"THE 'ALABAMA INSERT'"

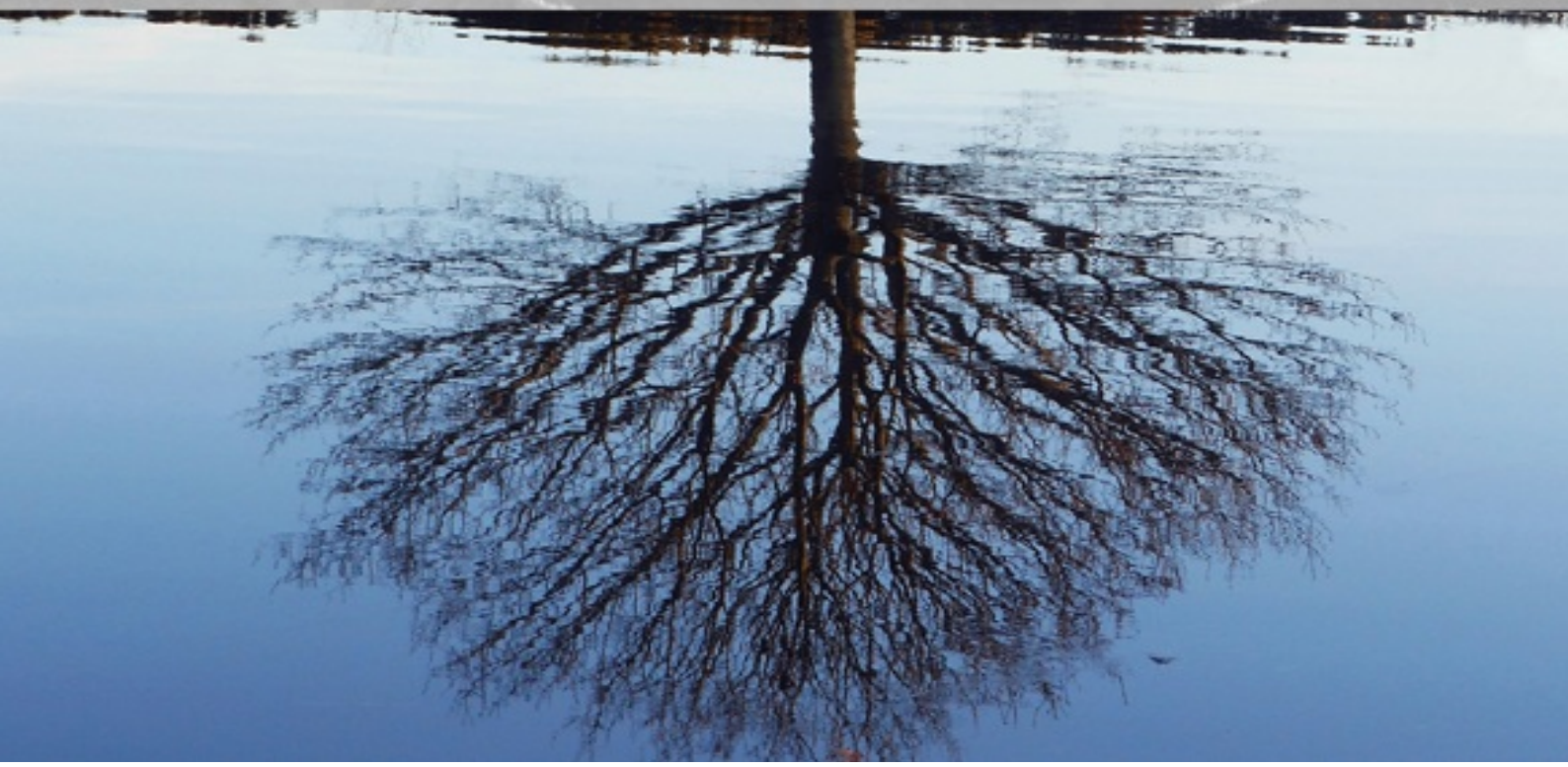
BY RICHARD DAWKINS

Excerpted from

CHARLES DARWIN

A Celebration of His Life and Legacy

Edited by James Bradley and Jay Lamar



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Introduction

Jay Lamar and James T. Bradley

Humankind is fortunate for the life of Charles Robert Darwin (1809–82). This volume, *Darwin: A Celebration of His Life and Legacy*, commemorates the 200th anniversary of Darwin's birth and the 150th anniversary of the first edition of his most famous book, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. Darwin changed th world forever with his 1859 publication of that book, whose title was shortened to *On the Origin of Species* with its sixth edition in 1872. The ideas in *On the Origin of Species* reordered the biological sciences; spawned new disciplines of inquiry such as evolutionary psychology, sociobiology, and evolutionary developmental biology (evo-devo); became foundational for modern biomedical researc and practice; inspired new literature and literary criticism; were grotesquely misused by 20th-centur eugenicists and social Darwinists; traumatized persons with certain theological views; and continue t alter humankind's view of itself and its place in the world.

The collective contributions to the present anthology tell an interdisciplinary story of Charles Darwin the person, Darwin's work and world-altering ideas, and Darwin's legacy. This celebratory volume is the result of a happy and stimulating collaboration between the College of Liberal Arts (CLA), the College of Sciences and Mathematics (COSAM), the Caroline Marshall Draughn Center for the Arts & Humanities, and the Outreach Committee in the Department of Biological Sciences at Auburn University, a land-grant institution on the eastern plains of Alabama. During the spring of 2009, the collaborators organized and sponsored a semester-long "Darwin Celebration" for the university and the larger community. The celebration included weekly lectures on diverse aspects of Darwin's life, ideas, and legacy, and a birthday party on February 12. The lecture series included 13 speakers from four CLA departments and two COSAM departments. In addition, three world-renowned science/evolution scholars and writers visited campus to lecture and interact with undergraduate students: paleoanthropologist Richard Leakey, author and evolutionary biologist Kenneth Miller, and science journalist and author Natalie Angier. Nine speakers and four additional Auburn University scholars contributed essays for this volume. For Darwin's birthday party, Department of Biological Sciences faculty and graduate students baked and gave away more than 800 cupcakes and distributed 2,000 commemorative bookmarks to students walking between classes.

