SPECIAL SECTION ORIGINS

Hunting the First Animal

Could slimy, shapeless creatures called placozoans resemble the last common ancestor of all animals? Inside the thorny debate over the tree of life

The identity of the first animal—or, more precisely, the last common ancestor of all animals—has stumped biologists for more than 100 years. Dubbed the "urmetazoan" (or "first animal"), this creature has inspired countless studies and intense debate. Today the explosion of DNA sequencing and other molecular analysis is re-igniting the discussion. One recent comprehensive analysis knocks the sponge off its throne as the most primitive living animal and the leading candidate for the urmetazoan.

A much less familiar creature—a flat, gnat-size, amoeba-like blob called *Trichoplax adhaerens*—emerged before sponges, the analysis concludes. There were other surprises in the study, too. Biologists have long believed that "simple" animals (sponges, for example) are at the base of the tree, with "complex" animals (like humans) branching off from them. But the new tree does not branch this way. Instead, simple and complex creatures developed in parallel (as did traits like the nervous system) from an unknown urmetazoan. The tree, in other words, has been turned on its side [see "What Does the Animal Tree of Life Look Like?" page 54]. As for the first animal, lead study author Bernd Schierwater, a biologist at the University of Veterinary Medicine in Hannover, Germany, has resurrected an old candidate, the placula, a hypothetical extinct animal that resembles the *Trichoplax* blob. Others, however, are far from convinced.

Biologist Bernd Schierwater collects* Trichoplax *specimens in 1989 from warm, shallow waters in the Mediterranean.

A Complex Tree

Five distinct groups make up the animal, or metazoan, tree. The most familiar are the bilaterians, animals with a front and back as well as a top and bottom. Humans, worms, fish, insects—most of the creatures we think of as animals—are bilaterians. These animals are also known as triploblasts for the three germ-cell layers from which they develop. The other four groups, the so-called diploblasts, are the poriferans (sponges), ctenophores (including jellyfish-like comb jellies), placozoans (*Trichoplax*, among other still unnamed species) and cnidarians (corals and jellyfish, for example). Following a fundamental principle of evolutionary biology, in which complex life derives from more-primitive ancestors, triploblasts are believed to have developed from diploblasts.

"Very possibly, the five groups arose in quick succession," says biologist Neil Blackstone of Northern Illinois University. "Determination of the group relationships will give us a better idea of the features of the first animals." But these relationships are murky, with controversy raging on the relative positioning of the simple animal groups. Most morphological and

Trichoplax ***have no fixed shape, but they do have a top and bottom. Here, a bottom view of a placozoan found in Belize.***

molecular analyses conclude that sponges are the most primitive diploblasts. Bolstering the sponge's primitive status, sponge cells called choanocytes resemble the microrganisms that are most closely related to animals, choanoflagellates.

Schierwater, who has been studying *Trichoplax* since 1989, disagrees with the sponge model. The recent analysis done by him and scientists at the American Museum of Natural History in New York and at Yale University strongly supports the placement of *Trichoplax* (and, by association, other placozoan species) at the base of the diploblast tree, bumping up the sponge.

Getting to Know *Trichoplax*

Trichoplax was first discovered by German biologist Franz Eilhard Schulze, who in 1883 noticed several small organisms with hairlike cilia clinging to the side of his saltwater aquarium. He named them *Trichoplax adhaerens*, or "sticky, hairy plate." A new phylum, placozoa, was created for the uniquely simplistic animals, which are often referred to as placozoans.

The creatures, which reach a tenth of an inch in size, grow on algae and rocks in shallow water in warm seas and often hitch a ride into saltwater aquariums as well. They use the cilia on their lower body to crawl, but they can also expand and contract their bodies in a quick and directed movement that causes amoeba-like shape shifts. In the lab, *Trichoplax* reproduce by fission (splitting apart), although they sometimes produce eggs, too. Biologists say it's likely that they reproduce sexually outside the lab.

Trichoplax have just five cell types (sponges, in comparison, possess around twice as many, and mammals have hundreds). Their bodies are arranged into a top and bottom. Two types of epithelial (skin) cells, the upper and the lower, feature cilia for movement. Fiber cells sandwiched between the epithelial cells hold the body together and allow the animals to contract and change shape. The lower body also has glandular cells that secrete digestive enzymes used in feeding. The fifth type, proto-stem cells, found where the upper and lower epithelial cells meet, are a new discovery.

