

Ten Misunderstandings About Evolution

A Very Brief Guide for the Curious and the Confused

By Dr. Mike Webster, Dept. of Neurobiology and Behavior, Cornell Lab of Ornithology, Cornell University (msw244@cornell.edu); February 2010

The current debate over evolution and “intelligent design” (ID) is being driven by a relatively small group of individuals who object to the theory of evolution for religious reasons. The debate is fueled, though, by misunderstandings on the part of the American public about what evolutionary biology is and what it says. These misunderstandings are exploited by proponents of ID, intentionally or not, and are often echoed in the media.

In this booklet I briefly outline and explain 10 of the most common (and serious) misunderstandings. It is impossible to treat each point thoroughly in this limited space; I encourage you to read further on these topics and also by visiting the websites given on the resource sheet. In addition, I am happy to send a somewhat expanded version of this booklet to anybody who is interested – just send me an email to ask for one!

What are the misunderstandings?

1. Evolution is progressive improvement of species

Evolution, particularly human evolution, is often pictured in textbooks as a string of organisms marching in single file from “simple” organisms (usually a single celled organism or a monkey) on one side of the page and advancing to “complex” organisms on the opposite side of the page (almost invariably a human being). We have all seen this enduring image and likely have some version of it burned into our brains. Unfortunately, this widespread image is a horribly inaccurate characterization of the evolutionary process, and it has undoubtedly reinforced the ideas that evolution proceeds in a linear fashion, from simple to advanced, and that one species somehow magically morphs into another via some mysterious mechanism. In reality, evolutionary biology does not imply linear progression, modern species do not morph into other modern species, and evolution is not the outcome of some mystical force. Rather, modern evolutionary theory has three basic concepts:

- Modern species existing today have descended from pre-existing ancestral species (“descent with modification”),
- During this process single evolutionary lineages have repeatedly split into multiple lineages (“speciation”), and
- The primary force driving evolutionary change is a mechanism that Darwin labeled “natural selection”

As a consequence, any pair of existing species, such as humans and chimps, share a common ancestor that existed some time in the past. Evolutionary theory does *not* say that we evolved from chimps; rather it says that we share a common ancestor with chimps. The process of evolution leads to a branching pattern of relationships among organisms, not a linear progression. As the late evolutionary biologist Stephen J. Gould put it, “evolution is a bush, not a ladder.”

2. Evolution is random chance

Some people are bothered by the concept of biological evolution because living organisms are so very complex, and it is therefore difficult to imagine how “random” forces of nature could produce something as a complex living organism. Astronomer Fred Hoyle argued (in 1983) that a tornado blowing through a junkyard could not construct a 747 airplane, and creationists have seized on this argument to say that the evolution of complex organisms is virtually impossible (Hoyle was actually talking about the origin of life, see # 7 below). But the beauty of Darwin’s insight is that the process of natural selection – the primary driving force of evolutionary change – is anything but random. Evolutionary theory postulates that mutations (which likely do occur more-or-less at random) create variation among organisms within a population, and then those individual variants that are best equipped to survive and reproduce in a particular environment will leave more descendents. Thus, natural selection is explicitly *non*-random – only those individuals well suited to the environment will leave descendents. After many rounds of mutation and selection, the population can change dramatically, and ever more complex structures can be evolved for particular functions. For example, a population of flowers that are only moderately good at attracting pollinators can become better adapted to attracting pollinators.

