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Characteristics of the Universe Revealed by the Sciences

What is the proper starting point for a Christian theology of divine action? A little reflection suggests that, if it is to be truly a Christian theology, then it will certainly be grounded in the Christian tradition and the central conviction of this tradition, that God has acted to bring salvation to our world in the life, death, and resurrection of Jesus and in the outpouring of the Spirit. This will be taken up as the theme of the next chapter. But, I believe, a theology of divine action depends as well on the worldview that the theologian brings to his or her work. And if this worldview is to be as faithful as possible to the world we actually encounter, it will be shaped by the best insights of the sciences.

When twenty-first-century cosmology describes the emergence and expansion of our universe, and when contemporary biology describes the evolution of life on Earth, the theologian takes these scientific findings seriously, because she interprets the history of the universe that cosmology describes, and the story of life that biology articulates, as the fruit of the divine act of creation. When the sciences come to a broadly held consensus that, for example, the observable universe has been expanding for 13.7 billion years from a tiny, compressed state, or that natural selection has played a fundamental role in the evolution of life on Earth, the theologian will see such a consensus as the best description we have to date of the concrete and specific ways in which God's action takes effect in a universe of creatures. Of course, such a theology will need to be revised if and when the scientific picture changes or develops. But this is the nature of theology, to be done again anew in new contexts.

In this chapter, then, I attempt to articulate key insights from the sciences that contribute to a worldview that will form a dialogue partner for the theology of divine action that follows. I will ask this question: What are the key characteristics of the world revealed by the natural sciences that are significant for a theology of the action of God? William Stoeger offers some guidance here. He has provided a response to this question from the perspective of a cosmologist and philosopher of science.[1] He speaks of a universe that is evolving at all levels, that is relational, that has its own integrity, and that possesses some directionality. A further theme, which will be fundamental for this book, is that evolution is costly for many creatures. Stoeger's assessment seems in general agreement with that of others involved in the contemporary discussion among science, philosophy, and theology, including Ian Barbour, Arthur Peacocke, John Polkinghorne, Robert John Russell, Nancey Murphy, George Ellis, John Haught, Philip Clayton, and Christopher Southgate.[2] I will follow Stoeger's line of thought, outlining an understanding of characteristics of the worldview revealed by the natural sciences that will be basic to the theology of divine action developed in the rest of this book.

A Universe That Evolves at All Levels

We owe the discovery of the evolution of life by means of natural selection to the work of Charles Darwin and Alfred Russel Wallace in the nineteenth century. The discovery that the universe itself is expanding and evolving is the achievement of twentieth-century science, as it built on Albert Einstein's theory of general relativity and Edwin Hubble's astronomical observations. With some confidence, cosmologists can now trace the history of the observable universe back to the first second of its existence, about 13.7 billion years ago, when it was unimaginably small, dense, and hot. They think a great deal happened in the first second, including the emergence of the four fundamental forces—gravitation, electromagnetism, and the strong and weak nuclear forces—and the fundamental particles, such as neutrons, protons, electrons, and neutrinos.

According to many influential theories in cosmology, early in the first second, the young universe went through a period of very rapid inflation. In the first few minutes, as the universe expanded more gently and continued to cool, protons and neutrons were able to combine to form the nuclei of hydrogen, the simplest element, and the first helium. By the end of the first three minutes, the observable universe existed as an expanding and cooling fireball of hydrogen and helium nuclei. When it was about 400,000 years old, it entered a new stage of its evolution. It was cool enough for nuclei to bond with electrons to form atoms of hydrogen and helium. In this process, matter was decoupled from radiation. The universe became transparent to the radiation that fills it—the cosmic microwave radiation. This radiation, predicted by the theory of big bang cosmology, was discovered in 1967 and is now mapped by astronomers, who find it gives them a kind of snapshot of the early universe.

