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BOOK REVIEW

One Plus One Equals One: Symbiosis and The Evolution of Complex Life. J. Archibald. 2014. (2016 PB). Oxford University Press, Oxford, UK. 208 pp.

The Nova Scotian Institute of Science has amongst its members retired academics and government scientists, as well as those from many other walks of life with an interest in natural history and science. They have in common with high school and college students the experience of coming day to day with phrases and words such as molecular biology, molecular clocks, genetic engineering, genomes, genetic code, DNA and RNA. As well, there are terms like prokaryotes, eukaryotes, Archaea, symbiosis and endosymbiosis. Many of the older age group went to college before these became part of current vocabulary, while students with their limited focus on internet information tend to have a view that is far too narrow.

This book on symbiosis by John Archibald of Dalhousie University, also one of our NSIS speakers, provides a readable and well explained tutorial for all. The author provides on the one hand a glimpse into the historical context and, on the other, a look at impact of the latest discoveries. He weaves a narrative in fascinating details about the scientists who have made key contributions. The book is illustrated by 11 informative figures/diagrams, several of which would have been more easily understood had they used a whole page.

The book first summarizes what is known about cell structure in eukaryotes and prokaryotes and the genetic code. In the chapter "The Seeds of Symbiosis", we learn how it came to be realised that the organelles mitochondria and chloroplasts, whose ancestors were once free living microbes, became components of animal and plant cells. It seems that this was a result of being ingested but not digested by a host cell via endosymbiosis. This very ancient incorporation of cells is paralleled by more recent associations of a less intimate nature. For these, like the association of algae and fungi in lichens, we use the term 'Symbiosis', first used in a biological context by De Bary in 1878*. The eventual acceptance of the process of endosymbiosis, and the key role that it played in the evolution of eukaryotic organisms, only became recognized in the decades following the publication in 1970 by Lynn Margulis of 'The Evolution of the Eukaryotic Cell'.

Details of the follow up studies are presented and of the scientists who carried out research to test the hypothesis that endosymbiosis was really involved in the evolution of eukaryotic cells, i.e., in the evolution of all higher plant and animal cells. Part of this account includes a summary of the research carried out by Ford Doolittle and his associates at Dalhousie University. Other information came from studies on an anaerobic microbe isolated from a pond in which an elephant carcass had been dumped to decompose behind the Natural History Museum at Oxford University!

As everyone knows from grade 12 biology or first year university, the eukaryotic cell as we see it under the electron microscope is complex and as far as we know, the organisms that bridge the gap between these cells and prokaryotic cells have long gone extinct. However, the likely steps and evidence from both biology and atmospheric sciences are assembled in the book to argue a key role for endosymbiosis. A wide range of organisms are considered including odd parasites such as those found in the urogenital tracts of cats, cows and humans. In the end, the conclusion is that without the evolution of mitochondria, it is inconceivable that complex multicellular organisms like ourselves would exist today.

A chapter on the 'Green revolution' explains how the structure and function of chloroplasts are related to that 'all important' process of photosynthesis. This captures solar energy to produce sugars and release oxygen, the gas we all breath. This was dependent on the establishment of an endosymbiosis between cyanobacteria and a eukaryotic cell and genes were moved to the nuclei of the latter. The overall picture has been elucidated by molecular sequencing of the DNA and RNA in the nuclei and the chloroplasts of plant cells. However, there is biodiversity and evidence that some non photosynthetic eukaryotes, in the past, ingested but not digested whole photosynthetic eukaryotes. These evolved into the red algae, the largest of which we call the red seaweeds. Other fascinating examples of secondary endosymbioses are described, as found in the single-celled flagellate, *Euglena*. These reveal that chloroplasts are organelles that were derived from a single endosymbiotic event that occurred millions of years ago. This was part of a chain of events that 'led to the transformation of the ocean land and atmosphere'.

The penultimate chapter, 'Back to the Future', discusses a series of odd-ball organisms such as *Paulinella* and *Rhopalodi*a; these appear to have captured a photosynthetic cyanobacterium much more recently and which is in the process of becoming integrated with the host, suggesting what may have happened in the case of chloroplasts. Examples are also mentioned of organisms that steal chloroplasts and keep them functional for a period, like sea slugs, and organisms which acquire microbial endosymbionts, such as sap-sucking insects.

The final chapter, 'Epilogue', touches on advances in genetic engineering, the use of microbes like E. coli, and the achieved benefits. But there are problems. In the microbial world, genes are 'coming and going all the time' and 'the emergence of multidrug resistant bacteria by gene exchange concerns us all'. In a final postscript, two recently discovered and strange organisms are noted. One is from a hydrothermal vent in the deep ocean and another, *Monocercomonoides* has eukaryotic characteristics but apparently no trace of mitochondria. This emphasizes the fact that there is still much research to do, especially on deep-sea organisms and much to be learned about the prokaryote to eukaryote transition, the very key to our own existence.

This is a fascinating book and well-worth reading by anyone interested in our biological world.

Note: Within the last couple of years English translations of early pioneering research on Symbiosis by German Scientists have been published and make fascinating reading.

REFERENCES

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