Viewing life as cooperation

Can symbiosis and genome acquisition account for all speciation?

Acquiring Genomes: A Theory of the Origin of Species
by Lynn Margulis & Dorion Sagan
Basic Books: 2002. 256 pp. $28, £16.95

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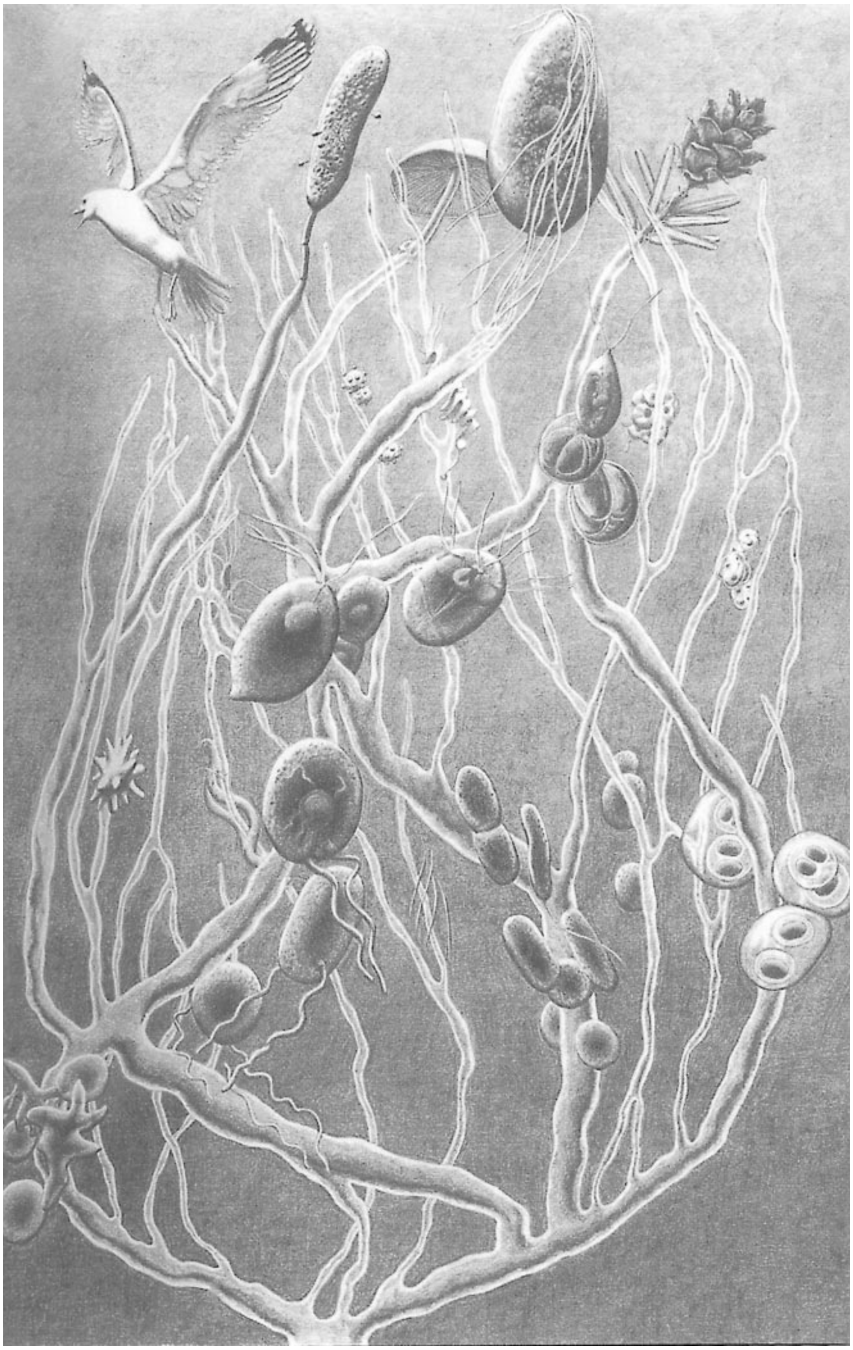

CHRISTIE LYONS

Life changing: widespread genome acquisition would radically affect our view of the tree of life.

