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Is Nature Purposeful?

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At the intersection of biology, philosophy, and theology stands the question of whether natural things apart from human intervention are purposeful. The author traces the dismissal of purpose from the biological sciences to Darwin. It is then argued that since neo-Darwinism itself is currently criticized from within biology that it is reasonable to reconsider the question of purpose on its own merits. Some evidence for purposefulness in nonliving things is briefly indicated from astronomy and astrophysics. The article concludes with a detailed discussion of the various ways purpose is used in the work of biologists when they account for living things.

Does nature act for an end? Is purposefulness found in natural things apart from human intervention? These are questions of major import for biology, philosophy, and theology. It makes a world of difference in the method of biology whether or not we can assign the purpose of a structure, a material, or a process. The question also has important repercussions for the philosophic investigation of nature. Plato argues that the good is a cause in natural things.[1] Aristotle devotes an entire chapter in his *Physics* to manifesting that nature acts for an end. He also discusses the question at length in his biological treatises.[2] There are implications for theology as well. Natural things acting for an end imply a Mind behind nature directing them to their goals. Thomas Aquinas' famous fifth proof for the existence for God uses the purposefulness of nature as a key premise:

A fifth way is taken from the governance of things. For we see that some things lacking knowledge, namely natural bodies, act for the sake of a goal. This is clear from the fact that they act always or for the most part so that what results is best, whence it is obvious that it is not by chance but by intention that they reach the goal. But things which do not have knowledge do not tend toward a goal unless they are directed by something knowing and intelligent, as the arrow by the archer. Therefore, there exists an intelligence by which all natural things are ordered to a goal, and this intelligence we call God.[3]

Up to the middle of the nineteenth century, biologists took for granted the purposefulness of nature and adopted the natural theology that followed from it.[4] Since then, however, the purposefulness of living

things is thought to have been overthrown by Darwin. Julian Huxley, for example, declares: "At first sight the biological sector seems full of purpose. Organisms are built as if purposefully designed, and work as if in purposeful pursuit of a conscious aim. But the truth lies in those two words `as if.' As the genius of Darwin showed, the purpose is only an apparent one."[5] Darwin's friend, biologist T. H. Huxley, thought that "teleology " received its death blow at Mr. Darwin's hands."[6]

This article will argue that nature acts for an end. The article falls into two main parts: the first is a scientific critique of the denial of purpose in biology based on Darwinian claims; and the second is a look at the positive evidence for purposefulness, first in nonliving things and then in living things.

Darwin's Failure to Refute Purpose

If the exclusion of purpose from modern biology relies on Darwin's theory of evolution, then any serious doubt about Darwinian theory will require a reexamination of the status of purpose in biology. However, key features of Neo-Darwinism, especially gradualism and natural selection, are under serious criticism currently, not from creationists but from within biology itself. I will indicate very briefly some of the difficulties for Darwin arising from paleontology, ecology, genetics, and molecular biology. Note well that the following critiques aim not at evolution as such but at the specific mechanisms Darwin proposed to account for evolution.

Paleontologists Stanley, Eldredge, and Raup, among others, point out that the fossil record contradicts the gradual shifting of one species to another required by Darwinian theory. The typical pattern is for new species to appear for the first time in the fossil record abruptly, without slow transition, and then to remain stable for long periods without significant change,[7] just the opposite of Darwin's predictions. Stanley declares, "The known fossil record is not, and never has been in accord with gradualism,"[8] a discrepancy that paleontologist Steven Gould calls the trade secret of paleontology.[9]

To this may be added the evidence of mass extinctions which have occurred on six occasions according to the fossil record, some of them destroying 90% of all things living at that time. If, as Newell points out, mass extinctions affected quite unrelated groups in different habitats,[10] then the majority of extinctions in the history of life have nothing to do with competition or adaptation as predicted by Darwin but are simply the result of global disasters.

Another central mechanism in Darwin's explanation is undermined by modern ecological studies. Ecologists Simberloff, Kormondy, Messenger, Ricklefs, and Colinvaux, basing their conclusions on hundreds of field studies, declare that in nature competition between species is rare to nonexistent.[11] Eldredge points to the many "ecologists skeptical of the very concept of competition between species " who claim they simply cannot see any evidence for such raw battling going on nowadays in nature."[12] But if universal competition between species and between individuals is not factual, then Darwin's argument for natural selection fails. Ecological studies have also documented that species regulate their population size without recourse to disaster, predation, and disease as Darwin postulated.[13]

Further, thousands of genetic experiments with fruit flies subjected to X-ray treatments to increase their mutation rate up to 150 times the normal rate failed to confirm Darwin's assumption that the accumulation of small varietal differences will produce organisms differing in species. No new species emerged from any of these experiments.[14] Rather than the unlimited plasticity within each species that Darwin assumed, modern research in genetics indicates that random mutations are either insignificant or lethal.