3. Evolutionary theory has changed little since Darwin first proposed it 150 years ago.

Opponents of evolution often label it “Darwinism” and imply that it has changed little since first being described in the Victorian era. Nothing could be further from the truth: evolutionary theory has grown and expanded, and become much stronger, as it has incorporated findings from a vast array of scientific disciplines. Indeed, evolutionary biology did not become the science that it is today until the “modern synthesis” in the early 20th century, when Darwin’s ideas were combined with the newly formed science of genetics. Currently we are undergoing a second renaissance as evolutionary concepts are being combined with modern molecular and developmental biology. Indeed, today the greatest insights into the evolutionary process, as well as the strongest evidence for evolution in general, come from molecular genetics – a field that originated only after the discovery of DNA 100 years after Darwin introduced the concept of evolution by natural selection. It is interesting and revealing to consider the history of scientific acceptance of Darwin’s initial ideas. Very soon after Darwin published *The Origin of Species*, the scientific community of Darwin’s day quickly came to accept that evolution (i.e., descent with modification) had occurred. However, scientists of the day did *not* readily accept natural selection as an important mechanism; it was not until the 20th century when genetics was introduced to the theory and it underwent extensive testing that scientists came to accept this mechanism.

4. There is a scientific debate

The most basic misunderstanding about the current evolution debate is that there is a debate at all (at least among scientists). Opponents of evolution have implied that many scientists question the evidence supporting the theory of evolution, and that there is an ongoing debate within the scientific community regarding the validity of Darwinian evolution. This is not true; the vast majority of scientists, particularly biologists, agree

that the scientific evidence overwhelmingly supports the central claims of evolutionary theory outlined above. Of course, there are significant debates within science about evolutionary theory, but these debates are about *how* evolution occurs, not *whether* it has occurred. Polls and surveys of scientists show that the vast majority (95-99%) agree that the scientific evidence overwhelmingly supports evolutionary explanations for the origin and diversification of life on Earth (this is in contrast to the American public, a large proportion of whom do not accept evolution). Also, dozens of scientific organizations, including the American Association for the Advancement of Science and the National Academy of Sciences, have issued position statements confirming their support for the theory of evolution. Several of these statements can be viewed at the website of the Society for the Study of Evolution (<http://www.evolutionsociety.org/statements.html>).

5. Evolution is “just a theory” with little supportive evidence and lots of holes

The reason that there is so little debate among scientists over the validity of evolution is simple: the available scientific evidence overwhelmingly supports it. To many, this seems at odds with the fact that evolution is referred to as a “theory,” because in everyday language the word “theory” implies an educated guess with little supportive evidence. But in science, the word “theory” has a specific and quite different meaning: a theory is a large explanatory framework “that has been confirmed or established by observation or experiment, and is propounded or accepted as accounting for the known facts” (Oxford English Dictionary). Evolutionary theory is supported by mountains of evidence from fossils, development, anatomy, genetics, and numerous other scientific fields. Thus, it is highly misleading to say that “evolution is only a theory, not a fact” (as is claimed on stickers that have been placed in some science textbooks). Along with evolution, scientific theories include the theory of gravitation (which explains why objects fall to earth and the planets orbit the sun), germ theory (which explains how diseases are caused and spread), and atomic theory (which explains the nature of matter).

Opponents of evolution claim that there are significant problems with the evidence supporting evolution. The argument seems to be that if one can identify gaps in our understanding of evolution (e.g., how some complex trait has evolved, see next point), then the entire theory should be thrown out. But a current lack of a scientific explanation does not mean that such an explanation cannot exist (see next point). In a similar vein, some opponents of evolution have attacked evidence that are used to support evolutionary theory. One prime example is “intelligent design” spokesman Jonathan Wells, who in his book *Icons of Evolution* attacks some of the evidence found in several biology textbooks used in public schools. There is not enough space here to detail how Wells and others have mischaracterized much of this evidence in these attacks, but the National Center for Science Education gives an excellent summary (you can read it at their website, <http://www.ncseweb.org/icons/>). On the whole, the evidence supporting evolutionary theory is solid as well as overwhelming.