The purpose of Auburn University's Darwin Celebration was to present Darwin's ideas and their impact on diverse disciplines for general audiences in a friendly, clear, accurate, non-proselytizing way. Commemorative bookmarks with a copy of the image of Darwin and the Galapagos finches in the frieze outside the entrance to the Auburn University's Science Center Classroom were distributed

to all event attendees.

We note with interest that the centennial celebration of publication of *On the Origin of Species* occurred in the same year as the famous 1959 Rede Lecture, "The Two Cultures," by British scientist and novelist C. P. Snow.[1] Snow lamented the disconnection between science and the humanities. In fact, he noted the downright hostility that often exists between the two cultures brought on by different professional languages and differing views of the human condition. Snow wrote of the optimism of scientists and contrasted it with literary artists' focus on human tragedy and loneliness. With rare exceptions, little has happened to bring Snow's two cultures amicably together during the past fifty years. Most universities still operate within a "silo system" that isolates faculty and student into geographical and intellectual spaces: natural sciences, humanities and fine arts, business, agriculture, engineering, law, and medicine. In 2009 Jerome Kagan expanded Snow's theme in his book, *The Three Cultures*, by adding the social sciences as a distinct intellectual culture.[2]

We are gratified that Snow's two cultures and Kagan's third culture are all represented by the essays gathered here under a Darwinian roof. Essay contributors are faculty members representing si academic departments at Auburn University: Biological Sciences, Foreign Languages and Literatures Geology, History, Philosophy, and Psychology. Moreover, we are especially pleased that the volume comes from a university in the Deep South, a region known to harbor deep and strong opposition to the theory of evolution. For us, publication of *Charles Darwin: A Celebration of His Life and Legacy* feels like a springtime breeze anticipating sunshine, warmth, thaw, emergent life, and change. The editors and contributors thank Randall Williams, Suzanne La Rosa, Margaret Day, Brian Seidman, Sam Robards, Matt Johnson, Robert Carter, Lisa Harrison, Noelle Matteson, Lisa Emerson, and Jeff Benton of NewSouth Books for their hard work on this volume, including their superb editing and, most important, their willingness to make available to a wide audience these discussions of Darwin's life and work.

The 13 chapters of *Charles Darwin: A Celebration of His Life and Legacy* (2013, Montgomery: NewSouth Books, ISBN 978-1-58838-281-8) have also been published as standalone short books for the convenience of readers, teachers, and students who may have a specific interest in the subject matter of one chapter. The page numbering of the standalone chapters remains the same as in the full volume, for the convenience of teachers and to maintain the index references; the full index of the fu volume is printed at the end of each standalone booklet.

The present booklet consists of Chapter 1, in which public educator, author, and evolutionary biologist Richard Dawkins, with characteristic clarity and wit, discusses the basic principles of evolution and responds to creationists' standard arguments against evolutionary theory. Dawkins's essay is a transcript of a lecture he delivered at Auburn University in 1996. While en route to Auburn Professor Dawkins heard about the "Alabama Insert," a disclaimer of evolution by the Alabama State Board of Education pasted inside the cover of biology textbooks. Dawkins set aside his prepared lecture and extemporaneously critiqued the "Insert." Later he gave permission for a transcript of his talk to be used to further the public understanding of evolution.

The other chapters in the full volume are:

Chapters 2–5 describe what Darwin did during his lifetime and give insight into what led to his theor of evolution via natural selection.

David King (Chapter 2) documents Darwin's training in geology and his little-known accomplishments as a geologist. Two great 19th-century geologists, Adam Sedgwick (1785–1873) an Charles Lyell (1797–1875), were strong and positive influences on Darwin. Cambridge's Sedgwick showed Darwin the methods of a field geologist, and his inspiring teaching countered Darwin's earlie negative experience with a poor teacher of geology at Edinburgh. Lyell authored *Principles of Geology*, of which Darwin read *Volume 1* while on the voyage of the HMS *Beagle* (1831–36). Lyell's geological uniformitarianism provided the framework Darwin needed for the vast periods of time for natural selection to produce the biological change and diversity that he observed in the fossil record and in the living world all around him. King tells how Darwin came to write four significant books o geology and then speculates about why Darwin did not pursue his love of geology after returning home from the *Beagle's* voyage.

Jon Armbruster (Chapter 3) writes about the grand age of Natural History (late 1700s to about 1900), how it helped shape Darwin as a biologist, and how Darwin in turn influenced the character of the age. From this essay we learn what for some will be shocking news—that magpies were more important than the famous finches of the Galapagos Islands for Darwin's development of the concept of natural selection. Armbruster brings us up to date about the state of natural history collections worldwide and in Alabama, their value, and a recent use made of some of Darwin's specimens that th collector could never have anticipated.

Gerard Elfstrom (Chapter 4) describes the influence that the writing of Thomas Robert Malthus (1766–1834), British demographer and political economist, had on Darwin and Darwin's contemporary, Alfred Russel Wallace (1823–1913), who independently developed a theory of evolution by natural selection. Especially interesting is how Darwin and Wallace interpreted a part o Malthus's "Principles of Population" differently in the context of the origin of human morality. Elfstrom concludes with a Malthusian analysis of current and future human growth and development of a logical and morally satisfying strategy for lowering birth rates in regions of the world least able to support greater numbers of human beings.