From molecular biology comes further evidence that when DNA and protein sequences are compared none of the organisms conventionally thought to be transitional are in fact intermediaries. For example, since Darwin, amphibians have been thought to be transitional between fish and reptiles. However, in molecular terms, amphibians are equidistant from fish, reptiles, birds, and mammals. Biologist Michael Denton argues on molecular evidence that plant and animal species do not form a continuum as Darwin thought but are discrete, like the elements in the periodic table. Denton demonstrates that there is no biochemical

foundation for claiming that certain extinct groups are ancestors of others. After reviewing the arguments on both sides, he concludes that "the Darwinian theory of evolution is no more or less than the great cosmogenic myth of the twentieth century."[15]

In addition to these difficulties, the Darwinian rejection of purpose falls into logical inconsistencies. Natural selection requires that the reproductive system of a species be functioning correctly, otherwise there would be no way to pass on advantages. But the reproductive system is itself clearly purposeful. Its organs, actions, and processes all aim at a definite goal: the production of new individuals of the species. It seems, therefore, that natural selection cannot rule out all purposefulness from nature and still function as a mechanism of evolution.

The difficulties in Darwinian theory outlined above are not light or marginal. On the contrary, they attack the essence of the theory in its fundamental premises and in its necessary consequences. Nor can they be dismissed as the fulminations of a few cranks, coming as they do from leading biologists in several disciplines. On the other hand, this cursory review of the difficulties, in no way constitutes a refutation of natural selection.[16] It is offered merely as a sign that Neo-Darwinism is far from a conclusive and rigorous demonstration of the sufficiency of random chance in accounting for the origin and structure of living things. T. H. Huxley claimed, "Teleology received its death blow at Mr. Darwin's hands." If the criticisms just outlined are valid, it seems more likely that Darwin's theory may receive its death blow at the hands of modern paleontology, ecology, genetics, and molecular biology. Indeed, paleontologist Steven Jay Gould of Harvard has declared, "The synthetic theory [of evolution] " as a general proposition, is effectively dead, despite its persistence as textbook orthodoxy."[17] My aim, however, is not to overthrow Darwin, but to open the issue of purpose. Thus, rather than banning purpose from nature on the authority of a theory now being called into question, it seems more reasonable to reconsider the evidence for purpose on its own merits.

Signs of Purpose in Nonliving Things

There is mounting evidence from sciences other than biology that the universe as a whole is purposeful. Contemporary physics and cosmology offer evidence that the universe is uniquely subordinated to the possibility of life. For example, astrophysicist Steven Hawking argues that the present rate of expansion of the universe is critically adjusted to what is needed to have a universe where life is possible.[18] Physicist John A. Wheeler in a similar way argues that the size of our universe had to be what it is in order for heavy elements to occur and hence for life to exist.[19] Astronomer Hugh Ross documents sixteen physical and astronomical features of our universe that appear uniquely designed for life and shows nineteen other delicately-balanced parameters of the planet earth that make it a hospitable environment for living things.[20] Astronomer John Barrow and physicist Frank Tipler, in a comprehensive study of purpose in science, argue that ours is a life-breeding universe.[21] Physicist Freeman Dyson points out that the forces within the nucleus of atoms had to lie within a very limited range to make life possible.[22] So on the small scale and on the very large scale, there is now much probable evidence from physics, chemistry, and cosmology that our universe, its history, and its material laws are uniquely subordinated to the possibility of life. This suggests, quite independently of any evolutionary considerations, the purposefulness of nature on the grandest scale.