6. Some biological features are too complex to be explained by natural selection

Michael Behe, who is a biochemist at Lehigh University and a leading proponent of “intelligent design” (ID), argues in his book *Darwin’s Black Box* that many biological features could not possibly have evolved via Darwinian natural selection because they

are “irreducibly complex.” What Behe means here is that certain traits, such as the flagellum that allows some single-celled organisms to swim or the biochemical cascade that causes blood to clot, involve a suite of inter-connected parts that are all necessary for the feature to operate properly; remove any single part and the flagellum can’t propel a cell or blood won’t clot. Behe goes on to argue that, since such a mechanism won’t work without all of its parts, it could not possibly have arisen through a series of successive changes from some simpler design, and thus could not have evolved gradually as required by evolution. This clever argument is not a new one -- it dates back to 18th century when the theologian William Paley argued that biological traits as complex as the human eye could not possibly have arisen by chance and are therefore proof of the existence of God. Behe has taken Paley’s argument and recycled it using more modern examples from molecular biology, and this “proof” against evolution has gained a lot of traction with ID advocates. The problem with Behe’s argument is that it is incorrect, and in several ways:

- It is wrong to conclude that something *can’t* be explained by evolution just because we haven’t yet figured out the puzzle: *unexplained* is not the same as *unexplainable*. Indeed, the entire history of science is one long series of discoveries that helped explain phenomena that were previously unexplained. Paley’s original example of the vertebrate eye is an excellent case-in-point: we now know that the eye could indeed evolve from earlier precursors, and we see these simpler precursors in living organisms today (understanding the exact steps involved is an active area of research today).
- A fundamental tenet of evolution is that natural selection acts on pre-existing traits, often modifying them to perform new functions. Thus, most of the enzymes involved in the blood-clotting cascade are also involved in digestion, and the cellular flagellum is only a slight modification away from the apparatus used by bacteria to inject other cells (see website of Dr. Kenneth Miller); selection did not have to produce these intricate mechanisms from scratch.
- Behe ignores the likely possibility, predicted by evolutionary theory, that as new components of a mechanism are added the existing components evolve to depend on them, leading to a situation in which pieces of the machinery that were once “optional” become “essential.”
- Finally, we know that several “irreducibly complex” traits have evolved gradually from ancestral traits. The mammalian middle ear is a great example: it is composed of three bones, all three of which have to be present for the middle ear to function. However, because they are bones, we have an excellent fossil record of how reptilian jaw bones were modified, gradually over evolutionary time, to produce the complex middle ear.

7. Evolutionary theory is aimed at understanding the origins of life

Proponents of ID (and creationists in general) are mainly debating about the origins of life, whereas the vast majority of evolutionary biology is concerned mainly with the modification and diversification of life *after* it arises. It is true that some evolutionary biologists (and chemists and other scientists) are very interested in how life arose, and developing and testing hypotheses on this topic is an active area of research. It is

misleading, however, to characterize this as *the* major focus of evolutionary biology. For example, the leading journal for research in evolutionary biology is *Evolution*, which published 317 scientific articles during the year 2002; not one of these articles addressed the origin of life.

8. There are scientific alternatives to evolution, such as “Intelligent Design” (ID)

Proponents of ID claim that it is a legitimate science that deserves to be given time in science classrooms, and indeed several have claimed that these “legitimate alternatives” are being actively excluded from the classroom via some sort of vast conspiracy (see, for example, Ben Stein’s movie “Expelled”). However, ID is *not* a scientific alternative to evolution because, unlike evolutionary theory and all other legitimate scientific theories, ID does not make any specific predictions that can be tested. The “evidence” for ID consists of trying to punch holes in evolutionary explanations (see above), the idea being that if evolution is shown to be incorrect then this proves the existence of an intelligent designer. If scientific evidence were to emerge casting serious doubt on the theory of evolution (which has not yet happened), then scientists would search for alternative scientific hypotheses grounded in the natural laws known to govern the operation of the universe – this is all that science *can* do. Appeals to supernatural causation, because they are not testable, fall well outside of the operations of science. The fact that ID is not a true science is evidenced by the lack of peer-reviewed articles in scientific journals: to date only two such articles have appeared, one of which was a summary of the ideas of ID rather than a test of those ideas (the journal later retracted the article). Along similar lines, advocates of ID argue that their “theory” should be taught in public schools because it is important and “fair” to teach alternative explanations. This is highly misleading; in science classes we teach alternative *scientific* theories, and those theories that reach the classroom are those that have undergone rigorous testing and survived. Ideas that have not been tested, such as ID, or those that have been tested and failed, such as “creation science” and the idea that the earth is the center of the solar system, do not belong in the classroom.