As the universe continued to expand, slight unevenness in density meant there were locations where large clouds of hydrogen and helium accumulated, the beginning of galaxies. Under the influence of gravity, these pockets of gas eventually stopped expanding and began to collapse, heat up, and fragment. Massive enough fragments increased in temperature to the point where nuclear fusion processes were triggered, converting hydrogen into more helium. The first stars were born, lighting up the universe. Further nuclear reactions would convert helium into heavier elements, including the carbon, nitrogen, and oxygen from which we are made. Very large stars ended in supernova explosions that produced still heavier elements, seeding their galaxies with elements for the formation of further stars and their planets.

Our Milky Way is one of about 200 billion galaxies in the observable universe. The Milky Way contains more than 100 billion stars. Because of the material produced by stars and supernova explosions, and the subsequent chemical processing in cooler astronomical environments, interstellar clouds, comets, asteroids, planets, and moons contain complex organic molecules and amino acids. These are fundamental to the emergence of life on Earth. Our own solar system formed from a great molecular cloud of gas about 4.6 billion years ago. The raw materials for life were assembled as Earth took shape from the matter circling the newly emerged Sun and through the bombardment of the young Earth by meteorites.

Within about a billion years, life appeared on Earth in the form of bacterial cells without a nucleus (called prokaryotes). The next big step was the emergence of creatures that possess a developed cell nucleus (the eukaryotes). Early microbial forms of life began to change the atmosphere to one that was oxygen rich through photosynthesis. Developed multicellular animals appear in the fossil record from about 570 million years ago and took new and diverse forms in the seas of the Cambrian period (545 million to 495 million years ago). Dinosaurs, flying reptiles, and mammals appeared in the Triassic (248 million to 206 million years ago) and Jurassic (206 million to 144 million years ago) periods. Birds and flowering plants emerged at the beginning of the Cretaceous period (144 million to 65 million years ago). Various hominid species evolved between 4 million and 2 million years ago. *Homo erectus* emerged about 2 million years ago with a large brain and an athletic body and soon spread from Africa to other parts of the world. Modern humans seem to have evolved about 200,000 years ago, lighter than *Homo erectus* and possessing a much larger brain.

The universe and everything in it evolves in time. According to quantum cosmologists, time as we know it could not have been a characteristic of our universe in the tiniest fraction of the first second of its history (the Planck era), but emerged as the universe expanded from its primordial state. But ever since the first part of the first second, long periods of time have been essential to the emergence of the universe—above all of its galaxies and stars, with their capacity to produce elements like carbon, which then set the scene for the emergence of life and consciousness on a planet like Earth. The emergence of this kind of complexity requires something like the 13.7 billion years that have passed since the first second of our universe.

In a theological vision, this great story of an evolving universe is not only our story, but also God's story, the story of God's creation. The first particles, the emergence of stars, the production of heavier elements necessary for life, the development of complex molecules, the evolution of life on Earth—all of this is God's work, brought about by God working in and through the laws of nature over immense lengths of time and with great patience. Reflecting on this leads one to think that God must be a Creator who not only enables but respects and waits upon the processes by which things evolve in more and more complex ways. It seems that it is characteristic of God to create in an emergent and evolutionary way.

A Universe Constituted by Patterns of Relationship

When the various sciences look at an atom, a galaxy, or the most complex thing we know, the human brain, they find patterns of relationships. Quarks are the building blocks for protons and neutrons, and these combine in various ways to form the ninety-two kinds of atoms. Atoms form the basis of molecules, which combine to form macromolecules. Combinations of these make life possible in single-celled bacteria, in multicellular organisms, in neurologically developed animals with their social structure, and in human beings with their developed brains and their participation in and dependence upon society and culture.

At each level, entities are constituted from other entities structured in differentiated and cooperative interrelationships. Arthur Peacocke, among others, has described the picture of the world that the natural sciences give us as a complex "hierarchy." This word points to the way patterns of relationship nest upon one another: there is a series of levels of organization of matter, in which each member in the series is a new whole yet is constituted of parts that precede it in the series.[3]

Stoeger describes the patterns discovered by the natural sciences as "constitutive relationships." Constitutive relationships are "those interactions among components and with the larger context which jointly effect the composition of a given system and establish its functional characteristic within the larger whole of which it is a part, and thereby enable it to manifest the particular properties and behavior it does."[4] These relationships make an entity what it is, endowing it with unity of structure and consistency of action. Entities emerge and exist in such patterns of interrelationship. These include not only the interrelationship between the constituents that make up an entity, but also the interrelationship between the entity and its environment.

