturalists have long known that life slows down as animals get larger. Flies live for hours or days whereas turtles can live for more than a century. Surveying a wide variety of animals shows a uniform adherence to the "negative quarter-power scaling" for the relationship of metabolism to size. The number of heartbeats an animal has are roughly the same whether the animal is large or small; large animals live longer because their heartbeats are slower. This is the type of universal law that is embedded within biology, applying to animals, plants, and even bacteria. Evolution appears to be the same type of law.

CHANCE AND DETERMINACY

Chance provides the possibility for variation in different environments whereas necessity describes options bounded by natural laws. Chance does not necessarily mean a lack of design or control; a regular die is designed to make six outcomes equally likely. Chance imbues creation with diversity. A universe devoid of chance means that each event is predictable: all outcomes are known, or can be known. If life were possible in such an environment, there would be no creatures taking risks and the skills of life would be very different. In a scripted world God would be responsible for all actions, good and bad. A world without choice lacks surprises, or unique elements of character that differ and complement those of other individuals. While a predictable world might, at times, be preferable, living under such constrictions removes precisely those individual choices that make life so enjoyable and imbue life with meaning and significance. In short, chance allows individual freedom in an evolving universe.

Chance allows the possibility of events that may or may not be causally related. The collision of an enormous asteroid with early earth provides the most likely explanation for the origin of the moon. As a consequence, the earth's rotation slowed to provide twenty-four-hour periods of night and day, promoting biological evolution by providing natural periods for activity and rest. A seemingly chance event provides a fruitful outcome because of a shuffling of potentialities.

Quantum physics identifies chance being not only a result of intersecting and unrelated causal events but an intimate feature of reality.

Radioactive decay is radically indeterminate; no amount of data would allow a more accurate prediction of when a nuclei will decay. There is an irreducible degree of openness present in the world, described in quantum terms in Heisenberg's uncertainty principle, which means that a complete description of all physical motion is just not possible.

Evolution operates with the same Heisenberg-type uncertainty to explore potential new life forms. In the absence of uncertainty, life forms would be the same, whereas too much disorder would generate novelty but lack the constancy required for an organism to become established. Earth has just the right balance of constancy and novelty.

Countless examples occur in living systems where chance occurrences secure definitive outcomes. Fish produce thousands of eggs of which only a few will grow to maturity. The low probability of maturation is offset by the high number of eggs and the survival strategy insures diversity and survival of the population. Chance is harnessed within boundaries that point to a deeper element of design, order, and purpose inherent in biological systems.

The tension between chance and determinacy is essential for life to evolve. If DNA were faithfully copied with 100 percent accuracy, then life could not evolve. A delicate balance exists between accurate DNA copying that maintains an organism's integrity and "sloppy" copying that introduces beneficial variation. Complex organisms require low error rates whereas less complex organisms can have higher error rates. An error rate of roughly less than one in 10^8 is easily accommodated by higher organisms whereas bacteria, having fewer genes, can get by with higher copying errors. Paradoxically, although the earliest organisms' genomes must have been very short to avoid catastrophic copying errors, if the genome is too short then not enough information can be stored to build the copying machinery.

Infusing creation with chance means that life can be perceived as good or bad. Mutations are essential for diversity and change through natural selection. The same evolutionary mechanism that allows cells to mutate and evolve into higher life forms, creates the potential for perfectly normal cells to become cancerous. God is often blamed for not making a perfect world without disease, decay, and death. For centuries theologians have maintained that this world is the best of all possible worlds with science too revealing that the world exists as something of a package deal. The world is intricately linked as environmental issues are

dramatically illustrating. Chance operates in an open system where the good cannot be completely separated from the bad.

Has evolution been biased, or are the underlying scientific laws established in such a way as to make evolution into higher Hominids a predictable outcome? Estimates at the predictability of life vary tremendously because there is no definitive answer. Re-running the evolutionary "tape of life" is expected to lead to sentient beings but in a form different from those on earth today. A movement is developing in evolutionary biology stressing the convergence of evolution to the broad typology seen throughout earth. The evidence is complex and still debated but lies in the multiple times very similar forms and advantageous traits have emerged in separate locations and at different times. The emergence of the DNA and proteineous world only two hundred million years after the Hadean era is speculated by some to be an inevitable outcome thereby explaining the convergence of all life being based on the best possible code out of 270 million alternatives. The immensity of biological hyperspace, while appearing to have vast options to explore, may actually be much more limited. Without knowledge of the probability of such processes, God's presence or absence in the process is unknown.

