Highlight: Mitochondrial First Steps Found in Jakobid Protists

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Accepted: January 30, 2013

For success in science, as well as life, it is sometimes necessary to abandon the plan and embrace serendipity. In 1991, Charles O'Kelly tried, for several frustrating weeks, to separate a golden alga, collected from a New Zealand sheep pond, from a contaminating protozoan.

"I was trying to grow the alga and the protozoan would not die. So I thought, this is trying to tell me something," says O'Kelly, still a protozoan-diversity enthusiast. O'Kelly decided to prepare the culture for transmission electron microscopy with the protozoan still in it. At that time, TEM was the preferred method for analyzing cellular structures in phylogenetic studies. "That was when I noticed the similarity of the protozoan with the living protozoa that lack mitochondria, and were then thought to have never had them."

Most scientists at that time believed that the earliest eukaryotes were mitochondria-free. Endosymbiosis, when a free-living bacterium took up residence in the eukaryotic cell and began providing energy, they thought, occurred after organisms such as *Giardia* split from the tree of life.

"I thought, mitochondria evolved from this group somehow," O'Kelly says. "If this hypothesis is accurate, we should be able to find an organism that represents an early stage in mitochondrial acquisition." Hoping to find it, O'Kelly teamed up with a group of genome sequencers, including Gertraud Burger, to sequence the pesky protozoan's mitochondria.

"We were very lucky (with *Reclinomonas*)," says Burger, a professor of biochemistry and bioinformatics at the Université de Montréal. "We hadn't seen mitochondrial genomes that looked so similar to bacterial genomes before."

Since then it has been a mystery if *Reclinomonas* is unique for having such bacteria-like features. Burger wondered whether there might be similar critters, perhaps those whose mitochondrial genomes resemble bacteria more closely. Indeed there are. In a recent study published in *Genome Biology and Evolution*, Burger et al. (2013) report a new, deeper link. The most ancestral mitochondrial genome to date, they write, is found in a protist named *Andalucia*—with genes present in bacteria but not seen before in any mitochondrion—not even *Reclinomonas*.

Although endosymbiotic theory is well accepted, no living organism holds a mitochondrial genome that still looks like its bacterial ancestor. Many genes have been jettisoned. (Also, it was later discovered that mitochondria-free organisms such as *Giardia* once had mitochondria and subsequently lost them.)

"This transition from bacterium to mitochondria went so fast it could seem like everything has been lost in one shot," Burger says. "The intermediate steps have been missing. We're looking for links in that evolution."

One of those deep links is what they believe they have found in *Andalucia*—one of six jakobid species examined—belonging to the same group as *Reclinomonas*.

For the research team, sequencing and comparing genomes was relatively straightforward; assembling the study material was not.

"Choosing and getting the strains was our largest challenge," Burger laments. "You can't just look up early eukaryotes in a catalogue of a culture collection and say, 'I want this organism. Please send it to me.'" It was also a struggle to separate bacterial DNA from mitochondrial DNA, as jakobids need to be cultured together with live bacteria, their food source.

The team is interested in exploring other ways the jakobid protists may be similar to bacteria. Mitochondrial DNA replication, Burger suspects, may be very similar to bacterial DNA replication. To peer into this further, Burger et al. have begun a new project to sequence the nuclear genome of *Andalucia*. This should more definitively answer whether jakobid protists truly are the most ancestral eukaryotes alive. The organism could perhaps become, Burger believes, a eukaryotic model organism for biochemical studies, shedding light on eukaryotic life's earliest steps.

For all of our research, says Burger, "we are still very limited in the breadth of our knowledge about nature."

O'Kelly agrees: "It gives me incentive to go looking for the next protozoan weirdo."

Literature Cited

Burger G, Gray MW, Forget I, Lang BF. 2013. Strikingly bacteria-like and gene-rich mitochondrial genomes throughout jakobid protists. Genome Biol Evol., Advance Access published January 18, 2013, doi:10.1093/gbe/evt008

Highlights editor: George Jianzhi Zhang