Each entity is constituted by more fundamental entities; each entity is interrelated with others to form a larger system. Thus, a carbon atom is constituted from subatomic particles (protons, neutrons, and electrons). But a carbon atom in my body is constituted as part of a molecule, which forms part of a cell, which belongs to an organ of my body. I am part of a family, a human society, and a community of interrelated living creatures on Earth. The Earth community depends upon and is interrelated with the Sun, the Milky Way Galaxy, and the whole universe.

At all levels from fundamental particles to atoms, molecules, cells, and the universe, one level of reality is articulated upon another in new patterns of relationship. Stoeger finds that this kind of articulated structuring is a universal feature of the world revealed by the natural and social sciences. At every level, this nested organization is realized through the interrelationships among the components, together with the whole–part relationships that determine the distribution and collective function of components.[5] Constitutive relationships involve all those interactions that incorporate components into a more complex whole, and relate that complex whole into another level of unity. They may be physical, biological, or social in character.

We human beings depend upon many different systems both inside and outside ourselves. Atoms that make up the neurons of our brains were formed in long-dead stars. We are dependent upon and interrelated with the universe. Closer to home, we become who we are in relationship to families, communities, and the land to which we belong, with its animals, birds, trees, flowers, insects, and bacteria.

When we move beyond science to theology, we can add that the most important constitutive relationship of all, one that operates on a radically different level from all the others and is not accessible to empirical research, is the relationship of ongoing creation. This is the relationship by which the indwelling Creator Spirit is present to each creature, enabling it to be and to become in a world of interconnected relationships. This relationship with the Creator endows all things with existence in an interrelational and ordered world. While science suggests a world of constitutive relationships, a Christian theology locates this in relation to a Trinitarian God of mutual relations. It sees God's being as Communion. While it insists that there is an infinite difference between all the interrelationships of creatures and the divine Communion, a Trinitarian theology of creation sees every creature, whether it be an insect, a tree, a star, or a human being, as participating in the life of divine Communion. It sees their differentiated relationships with each other as already a limited, creaturely reflection of this divine life, and as in some way a sacrament of Communion.

A Universe Where Natural Processes Have Their Own Integrity

While science sees everything in our universe as interrelated, it also sees each entity and process as possessing a level of integrity. And as new systems and new organisms emerge in the course of evolutionary history, the sciences see them as emerging and being maintained by natural processes with their own integrity. Some scientists are convinced that within nature itself, there are self-ordering and self-organizing principles and processes that can adequately account, at the level of science, for the emergence of complexity and novelty.[6] While some of these principles and processes are already well known, others remain a matter of speculation. The gaps in scientific knowledge have not all been filled, but more are being filled every day.

Appealing to outside intervention is not an accepted option for science. Science is rightly committed to methodological naturalism, seeking natural explanations for empirical reality. There is no need to appeal to the "god of the gaps." At the level of empirical reality, the level at which all the sciences work, the natural world is understood as possessing a kind of autonomy, in the sense that it evolves and functions on its own, according to its own laws. Science has learned to be confident that natural processes are to be explained by the laws of nature. Even when, at a particular stage of research, something cannot be explained, there is still a well-based assumption that a natural explanation is to be sought and found. There is an expectation that science, working with its understanding of the laws and processes of the natural world, will be able to explain the origin and existence of atoms, stars, cells, the world of plants and animals and human beings.

There are, of course, important questions to ask that take us beyond the empirical sciences. These sciences cannot tell us why there is anything at all. They cannot tell us why there is a universe or why there is order in it. They cannot tell us the meaning of our own lives and deaths. They cannot tell us the significance of this immense cosmos in which we find ourselves or our own place in it. They cannot deal with the endless searching of the human mind and heart. They cannot tell us whether the ultimate meaning of the whole universe is personal love or bleak emptiness. They cannot tell us whether we are ultimately forgiven and loved. These are all urgent human questions, but they are philosophical and theological questions rather than scientific ones.