The animal's simple anatomy originally inspired biologists to place placozoans at the base of the animal tree. And in the 19th century, the German zoologist Otto Bütschli popularized the "placula hypothesis," in which an ancient *Trichoplax*-like creature was the ancestral animal. By the early 1900s, however, biologists began to believe that the placozoan line evolved later, having branched off from cnidarians. In this scenario, the animals lost certain characteristics over time, making them appear more primitive than they actually were.

Conflicting Reports

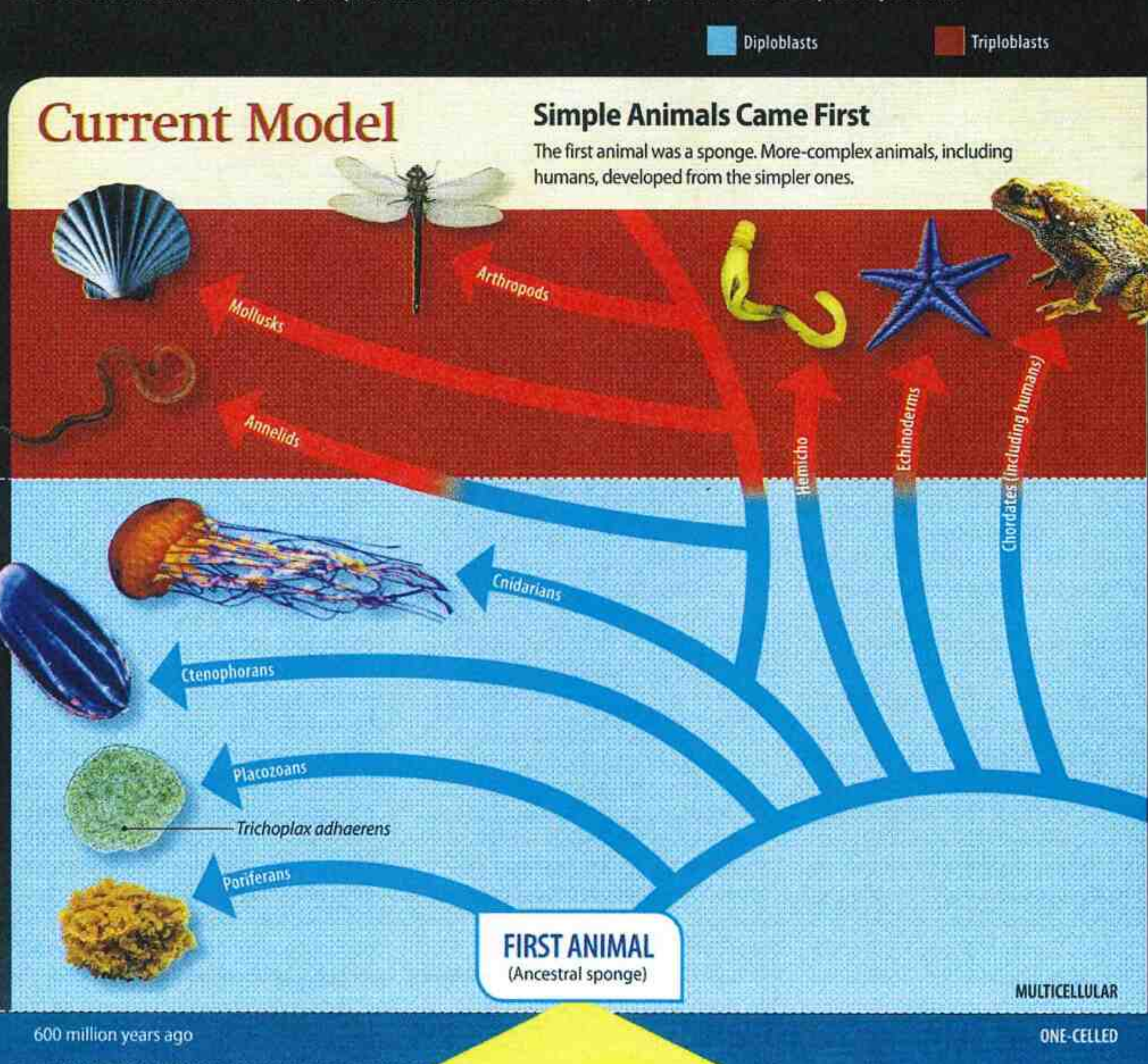
Today, DNA sequencing has largely eliminated the possibility that placozoans developed from cnidarians. So where do they fall on the tree of life? According to Blackstone, the mitochondrial genome of *Trichoplax* is twice as large as expected and contains unusual protein-coding regions. This data indicates that the animal evolved before other animals began shifting mitochondrial genes to the nucleus, where they are mostly found now. Other analyses of nuclear DNA, however, strongly indicate that sponges evolved first.