Purpose in Living Things

The testimony of eminent biologists concerning purpose is clear and emphatic. Oparin declares that "The universal `purposiveness' of the organization of living beings is an objective and self-evident fact which cannot be ignored by any thoughtful student of nature."[23] And Ayala agrees: "Teleological explanations cannot be dispensed with in biology, and are therefore distinctive of biology as a natural science."[24] Medawar writes: "Purposiveness is one of the distinguishing characteristics of living things. *Of course* birds build nests in order to house their young and, equally obviously, the enlargement of a second kidney when the first is removed comes about to allow one kidney to do the work formerly done by two." And he adds the example of the "body-wide monitoring system that exists in order to spy out and eradicate malignant variants of the body cells (immunological surveillance)."[25]

Monod compares the eye to a camera, arguing that both have the same purpose of recording images. He declares that purpose "is essential to the very definition of living beings."[26] Sinnott holds that "teleology, far from being unscientific, is implicit in the very nature of the organism."[27] Jacob contends "that structure is inseparable from its purpose."[28] Dobzhansky compares art to nature: "A living body " is a work of art. Its beauty resides in its internal teleology. The beauty of human artistic creations is imposed by their makers; it is external teleology."[29]

Thorpe points out that purpose opens a line of inquiry unique to the life sciences: "We can ask of the structures in a living organism, just as we can ask of the structures in a man-made machine, what is this for" We can often give fairly exact and plausible answers."[30] Simpson argues that in biology "`What for?'" the dreadful teleological question " not only is legitimate but also must eventually be asked about every vital phenomenon."[31]

The above testimonies are a representative sampling of the majority opinion among eminent biologists: purpose is a necessary part of the method of biology.

The attempt to drive purpose from biology was encouraged in part by an overzealous desire to imitate the methods of physics. This desire was misguided because purpose is one of the features that distinguishes the life sciences from physics. Physicist Niels Bohr states: "A description of the internal functions of an organism and its reaction to external stimuli often requires the word purposeful, which is foreign to physics and chemistry."[32] Ethologist Niko Tinbergen echoes the same sentiment: "Whereas the physicist or the chemist is not intent on studying the purpose of the phenomena he studies, the biologist has to consider it."[33]

On this basis the purposes apparent in living things cannot be dismissed as mere anthropomorphic impositions of the observer. First, we notice that the experts cited above insist that purpose is not an invention of the observer but is in the organisms themselves. They use such phrases as "essential to the very definition of living beings" and "implicit in the very nature of the organism." Second, even committed Darwinians do not deny that purpose *seems* to pervade every aspect of living things, and that the language of purpose is unavoidable in biology, as seen in the quotation from Julian Huxley at the beginning of this article. If, however, purpose were merely a part of the way the human mind must understand things, we should find purpose in every science. But we do not find it in every science. No one feels compelled to use the language of purpose in mathematics. Mathematicians do not strive to discover what prime numbers are *for*. They do not argue that triangles have three points to protect themselves against carnivorous squares. Mathematics is not plagued by an all-pervasive teleology. The same holds for physics and chemistry, as stated above. Therefore, the inevitability of purpose in biology comes not from the human mind but from the special subject matter of biology. Life incorporates genuine goals and purposes.

In biology we do not understand a structure if we do not know its function.[34] Ricklefs maintains that the flatness of leaves is much less intelligible if we do not see what purpose it serves: "Flatness makes the leaf an ideal organ to intercept light, the source of energy for the photosynthetic process of the tree, and for gas and heat exchange with the air. A flat object has a large surface and requires relatively little material for its construction."[35] The efficiency and usefulness of natural structures exemplify their purposefulness. The eggs of the guillemot, a cliff-dwelling sea bird, are pear-shaped. This can be understood most fully only by reference to purpose. Because of this shape, the eggs are incapable of rolling any distance in a straight line. Thus they do not roll off the flat cliff ledges on which the guillemot lays them without a nest.[36]

The best explanation *begins* with purpose. For example, the first thing a student should learn about lungs is that they are organs for breathing, that is, for assimilating oxygen and expelling carbon dioxide. Only then should the lungs' anatomy and physiology be studied, right down to the microstructures, respiratory pigments, and all the details of the necessary chemistry. These details make sense only in view of the purpose of lungs: respiration. Understanding the goal of respiration allows us to understand why the structures exist and why they are necessary.