9. Evolution is atheistic

One of the most unfortunate outcomes of the evolution/creationism/ID debate is that it has become so polarizing and has led to a general misconception that evolution is anti-Christian and more generally anti-God. Some proponents of ID have fanned this fire, perhaps intentionally, by equating evolution with atheism in their writings. Some prominent evolutionary biologists, such as Richard Dawkins, have also added to this misperception by suggesting that evolution has reinforced their own (personal) atheistic views. However, in reality evolutionary biology, and science in general, say nothing about whether God does or does not exist. The scientific process that guides evolutionary research is absolutely unable to address the existence of supernatural forces, which by definition are able to defy the limits of testable natural laws. Numerous theologians and philosophers have written on this topic. For example, the philosopher of science Robert Pennock puts it this way: “evolution is godless in exactly the same way that plumbing is godless” (I highly recommend Pennock’s excellent book *The Tower of Babel*). His point here is that God may or may not be responsible for your clogged drain (or the diversification of life) – all that the plumber (or the scientist) can do is test

hypotheses to find a mechanistic explanation for the lack of water flow (or the diversity of life). Moreover, rather than being a strict dichotomy of atheistic evolution versus religion, there are actually a number of religious viewpoints on the issue ranging from "young-earth creationism" (which accepts a literal interpretation of the Genesis account of a 6-day creation and rejects all of evolutionary biology, along with much of physics, chemistry, and geology) to "theistic evolution" (which largely accepts most of the tenets of evolution but holds that God initiated and possibly guides the process).

The lack of true conflict between evolutionary science and religion can be seen:

- Many major religions have issued statements clarifying that evolutionary biology (and scientific understanding in general) does not conflict with their religious beliefs. You can find a number of these statements, and also statements by educational and other organizations, posted at the website of the National Center for Science Education (<http://www.ncseweb.org/article.asp?category=2>). Also, the PBS evolution website includes an interesting roundtable discussion about evolution and religion (<http://www.pbs.org/wgbh/evolution/religion/faith/>). I have included a statement from the National Council of Churches, which strongly supports the teaching of evolution in public schools, as a supplement at the end of this document (see appendix).
- Polls show that a large number of Americans are deeply divided about the issue of creationism and religion, but also that many are religious and yet comfortable with the idea that life on Earth has evolved over time. You can find a summary of some of the polls at http://www.religioustolerance.org/ev_publi.htm, and also at <http://www.cbsnews.com/stories/2004/11/22/opinion/polls/main657083.shtml>.
- Significant numbers of evolutionary biologists and other scientists are deeply religious. One prime example is Dr. Kenneth Miller, a biochemist at Brown University who is also a practicing Catholic and who wrote *Finding Darwin's God*. You can find discussions on evolution and religion at Dr. Miller's home page (<http://www.millerandlevine.com/km/evol/>).

