EVOLUTIONARY BIOLOGY

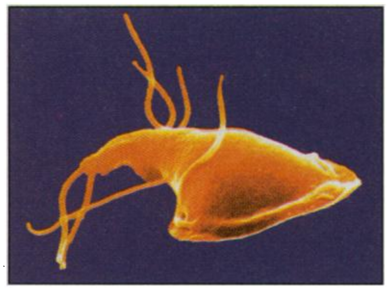
Searching for Living Relics of The Cell's Early Days

CHAFFEY'S LOCKS, ONTARIO—Some 50 evolutionary biologists gathered here for an annual meeting held from 23 to 27 August by the Canadian Institute for Advanced Research. The meeting saw model organisms and cherished hypotheses rise and fall as participants discussed how to tease out clues to the emergence of the first complex cells.

Model Organisms Unseated

Because ancient fossils are scarce, scientists trying to look back billions of years to the early days of life turn to single-celled organisms that appear very primitive. But two findings presented at the meeting suggest that creatures thought to represent the earliest stages in the evolution of complex cells may not be such good models after all.

At stake is a glimpse of what eukaryotic cells—cells with nuclei—looked like before they acquired the energy-producing organelles called mitochondria. Only eukaryotes have mitochondria, which have their own small complement of genes, and most scientists believe that these organelles originated when a bacterium took up residence inside a primitive eukaryotic cell. Scientists had identified certain protists that have nuclei but no mitochondria—called Archezoa—as possible direct descendants of the first eukaryotes. But it now appears that mitochondria may have appeared well before these "ancestors." The findings, says molecular evolutionist Geoffrey McFadden of the University of Melbourne in Australia, have "blasted apart our ideas about the earliest eukaryotic cell."



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Ancient baggage? *Giardia* may have gained and lost a mitochondrion.

Other Archezoa have lost their ancestral status in recent years when closer examination of their DNA revealed genes that code for proteins typically associated with mitochondria in other organisms. The implication was that these organisms once had the organelles, then somehow lost them. Now Andrew Roger, a postdoctoral fellow at the Marine Biological Laboratory (MBL) in Woods Hole, Massachusetts, reports that another Archezoan, *Giardia lamblia*, may have also had a mitochondrion at one point. The organism causes giardiasis, often caught by hikers who drink unfiltered stream water—and it has been one of the primary models for early eukaryotes.

Roger, MBL molecular evolutionist Mitchell L. Sogin, and their colleagues found that the parasite has a gene for a protein called chaperonin 60, which helps other proteins fold properly. This gene is thought to be a good tracer for mitochondria, because it is thought to have moved from the mitochondrion to the nucleus in other organisms.

Another model organism was struck down by Martin Embley, a microbiologist from the Natural History Museum in London. He and postdoctoral fellow Robert Hirt found that an organism in the group called Microsporidia, microbes that can cause deadly infections in immune-compromised people, contain heat shock protein 70, which helps stabilize other proteins after heat exposure. It closely resembles a heat shock protein in other organisms that is thought to be derived from mitochondria. The good news, Embley says, is that data from other proteins suggest that the Microsporidia are closely related to fungi. So if the organisms once had mitochondria but lost them, they may be true fungi, susceptible to antifungal drugs in patients.

One candidate for a truly premitochondrial eukaryote is still unchallenged, says Roger: the oxymonads, a little-studied group of organisms that live in the hindgut of termites. But data on those creatures—which have yet to be cultured in the laboratory—are scarce.

If mitochondria had already taken up residence before the "model" organisms evolved, Roger says, these organelles must be far more ancient than scientists had thought. They may have originated at the same time or even earlier than the cell nucleus, implying that the mitochondrion played a crucial role in the development of the eukaryotic cell. That idea intrigued the other scientists at the meeting, although not everyone is convinced that mitochondria predate the surviving eukaryote ancestors. "It's still a debatable story," says molecular evolutionist Michael Gray of Dalhousie University in Halifax, Nova Scotia. Still, participants agreed that the discoveries have created an opening for new theories of how complex cells were put together.

Ancient Organelle Glimpsed

Evolutionary biologists may be losing their models for the ancestral eukaryotic cell, before it acquired the energy-producing organelles called mitochondria. But they may be gaining a whole gallery of models for the steps that took place later, after specialized bacteria took up residence to form these organelles.

At the meeting, molecular evolutionist Gertraud Burger of the University of Montreal presented genetic portraits of three mitochondria, from three different organisms, that may chronicle the transition from newly acquired bacterium to highly modified organelle. One of these organisms, from a recently discovered freshwater protist called *Reclinomonas americana*, provides the best link yet between the mitochondria of plants and animals and the bacterial precursor, says Burger's colleague, Michael Gray of Dalhousie University in Halifax, Nova Scotia. "You'd be hard pressed to look at it and say this wasn't a compressed bacterial genome," he says. The other two may offer glimpses of later stages in the process.

Burger and her colleagues suspected they had unearthed an ancestral mitochondrion in *Reclinomonas* when they sequenced its mitochondrial genes. As they reported in *Nature* in May, the sequence contained genes similar to every gene ever identified in any other mitochondrion, plus 18 new ones—many of which closely resemble those of bacteria. This complement of genes suggests, says Gray, that *Reclinomonas* inherited an ancestral mitochondrion but preserved it better than other organisms.

At the meeting, Burger also presented data from two nearly completed sequences from relatives of *Reclinomonas*, called *Jakoba libera* and *Malawimonas jakobiformis*. Although their mitochondrial genomes also contain almost all the genes found in other mitochondria, *Jakoba* has only 10 of the bacterial genes identified in its cousin, and *Malawimonas* has just four. This suggests, says Burger, that they may provide a link between *Reclinomonas* and other, more derived mitochondrial genomes—and clues to how and why cells lose mitochondrial genes or transfer them to the nucleus.

Now the team is preparing to sequence two more protists, one of which, called *Macropharyngomonas salina*, may have a mitochondrial genome three times larger than that of *Reclinomonas*, suggesting that it might be packed with bacterial genes—and may offer an even closer look at the ancestral organelle.

–Gretchen Vogel