Answers to Jonathan Wells's "10 Questions *to ask your biology teacher about evolution.*" These questions try to encourage students to doubt and distrust evolutionary theory.

Here are 10 brief answers to those questions provided by the National Center for Science Education. In the sections below, Wells's questions appear *in italics.*

Q: ORIGIN OF LIFE. *Why do textbooks claim that the 1953 Miller-Urey experiment shows how life's building blocks may have formed on the early Earth — when conditions on the early Earth were probably nothing like those used in the experiment, and the origin of life remains a mystery?*

A: The 1953 studies by Miller and Urey were the first to show that organic molecules could be produced from very simple precursors and inputs of energy. Their experimental apparatus made it possible to investigate the formation of organic compounds under a wide range of conditions. Numerous studies have been conducted since then with various combinations of chemicals thought to have existed on early Earth. Nearly all of these studies have produced some of the building blocks of life. Origin-of-life remains a vigorous area of research. Evolutionary theory can work with just about any model of the origin of life on Earth. Therefore, how life originated is not strictly a question about evolution.

Q: DARWIN'S TREE OF LIFE. *Why don't textbooks discuss the "Cambrian explosion," in which all major animal groups appear together in the fossil record fully formed instead of branching from a common ancestor — thus contradicting the evolutionary tree of life?*

A: Wells is wrong: fish, amphibians, reptiles, birds, and mammals all are post-Cambrian — aren't these "major groups"? We would recognize very few of the Cambrian organisms as "modern"; they are in fact at the roots of the tree of life, showing the earliest appearances of some key features of groups of animals — but not all features and not all groups. Researchers are linking these Cambrian groups using not only fossils but also data from developmental biology.

Q: HOMOLOGY. *Why do textbooks define homology as similarity due to common ancestry, then claim that it is evidence for common ancestry — a circular argument masquerading as scientific evidence?*

A: The same anatomical structure (such as a leg or an antenna) in two species may be similar because it was inherited from a common ancestor (homology) or because of similar adaptive pressure (convergence). Homology of structures across species is not assumed, but tested by the repeated comparison of numerous features that do or do not sort into successive clusters. Homology is used to test hypotheses of degrees of relatedness. Homology is not "evidence" for common ancestry: common ancestry is inferred based on many sources of information, and reinforced by the patterns of similarity and dissimilarity of anatomical structures.

Q: VERTEBRATE EMBRYOS. *Why do textbooks use drawings of similarities in vertebrate embryos as evidence for their common ancestry — even though biologists have known for over a century that vertebrate embryos are not most similar in their early stages, and the drawings are faked?*

A: Twentieth-century and current embryological research confirms that early stages (if not the earliest) of vertebrate embryos are more similar than later ones; the more recently two species shared a common ancestor, the more similar their embryological development. Thus cows and rabbits — mammals — are more similar in their embryological development than either is to alligators. Cows and antelopes are more similar in their embryology than either is to rabbits, and so on. The union of evolution and developmental biology — "evo-devo" — is one of the most rapidly growing biological fields. "Faked" drawings are not relied upon: there has been plenty of research in developmental biology since Haeckel — and in fact, hardly any textbooks feature Haeckel's drawings, as claimed.

Q: ARCHAEOPTERYX. *Why do textbooks portray this fossil as the missing link between dinosaurs and modern birds — even though modern birds are probably not descended from it, and its supposed ancestors do not appear until millions of years after it?*

A: The notion of a "missing link" is an out-of-date misconception about how evolution works. Archaeopteryx (and other feathered fossils) shows how a branch of reptiles gradually acquired both the unique anatomy and flying adaptations found in all modern birds. It is a transitional fossil in that it shows both reptile ancestry and bird specializations. Wells's claim that "supposed ancestors" are younger than Archaeopteryx is false. These fossils are not ancestors but relatives of Archaeopteryx and, as everyone knows, your uncle can be younger than you!

Q: PEPPERED MOTHS. *Why do textbooks use pictures of peppered moths camouflaged on tree trunks as evidence for natural selection — when biologists have known since the 1980s that the moths don't normally rest on tree trunks, and all the pictures have been staged?*

A: These pictures are illustrations used to demonstrate a point — the advantage of protective coloration to reduce the danger of predation. The pictures are not the scientific evidence used to prove the point in the first place. Compare this illustration to the well-known re-enactments of the Battle of Gettysburg. Does the fact that these re-enactments are staged prove that the battle never happened? The peppered moth photos are the same sort of illustration, not scientific evidence for natural selection.

Q: DARWIN'S FINCHES. *Why do textbooks claim that beak changes in Galapagos finches during a severe drought can explain the origin of species by natural selection — even though the changes were reversed after the drought ended, and no net evolution occurred?*

A: Textbooks present the finch data to illustrate natural selection: that populations change their physical features in response to changes in the environment. The finch studies carefully — exquisitely — documented how the physical features of an organism can affect its success in reproduction and survival, and that such changes can take place more quickly than was realized. That new species did not arise within the duration of the study hardly challenges evolution!

Q: MUTANT FRUIT FLIES. *Why do textbooks use fruit flies with an extra pair of wings as evidence that DNA mutations can supply raw materials for evolution — even though the extra wings have no muscles and these disabled mutants cannot survive outside the laboratory?*

A: In the very few textbooks that discuss four-winged fruit flies, they are used as an illustration of how genes can reprogram parts of the body to produce novel structures, thus indeed providing "raw material" for evolution. This type of mutation produces new structures that become available for further experimentation and potential new uses. Even if not every mutation leads to a new evolutionary pathway, the flies are a vivid example of one way mutation can provide variation for natural selection to work on.

Q: HUMAN ORIGINS. *Why are artists' drawings of ape-like humans used to justify materialistic claims that we are just animals and our existence is a mere accident — when fossil experts cannot even agree on who our supposed ancestors were or what they looked like?*

A: Drawings of humans and our ancestors illustrate the general outline of human ancestry, about which there is considerable agreement, even if new discoveries continually add to the complexity of the account. The notion that such drawings are used to "justify materialistic claims" is ludicrous and not borne out by an examination of textbook treatments of human evolution.

Q: EVOLUTION A FACT? *Why are we told that Darwin's theory of evolution is a scientific fact — even though many of its claims are based on misrepresentations of the facts?*

A: What does Wells mean by "Darwin's theory of evolution"? In the last century, some of what Darwin originally proposed has been augmented by more modern scientific understanding of inheritance (genetics), development, and other processes that affect evolution. What remains unchanged is that similarities and differences among living things on Earth over time and space display a pattern that is best explained by evolutionary theory. Wells's "10 Questions" *fails* to demonstrate a pattern of evolutionary biologists' "misrepresentations of the facts."