SCIENCE
EVOLUTIONARY BIOLOGY

Setting Back the Clock on a Simple Ancestor

By Alan Jay Kaufman
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When Charles Darwin came up with his theory of evolution, he had a problem. While he predicted that evolution was a slow and gradual process that occurred over vast expanses of time, the actual fossils that scientists had found seemed to show that virtually all the major body plans of the animals we know today arrived fairly simultaneously, in a narrow window of time more than 500 million years ago.

There must have been a common ancestor to the cornucopia of creatures that originated in the big bang of animal evolution, Darwin said. But after decades of searching, scientists have yet to find hard evidence for true animal ancestors in older rocks.

Now, molecular biologists may be coming to Darwin's rescue. They have found a way to read time off molecular "clocks" ticking away in the genetic material inside cells of animals since their primordial birth. Using this approach, researchers are finding that the earliest animal groups split off from a common ancestor as much as half a billion years earlier than the fossil record leads scientists to believe. While it may not be hard fossil evidence, the molecular data collected over the past 20 years supports Darwin's vision by suggesting that the tree of animal life had much deeper roots.

"These clocks allow us to time the points in the distant past when the most important innovations of animal life arose," says Jeffrey Levinton, an evolutionary biologist at the State University of New York and a U.S. authority on the evolution of animals.

A common ancestor for all animal life has never been found in the fossil record, and probably never will. That's because the earliest forms of life probably had no shells or other hard parts that could be easily preserved. The precursors of animals with shells that appeared explosively at the base of the Cambrian Period—some 530 million years ago—may have been microscopic, larval forms, says Gregory Wray, an evolutionary biologist also at the State University of New York. They were likely "eency weency things living between sand grains."

The only traces of Darwin's ancestral animals may be the tiny tracks and burrows left behind when worm-like creatures crawled through mud on the sea floor in search of food. The soft-bodied animals that made these markings, known as trace fossils, probably had a head and a primitive circulatory and nervous system, as well as a rudimentary gut, says Guy Narbonne, a paleontologist at Queens University in Canada.

But, like the fossil shells that appear suddenly in the Cambrian explosion of animals, these trace fossils don't have a long history leading back to the time of a common ancestor. "Even the trace fossils appear late in the game," says Narbonne. Further back in time, the only living things paleontologists have been able to positively identify are seaweeds and single-celled algae and bacteria.

The molecular search for evidence of animal ancestors that would prove Darwin's theory right began in 1982 when Bruce Runnegar, a paleontologist at the University of California at Los Angeles, decided to try to use a "molecular clock."

A molecular clock is a gene or protein common in the cells of all living things, from bacteria to plants to animals. These molecules change, or mutate, with clock-like regularity, some researchers say. Over millions of years, mutations begin to build up within the molecular clocks of different animal groups once they split off from a common ancestor.

Scientists calibrate the speed of these genetic clocks by counting the number of mutations that have accumulated over a known interval of time, in specific groups of modern fish. Skeletons of the earliest fish are well preserved in rocks that have already been dated using other methods. Thus, by knowing the speed of the molecular clock, researchers need only count up the number of genetic mutations in a wide range of animal groups to project back to the time, before there were fossils, when each group of animals presumably evolved.

Using this method, Runnegar compared the genetic code in the hemoglobin molecule from the blood of a selected number of modern groups of animals. Relating the differences between the number of hemoglobin mutations in different groups to time, Runnegar calculated that the major body plans of animals emerged from a simple ancestor some 900 million to 1 billion years ago, almost twice the age suggested by the fossil record.

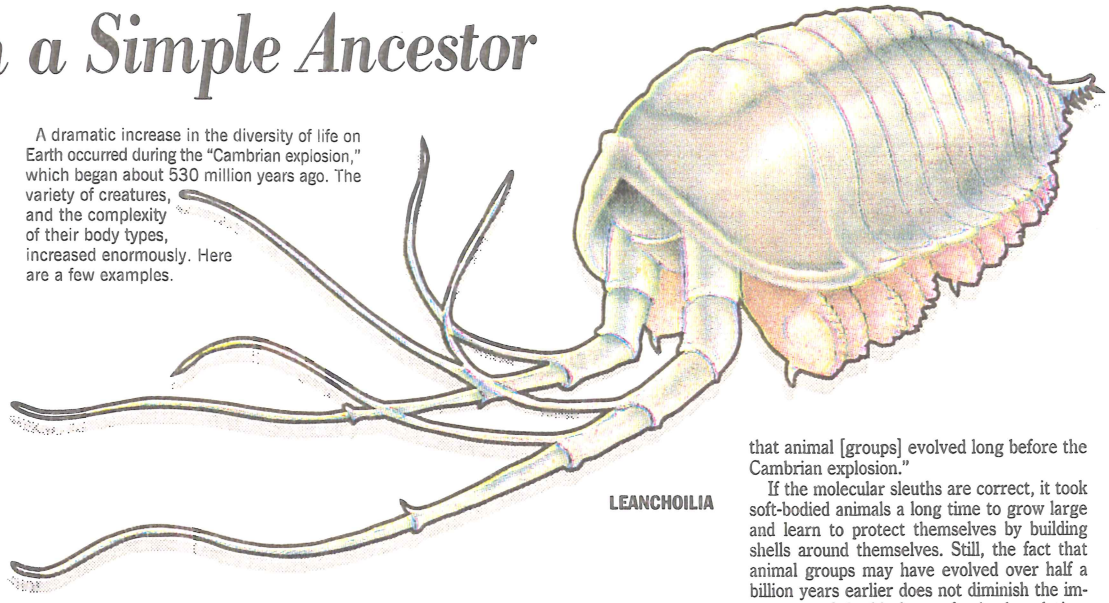
The storehouse of genetic information on animals has grown to the point that Wray and Levinton, along with their colleague Leo Shapiro, used the genetic sequences in seven very different molecules within 16 different groups of animals to push the primordial birth of animals even further back in time, between 1 billion and 1.2 billion years ago. According to the researchers, later modification of these basic body plans, such as the evolution of skeletons and circulatory systems, probably occurred hundreds of millions of years later, nearer to the Cambrian explosion.