10. Evolution is an insignificant part of biology that can be ignored

A common perception in the public is that evolution is a minor part of biology, with little active research and little importance to other aspects of biology. This, in part, stems from the misperception that evolutionary biology is about the origins of life and little else (see above). As a consequence, many teachers eager to avoid conflict will skim over the topic or even skip it entirely, generally thinking that evolution is a small issue that isn't relevant to the rest of biology. This is not correct:

- *Evolutionary biology is a large and active field of research.* The Society for the Study of Evolution, which is the primary scientific organization to which most evolutionary biologists belong, currently has nearly 2,000 members, and the scientific journal of this society (*Evolution*) publishes approximately 300-400 peer-reviewed research articles per year. Numerous other research societies and journals are devoted to research on the processes and outcomes of evolution (e.g., *Journal of Molecular Evolution*, *Evolution and Development*, and well over 30 other scientific journals). Indeed, the two leading science journals in the world regularly publish research articles on evolutionary topics: *Science* published over

1,000 articles under the heading “evolution” during the decade 1995-2005, and *Nature* published 35 research articles on evolution in 2001 alone.

- *Evolution is a central unifying principle of biology.* As Theodosius Dobzhansky put it, “nothing in biology makes sense except in the light of evolution.” While most branches of biology strive to explain *how* biological organisms work, evolution explains *why* they work that way; it provides the framework that explains the diversity of life on Earth. Accordingly, evolution is listed as one of five unifying concepts in science in the National Science Education Standards.
- *Evolutionary concepts have important applications to other areas of biology.* Because evolutionary theory ties together and explains many other fields of biology, evolutionary concepts are central to numerous fields with applications to human life and well-being. Indeed, evolutionary concepts are increasingly being applied to areas as diverse as medicine, agriculture, fisheries management, wildlife conservation, and even engineering. Better understanding of evolution will continue to benefit human endeavors in these and other fields. A discussion of the relevance of evolutionary biology to other disciplines is found in the “White Paper on Evolution, Science and Society,” produced by the Society for the Study of Evolution and posted at their website (<http://www.evolutionsociety.org/>).

Because evolution is such an integral part of biology, the National Association of Biology Teachers (NABT) has issued a strongly worded statement on the teaching of evolution in public schools (see appendix 2).

Appendix 1: Evolutionary Biology Resource Guide

General Information Websites on Evolution

1. *PBS evolution*: <http://www.pbs.org/wgbh/evolution/index.html> Extremely well developed site with incredible graphics and many links to resources, videos, images and an “Evolution FAQ” page. This is a **perfect** place to start.
2. *Talk Origins*: <http://www.talkorigins.org/> Explores the evolution/creation controversy. General information on evolution, archives articles on much more specific topics (human evolution, extinction, ID, etc.) and includes a well-developed FAQ page.
3. *Evolution Update*: <http://users.mstar2.net/spencersa/evolutus/> This page includes links to a number of informative sites.
4. *Evolution, Science and Society*: <http://evonet.sdsc.edu/evoscisociety/> This site covers societal issues and the relevance of evolution to other areas of biology.
5. *Understanding Evolution*: <http://evolution.berkeley.edu/> Concisely summarizes evolutionary theory, supporting evidence, its history and the relevance of evolution to our everyday lives. Also included is a teacher resource page.
6. *About Darwin*: <http://www.aboutdarwin.com/> Detailed information about Charles Darwin himself.
7. *Evolution Happens*: <http://www.evolutionhappens.net/> Dedicated to answering common and confusing questions about evolution.
8. *Tree of Life*: <http://tolweb.org/tree/phylogeny.html> Presents results from the “tree of life” project. Describes diversity of life, explains relationships among organisms and even includes teaching tools and resources for K-12 and college instructors (called “treehouses”).
9. *Evolution, Darwin’s Dangerous Idea*: <http://www.pbs.org/wgbh/evolution/darwin/index.html> PBS website and video (12 chapters) on the life and works of Charles Darwin.
9. *Dr. Greg Wray’s lab webpage*: <http://www.biology.duke.edu/wraylab/resources/> Resources for teaching evolutionary biology and for conducting research. The latter includes a PowerPoint presentation and links to notable peer-reviewed publications from the scientific literature.

