Jen Johnson BIOL 310 HW1

Eukaryotes evolved nuclear membranes because they provide evolutionary advantages. Nuclear membranes provide protection for genetic material, allowed for the development of specialized functions in the unicellular organism, and led to the further diversification of species. These factors not only increased the fitness of a single microbial species, but also of the eukaryotic domain.

The development of the nuclear membrane protected DNA. Before the development of the nuclear membrane, prokaryotes underwent a period of “radical innovation.” (1) Species were trying different methods to gain the evolutionary advantage in the oxygenated and competitive conditions at the time. One successful method was the invagination of the plasma membrane into the cell to form a compartment. In the early stages of nuclear membrane development, there was selection for proteins that “stabilized and mechanically reinforced the structure of infolded membranes.” (2) Like plasma membranes, nuclear membranes are selectively permeable. (3) Therefore, they prevent unnecessary and destabilizing access to DNA. They prevent the bacterial equivalent of DNA replication enzymes from accessing DNA when the cell is not at the correct life cycle stage. This prevented DNA replication from occurring at the wrong time, conserving energy for the organism and therefore increasing its fitness.

Nuclear membranes also help prevent replication errors on a larger scale. Early eukaryotes divided by binary fission. The bacterial “motor” proteins that separate the centromeres of plasmids during this process are highly conserved in prokaryotes, which suggest that they are essential to successful replication. (2) Therefore, their function needed to evolve along with the development of the nuclear membrane. Therefore, nuclear membranes needed to anchor and stabilize DNA within the cell, as well as promote successful chromosome segregation. Wilson and Dawson suggest that the “evolution of nuclear structure was tightly coupled to genome partitioning during mitosis.” (2) Nuclear membranes increased the fitness of organisms because they protected the genetic material while keeping the ability to properly partition DNA, which is essential to the success of replication.

The protection provided by the nuclear membrane also allowed for the diversification of functions within cells. The development of organelles increased the efficiency of eukaryotes because they provided a separation of different processes in the cell. (3) This allowed for more specialized enzymes because of the “greater control over surface composition and complexity.” (1) This separation allowed more efficient reactions because enzymes could work under optimal conditions, instead of being restricted to working under conditions that do not degrade genetic material. The last common eukaryotic ancestor is said to have contained the “basic complement of membrane-trafficking organelles” such as lysosomes. (1) Lysosomes break down materials into usable monomers. This function would have never been evolutionarily favored since the risk of damaging genetic material would have been too high. However, the nuclear membrane allowed this function because it provided a protective layer for the genetic material from lysozymes. Lysosomes and other specialized functions increased the efficiency of the cell, which increased its fitness.

Because of the many competitive advantages of the nuclear membrane, this trait spread to many species through horizontal gene transfer. Nucleoporins, or the adhesive proteins that assist in membrane folding, show “structural conservation across the entire eukaryotic spectrum,” and provide evidence of the spreading of this trait. (3) For follower species, the genes that coded for alternative methods to gain the evolutionary advantage were no longer necessary. This space could potentially be filled with other genes, which increased the capacity of genetic material. Mutations could occur in these regions without impacting the fitness of the organism. This “allowed for the accumulation of sequence variation” (1) , the eventual acquisition of functions, increased fitness, and further diversification.

It has been seen that the nuclear membrane’s protection increases fitness by decreasing replication errors in terms of access to DNA by the correct enzymes and the segregation of chromosomes. The resulting diversification allowed for more efficient organisms. However, the first eukaryotes lacked nuclear morphology. (2) This suggests that while the nuclear membrane provides evolutionary advantages, there are many ways that organisms can survive without it. This could explain why prokaryotes, a diverse group of organisms, can survive without a nuclear membrane, and instead using their own methods.

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I have neither given nor received unauthorized aid on this assignment. Jennifer Johnson