Debbie Folkerts (Chapter 5) tackles the controversial topic of sexual selection, competition between members of the same sex for possession of mates and/or the choosing of mates by the members of one sex. Folkerts deftly describes the controversy among biologists over whether sexual selection is distinct from natural selection or just a special case of the latter. With numerous examples, from cannibalistic spiders to colorfully gaudy bird and flower displays, Folkerts makes thi little-known and poorly understood subject come alive. She convincingly argues that, as is almost always the case, Darwin's 150-year-old ideas are still on the mark.

Chapters 6 and 7 deal with two early applications of Darwin's theory of evolution by natural selectio human origins and social Darwinism. Near the end of *On the Origin of Species* Darwin cryptically remarked, "Light will be thrown on the origin of man and his history." And Darwin did just that in 1871 with publication of *The Descent of Man, and Selection in Relation to Sex*.

Shawn Jacobson (Chapter 6) uses the huge corpus of knowledge about human evolution and uniqueness accumulated since Darwin as a jumping-off place for informed speculation about the future evolution of *Homo sapiens*. What Darwin could not anticipate is now here: biotechnology that empowers us to shape our own evolution. Jacobsen combines his knowledge as a professional biologist and his creativity as a science fiction writer to urge reflection on how we ought to apply our newly acquired biotechnologies.

Guy Beckwith (Chapter 7) compares the impact of Darwin's ideas on humankind to that of the Copernican Revolution. Nicolaus Copernicus (1473–1543) and Galileo Galilei (1564–1642) removed Earth and humankind from the center of the universe. Then Darwin dealt the human ego a second blo by making humankind the product of natural selection acting on chance variations, not necessarily th purposeful creation of a Creator. Beckwith details the Victorian world's strong opposition to evolutio by natural selection after publication of *On the Origin of Species*. Yet Darwin's ideas not only persisted, they flourished. Why? Beckwith persuasively argues for two major factors: (1) Darwin's personal characteristics as a scientist and (2) the ease with the theory of natural selection was coopte by those with social and political agendas.

A major part of Darwin's legacy is the spawning of entirely new areas of investigation in which evolution by natural selection makes sense of otherwise relatively incomprehensible observations. Comparative and evolutionary psychology, evolutionary developmental biology (evo-devo), and origin of life studies exemplify such areas.

In the conclusion to *On the Origin of Species*, Darwin wrote: "In the distant future I see open field for far more important researches. Psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation." Lewis Barker (Chapter 8) and Jeffrey Katz and his co-authors (Chapter 9) chronicle Darwin's legacy in psychology.

Barker describes the pre-Darwinian philosophical roots of psychology, Darwin's forthright contributions to psychological theory, Darwin's influence on early psychologists, and the role of neo Darwinian thinking in contemporary psychology. He argues that Darwin's *On the Origin of Species* has been more influential in psychology than the great biologist's later works that are directly related to human evolution and mental life: *The Descent of Man, and Selection in Relation to Sex* (1871) and *The Expression of Emotions in Man and Other Animals* (1872).

Comparative psychologists Katz and his co-authors acknowledge Charles Darwin as the most important figure in the creation of their discipline. Every day comparative psychologists rely on the Darwinian concept of common descent. The fact that the human brain/mind arose from ancestral nonhuman brains/minds suggests that we can gain insights about human behavior and cognitive abilities by studying the behavior and abilities of animals such as rats, pigeons, monkeys, and chimps The question is whether the behavioral and cognitive differences between humans and modern-day nonhumans are of degree, as Darwin suggested, or of kind. Their own work with pigeons and monkey leads Katz and his co-authors to side with Darwin.

Kenneth Halanych (Chapter 10) describes Darwin's debt to the studies of 19th century German

embryologists, particularly Karl Ernst von Baer (1792–1876). He credits Von Baer's observations on animal embryos for providing Darwin with his strongest evidence for the idea of common descent. Publication of *On the Origin of Species* greatly influenced another German embryologist, Earnst Heinrich Philipp August Haeckel (1834–1919). Halanych relates how through correspondence the two scientists influenced each others' thinking about human origins and how Haeckel fanned the firestorm of controversy surrounding the theological implications of Darwin's work. The chapter concludes with the latter-20th-century revival of the importance of evolutionary theory to recent and current molecular biological studies of animal development, including emergence of the new discipline of evo-devo.

Anthony Moss (Chapter 11) contributes a thorough historical account of science's attempt to answer the question of how life first emerged from inanimate matter. Beginning with the Greeks, Moss tells a captivating story about the evolution of scientists' thinking and experimentation on the origin of life question. In one of his many letters, Darwin even mused about a warm little pond on the early Earth where simple chemicals exposed to heat, light, and electricity may have begun the changes that ultimately led to life.[3] From the 1970s onward, sophisticated primitive earth "simulation" experiments and laboratory studies of molecular evolution have provided a wealth of data about life's possible origin. Darwin's principle of natural selection guides and inspires all of this work. But now, instead of a shallow, warm little pond, the evidence points to the depths of the ocean as the cradle of life. To say more would spoil this exciting, still unfolding, skillfully told tale.

For readers enjoying chapters chronologically, Giovanna Summerfield's contribution on *The Adventures of Pinocchio* (Chapter 12) offers a refreshing respite from science and the history of science. Charles Darwin and Carlo Collodi (1826–90), the Florentine children's writer and creator of Pinocchio, almost certainly never met or even corresponded. Nevertheless, they had in common their free-thinking, speculative minds, perhaps nurtured by membership in the sectarian Masonry. Summerfield deftly places the struggles of the wooden puppet into the context of 19th-century Italy's struggles for betterment as a newly united nation. Also not lost on Summerfield is the very interesting stepwise evolution of a lifeless chunk of matter into a living, moral being.