Linus Pauling is reported to have said that one needs to have many ideas to have a few good ones. Lynn Margulis has had many ideas, some of the most heretical of which were initially thought to be plainly wrong. Some of them turned out to be brilliant insights that changed current thinking on the early history of life and the origin of the eukaryotic cell. After long battles, Margulis convinced biologists that eukaryotes originated through the fusion long ago of an archaebacterium with some eubacteria. It is also now well accepted that mitochondria and the chloroplasts of plants were once independently living prokaryotes. We also know that corals, lichens and cows, as well as many other familiar life-forms, are the products of integrating symbionts.

Many less-familiar species in the microbiological world took symbiosis events to the next level of integration: true genomic unions. These cannot be broken up again and have to follow joint evolutionary trajectories. Furthermore, it is well established that, early in the history of life, combination of genomes or portions of genomes took place through lateral gene transfers. As a result, establishing the 'tree of life' through DNA sequences is all the more challenging.

In *Acquiring Genomes*, Lynn Margulis and Dorion Sagan apply their ideas of a symbiotic origin of life to a theory that all speciation is not due to random events and accepted neodarwinian processes, such as mutations and natural selection acting through competition and sexual selection on variants among members of one species. Rather, they argue that all speciation events are caused by symbioses, cooperation and the reticulation of genomes, questioning some of Charles Darwin's central ideas. In their view, Darwin was wrong to emphasize competition and selection as the sole forces shaping the origin of species; they postulate instead that cooperation and symbiosis drive evolution.

I think it is a remarkable tribute to Darwin that almost 150 years after his *Origin of Species* was published, it is still seen as the benchmark against which many authors are compared. It attests to the profundity of Darwin's insights that new ideas are still pitted against his words from two centuries ago. What other scientific discipline can look back at the work of a single individual whose main work was published so long ago and yet is still vigorously debated today? Why should one even expect that Darwin could have been correct all the time? Of course, genes, genomes and any form of molecular biological knowledge were unknown to Darwin; how then could his ideas even begin to explain all that we know about evolution today?

In this age of genomics we are forced to re-evaluate some of his ideas in light of the new data on the genetic variation and conservation among individuals, species, phyla and kingdoms. However, I believe that Margulis and Sagan are wrong to postulate that speciation is driven by symbiogenesis (defined as long-term stable symbiosis that leads to evolutionary change), rather than by the time-honoured processes that have been amply documented since Darwin's day. Surely, symbiosis was important in evolution, and possibly in some instances of speciation, but these events only account for some of the exceptions to the rule.

Margulis and Sagan go so far as to define species as sets of individuals that are composed of the same set of integrated genomes. They argue that species are unique products of symbiogenesis, and postulate that "no visible organism or group of organisms is descended from a single common ancestor". Consequently, because no bacteria (either eubacteria or archaebacteria) evolved from the genomic integration of formerly independent bacteria, they must lack species altogether. The biological-species concept and several alternatives have difficulty in defining species among bacteria or unisexual species, but most researchers would not doubt that bacteria have independent evolutionary lineages that are justly considered to be species. Margulis and Sagan also argue that the primary level of selection is not the gene, the individual or the species, but rather the cell.

In his foreword to the book, Ernst Mayr, while supporting the general message that genomes have been acquired, warns of trying to stretch a good idea too far. He cautions that the authors "sometimes arrive at interpretations others of us find arguable" and says: "let the readers ignore those [ideas] that are clearly in conflict with the findings of modern biology." Mayr is pleased that Margulis and Sagan counteract reductionist tendencies in modern biology, which focus exclusively on the level of the gene, by pointing out that some organelles (such as mitochondria and chloroplasts) were once a different species of bacteria. As a result, they argue, the organism as a whole needs to be considered in attempts to understand how it came into being, and how it is functioning now.