A striking subordination to an end is found in the temporary structures of many organisms. Tinbergen speaks of the neck muscle in chicks, specially designed to help them hatch: "The chick's initial act in entering the world consists of pushing off the egg's `lid' through a series of forceful stretching movements of the neck. The special muscle used for this shrinks after it has done its duty."[37] This precise timing makes it difficult to deny that the muscle is specifically designed for one activity. Ricklefs observes that reproductive capacity is delayed in many species until the individual animal has developed sufficient experience and hunting skills.[38] The benefit is obvious. Reproduction itself is also beautifully timed. Ethologist John Crook describes how the Stellar sea lion coordinates conception, implantation, and birth for the benefit of its young:

The animals roam the oceans for most of the year, then congregate in early summer. Mating occurs soon after the cows have "hauled out" from their year's wanderings and given birth. This is convenient, since otherwise the males and females would have to seek each other over the trackless sea. But only eight months are needed for development of the embryo, and this would mean that births would occur at an unsuitable time [midwinter]. Seal cows "solve" the problem by carrying the fertilized egg within their bodies in a kind of suspended animation. Attachment of the egg to the uterus " implantation " is delayed until eight months before the ideal time.[!][39]

Another striking subordination is found among molting birds. Ornithologist George Ruppell notes that among birds that must "remain capable of flight during molting, the primaries [flight feathers] are replaced one after another, in a specific sequence."[40] Among plants, many woodland seeds have mechanisms that require the seed "to be chilled for a long time, occasionally two cycles of chill and thaw [before it can germinate] " Were it not for these mechanisms, a seed might sprout in the warm days of Indian summer or during a February thaw, only to be killed by the return of winter."[41] In all these examples, nature's elegant subordination of means to end is evident.

Purpose is also illustrated in countless instances where human beings discover the best way to do something, only later to find that nature has been exploiting the same principle all along. This is particularly frequent in military inventions. Sonar was developed to locate submarines years before ethologist Donald Griffin discovered that bats direct themselves at night by a similar echolocation system. In the same way, helicopter pilots found that if they flew at the proper angle behind another helicopter, they could exploit the resulting updraft and get a more efficient ride. Only subsequently was it recognized that migrating birds have taken advantage of this principle for millions of years by flying in V formation. Again, after camouflage experiments during World War I, the United States Navy found the most concealing color to be omega gray, which has the same optical properties, wavelength, absorption, and reflection as the color of an Antarctic bird, the petrel.[42] This implies that human ingenuity could not have given the petrel a better color for camouflage than it has received from nature. In such instances art imitates nature, either deliberately or unwittingly. But human art is purposeful. Therefore, so is nature.

Acknowledging end or purpose in no way excludes the need to consider other causes. On the contrary, purpose works only in and through material, structural, and mechanical causes. Bohr comments: "The attitudes termed mechanistic and finalistic are not contradictory points of view, but rather exhibit a complementary relationship."[43] Lorenz says the same: "The fact that life processes are directed at aims or goals, and the realization of the other fact that they are, at the same time, determined by causality, not only do not preclude each other but they only make sense in combination."[44] In human actions this is obvious. The goal of the art of medicine is to produce health in the patient. Everything the doctor does is directed to this end. But this orientation to a purpose does not encourage the doctor to ignore the mechanics of health and disease. On the contrary, the more thoroughly he understands these, the more efficacious will be his treatment. With respect to the end, all other causes are means. It is the same in nature. An animal's desire for food would be futile if it did not set into motion activities in the animal that were likely to procure food. The desire is clearly a cause of the activities.

The cause of animal behavior is unintelligible without reference to a goal or purpose. For example, in the presence of a predator a nesting plover puts on a broken-wing display, strongly suggesting injury. In this way it lures the predator hundreds of meters away from the nest and then suddenly flies off, returning to its

nest by an indirect route.[45] Although the animal is acting by instinct and does not understand why it acts the way is does; nevertheless, this is clearly goal-oriented behavior.

Other examples abound. Ricklefs explains that the elaborate courtship rituals in certain bird species are to identify a mate of the right species: "Reproductive isolation prevents the formation of unfit hybrids, which are a waste of both time and effort on the part of the parents."[46] Again a clear purpose is served. One sees here also nature's efficiency and economy. The female of the South American arrow poison frog, after bearing a live tadpole, induces it onto her back and then deposits it carefully into water trapped in a bromeliad (a plant related to the pineapple). She later returns to each "aquarium" to lay in it infertile eggs as food for the youngster until it can fend for itself. The spider's web, the beaver's dam, and all animal artifacts also serve evident purposes. In these instances and in countless others, animals clearly act for an end. But animals do not intellectually understand the end as such. They act out of instinct, not grasping the what or the why of things. Therefore, nature, in the cases of instinct, is acting for the sake of something.