Schierwater's study, published earlier this year, attempts to reconcile the conflicting models by combining mitochondrial and nuclear DNA information, along with data on the structure of RNA molecules, into one analysis. Researchers examined 50 genes from 24 animal species across the kingdom, focusing on genes coding for proteins that vary from species to species. These variations allowed a computer program to deduce relationships between the species and build a model for the tree. Not only did *Trichoplax* emerge first among the diploblasts, according to this tree, but the diploblasts and triploblasts evolved independently.

If the simple and more complex animals developed separately from the start, such complex entities as the nervous system evolved twice—once in the animals that developed from the placozoans and once in the bilaterians. One way such parallel evolution could be explained is if the genetic toolkit for features such as the nervous system were in place before the simple and

What Does the Animal Tree of Life Look Like?

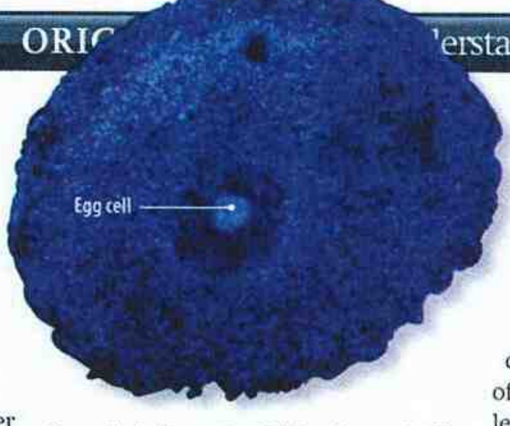
Sometime before 600 million years ago, the first animals evolved from protists, mainly single-celled microorganisms. What happened next is up for debate. The two simplified animal family trees shown here are among the many theories. The new model, proposed by Bernd Schierwater, posits that a hypothetical predecessor of *Trichoplax adhaerens*called the placula was the first animal, and that simple diploblasts and the more complex triplobasts evolved separately from it.



more complex animals diverged.

Schierwater believes *Trichoplax* possesses that toolkit. It has a surprising 11,514 genes, with "all the basic complexity of genes and gene families we know from flies to humans," he says. Its genome contains the recipe for receptors, for example, proteins that receive signals from other cells and that, among higher animals, contribute to the development and function of the nervous system. *Trichoplax* also has a gene called Trox-2, a prototype of genes that control body formation in higher animals.

For Schierwater, the placula hypothesis is the next logical step. "If the placula was the urmetazoan, then



