Static Evolution

Is pond scum the same now as billions of years ago?

By ELIZABETH PENNISI

To understand evolution, researchers from all walks of science typically search for signs of change. Paleontologists seek fossils that link extant organisms with ancient ancestors. Biologists tracking populations of plants and animals get excited when they detect one species splitting into two. Chemists and molecular biologists cheer when alterations they induce in some laboratory brew mimic the processes by which life originated (SN: 8/7/93, p.90).

But what intrigues J. William Schopf most is lack of change. Schopf, a paleobiologist at the University of California, Los Angeles, was struck 30 years ago by the apparent similarities between some 1-billion-year-old fossils of blue-green bacteria and their modern microbial counterparts, which often form a living film on stagnant water.

"They surprisingly looked exactly like modern species," Schopf recalls.

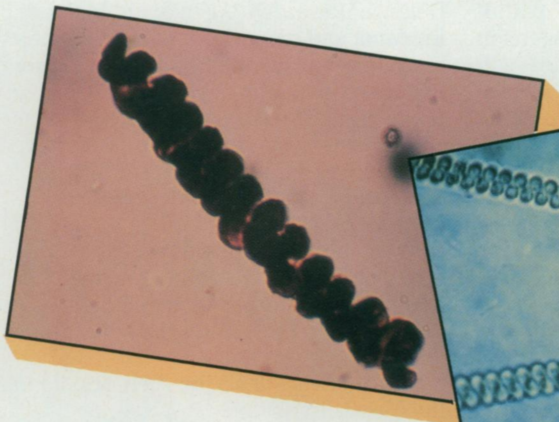
At the time, researchers had unearthed very few fossils dating that far back, so for all they knew, the similarity was nothing more than a fluke. "The question then became: How widespread, or general, was this observation?"

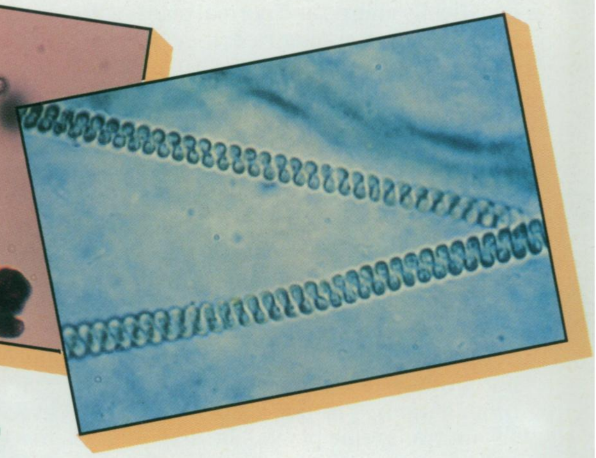
Now, after comparing data from throughout the world, Schopf and others have concluded that modern pond scum differs little from the ancient blue-greens. "This similarity in morphology is widespread among fossils of [varying] times," says Schopf.

As evidence, he cites the 3,000 such fossils found; these represent about 300 species, some 90 of which have modern look-alikes. Exquisitely preserved specimens have the same sizes, shapes, organization, even colonial structures as modern bacteria, he reported in late February at the annual meeting of the American Association for the Advancement of Science, held in San Francisco. Billions of years ago, these bacterial cells even divided as they do today—asexually.

"Species after species, I find remarkable identity," Schopf emphasizes.

This lack of change prompted him to rethink how evolution occurs.





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Almost 50 years ago, evolution researchers divided organisms on the basis of how quickly they evolved, suggesting that different mechanisms might underlie differences in rate of change. The most slowly evolving species included horseshoe crabs, crocodiles, and coelacanth fish, all of which still resemble their earliest fossils, from 100 million years ago.

Those scientists didn't know about the lineages of blue-green bacteria, also called cyanobacteria. "The fossil record is now seven times longer," says Schopf (SN: 5/1/93, p.276). He thinks these bacteria belong to an even slower evolutionary category — one, perhaps, of arrested evolution. "As far as I can tell, I think they've stopped," he told SCIENCE NEWS.

Genetic changes underlie evolution. Because sexual reproduction involves the mixing of genes between two organisms, new combinations of DNA arise more readily, speeding up the evolutionary process. As asexual organisms that reproduce without mating, blue-green bacteria depend solely on mutations and therefore would evolve more slowly.