While molecular clocks are the only tools researchers have to date the earliest origin of animals, some argue that the clocks don't keep very accurate time. "Relying on the molecular clock is a lot like believing in the Easter bunny," says Douglas Erwin, a paleontologist at the Smithsonian Institution who studies the early fossil record of animals. Erwin is skeptical of the very old ages indicated by the molecular clocks. "I am very suspicious of claims that there is a long history of protracted animal evolution before the Cambrian."

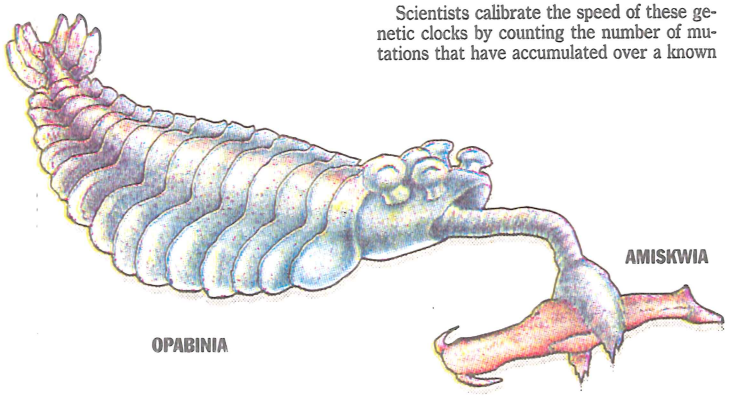
Some researchers suggest that the speed of genetic mutations may accelerate at times when animals are evolving rapidly into different shapes and body plans. Wray admits that the clocks "are neither extraordinarily accurate nor extraordinarily precise," but while "the uncertainty makes it possible that the dates are a bit too old, they still suggest that animal [groups] evolved long before the Cambrian explosion."

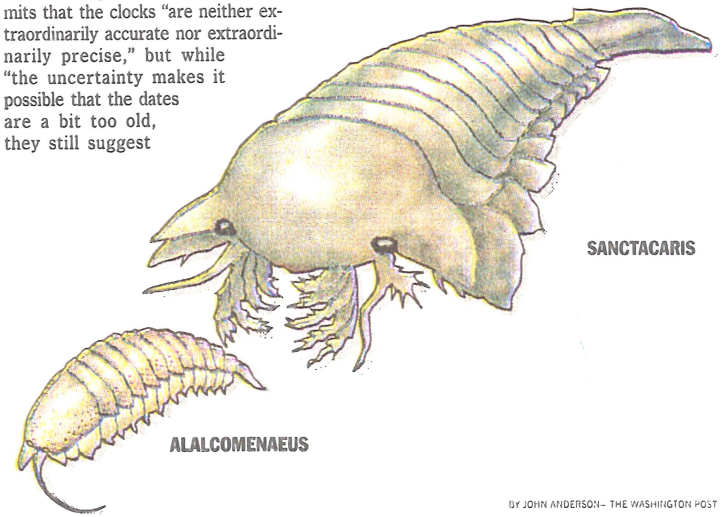
If the molecular sleuths are correct, it took soft-bodied animals a long time to grow large and learn to protect themselves by building shells around themselves. Still, the fact that animal groups may have evolved over half a billion years earlier does not diminish the importance of the big bang of animal evolution, "it only means that the Cambrian explosion had a longer fuse," says Andrew Knoll, a paleontologist at Harvard University.

Knoll and his colleagues believe that major climatic and environmental changes at the surface of the Earth may have caused animals to grow in size and start forming shells. These researchers have shown that an origin of animals between 600 million and 900 million years ago is likely, based on new chemical evidence that suggests the amount of oxygen in the atmosphere increased dramatically at this time.



A dramatic increase in the diversity of life on Earth occurred during the "Cambrian explosion," which began about 530 million years ago. The variety of creatures, and the complexity of their body types, increased enormously. Here are a few examples.





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