The last chapter deals with society's continuing struggle with biological evolution. James Bradley (Chapter 13) writes for would-be teachers of evolution, their students, and others with minimal knowledge about evolution but with minds willing to seek. Calling upon thirty-five years of experience teaching about biological evolution and origin of life studies to university students, Bradley distills the overwhelming wealth of information about the topic into what he believes all citizens should know: what evolution is, what evolution is not, and why knowing about evolution matters. He suggests using Plato's *Allegory of the Cave* as a tool for preparing students to learn about evolution.

Some say that if Darwin had never lived, someone else would have given us the same insights about

life's origins. That is surely true, for Alfred Russel Wallace, working in the same nation at the same time, came up with insights similar to Darwin's about the origin of life's diversity. But the figure we know today as the father of evolution is the iconic, white-bearded, contemplative Charles Darwin. W know about his family, which nurtured free thinking; his inspiring teachers; his voyage as a young man on HMS *Beagle*; the belated publication of his famous book; and the torment and struggles that his ideas hailed down upon him during his lifetime and bequeathed to generations following him. Darwin's story is a tale told around the world, one of scientific genius and personal perseverance. Lif in the 21st century, including all of the biological sciences and their applications, is unimaginable without Darwin. From across 15 decades, Darwin invites us into his world with sheer poetry in the final sentence of *On the Origin of Species*:

> There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.[4]

Notes

1 - Snow, C. 1959. The Rede Lecture. In *The Two Cultures*. Cambridge: Cambridge University Press.

2 - Kagan, J. 2009. *The Three Cultures: Natural Sciences, Social Sciences, and the Humanities in the 21st Century*. New York: Cambridge University Press.

3 - Darwin, F., ed. 1887. *The life and letters of Charles Darwin, including an autobiographical chapter*, vol. 3. http://darwin-online.org.uk/.

4 - Darwin, C. 1859. *On the Origin of Species by Means of Natural Selection*. Mineola: Dover Publications, 2006, 307. This is an unabridged republication of the work originally published by John Murray, London, in 1859.

Amendment to the Alabama Course of Study—Science

Legislature of the State of Alabama

Text of the amendment to the Alabama Course of Study—Science, adopted by the Alabama State Board of Education in 1995, and to be pasted in all state-approved biology textbooks beginning fall, 1996:

A MESSAGE FROM THE ALABAMA STATE BOARD OF EDUCATION

This textbook discusses evolution, a controversial theory some scientists present as a scientific explanation for the origin of living things, such as plants, animals and humans.

No one was present when life first appeared on earth. Therefore, any statement about life's origins should be considered as theory, not fact.

The word "evolution" may refer to many types of change. Evolution describes changes that occur within a species. (White moths, for example, may "evolve" into gray moths.) This process is microevolution, which can be observed and described as fact. Evolution may also refer to the change of one living thing to another, such as reptiles into birds. This process, called macroevolution, has never been observed and should be considered a theory. Evolution also refers to the unproven belief that random, undirected forces produced a world of living things.

There are many unanswered questions about the origin of life which are not mentioned in your textbooks, including:

1. Why did the major groups of animals suddenly appear in the fossil record (known as the Cambrian Explosion)?

2. Why have no new major groups of living things appeared in the fossil record in a long time?

3. Why do major groups of plants and animals have no transitional forms in the fossil record?

4. How did you and all living things come to possess such a complete and complex set of “instructions” for building a living body?

5. Study hard and keep an open mind. Someday you may contribute to the theories of how living things appeared on earth.

1

The 'Alabama Insert'
A Study in Ignorance and Dishonesty

Richard Dawkins was invited in 1996 to present one of the lectures in the annual series now known as the Littleton-Franklin Lectures in Science & Humanities at Auburn University. During his visit, Professor Dawkins learned of the "Alabama Insert" and put aside his prepared text, choosing instead to deconstruct the statement by the Alabama State Board of Education. He gave permission for a transcript of his remarks and accompanying illustrations (by Lalla Ward) to be used to further evolution education in Alabama, and the lecture was published in 1997 in the Journal of the Alabama Academy of Science *68(1): 1–19. The "Alabama Insert" underwent slight revision in 2001, but because Professor Dawkins's critique of the 1995 version of the "Insert" addresses so many current misconceptions about the theory of evolution, it is republished here with permission of the journal's editor.*

Richard Dawkins

As a former prime minister of my country, Neville Chamberlain once said: "I have here a piece of paper." It says "A message from the Alabama State Board of Education." This is a flier that is designed to be—ordered to be—stuck into the front of every textbook of biology used in the public schools. What I thought I would do, with your permission, is to depart from the prepared text I brought with me. Instead I should like to go through every sentence of this document, one by one.

> "This textbook discusses evolution, a controversial theory that some scientists present as a scientific explanation for the origin of living things such as plants, animals and humans."

This is dishonest. The use of "some scientists" suggests the existence of a substantial number of respectable scientists who do not accept evolution. In fact, the proportion of qualified scientists who do not accept evolution is tiny. A few so-called "creation scientists" are much touted as possessing PhDs, but it does not do to look too carefully where they got their PhDs from nor the subjects they got them in. They are, I think, never in relevant subjects. They are in subjects perfectly respectable in themselves, like marine engineering or chemical engineering, which have nothing to do with the matter at hand.

> *"No one was present when life first appeared on Earth."*

Well, that is true.

"Therefore, any statement about life's origins should be considered as theory, not fact."

That's also true but the word *theory* is being used in a misleading way. Philosophers of science us the word *theory* for pieces of knowledge that anybody else would call fact, as well as for ideas that ar little more than a hunch. It is strictly only a theory that the Earth goes around the sun. It is a theory b it's a theory supported by all the evidence. A fact is a theory that is supported by all the evidence. What this is playing upon is the ordinary language meaning of *theory* which implies something really pretty dubious or which at least will need a lot more evidence one way or another.

