

Note: I received an email from a Utah resident on 12/2/11, and wrote back to answer his 7 specific questions. I've deleted his name and email address to protect his privacy, and have posted my response hoping it might be useful to educators faced with similar challenges.
[Ken Miller]

From: **Miller, Kenneth Raymond** [mailto:kenneth_miller@brown.edu]
Date: Tue, Dec 6, 2011 at 4:15 PM
Subject: Re: evolution

Dear Friend,

Thanks you very much for your email of December 2, 2011. I am always happy to answer questions about our textbook. I've been a frequent visitor to your beautiful state, and on October 29, 2009 I was honored to present the John Tanner Lecture at Brigham Young University. In the same year I also lectured at Southern Utah University (March 24). I'm sure I'll be back in Utah sometime soon, and would be delighted to meet with you in person if the opportunity presents itself. In the meantime, I will do my best to address your concerns.

In addition to challenging a sentence on page 465 of our textbook, you asked 7 specific questions:

1) What scientific experiment has proven Darwin's theory of macro-evolution?

Charles Darwin did not develop a "theory of macro-evolution." Rather, Darwin was responsible for what we call today the theory of evolution by means of natural selection. His ideas had four main points, each of which is testable scientifically.

- Substantial variation exists in natural populations.
- Many more offspring are produced by each species than can possibly survive to maturity.
- As a result, there is a struggle for existence and reproductive success.
- Characteristics beneficial in this struggle for existence will tend to become more common in a population, changing the characteristics of a species.

From these four observations, each of which have been experimentally verified, he drew a conclusion:

- Over time and given a steady input of new variation into a population, these processes lead to the emergence of new species.

As you will see, this conclusion has also been verified. We do indeed see the emergence of new species in the world around us, and I will provide several examples in a moment.

However, you asked if “macro-evolution” had been “proven.” Scientific theories are never “proven” in the sense that mathematics speaks of proofs. To earn the status of a “theory” a scientific idea must be strongly supported by abundant evidence and must have predictive power. Evolution has both, as I will explain below.

Scientific theories, including cell theory, the germ theory of disease, and atomic theory, are never considered as “proven” and are always subject to doubt, testing, reconfirmation, and are always regarded as tentative. That applies to the theory of evolution as well.

With respect to “macro-evolution,” my own experience is that the use of such a term is really just a debating tactic on the part of many opponents of evolution. The term is used so that any experimental evidence demonstrating evolutionary processes can be labeled as “micro-evolution,” and thereby dismissed. I’ve found that people using the term “macro-evolution” usually refuse to define it precisely, and this is part of the strategy. If, however, one takes “macro-evolution” to mean genetic changes sufficient to produce a new species, which is the only reasonable definition I can think of, then, yes, macro-evolutionary processes have indeed been observed in nature, as I will explain later.

2) What is the mechanism that causes this to occur?

The mechanisms that produce the genetic changes that drive evolution are well known. They include mutations in protein-coding genes, mutations in regulatory genes, gene duplication and amplification, transversions, translocations, genetic recombination, and horizontal gene transfer. Now we have been able to obtain the complete DNA sequences of so many organisms, we can indeed confirm that these mechanisms are capable of producing the genetic changes necessary to produce new species with novel characteristics.

3) Where did the information in DNA come from?

The information in DNA comes from variation produced by the genetic mechanisms listed above, and the process of natural selection. For example, in just a few decades, a species of bacterium (specifically, *Flavobacterium*) has evolved a new gene that breaks down chemical compounds used in the synthesis of nylon. Where did the information in this new gene come from? From the processes outlined in my answer to your second question (above), and the process of natural selection. These bacteria evolved in ponds of waste products near nylon-producing factories. In such environments, the gradual appearance of an enzyme capable of metabolizing nylon byproducts was strongly favored by natural selection.

Similar studies have shown the development of new genetic information in many

systems, and the answer in each case is that genetic information is produced by the selection of favorable variants of DNA sequences. Now, that information isn't "free." It comes at great cost. The species generates many hundreds (or thousands) of unsuccessful variants for each one that actually improves its chances of survival. That means that the new information produced by variation and selection requires a substantial input in terms of time, food, and energy.

4) How did dead matter turn into living matter?

"Dead" matter turns into living matter all the time, as I am sure you know. That takes place every time we eat a candy bar or munch on a sandwich. The dead matter of our food is converted into living matter by the process of metabolism.