Christian theology sees God as the Creator who is profoundly and intimately present to every aspect of the universe, enabling it to be and to become at every point. It proclaims that the ultimate meaning of the universe, and that which guides and empowers it, is the love revealed in Jesus and poured out in the Spirit. But with Stoeger, I believe that this kind of theological position is entirely coherent with a profound respect for the autonomy of the sciences, and for their assumption that it is the task of science to explain the emergence of the universe, the evolution of life, and the whole of empirical reality according to scientific methods, which involve methodological naturalism and do not invoke the "god of the gaps."

A theology that takes science seriously will respect the integrity of the natural sciences and the integrity of nature itself and will see both as God given. After all, Thomas Aquinas long ago proclaimed that God works creatively and providentially through the whole network of created causes, which he called secondary causes. This is something I will need to address more fully later in this book. For now, it is enough to note that Aquinas does not see this as a diminishment of divine power, but as the way divine power works. God acts in and through creaturely causes because of the divine goodness that wants to give creatures "the dignity of causing." Aquinas sees God as creating in such a way as to give creatures their own integrity and relative independence as causal agents.

A Directional Universe

Does the universe give evidence of purpose? Does science support a teleological view of evolution? At the beginning of the twenty-first century, it seems clear that the sciences do not offer clear evidence of a goal-directed universe. Some biologists, including Stephen Jay Gould, have challenged the general idea of "progress" in evolutionary history.[7] Gould also famously introduced the metaphor of "replaying life's tape," insisting that were the tape to be played again, the randomness and contingency of the process would mean that life would not evolve in anything like the same way.[8] While others fully accept the role of contingency in evolution, they come to a different conclusion. Simon Conway Morris presents many examples of parallel and convergent evolution, where very different lineages have evolved similar adaptations in similar contexts.[9] Evolution is not entirely random but is constrained along certain lines, as selection pressures organisms toward possible functional spaces. This means that if features of organisms are of great adaptive value and genetically possible, these features will eventually arise. Such features include intelligence, and Conway Morris thinks that something like the human was bound to emerge.[10]

The eye is a common example of convergent evolution. It has emerged independently at least three times: in vertebrates, in the cephalopods (squids and octopus), and in some marine worms. A case can be made for the independent but convergent evolution of intelligence, not just among primates (monkeys, apes, and humans) and the cetaceans (whales and dolphins), but also among crows and parrots.[11] The emergence of intelligence in birds is all the more remarkable, in that birds and mammals evolved from distinct reptilian ancestors and have very different brains. Their last common ancestor lived over 280 million years ago. It seems clear that recent work on convergent evolution supports the idea of some overall direction in the patterns of evolutionary emergence.

From the perspective of a cosmologist, William Stoeger believes that a strong case can be made that the sciences reveal some overall directionality in the evolution of the universe at large, and of systems within it. This overall directionality is indicated first of all by the fact that the universe is expanding and cooling and that its structure is dominated by gravity. This means that the universe in fact evolves in the direction of greater complexity, from quarks, to stars, to bacteria, to the human brain. Chance plays an essential role in this pattern, particularly at the level of random genetic mutations, which can have disastrous consequences for organisms but also give rise, in some cases, to new evolutionary developments. Chance is involved at the planetary level when a comet collides with Earth, bringing death and extinction of species. Such deadly chance events occur within a framework of lawfulness, and they can provide opportunities for the emergence of new systems or new species of organisms. In this sense, chance is not opposed to overall directionality but, when combined with the lawfulness of the universe, is part of the pattern by which it occurs.

