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By fits and starts, life may have begun

New evolution theory is survival by gene sharing

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Life on Earth did not start just once, as biology books have long taught, but possibly millions of times. Most of these experiments of nature failed, but three managed to beg, borrow or steal enough genes from the losers to hang on.

In fact, if rambunctious prelife bundles of chemicals hadn't cooperated 3.8 to 4.5 billion years ago and exchanged primitive genes on a wholesale basis, thereby sharing newly invented survival skills, life would probably still be in a retarded stage of evolution.

At least that is the picture taking shape as molecular biologists, using their new ability to decipher the genes of different species, seek to solve biology's most important problem--the evolution of modern cells.

Until now, scientists thought they knew the great founding parent from which all other life evolved: a single-celled organism that managed to put together a group of chemicals that carried instructions for building cell walls and other cellular structures. Today, we call those chemical instructions genes.

But like the story of the stork, it made the emergence of life an improbably lucky event.

Now the University of Illinois' Carl Woese, who once before shook up the world of biology with a new classification of life, wants to rewrite the biology books on the beginning of life.

There wasn't one founding parent but three, according to Woese, the leading proponent of a growing consensus that life had multiple starts. His report on the new theory appears in the current issue of the Proceedings of the National Academy of Sciences.

Millions of prelife forms cooperated in a frenzy of gene exchange to produce innumerable numbers of different single-cell organisms. By borrowing the best genetic attributes from one another, they gave evolution a giant leap forward, making the emergence of life much more probable, if not inevitable.

"I don't know that they knew they were cooperating, but those things which succeeded were the ones that did cooperate by sharing their genetic inventions," Woese said.

Three survivors

Out of this vast number only three survived to become the triumvirate of life: eukaryotes like people, animals and plants, whose genes are headquartered in the nucleus of a cell; prokaryotes like bacteria, individual cells whose genes are free-floating; and single-cell archaea discovered by Woese. Those are somewhere between human cells and bacteria.

"The idea that there was a community exchanging DNA is the new focus in evolutionary biology," said William Whitman, a microbiologist at the University of Georgia, Athens.

"The question is whether the universal common ancestor was an individual or whether it was a community of organisms that were exchanging genes," he said. "The evidence indicates that there was a community of organisms exchanging genes and that three dominant cell lines emerged."

U. of I. microbiologist Gary Olsen said the key to rewriting the history of life is the new access scientists have to the histories of individual genes.

"Gene transfers have played an incredibly important role in allowing organisms to share their abilities and to acquire new ones, not by inventing them or inheriting them from their ancestors, but from actually acquiring them from other cells in the environment," Olsen said.

Once these cellular forms were in place, the massive gene-swapping free-for-all slowed dramatically but never stopped. This type of horizontal gene transfer is still all around us. That random mixing of genes established a blueprint for successful evolution, and different versions of it are used by all living things today.

Humans engage in massive horizontal gene transfer when they reproduce, giving their offspring half of their genes. Bacteria swap genes as a means of attaining new properties such as antibiotic resistance.

Nature apparently found cooperation so important for the success of evolution that it seems to have incorporated it in the brain's reward center. The reward center is designed to make a person feel good when doing something that enhances survival, such as sex and eating.

Other things will trigger the reward center as well, such as addictive compounds.

"We are the way we are because of everything that's happened on this planet," said Emory University neuroscientist Gregory Berns. "It's not far-fetched to believe that cooperative strategies evolved into us and that they might confer survival value both individually and for groups of people."

Using MRI scans to image brain functions, Berns and his colleagues found that the reward centers of women who cooperated in a task lit up compared with women who chose not to cooperate.

For the women who cooperated, it wasn't winning that activated their reward system but the act of taking the risk of being cooperative and then having another person cooperate in return, he said.

"Everything that we're observing biologically is a result either of something that's programmed into us genetically or how we develop in our society," he said.

Complementary organisms

"No man is an island," John Donne noted some 400 years ago, an observation that has been made time and again by modern scientists who are finding that the more successful organisms are, the more they live as cooperative communities.

"That's the name of the game," Olsen said. "What you find are communities that are mutually complementary. It's not because they want to be nice guys. It's just that that's what succeeds. In that environment different organisms are harvesting different resources and in their own way contributing other factors back to other members of the community."

Even viruses still follow the old blueprint of transferring genes across species. Viruses can incorporate their genes--some of which may be beneficial--into human genomes, performing the duties of early prelife forms. Woese believes that viruses may be failed relics of that early prelife jamboree.

"There were a number of other cell designs that never made it to the modern world," he said. "They somehow died out or else they turned themselves into other entities like viruses."

This pattern of great overproduction of organisms followed by the extinction of most has since been repeated. More than 3 billion years after life first formed, the Earth experienced another great effusion of living things. During the Cambrian explosion, untold numbers of different body shapes were created, only to vanish.

Each of the three founding cell forms survived because their borrowed genes enabled them to adapt to changing environments. They then evolved along separate paths.

All living things still retain some common starter genes, such as those used to translate DNA into proteins, a recent finding that Woese says bolsters the theory of widespread gene swapping early on.

"Genomics allows one to think of evolutionary problems that occurred much further back in time than was the case in the Darwinian era when we were dealing with whole organisms," Woese said. "Now we're dealing with sequences of genes, none of which was possible until recently. You can see in great detail how they are different and how they are similar."

Beyond Darwin's doctrine

"We cannot expect to explain cellular evolution if we stay locked in the classical Darwinian mode of thinking. The time has come for biology to go beyond the Doctrine of Common Descent."

Darwin's doctrine postulates that all living things eventually can be traced to a single founding cell. This notion creates the hurdle of trying to explain how all the genetic building blocks for life managed to come together in one place at the same time to form the first founding parent, a feat that many scientists argue defies the odds.

The massive gene transfer hypothesis, on the other hand, makes it much more plausible that the basic ingredients for life came together many times in many places. Innumerable protocells were formed, and from these prelife cells modern cells emerged independently three times. They had borrowed enough genes from a common pool of genes to become alive and survive through the ages.

"This seems a reasonable path, simpler and more likely than just everything miraculously coming together," Olsen said. "In terms of fitting into the big picture, this is providing stepping stones from earlier and earlier stages of how we got to the modern cell."

Although a lot of the detail is missing, the process is thought to start with raw chemicals abundant on the early Earth, doing what they do best--combining to form more complex molecules in warm ponds. Some of the combinations were primitive genes that could make copies of themselves and also make the proteins that form cellular structures.

Each of these cell types found its niche. Animals and plants populated the oceans and the Earth's surface, and bacteria thrive almost everywhere, even miles below the surface. Archaea took what was left, the most inhospitable environments such as those around boiling deep thermal vents on the ocean floors, in acidic pools and in oxygenless nooks, like the human gut.

Cooperation has been fabulously successful. Bacteria, plants and animals have become the major shapers of the Earth's environment.

Bacteria and archaea exert the greatest influence because there are a thousand billion, billion, billion of them, said Georgia's Whitman. They go back about 4 billion years, while eukaryotes like animals only began to proliferate 1 to 1.5 billion years ago.

"The world we live in today is largely produced by biological processes," Whitman said.

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