However, I assume that your question is about the origins of the first living cells on planet Earth. The truth is that at this point no one can say for certain, and this is typical of many unsolved questions in science. Do keep in mind, however, that the origin of life is a completely different question from the origin of species. Darwin's theory of evolution by natural selection deals with the ways in which species change and split, giving rise to new species. It is *not* a theory of the origin of life.

If you care to open our textbook to pages 553-558, you will see a complete treatment of this question. The sub-heading for this section (Lesson 15.3) of our textbook is entitled "The Mystery of Life's Origins," and I would emphasize our use of the word "mystery." We are quite direct in telling students that we do not have a complete picture of the origin of the first living cells. However, that does not mean that we haven't glimpsed some interesting clues to the puzzle. These include, as I am also sure you know, the fact that the organic building blocks of life form quite easily under conditions present on the primitive earth. This has been confirmed not only by laboratory experiments, but also by the recovery and identification of such compounds from meteorites and comets.

5) How did the first living cell form and how did it know what parts were necessary for it to function?

Like your Question #4, this is not a part of the theory of evolution. We do, however, address this unsolved question in Lesson 15.3 of our textbook. On these pages, we describe fossil and geologic evidence for the appearance of the earliest cells on Earth, and also describe the endosymbiotic theory of the origin of cellular organelles.

Not for a second would any biologist argue that the first living cells "knew" which parts they needed. One of the key characteristics of life is the process of replication (or, reproduction). Once a self-replicating chemical system became established on the primitive earth, the stage for cellular life would have been set, requiring only that such systems developed ways to separate their own chemistry from the rest of the world via a cellular membrane. And, as I am also sure you know, certain chemical compounds assemble spontaneously into membrane-like structures.

Our textbook does not present any of these issues as solved problems. Rather, we have done our best to ensure that students understand the current state of research on origin of life.

6) Why do we only see animals reproducing after their own kind? Has Darwinian evolution stopped?

You're quite wrong in suggesting that we don't see current examples of evolution in the living world. In fact, it is quite easy to see the process of speciation in action. I would especially recommend these studies of speciation:

Wake (1997) Incipient species formation in salamanders of the *Ensatina* complex. *Proceedings of the National Academy of Sciences* 94: 7761-7767.

Filchak et al (2000) Natural selection and sympatric divergence in the apple maggot *Rhagoletis pomonella*. *Nature* 407: 739-742.

Mosil et al (2002) Host-plant adaptation drives the parallel evolution of reproductive isolation. *Nature* 417: 440-443.

I'd be glad to send you PDF copies of these papers if you are interested. In addition, more examples are given in this web resource, and I'd invite you to examine them in detail:

<http://www.talkorigins.org/indexcc/CB/CB910.html>

So, the bottom line is that evolution has not stopped at all. In fact, it proceeds every day in the world around us. All we have to do is to look.

7) In the fossil record we see evidence of the Cambrian explosion where all species appeared at once. Where is the evidence that supports Darwin's tree of life?

The notion that "all species appeared at once" in the Cambrian period is a common misconception. The process took between 10 and 20 million years. That's actually a pretty long time. Plus, as I'll detail below, these animals didn't come from nothing.

I've seen discussion sites where people clearly think that "all major animal groups" means all the kinds of animals we see today. For example, I've seen the assertion that whales were found in the Cambrian. This is so absurd as to not be worth commenting on. This issue is that many of the animals known then, all of which are long extinct, can be argued to be early members of today's major groups of animals (phyla). The only animal found in the Cambrian that seems to belong to our phylum (Chordata) --- *Pikaia* --- would be thought by most people to look like a little worm. The only way we can link it to us is some specialized features not seen in any other animals ---- for example muscles along its side that form in a zig-zag pattern (like you

see on a piece of fish), not in simple straight segments as in an earthworm. In other words, it is only by applying evolutionary analysis to *Pikaia* that we can identify it as a possible ancestor to other chordates, ourselves included.

In simple terms, "all species" did not appear in the Cambrian, nor did all major groups of organisms. Mammals, reptiles, amphibians, fish, insects, flowering plants, and other major groups did not appear until many millions or hundreds of millions of years after the Cambrian.

Now, where did the Cambrian animals come from? Did they arise without ancestors? No. We actually have good fossil evidence of fairly complex animals stretching into the Precambrian. There is an animal called *Kimberella* that is known from the Ediacaran fauna, 5-10 million years before the Cambrian that is certainly a complex animal, perhaps some sort of mollusk (see <http://en.wikipedia.org/wiki/Kimberella>), and there are lots of other animals then that might represent some sort of more primitive forms such as sponges or jellyfish. So there was plenty of biology going on before the Cambrian radiation, and these animals didn't appear suddenly from nowhere.