Stoeger points out that science does not offer grounds for the idea that there is a preplanned outcome to evolution or for the idea that the evolutionary process is consciously directed. There is no evidence for the existence of a blueprint of the final outcome. Science does not indicate purpose or design, but neither does it rule them out. The kind of directionality that science indicates is that of a chain of realized possibilities that build upon one another: "The realization of any given possibility presupposes the prior realization of other possibilities, which are the stepping stones to those involving greater complexity or organization."[12] At any given point in the evolution of the universe and of life, there is a limited range of developments that either will occur or may occur. At any one point, there is a developing, nested set of directionalities. Some of these can emerge in specific ways in particular locales. So where a stable star system contains a planet that is rich in minerals and water, and is the right distance from the star to have a moderate temperature, there is the rich possibility of future evolutionary development.

The cosmological "anthropic principle" seems to support the idea that directionality is built into the evolution of the universe. This principle points to the insight that the universe has to be finely tuned in precisely the right ways if life, particularly human life, is to emerge within it. A very small change in any one of the many constants, such as the gravitational constant, that characterize the forces and particles of the universe would leave it completely lifeless.[13] These constants need to be precisely tuned, very close to what we find in the universe as it is, if galaxies are to form in the early universe, stars are to ignite to produce elements like carbon, and life is to evolve on a planet like Earth. It takes billions of years of star burning to produce the elements that make life on Earth possible. There is, then, a close relationship between the age and size of the universe and the emergence of life on our planet.

I am not suggesting that the anthropic principle proves the existence of the Creator, nor am I arguing that it proves the universe is designed. Advances in science, such as inflationary theory, may well offer ever better explanations for what we observe as the fine-tuning of the universe. All I am suggesting here is that the anthropic principle, as we now understand it, does fit naturally with a theological view of a God who is acting purposefully in creation. While there is this congruence with the anthropic principle, it is worth noting that there is no such natural fit between Christian hope for a future transformation of creation and cosmology's prediction of a universe endlessly expanding and dissipating into a bleak and lifeless future or, as seems less likely, collapsing back on itself. This issue has begun to be addressed by the science–theology dialogue, in the work of scholars including Robert John Russell and John Polkinghorne, and it will require much more work from theologians.[14]

Stoeger's generalization from the scientific evidence is a modest one. What the sciences show is that the universe does evolve with time, in the direction of increasing complexity that includes the emergence of stars, the appearance of the first self-replicating bacteria, and the evolution of human beings. The sciences do *not* reveal a divine design or blueprint. But the scientific evidence is open to a Christian interpretation. This modest claim, that the sciences support an overall directionality in the evolution of the universe and life, fits well with the idea of a God who is achieving purposes in creation, redemption, and final fulfillment. It is congruent with a view of God who acts creatively and providentially in and through the laws of nature, in all the randomness and lawfulness that allows and enables a life-bearing universe to evolve.

The Costs of Evolution

Following Stoeger, I have been proposing that specific characteristics of the universe that are relevant for a Christian theology of divine action can be distilled from the natural sciences: the sciences reveal a universe that is evolving at all levels, that is constituted by relationships, that has its own integrity, and that has an overall directionality. The evolutionary character of the universe is something that Christian theologians are able to embrace positively and to understand as the way God creates.[15] But evolution is costly, and this constitutes another characteristic of the universe revealed by the natural sciences. They reveal that the costs of evolution are intrinsic to the process.

It has become clear from the evolutionary biology of the past two centuries that competition for resources, predation, death, pain, and extinction are built into the evolution of life. They are not simply unfortunate circumstances that sometimes accompany the emergence of a world of beauty and diversity. They were already part of the pattern of life long before the emergence of human beings and cannot be caused by human sin, as many Christians of the past have thought. The costs of evolution are intrinsic to the process by which life has come to flourish on Earth.