Any divine coaxing of the evolutionary process has so far eluded detection. An extremely subtle divine encouragement would be commensurate with the "Spirit of God" working for a divine purpose, namely, to set the stage for the drama of human existence. If life is a cosmic accident then each person is truly alone in a universe devoid of meaning. If the fabric of the universe is scripted for life then understanding the origin of life may provide insight into the character of God.

GOD IN THE MACHINE

Does God guide the process of evolution? Chance events that occur within the context of natural processes allow numerous possibilities to be explored and realized. In this sense chance is a shuffling operation that provides the opportunity for different outcomes to be explored. Each dealing of a hand of cards holds different potential for the play. The operation of chance within the limits of natural processes, converges on a limited number—perhaps only one—of potential outcomes. In a very real sense God as the creator can be viewed as guiding evolution without direct intervention.

History has dealt harshly with those who identify a specific gap in evolution with intervention by God. Quantum physics suggests two potential ways in which God may subtly interact in the world. In both cases the intervention is beyond detection because extremely small influences at the quantum level initiate domino processes that cause changes at the physical level. Chaotic processes provide one possibility where minute divine intervention could significantly influence creation while evading detection. Chaotic events are readily apparent in the world's weather patterns where large changes from a small specific input reverberate through the system in a fashion undetectable to the observer. The butterfly effect famously states that the beating of a butterfly's wings in Brazil can trigger events that change the weather in New York.[5] The small input of information may be the scientific equivalent of the Spirit working in creation.

Another approach to finding God's influence lies in the far reaches of the quantum realm. At the quantum level, action depends on probabilities of events occurring. Radioactive decay is an example. Which atom spontaneously decays cannot be predicted despite the rate of decay being statistically predictable. God's involvement at the quantum level could trigger a series of events that might appear random if analyzed scientifically, but which cause events of deep significance. In either case, the key causal joint, the point at which God interacts with the physical realm, is too subtle to detect. Faith may allow individual discernment but with sufficient unpredictability as to be ambiguous.

CONCLUSION

Death is intrinsic to evolution and yet seems anathema to a loving God. Why God allows the pain and suffering inherent in evolution is a modern twist on the perennial question of how a good God allows evil. Although there are no logically conclusive arguments, like many issues in religion, there are pointers to support belief in God. Death is necessary for life, plants must be harvested for seed to reproduce, and animal death provides protein for other animals to live. In the process, the entire created realm remains healthy by removing less fit individuals, keeping disease in check, and maintaining a balanced ecosystem.

5. Polkinghorne, "So Finely Tuned a Universe of Atoms, Stars, and Quanta, and God," 16.

Nature has an inherent freedom which can impact individuals positively and negatively. Cells with the ability to mutate into organisms better adapted to their environment also have the ability to mutate into cancerous cells. The same absorption of solar energy that powers wind currents to spread rain around the globe can also generate destructive tornados. Both beneficial and harmful natural processes arise from the freedom inherent in predictable laws of nature. In much the same way, personal freedom allows choices between good and evil.

Much evolutionary advantage is promoted by ruthless selfishness, a character trait at the core of sinfulness. Keeping the knowledge of a bountiful fishing spot hidden ensures continued sustenance and a fitter individual. The same characteristics that favor individual survival can be expressed at the individual level as greed, envy, manipulation, conspiracy, and exploitation of others. One role of religion is to show that these characteristics do not have to be acted on. Individual actions are not determined by evolution. People have the option to choose not to act on the arguably less noble qualities that evolution may have bestowed. Individuals control the choice to act on these impulses or not. Any inherent instinct does not absolve an individual of the moral responsibility to act above what might be called "animal instinct."

Pain and suffering are inherent ills in the world, though not without some redemption. Pain triggers an immediate response to avoid the cause: withdrawing a hand from heat, removing a splinter, shifting weight to minimize pain in a joint. Mental and physical pain cause suffering which, when endured, can build character. Without pain and suffering, life's great lessons would not likely be learned. There would be no great heroes and no great quests against the forces of wickedness. There would be no *Count of Monte Cristo*, no *Les Miserables*, no suffering Christ, and no encouragement for people to dispense love in the face of evil.

DISCUSSION QUESTIONS

1. Evolution explores new variations through seemingly blind chance. Does the seeming lack of intentionality in evolution fit with the character of the God of the Bible?
2. Will all "irreducibly complex" systems eventually be understood in terms of an evolutionary, stepwise development?