In fact, the classic "Cambrian explosion" begins around 10 million years into the Cambrian Period, and we have good evidence for the initial radiation starting off in the Early Cambrian. Bear in mind that the Burgess Shale Fauna (where we know most of these animals from) is a site of exceptional preservation ---- a lot more might have been going on earlier that we just don't have evidence of because we're only preserving hard parts like shells.

Why did so much happen in the Cambrian? It may well be true that complex life had to wait until the Cambrian to get a foothold. We know from geochemical evidence that the original earth had almost no atmospheric oxygen, and it took a long time to evolve the kind of bacteria that could photosynthesize and start to release oxygen into the atmosphere. A significant rise in atmospheric oxygen took place right before the Cambrian, and that is significant. Why? Well, quite apart from the fact that larger more complex animals are dependent on oxygen, the main molecule that forms animal connective tissue, collagen, cannot be synthesized in low oxygen levels.

Our textbook discusses the Cambrian Period in several places, and presents an accurate and balanced view of animal evolution and diversity in Chapter 26 (pp. 752-773). I'd be glad to send you a copy of this chapter for your inspection if you like.

Finally, let me return to your original point. You cited our statement (on page 465) that "*Astonishingly, every scientific test has supported Darwin's basic ideas about evolution.*"

You seem to take issue with this statement, and I certainly drew the impression from your email that the seven questions you listed were intended as challenges to this assertion in our textbooks.

Quite frankly, the statement in our text is still correct. Please remember that we referred to "Darwin's basic ideas about evolution." Those ideas were essentially that processes acting in the living world today, including variation and natural selection, are sufficient to account for the origin of species. More than a century and a half of study has indeed confirmed those ideas. It is a fact, of course, that there are many characteristics of living organisms and many events in earth history that cannot yet be completely explained by evolutionary theory. But the same is true of any scientific theory — including the basic theories of physics such as gravitation, atomic theory, string theory, and quantum mechanics. The existence of unexplained phenomena is not evidence against a particular theory, and that's why we made the statement we did.

It is worth noting that Darwin sketched the basic outlines of his theory of evolution in an age before fields such as genetics, biochemistry, molecular biology, and genomics were established. To be valid, evolutionary theory had to make and fulfill scores of predictions in each of these fields, and it has. Evolutionary theory has successfully been applied to modern studies in biology in countless ways, and it has survived every attempt at disproof.

As my friend Neil Shubin, a distinguished paleontologist at the University of Chicago, has said, "Darwin didn't even know about molecular biology and DNA, and yet that's where some of the most profound evidence is being uncovered today. Think about that. That somebody in the 1800s made predictions that are being confirmed in molecular biology labs today. That's a very profound statement of a very successful theory." I think that Dr. Shubin got it exactly right.

Thanks very much for your interest in our textbook.

I do apologize for the length of this email message. However, you asked a number of important questions, and I thought those questions deserved an answer in detail.

With Best Wishes,

Kenneth R. Miller
Professor of Biology
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On Fri, Dec 2, 2011 at 11:51 AM:

December 2, 2011

Dear Professor Miller,

In September 2011 I attended an education meeting which dealt with the purchasing of biology text books for Davis School District in Utah. The one book by Pearson publishing had your name and Levine on the cover. The presenter said that if anyone needed to have any questions answered all they had to do was to call you.

I'm not a teacher but I'm interested in a statement that was made in the biology book. On page 465 it states "Astonishingly, every scientific test has supported Darwin's basic ideas about evolution." I have a few questions about that statement.

1. What scientific experiment has proven Darwin's theory of macro-evolution?
2. What is the mechanism that causes this to occur?
3. Where did the information in DNA come from?
4. How did dead matter turn into living matter?
5. How did the first living cell form and how did it know what parts were necessary for it to function?
6. Why do we only see animals reproducing after their own kind? Has Darwinian evolution stopped?
7. In the fossil record we see evidence of the Cambrian explosion where all species appeared at once. Where is the evidence that supports Darwin's tree of life?

Your answers to these questions would help me and others feel more confident about Darwin's theory. You probably have answered these questions a number of times so I should be able to hear back from you within a month? Just in case you can't answer them let me know.