In the world as we know it from the biological sciences, eagles, dolphins, and humans could not be what they are without death. The evolution of each species occurs only through the long processes of evolutionary history, the repeated cycles of birth, reproduction, and death. The evolution of organs like the eye depends upon the pattern of life and death repeated over countless generations, by which random genetic changes give an advantage in adapting to an environment and reproducing. Natural selection is unthinkable without the cycle of generations. It depends upon lives that end in death. Ursula Goodenough points out that part of the evolutionary strategy of organisms like our own is that their somatic cells are programmed for death. Death is the price paid for living in a complex world with developed forms of life, including sentient life. Death is the price we pay for a world in which there are wings, eyes, and brains.[16]

Both cooperation and competition for resources have shaped life on our planet, and the evolution of many species depends upon the predator–prey relationship. As Holmes Rolston puts it, "The cougar's fang has carved the limbs of the fleet-footed deer, and vice-versa."[17] Christopher Southgate takes up this theme: "No-one who has seen at close quarters the surge of a full grown orca through the water, the prowl of a leopard through long grass, or that quicksilver stalling turn by which a peregrine returns to the stoop—all products of the refinements of predation over millions of years—can doubt the value that arises from the process."[18] This value is, in some cases, closely related to behavior that inflicts pain on other animals: an orca batters a gray whale until it has no more strength, a leopard may take minutes to kill an antelope, a peregrine may maim its prey, leaving it to die a lingering death. Suffering among the weak, the young, and the less adapted is intrinsic to the evolution of the wonderful attributes of living creatures.[19]

Pain seems to accompany sentience. An increase in the brain's capacity to receive and store information brings with it an increase of an organism's sensitivity to its environment. Consciousness involves awareness not only of what is life enhancing but also of what is damaging. In the context of natural selection, pain has survival value. It acts as a warning and a spur to action. Pain is "an energizing force," which because of its high survival value, will tend to be selected for in evolution. Excessive pain would be counterproductive in terms of survival and would tend to not be selected for overall.[20] In the forms of life we know, increased consciousness involves the capacity to experience pain, and with the emergence of reflective consciousness, there is an increase in the capacity to experience suffering, in that what is painful can be remembered, dwelled upon, and feared.

Extinction is part of the evolutionary pattern of life on Earth. Species disappear, and new ones emerge. Only about 2 to 4 percent of the species that have existed on Earth survive today. In this sense, extinction is part of the natural cycle of life. But there have also been a number of catastrophic extinctions in the 3.7-billion-year history of life on Earth. In the worst of these, 250 million years ago, most of life was annihilated. In a short time, something like 96 percent of species was lost. In the extinction of 65 million years ago, the dinosaurs disappeared, along with perhaps 70 percent of the species on Earth. Today, many species are being driven to extinction or are under threat of extinction because of human activity. Something of value is lost with every extinction. Theologically, every species is an expression of God in our world, a word of God spoken on our planet. But it is also true that with the mass extinctions on our planet, life has emerged in creative new ways. With the extinction of the dinosaurs, for example, it seems that mammals had more opportunity to diversify and flourish.

Christopher Southgate analyzes the issues that might be thought to constitute the problem of evolutionary theodicy, including death, the pain involved in parasitism, predation and disease, the waste involved in the abundance of organisms, and the extinction of species. He sees death as a thermodynamic necessity, which does not need to be considered a problem if it follows a fulfilled life. He proposes that the two issues that need to be dealt with are the suffering of sentient creatures and the extinction of species, which he sees as always a loss of value to the biosphere as a whole.[21] I find logic to this position and the distinction it allows between pain that assists survival and death that follows a full life, on the one hand, and the suffering of sentient animals, on the other. This may well be helpful for the kind of theodicy Southgate is arguing.

For the purposes of this book, however, it is helpful to consider the costs of evolution as a whole. These costs are involved in the way complexity arises in one location by drawing energy from another, in the way life evolves through genetic mutations that are mainly damaging to organisms, in the way living creatures prey on others, in the way decay and death seem intrinsic to the evolution of the biosphere, and in the way that extinction seems to be part of the pattern of life on Earth. The costs of evolution are the pain, suffering, and loss that occur in all of these. It is all of these costs that I want to bring into the dialogue of this book.

In this chapter, I have outlined some of the key characteristics of the universe that emerge from the natural sciences: the universe is emergent and evolving, is constituted by relationships, possesses its own integrity, has a level of directionality, and has costs that are intrinsic to the process. I have proposed that each of these is relevant to a theology of divine action. With this kind of scientific worldview in mind, I will turn to the Christian tradition itself, asking what it brings to a conversation about divine action.