Websites Related to the Debate over Intelligent Design

1. *Judgement Day; Intelligent Design on Trial*. <http://www.pbs.org/wgbh/nova/id/program.html> Nova presentation (12-10 min chapters) produced by PBS. Reenactment of “Dover trial” that pitted the ID supporters on the local school board against, among others, the schools’ science teachers and parents who won the case. Includes statements/interviews by the Bush-appointed federal judge who presided over the case, representatives from the Discovery Institute, scientists who testified and others. This is a **MUST** see.
2. *Action Bioscience*: <http://www.actionbioscience.org/evolution/nhmag.html> Includes lesson plans.
3. *National Center for Science Education (NCSE)*: <http://www.natcensci.org/> Devoted to keeping ID and other creationist philosophies out of public classrooms and includes a wealth of information and useful links.
4. *Talk Design (sister-site to Talk Origins)*: <http://www.talkdesign.org/> Information archive.

5. *Skeptic's Dictionary*: <http://skepdic.com/intelligentdesign.html> Summarizes scientific objections to ID.
6. *Dr. Ken Miller's webpage*: <http://www.millerandlevine.com/km/evol/> Includes a number of very readable essays on ID and the relationship between evolution and religion.
6. *"Expelled Exposed"*: <http://www.expelledexposed.com> Discusses the Ben Stein movie "Expelled", its many misrepresentations and errors as well as the link between religion/creationism and ID.

Resource Websites for Teaching Evolution

1. *NCSE (see above)*: <http://www.natcensci.org/> The National Center for Science Education is dedicated to the defense of teaching evolution in public schools. Their website includes a number of resources and information about evolution as well as the debate itself.
2. *National Science Teachers Association*: <http://www.nsta.org/evresources> Dedicated to resources for teaching evolution.
3. *PBS Teachers Page*: <http://www.pbs.org/wgbh/evolution/educators/> The teachers' and students' page that accompanies the PBS series on evolution. Includes a teacher's guide and on-line courses.
4. *Dr. Colin Purrington*: <http://www.swarthmore.edu/NatSci/cpurrrin1/evolk12/teaching/resources.html> This site is maintained by the Department of Biology at Swarthmore College and provides teacher resources for teaching evolution at different grade levels.
5. *Tree of Life*: <http://tolweb.org/tree/home.pages/treehouses.html> The "treehouses" portion of the Tree of Life site that provides teaching resources including investigations, games and more.
6. *1995 Biology Institute*: <http://www.woodrow.org/teachers/bi/1995/> A huge assemblage of teaching activities/lessons compiled by 1995 Biology Institute (Woodrow Wilson Foundation) participants.
7. *Understanding Evolution (UC Berkeley)*: <http://evolution.berkeley.edu/> A general guide to teaching all aspects of evolutionary biology.
8. *Voyages Through Time*: <http://www.voyagesthroughtime.org/hominid/> Hominid evolution module for high school curriculum and includes lessons on human evolution.
9. *Evolution & the Nature of Science Institutes*: <http://www.indiana.edu/~ensiweb/lessons/unt.he.f.html> General introduction to human evolution for high school teachers making lesson plans.
10. *Evolution & the Nature of Science Institutes*: <http://www.indiana.edu/~ensiweb/lessons/hom.cran.html> Lab with detailed lesson plan for comparing human, fossil hominid, and ape crania, with several resource links.

Websites Dedicated to Human Evolution

1. *Leakey Foundation*: <http://www.leakeyfoundation.org> Reviews different areas of research in human evolution with an interactive timeline (under "Discoveries and Projects") and "Ask a Scientist".

2. *Smithsonian Institution*: <http://www.mnh.si.edu/anthro/humanorigins/> Smithsonian Institution's human origins program that allows visitors to email researchers with questions.
3. *Evolution & the Nature of Science Institutes*: <http://www.indiana.edu/~ensiweb/lessons/hom.cran.html> See above.
4. *Neanderthals on Trial*: <http://www.pbs.org/wgbh/nova/neanderthals/> Companion site to the film. Discusses the controversy of Neanderthal relationships to modern humans.
5. *eSkeletons Project*: <http://www.eskeletons.org/> Interactive comparisons among human, chimpanzee, orangutan, baboon and marmoset skeletons
6. *Institute of Human Origins*: <http://www.becominghuman.org/> Documents the story of human evolution (see also the main site for the institute at <http://www.asu.edu/clas/iho/>).