For example, nobody knows why the dinosaurs went extinct and there are various theories of it which are interesting and for which we hope to get evidence in the future. There's a theory that a meteorite or comet hit the Earth and indirectly caused the death of the dinosaurs. There's a theory tha the dinosaurs were killed by competition from mammals. There's a theory that they were killed by viruses. There are various other theories and it is a genuinely open question which (at the time of speaking) we need more evidence to decide. That is also true of the origin of life, but it is not the cas with the theory of evolution itself. Evolution is as true as the theory that the world goes around the sun.

While talking about the theories of the dinosaurs I want to make a little aside. You will sometime see maps of the world in which the places where people speak different languages are shaded. So, you'll say, "English is spoken here," "Russian is spoken there," "French is spoken here," etc. And that's fine; that's exactly what you would expect because people speak the language of their parents.

But imagine how ridiculous it would be if you could construct a similar map for theories of, say, how the dinosaurs went extinct. Over here they all believe in the meteorite theory. Over on that continent they all believe the virus theory, down here they all believe the dinosaurs were driven extinct by the mammals. But if you think about it that's more or less exactly the situation with the world's religions.

We are all brought up with the religion of our parents, grandparents, and great-grandparents and b golly that just happens to be the one true religion. Isn't that remarkable! Creation myths themselves are numerous and varied. The creation myth that happens to be being taught to the children of Alabama is the Jewish creation myth which in turn was taken over from Babylonian creation myths and was first written down not very long ago when the Jews were in captivity. There's a tribe in West Africa that believes that the world was created from the excrement of ants. The Hindus, I am told, believe that the world was created in a cosmic butter churn. No doubt every tribe and every valley of New Guinea has its own origin myth. There is absolutely nothing special about the Jewish origin myth, which is the one we happen to have in the Christian world.

Moving on in the "Alabama Insert," as I shall call it:

> *"The word 'evolution' may refer to many types of changes. Evolution describes changes that occur within a species (white moths, for example, may "evolve" into gray moths). This process is called microevolution which can be observed and described as fact. Evolution may also refer to changes of one living thing into another such as reptiles changing into birds. This process called macroevolution has never been observed and*

should be considered a theory."

The distinction between microevolution and macroevolution is becoming a favorite one for creationists. Actually, it's no big deal. Macroevolution is nothing more than microevolution stretched out over a much greater time span.

The moth being referred to, I presume, is the famous peppered moth, *Biston betularia*, studied in England by my late colleague Bernard Kettlewell. There is a famous story about how, in the Industrial Revolution when the trees went black from pollution, the peppered pale-colored version of this moth was eaten by birds because it was conspicuous against the black tree trunks. After the Industrial Revolution years, the black moths became by far the majority in industrial areas of England. But if you go into country areas where there is no pollution, the original peppered variety is still in a majority. I presume that's what the document is referring to.

The point about that story is that it's one of the few examples we know of genuine natural selection in action. We are not normally privileged to see natural selection in action because we don't live long enough. The Industrial Revolution, however unfortunate it may have been in other respects, did have the fortunate byproduct of changing the environment in such a way that you could study natural selection.

To study other examples of natural selection I recommend the book *The Beak of the Finch* by J. Weiner. He is describing the work of Peter and Rosemary Grant on the Galapagos finches. Those finches, perhaps more than any other animal, inspired Charles Darwin himself. What the Grants have done studying Galapagos Island finches is actually to sample populations from year to year and show that climatic changes have immediate and dramatic effects on the population ratios of various physical structures such as beak sizes.

Darwin was inspired by the example of the Galapagos finches; he was also inspired by the examples of domestication.

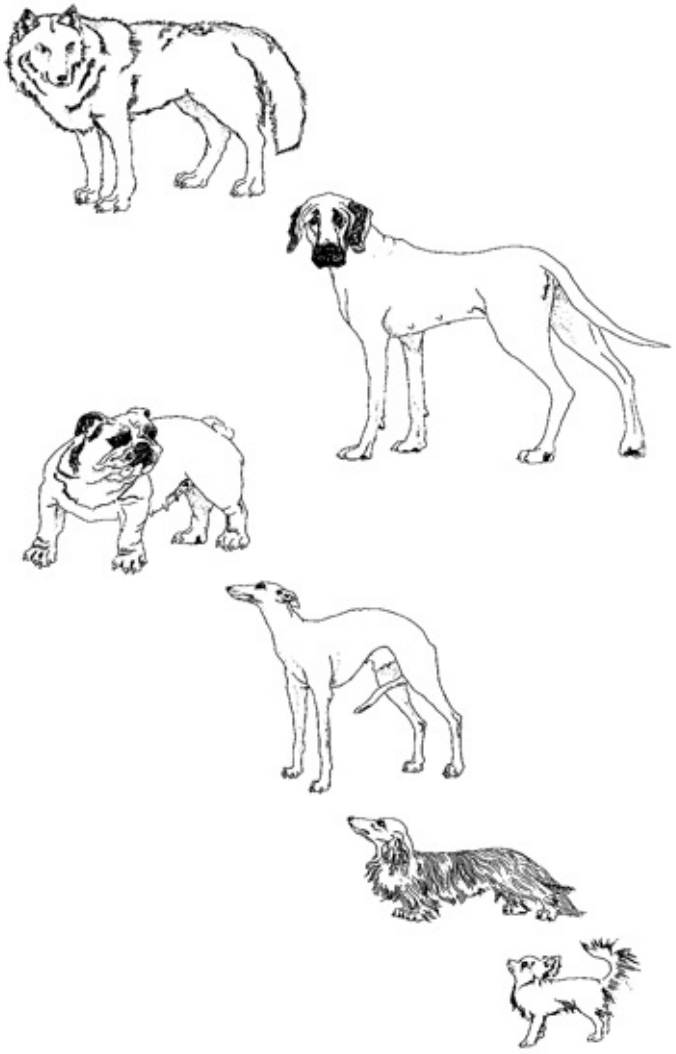

Figure 1.1 - The power of artificial selection to shape animals. All these domestic dogs have been bred by humans from the same wild ancestor, a wolf (top): Great Dane, English bulldog, whippet, long-haired dachshund and long-haired chihuahua.