The organs of plants and animals also manifest purpose. From simple inspection of the bills and feet of various species of birds, one can infer the special operations they perform to make a living. No organ can be defined or understood without looking to its purpose, which is the activity it performs. Ayala insists that "a causal [exclusively mechanistic] account of the operation of the eye is satisfactory as far as it goes, but it does not tell all that is relevant about the eye, namely that it serves to see."[47] Tributsch describes a small tropical fish, *Anableps anableps,* that has two sets of eyes, one set specifically designed for seeing in air and the other for seeing underwater.[48] The fish swims along the surface with its upper eyes just out of the water. Thus it can observe simultaneously prey and predators above and below the surface. Hippopotamuses, frogs, and crocodiles can submerge their entire bodies except for their nostrils and eyes. In this way they are well hidden but can still smell and see what is going on around them. Even apparently insignificant features often serve important ends. Hertel points out that the thick hair covering the body of certain moths absorbs high-frequency sound waves so that the moths do not appear on bat sonar.[49] The resemblance, then, between human tools and animal tools is neither chance nor fancy. Biologist Andree Tetry concludes a book devoted to the study of animal tools with these words: "The natural tool bears witness to an incontestable purposefulness " The tool always carries out " a determinate and limited task; it attains an end."[50]

Geneticist Lucien Cuenot sums up the marvel of organic design:

> Birds that fly can do so because a thousand details converge: long wing and tail feathers, pneumatic bones, air sacs, breast bone and pectoral muscles, design of the ribs, neck, feet, spinal column, pelvis, automatic hooking of feather barbules, etc. Matisse thinks these features are joined together accidentally and that there is no need to wonder over the result, any more than over the properties of the oxygen or phosphorus atom, manifestations of a structure. I prefer to believe that the bird is made for flying.[51]

Some of the means that nature has invented are surprisingly ingenious. Ricklefs mentions that armadillos avoid inbreeding by giving birth in each litter only to identical quadruplets of the same sex![52] The cicada of North America live most of their lives underground. In the eastern half of the United States, the larvae emerge in adult form to reproduce only in seventeen-year cycles; in the southern states, the cycle is thirteen years. Thirteen and seventeen are prime numbers, so that no potential predator can coordinate its life cycle with the emergence of adult cicadas.[53] The squirting cucumber, through the buildup of internal pressure, can propel its seeds with an initial velocity of thirty-five miles per hour and up to a distance of forty feet.[54] This amazing mechanism guarantees optimal distribution of the seeds to an area where they will not compete with the parent plant for sunlight or nutrients.

Purposes abound in living things. Often we can distinguish two or more purposes served by the same organ. The tongue in the human species, for instance, serves for speaking, tasting, and eating. Tree roots absorb water and minerals, and also anchor the tree firmly in the ground. A whale's blubber serves three distinct ends: food storage, buoyancy, and insulation.[55] Energy is stored in the blubber for the whale's long migrations when food might not always be available. The blubber's superior buoyancy neutralizes the

weight of the whale's bones and internal organs so that the animal is effectively floating free in the water. The blubber also insulates the whale so efficiently that when the animal is active it must operate a cooling system through its flippers to avoid overheating even in frigid waters. Whale blubber is a marvel of nature's simplicity, economy, and purposefulness. The slime on a fish's body also accomplishes three goals with extraordinary efficiency: it protects against parasites, makes the fish more difficult to seize by predators, and provides a laminar boundary layer around the fish's body, allowing it to move through the water with 45% less effort.[56]

Birds' feathers serve for flight, heat regulation, protection, and ornament. Ruppell writes: "Feathers are wonderfully light objects. Despite their lightness they are sturdy, flexible, and easy to care for; they provide a cushion, a thermal insulation, a water-repellent cover, and most importantly, they are replaceable."[57] Biologist William Montagna lists some of the many ends served by skin:

> It holds in the body's fluids and maintains its integrity by keeping out foreign substances and microorganisms. It acts to ward off the harsh ultraviolet rays of the sun. It incorporates mechanisms that cool the body when it is warm and retard the loss of heat when it is cold. It plays a major role in regulating blood pressure and directing the flow of blood. It embodies the sense of touch. It is the principal organ of sexual attraction. It identifies each individual, by shaping the facial and bodily contours as well as by distinctive marking such as fingerprints.[58]

Blood also has several functions. It transports nutrients to each cell and carries away metabolic wastes; it distributes oxygen throughout the body and transports carbon dioxide away; it repairs injuries and attacks bacterial and viral invaders; and it distributes hormones, the body's internal chemical messengers. The intensity of purpose in these and like instances is remarkable. Purpose is not present simply here and there in some organisms, it saturates the whole of life at every level.