But Schopf contends that these microbes went one step further to guard against alterations. As evidenced by their ability to withstand X-ray, ultraviolet, and even gamma-ray exposure, these microbes possess incredibly efficient DNA repair mechanisms, Schopf maintains. Thus they fix mutations that do occur.

"Evolution is economical, and evolution is conservative," he explains. "The object of an organism is not to change; the object is to be well adapted to many different environments. What DNA does is establish a mechanism so that when [genetic] changes do occur, they are corrected."

True enough, cyanobacteria have learned to live almost anywhere. The harshness of Earth's early atmosphere demanded that they become largely self-sufficient. They use light to convert carbon dioxide into usable energy and possess the biochemical expertise to carry out this process using either water, like modern plants, or hydrogen sulfide.

Moreover, they can fix nitrogen from the air. During their early history, the ability of blue-green bacteria to use water — and to produce oxygen as a by-product — gave them a competitive edge by interfering with the metabolism of the other microbes existing then. "It was microbial gas warfare," says Schopf. "They [were] the first polluters of the world's environment."

In those days, cyanobacteria dominated all environments, having become the perfect ecological generalists, says

Schopf. Even today, these microbes exist in hot springs and on snow fields; in incredibly acidic, basic, salty, or pure water; inside rocks; in deserts; or with little, no, even excess oxygen present. Some can survive long periods with no light to drive their photosynthetic machinery.

"I don't think they have to evolve, because as a group, they don't go extinct," Schopf adds.

Not everyone agrees that these microbes simply undo mutations in their genetic code. "The fact is that whatever changes did occur were selected against," counters Stjepko Golubic, an evolutionary biologist at Boston University. "That doesn't mean that they didn't participate in the evolutionary process – that [their] genotypes are frozen [in time]." In support of his position, he points to evolving properties of blue-green bacteria grown for a long time in a laboratory.

Golubic and his colleagues have compared fossil and modern stromatolites, chalky disks and cylinders produced by certain cyanobacteria. These comparisons show that at both times, these organisms thrived along shorelines in intertidal zones and produced pigments on their upper surfaces to protect them from light. "They didn't undergo ecological changes, and they didn't undergo morphological changes," concludes Golubic. "But how much the genotype has changed is still a question."

Schopf admits that appearances can deceive. These bacteria could have kept their general structure and yet evolved into very different organisms biochemically. But he doesn't think so.

Blue-greens thrive now in environments very much like those that hosted pre-Cambrian blue-greens. The carbon isotopic record indicates that the type of photosynthesis practiced by blue-greens today went on in that period. Moreover, modern species retain the ancient metabolic pathways, showing little sign of innovation in their biochemistry.

Schopf's work on cyanobacteria has led him to view the period from 2.5 billion to 500 million years ago as a distinct evolutionary era with its own tempo and mode of change.

Until now, researchers had based most of their ideas about evolution on investigations of the most recent 500 million years. However, "this is a time of relatively rapid evolution," says Schopf. Most species last no more than 8 million years. During that span, they and other extant organisms partition the environment, specializing to fit a particular niche and changing quite a bit. Unfortunately, these organisms become very good at using resources under a particular set of conditions and can't adjust quickly enough to survive when conditions change. They become extinct, making room for other species.

In contrast, before 500 million years ago, species came on the scene and stayed. Asexual organisms prevailed, particularly the oxygen-generating cyanobacteria. These slow-growing generalists could handle Earth's unforgiving conditions. Eventually, however, changes wrought by these organisms primed the ancient environment for more complex life forms (SN: 12/9/89, p.376).

These new life forms could outstrip the plodding blue-green bacteria and took many habitats away from them, says Schopf. Consequently, cyanobacteria today exist primarily in less hospitable places, such as hot springs.

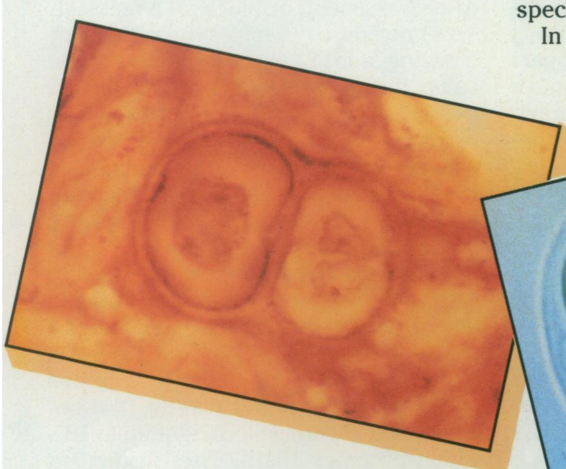
Golubic interprets the data about blue-green bacteria quite differently. Just because these organisms have persisted 2 to 10 times longer than other "living fossils" – crocodiles and the like – doesn't mean they follow a different set of evolutionary rules, he argues.