These are all domestic dogs [see Figure 1.1] except the top one which is a wolf. The point of it is, as observed by Darwin, how remarkable that we could go by human artificial selection from a wolf ancestor to all these breeds—a Great Dane, a bulldog, a whippet, etc. They were all produced by a process analogous to natural selection—artificial selection. Humans did the choosing, whereas in natural selection, as you know, it is nature that does the choosing. Nature selects the ones that survive and are good at reproducing, to leave their genes behind. With artificial selection, humans do the choosing of which dogs should breed and with whom they should mate.

Figure 1.2 - All these vegetables have been bred from the same ancestor, the wild cabbage, *Brassica olearacea*: (clockwise fr top left) Brussels sprout, kohlrabi, Swedish turnip, drumhead cabbage, cauliflower and golden savoy.

These plants [see Figure 1.2] are all members of the same species. They are all descended quite recently from the wild cabbage *Brassica olearacea* and they are very different—cauliflower, brussels sprouts, kale, broccoli, etc. This great variety of vegetables, which look completely different, has bee shaped—they have been sculpted—by the process of artificial selection from the same common ancestor.

That's an example of what can be achieved in a few centuries when the selection is powerful enough. When the selection goes on for thousands of centuries the change is going to be correspondingly greater—that's macroevolution. It's just microevolution going on for a long time.

It's difficult for the human mind to grasp how much time geology allows us, so various picturesque metaphors have been developed. The one I like is as follows: I stand with my arm outstretched and the distance from the center of my tie to my fingers represents the total time available since life began. That's about 4,000 million years. Out to about my shoulder we still get nothing but bacteria. At my elbow you might be starting to get slightly more complicated cells—eukaryotic cells—but still single cells. About mid-forearm you start getting multicellular organisms, animals you can see without a microscope. At my palm you would get the dinosaurs. Somewhere toward the end of my finger you would get the mammals. At the beginning of my nail you would get early humans. And the whole of history—all of documented written human history, all the Babylonians, Biblical history, Egyptians, the Chinese, the whole of recorded history would fall as the dust from a nail file across the tip of my furthest finger.

This is hard for the human brain to grasp, time spans of that order. Remember that the time represented by the dust from the nail includes the time it took these cabbage varieties to evolve by artificial selection (human selection) and dogs to evolve from wolves. Just think how much change could be achieved by natural selection during the thousands of millions of years before recorded history.

To reinforce that point there was a theoretical calculation made by the great American botanical evolutionist, Ledyard Stebbins. He wanted to calculate theoretically how long it would take to evolve from a tiny mouse-sized animal (ancestor) to a descendant animal the size of an elephant. So what we are talking about is a selection pressure for increased size. Selection pressure means that in any generation slightly larger than average individuals have a slight advantage. They are slightly more likely to survive for whatever reason, slightly more likely to reproduce. Stebbins needed a number to represent that selection pressure, a way to show how strong to assume it to be. He decided to assume (the pressure) to be so weak that you couldn't actually detect it if you were doing a field study out there trapping mice.

So Stebbins assumed his theoretical selection pressure to be so weak that it is undetectable; it vanishes in the sampling error of an ordinary research study. Nevertheless it's there. How long would it take under this small but relentless pressure for these mouse-like animals to grow and grow over th generations until they became the size of an elephant? He concluded that it would take about 20,000 generations. Well, mouse generations would be several in a year, elephant generations would take several years. Let's compromise and assume one year per generation. Even at five years per generation, that's not many years, say 100,000 years at the most. Well, 100,000 years is too short to b detected on the geological time scale for most of geologic history.

For most characteristics a selection pressure as weak as that, so weak that you couldn't even measure it, is sufficiently strong as to propel evolution so fast that it appears to be instantaneous on the geological time scale. In practice it probably isn't even as fast as that, but geological time is so vast that there is plenty of time for the evolution of all of life to have happened.

Another theoretical calculation was made by the Swedish biologist, Dan Nilsson. He took up the question which Darwin himself was interested in—the eye, the famous eye, the darling of creationist literature. Darwin himself recognized the eye as a difficult case because it is very complicated. Many people have thought, wrongly, that the eye is a difficult problem for evolutionists because—"Doesn't it have to be all there with all the bits working for the thing to work?"

No. Of course they don't all have to be there. An animal that has half an eye can see half as well a an animal with a whole eye. An animal with a quarter eye has a quarter vision. An animal with 1⁄100 eye has 1⁄100 quality vision. It's not quite as simple as that. The point 1 am making is that you can be aided in your survival by every little tiny increment in quality of eyesight. If you have 1⁄100 quality eyesight, you can't see an image but you can see light and that might be useful. The animal might be able to tell which direction the light is coming from or which direction a shadow is coming from which could portend a predator. There are all sorts of things you could do that help you to survive if you have a small fraction of an eye, to survive better than an animal which has no eye at all. With 1⁄100 of an eye you can just about survive. With 2⁄100 of an eye you can survive a little better. There

is a slow, gradual ramp of increasing probability of surviving as the eye gradually gets better.