Purpose is so much a part of organisms that it is rash to deny the efficiency of any structure or function in a living thing. For example, one textbook objects that the evaporation of water from tree leaves is excessive and useless. Because of evaporative loss to the atmosphere, a tree must take in 18 times more water than it needs for photosynthesis. The text concludes, "Here is a tremendous loss of water that apparently serves no function."[59]

Further investigation, however, reveals that the prodigious evaporation serves important purposes beyond providing the tree with water for photosynthesis. Evaporation permits leaves to avoid overheating and drying up in hot weather, operating in a way similar to evaporative cooling in animals.[60] As temperatures cool, evaporation automatically diminishes, and as they rise, it increases. Thus there is no excess at all, but a rather precise adjustment to the needs of the tree. Without evaporative cooling, a plant would become as hot as the hood of an automobile parked in the sun on a summer day. Also, if the ground water were never raised and recycled via evaporation in trees and other plants, huge amounts would become irretrievably locked underground. Hence, the evaporated water is not "lost? but, on the contrary, is regained. What at first glance seems to be useless turns out to be beautifully engineered for the benefit of both the tree and the whole ecology.

Considering the perfection of design in living things, it is not surprising that purpose is a principle of prediction and discovery in biology. Belief in purposefulness, writes Cuenot, "has shown a rare fecundity: it is because we thought that every instrument must have an end that we have discovered the roles of organs long considered enigmatic, such as internal secretionary glands."[61] One famous example of the predictive power of purpose was William Harvey's discovery of the circulation of the blood. Anatomical studies showed Harvey that the valves in veins all point in one direction. From his Aristotelian training, Harvey reasoned that nature does nothing without a purpose. Consequently, he hypothesized that the blood must circulate, a hypothesis he later confirmed by experiment and measurement.[62] In a similar way, when Crick and Watson discovered the molecular structure of DNA in 1953, they were able immediately to predict how it replicates.[63]

Conclusion

Purpose permeates every aspect of life. The metabolism of the cell is ordered to the needs of the organism. Growth aims at the completeness of form. The organ-tools of animals and plants, life's capacity for self-repair, and the efficiency of natural structures exemplify purpose. Matter is for the sake of form, and both are for the sake of function. The breadth and depth of evidence, the countless examples, and the testimony of biologists converge on the same conclusion: living things are ordered by purpose. The only thing holding some thinkers back from this conclusion and its theological implications appears to be Neo-Darwinism, a hypothesis itself under considerable criticism from within biology.

Notes

[1]Phaedo, 97c-99c.

[2]Physics II, 8 and *On The Parts Of Animals I, 2.*

[3]*Summa Theologiae Ia Q.2 art. 3, corpus. My translation.*

[4]*For a summary of the history of natural theology in Britain from Boyle to Paley, see New Interactions Between Theology and Science* (Open University Press, Milton Keynes: 1975), 8-42.

[5]Julian Huxley, *Evolution in Action* (New York: Harper & Row, 1953), 7.

[6]Thomas H. Huxley, *Lectures and Essays* (New York: Macmillan, 1904), 178-179.

[7]Niles Eldredge, *Time Frames: The Rethinking of Darwinian Evolution and the Theory of Punctuated Equilibria* (New York: Simon & Schuster, 1985), 82.

[8]Steven Stanley, *The Evolutionary Timetable: Fossils, Genes, and the Origin of Species* (New York: Basic Books, 1981), 71.

[9]Stephen Jay Gould, *The Panda's Thumb* (New York & London: W.<|>W. Norton, 1980), 181.

[10]Norman Newell, "Crisis in the History of Life," *Scientific American* 208 (February 1963): 79.

[11]E. J. Kormondy, *Concepts of Ecology* (Englewood Cliffs, NJ: Prentice-Hall, 1976), 143.

[12]Eldredge, 82.

[13]V. C. Wynne-Edwards, "Self-Regulating Systems in Populations of Animals," *Science* 147 (26 March 1965): 1543.

[14]Theodosius Dobzhanshy, *Genetics of the Evolutionary Process* (New York: Columbia University Press, 1970), 67.

[15]Michael Denton, *Evolution: A Theory In Crisis* (Bethesda, Maryland: Adler & Adler, 1986), 280-287, 292-293, 358.