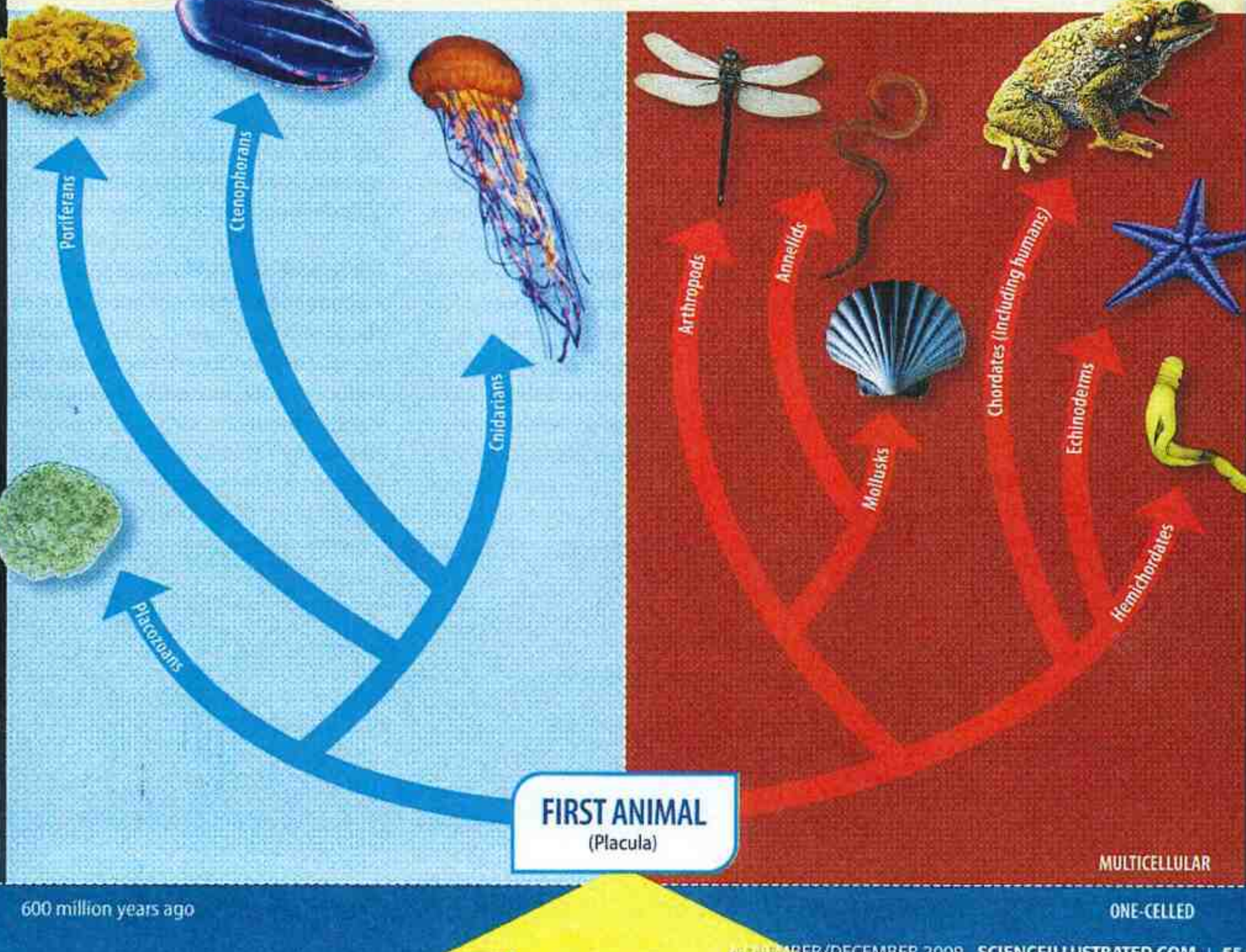
Egg cells indicate that* Trichoplax *probably reproduce sexually in nature.

Trichoplax, its closest living descendant, would harbor the closest proto-genes," he says. Yet despite his confidence, the matter is hardly settled. "The presence or absence of genes in the *Trichoplax* genome does not provide the necessary information to determine its position in the tree of life," says biologist Gonzalo Giribet of Harvard University. The largest evolutionary analysis of the genome, says Giribet, actually places another candidate, ctenophores (comb jellies), at the base of the tree. Geneticist Rob DeSalle, who led the recent analysis at the American Museum of Natural History, counters that the ctenophore study did not include placozoans. For now, the debate rages on. Perhaps only one thing is certain: Far more research and sophisticated methods of analysis are needed to better understand the evolutionary history of the animal kingdom. ■

New Model

Complex Animals Evolved Separately

The first animal was the placula, a hypothetical creature that most closely resembles placozoans such as *Trichoplax adhaerens*. The animal kingdom developed along two distinct paths.



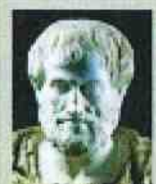
B. SCHIERWATER/TIHO HANNOVER

Putting the Puzzle Together

Examining Species through the Ages

The ancient Greeks believed that there were around 500 species. Generations of scientists have since added to the number, and today there is talk of as many as 100 million species.

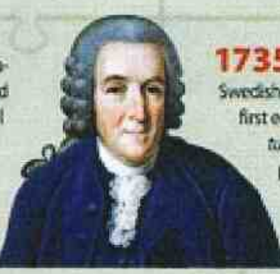
Entomologist Eric Guilbert collects insect specimens in the Andes.



CIRCA 350 B.C. Aristotle, the Greek naturalist and philosopher, carries out the first known attempt to systematize animal species in his *History of Animals*.

A.D. 77 Pliny the Elder, a Roman naturalist and scholar, publishes his *Natural History*, the largest and most comprehensive census of plants and animals of its time, although many of the animals he classified were actually mythological.