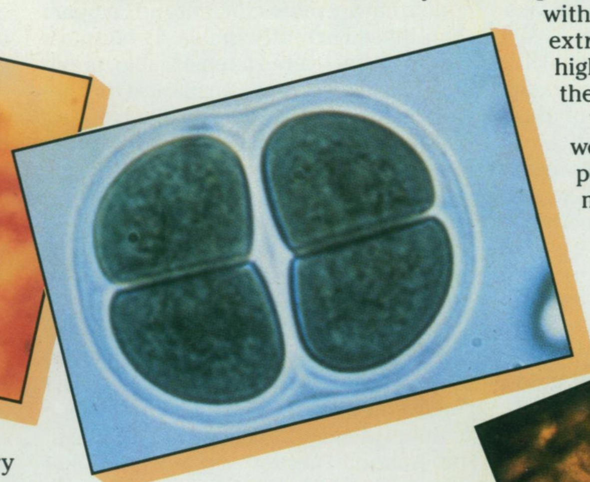
Nor does he think that blue-greens have been relegated solely to extreme environments. True, they often thrive in those places. But in 1979, other researchers discovered that huge numbers of oval and round blue-green bacteria populated the open ocean, sometimes reaching densities of 10 million cells per liter. They live everywhere except the cold polar regions and have adapted to both nutrient-rich and nutrient-poor waters, Golubic notes.

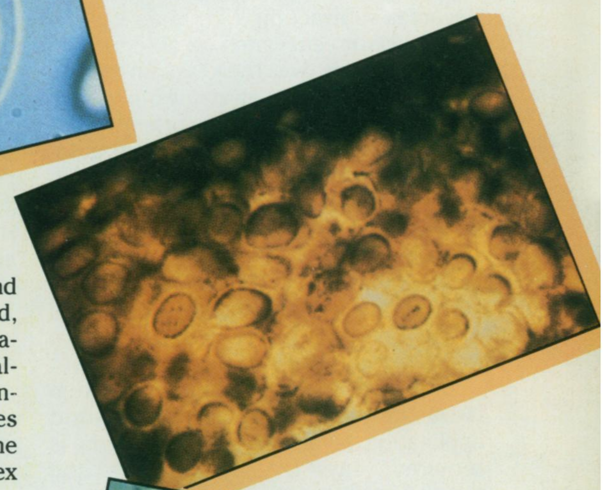
By themselves, these microbes account for 20 percent of the primary production in the seas, providing fodder for the rest of the marine food chain. Their presence means that cyanobacteria continue to play an important role in sustaining life on this planet, Golubic stresses.

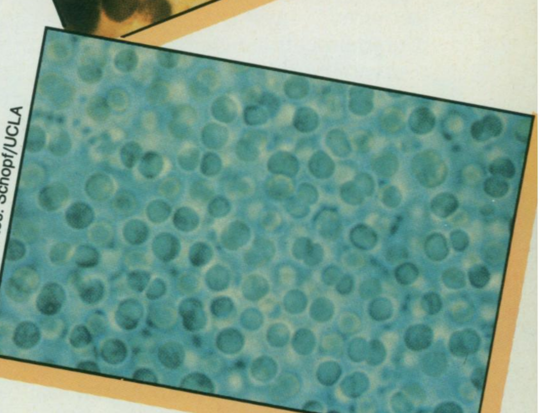
He argues, too, that these microbes have not forsaken other amenable environments. Rather, they have allowed themselves to become integrated into more complex creatures. Genetic studies indicate that all chloroplasts – whether from trees, grass, spinach, or algae – carry the genetic signature of blue-green bacteria (SN: 2/4/89, p.71). Thus he views blue-greens as still existing everywhere, but in such close partnership with higher organisms that they have become one with them. They may exist solo in extreme habitats simply because higher life forms could not follow them there.

"Anything which is green in this world is cyanobacteria in origin," he points out. "So who says they did not evolve?" □









Photos: Schopf/UCLA

These images pair ancient and modern versions of a spiral filamentous blue-green (left pair), a colony with few cells (middle), and one with many cells (above).