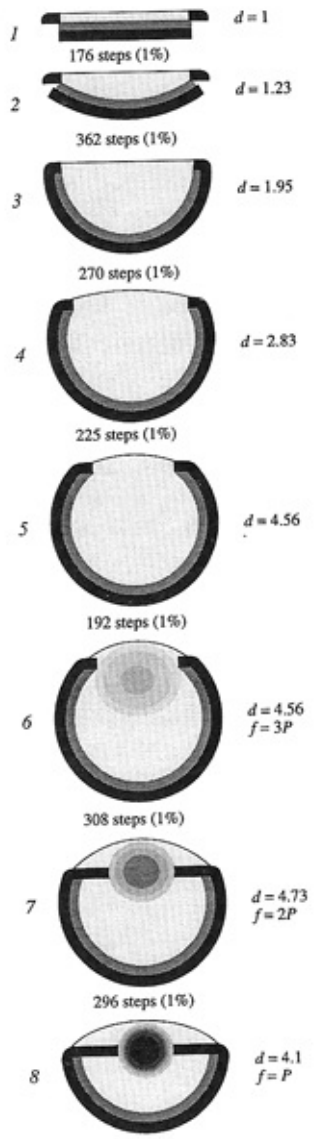

Figure 1.3 - Nilsson and Pelger's theoretical evolutionary series leading to a 'fish' eye. The number of steps between stages assumes, arbitrarily, that each step represents a 1 percent change in magnitude of something. See text for translation from these arbitrary units into numbers of generations of evolution.

Going back to the question of the rate at which all this happens, Nilsson did a computer modeling exercise of the evolution of the eye [see Figure 1.3]. He starts from a computer model which is not really eye shaped at all but is just a flat sheet of light sensitive cells. You've got to start somewhere. You could start before that if you wanted to, but that's where he started. He made the computer gradually change the shapes of this model eye. The only rule was that the changes had to be small and each change had to result in an improvement in vision. The beautiful thing about the eye is that by using the actual rules of physics, the ordinary rules of optics, you can calculate how good each of the hypothetical intermediates would be at forming an image.

These intermediates all formed spontaneously in the computer as a result of gradual improvement

in what the computer could measure as the optical quality of the model eye, and it goes all the way from a flat sheet of cells to a proper camera eye with a lens such as you might see in a fish. It is even better than that. The exact focusing of the lens is precisely as it should be. The details of this are written down in Nilsson's paper. By feeding in assumptions which are based upon field work in population genetics he was able to make calculations as to how long it would plausibly take under realistic conditions of natural selection. This is similar to the Stebbins calculation of how long it would take to go from the start of the series to the end.

Once again it was startlingly fast. Nilsson calculated that it would take fewer than half a million generations. The sort of small animals we are talking about, in which the eye originally evolved, would probably have had about 1 generation/year. Half a million years is a very short time on the geologic time scale.

Therefore, it's not surprising that when you look around the animal kingdom you find all the intermediates you could wish for in the evolution of the eye, in various groups of worms, etc. The eye has evolved no less than 40 times independently around the animal kingdom, and possibly as many as 60 times. So, "the" eye is really some 40 to 60 different eyes and it evolves very rapidly and exceedingly easily. There are 9 different optical principles that have been used in the design of eyes and all 9 are represented more than once in the animal kingdom.

> "*Evolution also refers to the unproven belief that random, undirected forces produced a world of living things.*"

Where *did* this ridiculous idea come from that evolution has something to do with randomness? The theory of evolution by natural selection has a random element—mutation—but by far the most important part of the theory of evolution is non-random: natural selection. Mutation is random. Mutation is the process whereby parent genes are changed, at random. Random in the sense of not directed toward improvement. Improvement comes about through natural selection, through the survival of that minority of genes which are good at helping bodies survive and reproduce. It is the non-random natural selection we are talking about when we talk about the directing force which propels evolution in the direction of increasing complexity, increasing elegance, and increasing apparent design.

The statement that "evolution refers to the unproven belief that random undirected forces . . ." is not only unproven itself, it is stupid. No rational person could believe that random forces could produce a world of living things.

Fred Hoyle, the eminent British astronomer who is less eminent in the field of biology, has likened the theory of evolution to the following metaphor: "It's like a tornado blowing through a junkyard and having the luck to assemble a Boeing 747." His statement is a classic example of the erroneous belief that natural selection is nothing but a theory of chance. A "Boeing 747" is the end product that any theory of life must explain. The riddle for any theory to answer is, "How do you get complicated, statistically improbable apparent design?" Darwin's theory of evolution by natural selection is the only known theory that can answer this riddle. It is also supported by a great deal of evidence. With his explanation Darwin, in effect, smears out the chance or "luck" factor. There is luck in the theory,

but the luck is found in small steps. Each generational step in the evolutionary process is only a little bit different from the step before. These little bits of difference are not too great to come about by chance, by mutation. However if, after the accumulation of a sufficient number of these small steps (perhaps 100), one after the other, you've got something like an eye at the end of this process, it could not have come all of a sudden by chance. Each individual step could occur by chance, but all 100 steps together could not. All 100 steps are pieced together cumulatively by natural selection.

Another metaphor along these lines is of a bank robber who went into a bank and started fiddling with the combination lock on the safe. Theoretically the thief could fiddle with the lock and have the luck to open the safe. Of course you know in practice he couldn't do that. That's why your money is safe in the bank. But just suppose that every time you twiddled that knob and got a little bit closer to the correct number, a dollar bill fell out of the safe. Then when you twiddled it another way and got a little closer still, another dollar fell out. You would very rapidly open the safe. It's like that with natural selection. Each step has a little bit of luck but when the steps are put together you end up with something that looks like a Boeing 747.

> *"There are many unanswered questions about the origin of life which are not mentioned in your textbook including: why did the major groups of animals suddenly appear in the fossil record known as the "cambrian explosion."*

We are very lucky to have fossils at all. After an animal dies many conditions have to be met if it is to become a fossil, and one or another of those conditions usually is not met. Personally, I would consider it an honor to be fossilized but I don't have much hope of it. If all the creatures which had ever lived had in fact been fossilized we would be wading knee deep in fossils. The world would be filled with fossils. Perhaps it is just as well that it hasn't happened that way.