It is my conviction that the history of a species and each of its members is laid down in its genome, allowing us, at least in theory, to reconstruct its entire evolutionary lineage. Despite such complicating phenomena as horizontal gene transfer, transposable elements and viral integration of genes, we can generally read from a species' genome how, when and from what a species evolved. Admittedly, things are more messy nearer the bottom of the tree of life, where evolutionary lineages crossed and fused probably on a larger scale than today. The events emphasized by Margulis and Sagan are probably occasional yet important cases of massive reticulate evolution, but today the expected vertical rather than horizontal mode of evolution prevails.

The authors try with admirable single-mindedness to convince the reader that their idea of symbiogenesis applies to most biological phenomena. Some of their fervour is surely overzealous; despite this, or perhaps because of it, *Acquiring Genomes* is one of the most stimulating and provocative books that I have read for a long while. ■

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Unravelling a heavenly mystery

The Biggest Bangs: The Mystery of Gamma-Ray Bursts, The Most Violent Explosions in the Universe
by Jonathan I. Katz
Oxford University Press: 2002. 218 pp. £14.99, $28

Flash! The Hunt for the Biggest Explosions in the Universe
by Govert Schilling, translated from Dutch by Naomi Greenberg-Slovin
Cambridge University Press: 2002. 320 pp. £18.95, $28

Luigi Piro

In with a bang: the explosion of a massive star led to the formation of the Crab Nebula.

The revolution that has transformed γ-ray bursts (GRBs) from an obscure riddle into one of the hottest topics in astrophysics is only a few years old. Discovered in the late 1960s, GRBs are intense flashes of γ-rays that appear suddenly in the sky, about once a day, from random and unpredictable directions. They typically last for a few seconds and then vanish below the detection threshold of γ-ray instruments. The limited ability of these detectors to identify exactly where in the sky the bursts were occurring meant that it was not until 1997 that GRBs were linked to events occurring at any other wavelengths and their distance scale was calculated.

Measurements made by the Burst and Transient Source Experiment (BATSE) onboard the Compton Gamma-Ray Observatory, launched in 1991, showed that GRBs were scattered across the sky, with no significant clustering in any direction. This suggested only two plausible explanations: that GRBs were produced by a previously unknown population of neutron stars in the halo of our Galaxy (a galactic origin) or that they were a result of extremely powerful stellar explosions in distant galaxies (a cosmological origin).

The launch of the Italian–Dutch BeppoSAX satellite in 1996 opened a new window on space. Its instruments and ground operations were able to deliver fast, precise positions of GRBs and, by rapidly reorienting the satellite, it was possible to search for any faint post-burst X-ray afterglows using a set of highly sensitive X-ray telescopes. On 28 February 1997, the first X-ray afterglow was detected, a faint, fading source marking the location of the GRB that had occurred eight hours previously. This and later detections of afterglows at optical and radio wavelengths enabled researchers to conclude that GRBs originate in galaxies that are billions of light years away from Earth, at distances similar to those of the most distant quasars. The energy output inferred from the intensity observed at Earth is 10^{51}–10^{54} erg, making GRBs the brightest sources in the Universe. In the past few years, the study of afterglows has provided evidence that GRBs are associated with star-forming regions and possibly with supernovae. We now know that GRBs and their afterglow emission are produced by a relativistic expanding fireball — a cauldron of γ-rays, electron–positron pairs and protons in which matter is blown away at almost the speed of light by the enormous energy released in the initial explosion. And investigations are currently under way to discover the central source of the explosion and its progenitors.

The Biggest Bangs by Jonathan Katz and *Flash!* by Govert Schilling are popular-science books that tell the story of the investigation into GRBs. Both introduce the reader to the theory and observations of these objects in layman's language, giving an inside view of how scientists set about unravelling the mystery of GRBs. And they show clearly how a scientific revolution is never the result of a simple linear progress of theory and observations — it is always