k24 The origin of eukaryotes < cell nucleus, mitochondria, chloroplasts >

Why me? Why now? —Nancy Kerrigan.[1]

Superkingdom Eukaryota includes all organisms (animals, fungi, plants, and protoctists) with cells containing membrane-bound organelles. What advantage do eukaryotes enjoy? We multi-celled conscious ones can smugly say our awareness. But what of others? Multi-celled plants appeared in the Silurian and multi-celled animals arose in the Late Proterozoic. Fungi were then too. Single celled plants, animals, and protoctists have been in abundance since the Early Proterozoic. But, exactly when eukaryotes originated per se is open to interpretation as, except for size, crucial differences in cell structure between eukaryotes and no-nucleus microbes are not preserved during fossilization. The billion year old Bitter Springs Formation microfossil *Glenobotrydion* is about 5 micrometers across and has what appears to be a nucleus. That these (as W. Schopf at first opined) are green algae (eukaryotic life) is lessened by a new consensus that the "nucleus" is the product of shrinkage of the cell contents. However, other spherical fossils of likely algal protists (the acritarchs) did exist 1.8 Ga.

Eukaryotes are capable of sexual reproduction. This has value in speeding the spread of variation within a species. But could this and the frisson of sex in higher animals be enough? Specialization that so makes a eukaryotic species "fit" has as a downside: the complexity of finding a mate in a changing ecology exacerbated by a heedless environment. This can lead to extinction. Bacteria and archaea without a nucleus or organelles (and incapable of true sexual reproduction) have always enjoyed greater numbers (each is 1000 times smaller than the volume of an average eukaryotic cell) are ecological generalists in environments that are always somewhere in that these can range in temperature from freezing to near incineration, from anaerobic to aerobic, from acidic to caustic. In fact bacteria and archaea are so successful that in their midst and their wastes, how can a eukaryote survive? The answer appears to be that eukaryotes are muddled together prior microbes that by mutualism do manage and evolve sophistications denied any true-to-itself cloning micobial solitaire.

Eukaryotes have intracellular organelles. That is, within a cell's cytoplasm are membraned bodies or structures, called *organelles*, that in their plan and function are distinct enough to be named but have no fixed locus. "Complete eukaryotes" have at a minimum the organelles: one nucleus, mitochondria,[2] endoplasmic reticulam,[3] gogli apparatus,[4] vacuoles and, typical of animals: two centrioles, and distinguishing plants: plastids and chloroplasts. Each organelle has special function in the orchestrated whole. Two examples: 1) Gunter Blobel in the 1970s noted that a protein in its construction moves through a compartment of the ribbon-like endoplasmic reticulum, is slightly larger than the same which do not. That extra size is code used by the endoplasmic reticulum, which removes it, to fine tune and place the protein on a path to a specific tissue building destination and role via the gogli apparatus which processes and packages proteins for export from the cell. 2) In eukaryotes, mitochondria generate energy by aerobic respiration.

Organisms that are capable of independent metabolism and reproduction are symbionts (***Footnote k24.1***) if they cannot live independent of each other. An undisputed example is lichen (symbiotic fungi and algae). Around the turn of the 18th century, Constantin Sergeevich Merezhkowsky (1855-1921) and Andrei Sergieevich Famintsyn (1835-1918)[5] separately concluded from their studies of botany that major evolutionary advances can be by symbiosis.[6] Their (correct) claim (published in Russian) that mitochondria originated as bacteria, remained widely unknown. In the west, Ivan Emmanuel Wallin (1883-1969), independently found for the same possibility. His startling discovery was that when eukaryote plant-cells divide, not only does the chromosomal content of the nucleus replicated but plastids and mitochondria also self-replicate.[7] This was demonstrated by removing plastids (and proplastids) from single-celled organisms like *Euglena*. Thereafter, the altered cell (which can survive heterotrophically) and its asexually produced descendants have no chloroplasts.

Apparently the genetic code to rebuild these structures is not present in nuclear chromosomes. But such a cell can be surgically reinfected with chloroplasts, and the new chloroplasts will divide and perpetuate themselves. Even if the reintroduced chloroplasts are abnormal (to the extreme that they do not replicate) the host cell subdivides normally. Wallin generalized his findings in *Symbionticism and the Origin of Species*, 1927. In this he claimed that the major components of cells have arisen through symbiosis; specifically bacterial symbionts. In 2001, was the first proof of one bacterium living inside of another living bacterium (the two-bacterial species live in the gut of the citrus mealybug).[8]

Lynn Margulis who "personally represents 250 million extant species of nonhuman mute microorganisms and their large descendants, many of which have remarkable fossil records: the protoctists."[11]

No priority squabble for symbiogenesis as an explanation for the origin of eukaryotes ensued. The word was in the air in 1909 when Constantin Merezhkowsky (1855-1921) used it in making his claim that in plant cells the little green dots, which make sugar in the presence of sunlight, were originally separate organisms. However, the biological community at large deemed the concept maverick (or more so the scandal of M's conduct)[9] and its pursuit inimical to tenure. Thus, in 1967, it was a brave **Lynn Sagan (Margulis)** who in *On the origin of mitosing cells* reproposed the hypothesis (***Figure k24.1***).[10] In her view, the separation of the genetic nucleus and some of the organelles within the cytoplasm of eukaryotes are evolved features and some of the organelles are additions that were recruited symbiotically. The possibility exists that the first protocyst was animal-like (because it incorporated bacteria) and later some of these became plant-like when they incorporated cyanophytes. This marvelous recapitulation leap-frogged neo-Darwinists, who would explain all by gradual evolution through natural selection of random mutation in DNA, and reinvigorated our understanding of the workings of nature.

Today, Margulis and others can write (and expect little dissent)[12] that: "Mergers of symbionts lead to large, functional evolutionary jumps: new organs, or major new groups of organisms, such as lichens." So the lie is given to the venerable: "*Natura non facit saltum*," and little surprise now that humans as genetic engineers play at G.O.D. (the Generation of Diversity) by purposefully creating transgenic organisms such as: Wheat with genes from maize; Tomatoes with a flounder gene that protects against freezing; Pigs with rat genes to increase their reproductive capacity, with saliva enzyme to digest phosphorus in phytate;[13] Salmon genetically modified to grow quickly to 40 times their normal weight; and, Cows with a human gene (that was transferred to a bull to see if next-generation of cows produce human milk proteins). About 10 percent (1000-2000) of our genes have coding which indicates that they were acquired by symbiosis and not by nonsymbiotic increases by evolution of initial of our genes in existence some 3.3 billion years ago.[14]

Margulis also reveals that symbiogenesis *is* Lamarckian. For example, when a fungi absorbs a photosynthetic algae that proliferates in its transparent flesh as a symbiote, it posses the capacity to use light to synthesize food. New for the fungi, this acquired characteristic can be passed on to its descendants. Genomes are shaped, in addition to natural selection, by hybridizations *and* symbioses.[15] Margulis and Carl Sagan in1986 could write uncontroversially that "Life did not take over the globe [solely] by combat [i.e. Darwinian evolution driven by competition], but by networking [i.e. by co-operation, interaction, and mutual dependence among organisms]."[16] The human as a symbiotic system[17] is composed of about 90% bacteria and but 10% eukaryotes, and a random shotgun sequencing of the human metagenome with its trillions of colonizing microbes would result in predominantly bacterial genome readouts of about 2 million genes with sporadic mammalian genes.[18]

Most startling is the realization that when you look at yourself in the mirror, what you see is a community of once unrelated individuals staring back at you. Your cells are composed of these. ❑