Because it is particularly difficult for an animal without a hard skeleton to be fossilized, most of the fossils we find are of animals with hard skeletons—vertebrates with bones, mollusks with their shells, arthropods with their external skeleton. If the ancestors of these were all soft and then some offspring evolved a hard skeleton, the only fossilized animals would be those more recent varieties. Therefore, we expect fossils to appear suddenly in the geologic record and that's one reason groups of animals suddenly appear in the Cambrian Explosion.

There are rare instances in which the soft parts of animals are preserved as fossils. One case is the famous Burgess Shale which is one of the best beds from the Cambrian Era (between 500 million and 600 million years ago) mentioned in this quotation. What must have happened is that the ancestors of these creatures were evolving by the ordinary slow processes of evolution, but they were evolving before the Cambrian when fossilizing conditions were not very good and many of them did not have skeletons anyway. It is probably genuinely true that in the Cambrian there was a very rapid flowering of multicellular life and this may have been when a large number of the great animal phyla did evolve. If they did, their essential divergence during a period of about 10 million years is very fast. However, bearing in mind the Stebbins calculation and the Nilsson calculation, it is actually not all that fast. There is some recent evidence from molecular comparisons among modern animals which suggests that there may not have been a Cambrian Explosion at all, anyway. Modern phyla may well have their

most recent common ancestors way back in the Precambrian.

As I said, we're actually lucky to have fossils at all. In any case, it is misleading to think that fossils are the most important evidence for evolution. Even if there were not a single fossil anywhere in the earth, the evidence for evolution would still be utterly overwhelming. We would be in the position of a detective who comes upon a crime after the fact. You can't see the crime being committed because it has already happened. But there is evidence lying all around. To pursue any case, most detectives and most courts of law are happy with two to three clues that point in the right direction.

Even discounting fossils, the clues that are left for us to see that prove the truth of evolution are numbered in the tens of millions. The number of clues, the sheer weight of evidence, totally and utterly, sledgehammeringly, overwhelmingly strongly supports the conclusion that evolution is true–unless you are prepared to believe the Almighty deliberately faked the evidence in order to make it look as though evolution is true. (And there are people who believe that.)

The evidence comes from comparative studies of modern animals. If you look at the millions of modern species and compare them with each other—looking at the comparative evidence of biochemistry, especially molecular evidence—you get a pattern, an exceedingly significant pattern, whereby some pairs of animals like rats and mice are very similar to each other. Other pairs of animals like rats and squirrels are a bit more different. Pairs like rats and porcupines are a bit more different still in all their characteristics. Others like rats and humans are a bit more different still, and so forth. The pattern that you see is a pattern of cousinship; that is the only way to interpret it. Some are close cousins like rats and mice; others are slightly more distant cousins (rats and porcupines) which means they have a common ancestor that lived a bit longer ago. More distinctly different cousins like rats and humans had a common ancestor who lived a bit longer ago still. Every single fact that you can find about animals is compatible with that pattern.

Similarly you can look at the geographical distribution of an animal species. Why do animals in the Galapagos Islands more closely resemble animals on neighboring islands and resemble less the animals on the mainland? It's all exactly what you would expect if evolution goes on in isolation on islands with occasional island-hopping. New foci for evolution start with migration from mainland to island and then progress from there to other islands.

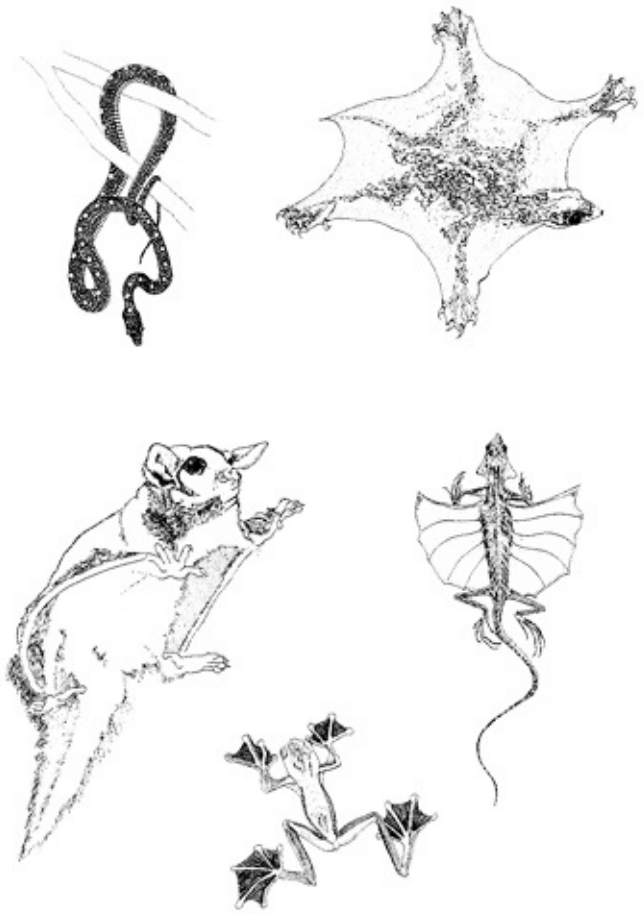

Figure 1.4 - Vertebrates that glide down from trees but do not truly fly: (clockwise from top right) colugo, *Cynocephalus volans*; flying lizard, *Draco volans*; Wallaces flying frog, *Rhacophorus nigropalmatus*; marsupial sugar glider, *Petaurus breviceps*; and flying snake, *Chrysopelea paradisi.*

If you look at the imperfections of nature you see evidence for evolution. Figure 1.4 shows anima that don't necessarily fly but are at plausible intermediate stages on the way to flight. These stages ar relevant to the discussion of what's the use of half an eye or what's the use of half a wing. These animals all glide and by gliding save themselves from falling out of trees.