Introns Pop up in New Places—What Does It Mean?

The discovery of introns in cyanobacteria has given comfort to both "introns-early" and "introns-late" camps

EVER SINCE THE 1977 DISCOVERY THAT genes are interrupted by introns—stretches of noncoding DNA that are spliced out after the genes are transcribed into RNA—researchers have wondered when introns originated and what their functions were. Some believe they date back to the time life originated and that they played an important role in piecing together the first genome. Others see them as latecomers, with no significant role in early evolution.

Until now, the evidence has seemed to favor the "introns-as-latecomers" view. While introns are abundant in animals and plants, none had been found in any member of the eubacteria: one of the three major categories of organisms (along with archebacteria and eukaryotes), all of which are thought to have shared a common ancestor. If the eubacteria didn't have introns, the thinking went, how could introns be primordial?

That simple argument has now been upset by two research teams who report (on pages 1566 and 1570 of this issue of *Science*) that one type of eubacteria—the photosynthetic cyanobacteria—does indeed have introns. But if you think this revelation settles the issue of "old versus new" introns, think again. The question is far from settled, with even the leaders of the two research groups differing on what their findings mean.

Both teams focused on a gene encoding a transfer RNA that inserts the amino acid leucine into proteins. In chloroplasts—photosynthetic organelles of plants—the gene has an intron. Chloroplasts are descendants of ancient free-living cyanobacteria, and so the researchers reasoned the chloroplasts may have inherited the intron from an ancestor they share with modern cyanobacteria.

Indeed, when the two groups independently examined the tRNA gene in a total of seven cyanobacteria species, they found introns in each case. The introns appear to be closely related to one another and also to the introns in the chloroplast genes. All of them belong to a class of introns called "self-splicing" because they have the capacity to splice themselves out of an RNA transcript.

David Shub of the State University of New York at Albany, the leader of one team, argues that the discovery suggests that the ancestral intron was already in place when an ancient cyanobacterium was engulfed by a eukaryotic cell, giving rise to chloroplasts, an event that occurred a billion or more years ago. "This shows that introns of the self-splicing type are clearly very ancient," he says, adding that it's going to be very difficult to "wiggle out" of that argument.

Jeffrey Palmer of Indiana University, who led the other team, agrees that the intron is ancient. He adds that his group has found it in the same tRNA gene in additional types of eubacteria. That suggests, he says, that it may have predated even the origin of the cyanobacteria more than 2 billion years ago.

But Palmer doesn't think finding one ancient intron implies that introns are or ever were plentiful in eubacteria. Indeed, he believes most introns were late invaders and predicts that the new findings won't tilt the debate conclusively. "Different people in the field will take the same result and use it to reach rather different conclusions about the general question of early versus late."

Right he is. On the introns-early side, Walter Gilbert of Harvard University is elated. "I think it is a very important finding...we're seeing introns in bacteria related to introns in chloroplasts. That strongly supports the idea that introns are very old." Gilbert says a self-splicing intron is "exactly the sort" that he would expect to find as a remnant of the "RNA world"—his name for a scenario in which RNA was the first enzyme and the first genetic material.

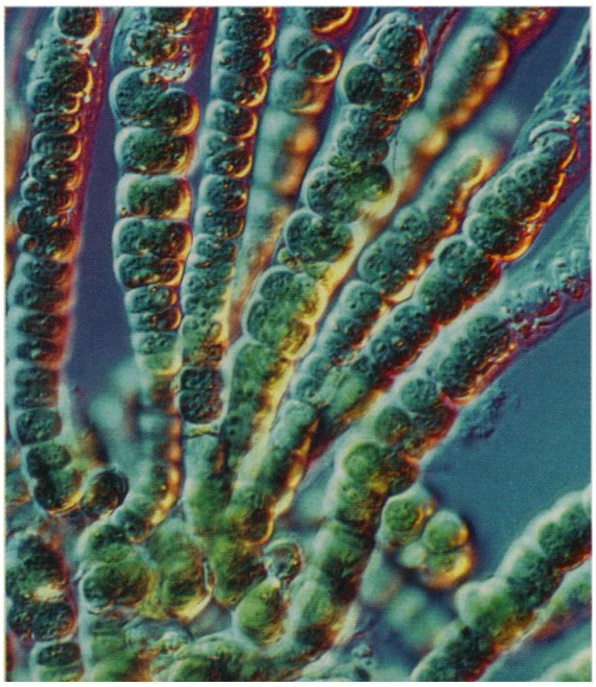
That scenario was inspired by University of Colorado chemist Tom Cech's 1982 discovery of self-splicing introns, and suggests that pieces of RNA with catalytic properties played an important role in early molecular evolution, combining both the ability to code information and the ability to join and split themselves to create the first genes.

The absence of introns from eubacteria has always been the Achilles' heel of the RNA world theory. Gilbert and others could only argue that selection for streamlined genomes may have been responsible for their loss from eubacteria. But to skeptics the lack of introns in eubacteria meant that introns arose later in evolution. The Shub and Palmer findings, says Gilbert, have now quashed that argument.

Not so, says Mitchell Sogin, an evolutionary biologist at the Woods Hole Marine Biological Laboratory who is on the introns-late side. "My view is that this class of introns does not have to be very old," he says. Sogin says that introns, especially the self-splicing type, can spread from gene to gene, inserting themselves at positions similar to their previous sites. Invasion of cyanobacteria by a hopping intron could account for Palmer's and Shub's findings just as well as inheritance of the intron from a common ancestor, Sogin says.

Now that the old dogma that there are no introns in eubacteria has been shattered, Palmer's, Shub's, and other labs will begin searching for early introns in other species of eubacteria and primitive eukaryotes—organisms central to this argument, whose DNA has been little studied up until now.

If that work succeeds in clarifying the origins of introns, it will be largely because of its experimental approach, a method Harvard paleontologist Andrew Knoll applauds. "It's clear that you couldn't have drawn this kind of conclusion...simply by looking at one laboratory organism" such as *E. coli,* says Knoll. "If there's a moral for the way we do biology, it's that exciting results will be obtained when the methods of molecular biology join with the methodological constructs of comparative evolution." ■ MARCIA BARINAGA


Susan Barnes

Algal evidence. *Introns have been found in cyanobacteria (blue-green algae). These cyanobacteria are known as* Fischerella PC 7414.