Books

1. The many works by the late Prof. Stephen J. Gould, Ph.D., Harvard University: *Ontogeny and Phylogeny*; *Ever Since Darwin*; *The Panda's Thumb*; *The Mismeasure of Man*; *Hen's Teeth and Horse's Toes*; *The Flamingo's Smile*; *Time's Arrow, Time's Cycle*; *An Urchin in the Storm*; *Wonderful Life*; *Bully for Brontosaurus*; *Eight Little Piggies*; *Dinosaur in a Haystack*; *Full House*; *Questioning the Millennium*; *Leonardo's Mountain of Clams and the Diet of Worms*; *Rocks of Ages*; *The Lying Stones of Marrakech*; *The Structure of Evolutionary Theory*; *I have Landed*; *The hedgehog, the Fox and the Magister's Pox*
2. *The Selfish Gene* and *The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe Without Design*, both by Prof. Richard Dawkins, Ph.D., New College, Oxford University
3. *Guns, Germs and Steel: The Fates of Human Societies* and *The Third Chimpanzee: The Evolution and Future of the Human Animal*, both by Prof. Jared Diamond, Ph.D., UCLA
4. *What Evolution Is*, Prof. Ernst Mayr, Ph.D., Harvard University

YouTube Videos

1. Exposing Ben Stein's "Exposed" (6:42). <http://www.youtube.com/watch?v=SwCp78--vGE>
2. Richard Dawkins Lecture at UC Berkeley (6 videos ~10 min/video). <http://www.youtube.com/watch?v=YcYDkZcLAug>
3. Eugenie Scott (NCSE) - Intelligent design creationism (10 videos, 8-10 min/video). http://www.youtube.com/watch?v=ETqdzDVzz_8

Appendix 2: NABT Statement on Teaching Evolution*

As stated in *The American Biology Teacher* by the eminent scientist Theodosius Dobzhansky (1973), “Nothing in biology makes sense except in the light of evolution.” This often-quoted declaration accurately reflects the central, unifying role of evolution in biology. The theory of evolution provides a framework that explains both the history of life and the ongoing adaptation of organisms to environmental challenges and changes.

While modern biologists constantly study and deliberate the patterns, mechanisms, and pace of evolution, they agree that all living things share common ancestors. The fossil record and the diversity of extant organisms, combined with modern techniques of molecular biology, taxonomy, and geology, provide exhaustive examples of and powerful evidence for current evolutionary theory. Genetic variation, natural selection, speciation, and extinction are well-established components of modern evolutionary theory. Explanations are constantly modified and refined as warranted by new scientific evidence that accumulates over time, which demonstrates the integrity and validity of the field.

Scientists have firmly established evolution as an important natural process. Experimentation, logical analysis, and evidence-based revision are procedures that clearly differentiate and separate science from other ways of knowing. Explanations or ways of knowing that invoke non-naturalistic or supernatural events or beings, whether called “creation science,” “scientific creationism,” “intelligent design theory,” “young earth theory,” or similar designations, are outside the realm of science and not part of a valid science curriculum.

The selection of topics covered in a biology curriculum should accurately reflect the principles of biological science. Teaching biology in an effective and scientifically honest manner requires that evolution be taught in a standards-based instructional framework with effective classroom discussions and laboratory experiences.

***Adopted by the National Association of Biology Teachers Board of Directors, 1995. Revised 1997, 2000, and May 2004. Endorsed by: The Society for the Study of Evolution, 1998; The American Association of Physical Anthropologists, 1998.**