PERSPECTIVE

An evolutionary biology paradigm shift brought about by the evolution of viruses and microbes?

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ABSTRACT

The primary, if not the only, objects of evolutionary biology were multicellular eukaryotes, primarily animals and plants, when Charles Darwin formulated the fundamental ideas of evolutionary biology in The Origin of Species, and the architects of the Modern Synthesis integrated these ideas with population genetics almost a century later. All attempts to apply evolutionary studies to bacteria had been fruitless prior to the development of effective genome sequencing. The development of the three-domain "ribosomalttree of life," which was widely believed to have clarified the evolutionary links between the cellular life forms, was made possible by the sequencing of the rRNA genes in thousands of microorganisms. The most fundamental of these are pervasive Horizontal Gene Transfer (HGT), which shapes the genomes of bacteria and archaea and requires a radical revision (if not abandonment) of the Tree of Life concept; Lamarckian-type inheritance, which appears to be crucial for antivirusddefense; and other types of adversity. Phylogenomics and metagenomics of virusesaand theirtheird associated selfish genetic elements in the non-cellular portion of the microbial world have shown vast genetic and molecular diversity as well as an extraordinarily high abundance of viruses, which appear to be the dominant biological entities on earth. Furthermore, one of the key characteristics of evolution is the ongoing competition between viruses and their hosts. Thus, even while Darwin's discovery of the principle of descent with modification and the principles of population genetics remain at the foundation of evolutionary biology, microbial phylogenomics expands on the basic picture of evolution.

Key Words: *Multicellular Eukaryotes; Phylogenomics; Metagenomics; Lamarckian; Horizontal Gene Transfer*

INTRODUCTION

The first convincing, in-depth account of biological evolution was provided by Charles Darwin's On the Origin of Species, which was published in London in 1859. This followed the simultaneous and independent brief summaries by Darwin and Alfred Russell Wallace that had been released the year before. The French botanist and zoologist Jean-Baptiste Lamarck published his monumental work Philosophie Zoologique exactly 50 years before the appearance of the Origin, outlining his conception of the history of life in great detail. Lamarck did not discover evolution, nor did he even provide the first coherent description of it. Lamarck's belief in the alleged inner motivation of living creatures toward "perfection," a manifestly illogical and unscientific notion, served as the cornerstone of his worldview.

Lamarck's understanding of the function of evolution in the history of life was also severely constrained. He rejected the idea that all living forms shared a common ancestor and instead believed that there were several acts of creation, maybe one for each species. The famous Roman philosopher Titus Lucretius Carus, in particular, offered foresightful theories on how organisms evolve centuries before Lamarck and Darwin.

However, it is still true that Darwin's first evolutionary synthesis was instrumental in establishing evolutionary biology in a manner resembling that of the contemporary era and has remained so for the past 150 years since "nothing in biology makes sense except in the light of evolution."

Darwin's theory lacked the necessary genetic underpinnings because, obviously, the mechanics of heredity were unknown in his day. Darwin was extremely concerned about the "Jenkin nightmare," an argument against his theory that suggested positive alterations would be "diluted" over numerous generations in the offspring of the creatures in which they originated. Following the rediscovery of Mendel's laws, population genetics developed in the first third of the 20th century, largely thanks to the ground-breaking work of Fisher, Wright, and Haldane. This work laid the foundation for the genetic basis of evolution.

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The Modern Synthesis of Evolutionary Biology, which is typically linked to the names of Dobzhansky, Julius Huxley, Mayr, and Simpson, solidified the new, expanded understanding of evolution, which was guided by theoretical and practical work in genetics. It appears that the Modern Synthesis came into its own at the Chicago Origin Centennial Celebration in 1959.

Evolutionary biology clearly faces a new, significant challenge 50 years after the Modern Synthesis was consolidated, but there is also hope for a new conceptual breakthrough.

The New Stage is Evolutionary Biology in the Light of Genomics and Microbiology if the Modern Synthesis may be summed up as Darwinism in the Light of Genetics (commonly referred to as neodarwinism). In the beginning of this new era of evolutionary biology, the coupling of genomes and microbiology is crucial. The existence of genomes and microorganisms was obviously unknown to Lamarck, Darwin, and even Lucretius. The Modern Synthesis' creators were aware of microbes and genomes "in principle," but in the former case they were only aware of formal genetics, which is significant but restricted, and in the latter case they were completely unaware of the significance of bacteria for understanding evolution. In this article, we try to summarise the most significant changes to the fundamental principles of evolutionary biology brought about primarily by comparative and functional microbial genomics and make the case that, in many ways, the genomic stage may represent a more radical departure from the Modern Synthesis than the latter was from traditional Darwinian concepts.