3. In the biblical story of the Israelites settling in Canaan, God says that he will not simply drive out the inhabitants, because the land will become wild before the chosen people could take over the area. Instead a gradual conquest allows the Israelites to settle in the chosen land.[6] The evolutionary process is similar in providing an environment just for humans. Did God intend this parallel, or is this pure chance?

4. Pain provides a biological mechanism for organisms to avoid bodily damage. Would God be good or evil to impart a strong sense of pain into sentient animals?

5. Darwin had four arguments for rejecting Christianity: 1. the early Genesis chapters are a "manifestly false history," 2. God as portrayed in the Old Testament was "a revengeful tyrant," 3. science makes miracles seem "incredible," and 4. the Gospels appear unreliable. Darwin also rejected eternal damnation because "almost all my best friends will be everlastingly punished."[7] Assuming that Darwin was alive today, what arguments do you think he might make for or against belief in God?

6. In supporting evolution Darwin wrote: "Why is it more irreligious to explain the origin of man as a distinct species by descent from some lower form, through the laws of variation and natural selection, than to explain the birth of the individual through the laws of ordinary reproduction?"[8] What are some possible answers to Darwin's question and what reasons support these positions?

Further reading for "Evolution: From Amoeba to Zebra"

1. Steve Stoller, *The Symphony of Creation: Science and Faith in Harmony*. Phoenix: ACW, 2002. Using musical metaphors, Stoller addresses many of the main issues of science and religion. Chapter 7 focuses on the interplay of good, evil, and free will within nature.

2. Kenneth Miller, *Finding Darwin's God: A Scientist's Search for Common Ground between God and Evolution*. New York: Harper Perennial, 1999. Miller is a biologist and a Catholic who passionately

6. Deut 1–4
7. Darwin, quoted in Thomson, *Private Doubt, Public Dilemma*, 80.
8. Darwin, quoted in Phipps, *Darwin's Religious Odyssey*, 125.

argues for a scientifically credible approach to evolution for religious believers. Miller is at his best when interpreting biological experiments. The later more philosophical parts of the book provide the author's speculations on theistic evolution.

3. Fazale Rana and Hugh Ross, *Origins of Life: Biblical and Evolutionary Models Face Off*. Colorado Springs: NavPress, 2004. Provides a comprehensive summary of recent advances in understanding the chemical and biological origin of life with extensive references to primary literature, reviews, and conference summaries. The material is covered from a Christian perspective and requires an undergraduate education in science to follow many of the arguments under discussion.

4. Michael Denton, *Nature's Destiny: How the Laws of Biology Reveal Purpose in the Universe*. New York: Free, 1998. Denton surveys a host of biological processes that point to the universe being finely tuned for the emergence of life. The fitness of a diverse set of chemical and biological processes is surveyed in an easily understandable level, although the volume of material can be overwhelming.

5. Ian Tattersall, *Paleontology: A Brief History of Life*. Conshohocken, PA: Templeton Foundation, 2010. Tattersall races through the evolution of life from the earliest rocks and fossils to the arrival of man a few billion years later. Tattersall, a curator at the Museum of Natural History in New York, chronicles the rise and fall of species by focusing on the beneficial traits that accrue over the millennia. A distinct feature of the book is the amount of knowledge woven through many diverse fields.

6. Richard Swinburne, *Providence and the Problem of Evil*. Oxford: Clarendon, 1998. Developing an understanding of good and evil is one of the most difficult philosophical problems that plagues the intellectual development of each person. Swinburne argues that God wants people to freely choose good over evil, to form character, and allow love. Within this perspective, such choices are only possible when the real possibility exists for evil through bad choices.

7. Keith Ward, *God, Chance, and Necessity*. London: Oneworld, 1996. Keith Ward deftly identifies the philosophical assumptions behind the Big Bang and evolution and then takes Peter Atkins and Richard Dawkins to task for promoting philosophical ideas from unsound

logic. Ward is at his best identifying philosophical space where God may play a role in guiding evolution without being a benign dictator.

8. Simon Conway-Morris, *Life's Solution: Inevitable Humans in a Lonely Universe*. New York: Cambridge University Press, 2003. The book provides an excellent overview of evolutionary processes by confronting major weaknesses in the development of life. Conway-Morris argues that, despite difficulties, life was destined to arise and result in sentient beings.