1623 The Swiss botanist and physician Gaspard Bauhin develops binomial nomenclature, a taxonomy system in which every organism gets a two-part Latin name.



1735 Carl Linnaeus [left], a Swedish botanist, publishes the first edition of his *Systema Naturae*, introducing a comprehensive taxonomy system that uses binomial nomenclature.

1749–1788 France's Count de Buffon categorizes each plant and animal according to its relationship to man in his 44-volume natural-history lexicon, paving the way for evolutionists like Charles Darwin.

1758 The 10th edition of Linnaeus's *Systema Naturae* is published, listing 4,400 animal species and 7,700 plants. It has since served as the foundation for all modern taxonomic work.

1768–1771 Joseph Banks collects 30,000 plant specimens during James Cook's first expedition to the Pacific Ocean. Among the collection are the shells pictured here, as well as 1,400 new species.

1859 Charles Darwin publishes *The Origin of Species*, in which he suggests that organisms should be classified according to their shared ancestry.

1950 Zoologist Willi Hennig publishes *Basic Principles of a Theory of Phylogenetic Systematics* in German. This seminal work on cladistics goes unnoticed for nearly 20 years.

LATE 1950s The Austrian-American biologist Robert Sokal and the English microbiologist Peter Sneath are the first to apply statistics to the classification of species: Numerical taxonomy is born.

MAIN IMAGE: PHILIPPE PSAILA; FROM TOP: GETTY/ALL OVER; THE ART ARCHIVE; SPL/FOCI; NATURAL HISTORY MUSEUM, LONDON. PRECEDING PAGES: COURTESY JAMES MILLER/AMERICAN MUSEUM OF NATURAL HISTORY tions for biologists, ecologists and conservationists, who seek to understand how a huge variety of species might fit into and help drive an ecosystem.

Carl Linnaeus's **Systema Naturae** *distinguished dolphins from fish and said that a shared environment—water—explained their physical similarities.*

The Earliest Species

The concept of species has been around for as long as humans have been assessing their surroundings. The earliest known grouping systems, used by ancient cultures like the Babylonians, were practical lists. Animals were divided into such categories as domesticated or wild, edible and inedible; plants were distinguished between edible and poisonous.

Aristotle (384–322 B.C.), the Greek philosopher and natural scientist, was the first to introduce a comprehensive and systematic method for organizing life. He arranged animals in relation to one another, with an emphasis on defining each fundamental kind—what we know as a species. Aristotle based his lists on his observations and his knowledge of the internal anatomy and the behaviors of various animals. He divided them into two groups: animals with blood, which more or less consisted of vertebrates; and animals without blood, which made up the rest. This latter group included cephalopods (squid, octopus and cuttlefish), insects, shellfish, crustaceans and "plant-animals," or organisms he thought looked like plants, such as jellyfish. Aristotle categorized more than 500 different animal species.

For centuries, these works were the absolute authority in natural science. Aristotle's overview was not significantly expanded until Pliny the Elder (A.D. 23–79), a Roman naturalist, published an enormous lexicon in A.D. 77. In it, he presented in detail all that was known on plant and animals at the time, including such fanciful species as dragons and mermaids, which we now know to be mythological. He devoted the majority of his text to describing uses for various plants and animals—which species were edible, for example, or which had healing properties. This practical approach was later adopted

1966 Willi Hennig's *Phylogenetic Systematics* is published in English and gains popularity within a few years.

1967 Walter Fitch, a chemist, and Emanuel Margoliash, a molecular biologist, build the first molecular evolutionary tree based on the protein cytochrome C.

1977 The American microbiologist Carl Woese identifies a new domain (a taxonomic rank higher than kingdom), archaea, or "ancient" bacteria, using RNA analysis. Previously, scientists believed there were only two domains: eukaryotes (cells with a nucleus) and prokaryotes (cells without a nucleus).

1980s Entomologist Terry Erwin calculates that the number of animal species is as many as 30 million—the first time an estimate is based on field research.

1993 The tree of life is disrupted again by molecular taxonomy: Using RNA analysis, Mitchell Sogin discovers that fungi are more closely related to animals than to plants.

2009 The German biologist Bernd Schierwater, using genetic analysis, suggests that a hypothetical amoeba-like creature called the placula is the ancestor of all animal life, rather than the sponge (see "Hunting the First Animal," page 52).