[16]For more thorough argument and documentation of these points see *The New Biology*, Robert Augros and George Stanciu (Boston & London: Shambhala, 1987). For a critique of Richard Dawkins' arguments against purpose see two articles by Kenneth T. Gallagher: "Dawkins, Darwin, and Design," in *American*

Catholic Philosophical Quarterly 47, no. 2; and "Dawkins in Biomorph Land," in *International Philosophical Quarterly* 32, no. 4 (Dec. 1992).

[17]Stephen Jay Gould, "Is a New and General Theory of Evolution Emerging"? *Paleobiology* 6 (1980): 120.

[18]Steven W. Hawking, "The Anisotropy of the Universe at Large Times," in *Confrontation of Cosmological Theories with Observational Data*, ed. M. . Longair (Dordrecht, Holland: Reidel, 1974), 285-286.

[19]John A. Wheeler, "Genesis and Observership," in *Foundational Problems in the Special Sciences*, ed. Robert E. Butts and Jaakko Hintikka (Dordrecht, Holland: Reidel, 1977), 18.

[20]Hugh Ross, *The Fingerprint of God* (Orange, California: Promise Pub., 1989), 119-138.

[21]John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (New York: Oxford University Press, 1986), 21.

[22]Freeman Dyson, *Disturbing the Universe* (New York: Harper & Row, 1979), 250.

[23]A. I. Oparin, "The Nature of Life," in *Interrelations: The Biological and Physical Sciences*, ed. Robert T. Blackburn (Chicago: Scott, Foresman, 1966), 194.

[24]F. J. Ayala, "The Autonomy of Biology as a Natural Science," in *Biology, History, and Natural Philosophy*, ed. Breck and Yourgrau, (New York: Plenum Press, 1972), 7.

[25]P. B. Medawar and J. . Medawar, *The Life Sciences: Current Ideas of Biology* (New York: Harper & Row, 1977), 11, 12.

[26]Jacques Monod, *Chance and Necessity: An Essay on the Natural Philosophy of Modern Biology* (New York: Knopf, 1971), 9.

[27]Edmund W. Sinnott, *Cell and Psyche: The Biology of Purpose* (New York: Harper & Row, 1961), 41.

[28]Francois Jacob, *The Logic of Life: A History of Heredity* (New York: Pantheon Books, 1973), 8, 88.

[29]Theodosius Dobzhansky, "Chance and Creativity in Evolution," in *Studies in the Philosophy of Biology*, ed. Ayala & Dobzhansky (Los Angeles & Berkeley: University of California Press, 1974), 330.

[30]W.H. Thorpe, *Animal Nature and Human Nature* (New York: Doubleday, 1974), 17.

[31]George Gaylord Simpson, "Biology and the Nature of Science," in *Interrelations* ed. Blackburn, 159.

[32]Niels Bohr, *Atomic Physics and Human Knowledge* (New York: Wiley, 1958), 92.

[33]Niko Tinbergen, *Social Behavior in Animals* (London & New York: Methuen & Wiley, 1962), 2.

[34]For a discussion of whether the term "function" avoids or implies purpose see "The Teleological Notion of `Function,'" by Karen Neander, in *Australian Journal of Philosophy* 69, no. 4.

[35]Robert Ricklefs, *Ecology* (Newton, Massachusetts: Chiron Press, 1974), 21.

[36]Helmut Tributsch, *How Life Learned to Live* (Cambridge: MIT Press, 1982), 22.

[37]Niko Tinbergen, *Animal Behavior* (New York: Time-Life, 1965), 128.

[38]Ricklefs, 250.

[39]John Crook, "The Rites of Spring," in *Marvels of Animal Behavior*, ed. Thomas B. Allen (Washington, DC: *National Geographic*) 294.

[40]George Ruppell, *Bird Flight* (New York: Van Nostrand Reinhold, 1975), 49.

[41]Peter Farb, *The Forest* (New York: Time-Life, 1969), 13.

[42]Adolf Portmann, *Animal Camouflage* (Ann Arbor: University of Michigan Press, 1959), 79.

[43]Bohr, 92.

[44]Konrad Lorenz, *On Aggression* (New York: Harcourt, Brace & World, 1963), 231.

[45]Donald R. Griffin, *Animal Thinking* (Cambridge: Harvard University Press, 1984), 88-89.

[46]Ricklefs, 236.

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[48]Tributsch, 151.

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