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 a 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 its development, prokaryotes were going through a period of “radical innovation.” (1) Species were trying different methods to gain the evolutionary advantage in the competitive conditions at the time. One successful method was the infolding 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 homologue of DNA replication enzymes from accessing DNA and its origin of replication when the cell is not at the correct stage of its life cycle. This prevents 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 circular chromosomes during this process are highly conserved in prokaryotes, which suggest that they are essential to successful replication. (2) Therefore, this function evolved along with the development of the nuclear membrane. Therefore, nuclear membranes needed to allow successful chromosome segregation by dissolving during separation as well as to anchor and stabilize DNA with a selectively permeable barrier. 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 retaining 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 separated 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 by 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 because of the risk of damaging genetic material. However, the nuclear membrane provided a protective layer for the genetic material from lysozymes and hydrolysis. 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 via horizontal gene transfer. Nucleoporins, or the adhesive proteins that assist in membrane folding, show “structural conservation across the entire eukaryotic spectrum,” and are highly suggestive of the widespread sharing of this trait. (3) For species that received the genes for nuclear membranes and nucleoporins, 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 noncoding 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. Diversification was beneficial to all species in the domain because it allowed for coexistence of species of species in many different niches with less competition.

The nuclear membrane’s protection increases fitness by decreasing replication errors. 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 with a wide range of optimal conditions, can survive without a nuclear membrane, and instead survive using their own methods.

1. Dacks JB, Field MC. 2007. Evolution of the eukaryotic membrane-trafficking system: origin, tempo and mode. J Cell Sci 120:2977–2985.

2. Wilson KL, Dawson SC. 2011. Functional evolution of nuclear structure. J Cell Biol 195:171–181.

3. Knockenhauer KE, Schwartz TU. 2016. The Nuclear Pore Complex as a Flexible and Dynamic Gate. Cell 164:1162–1171.

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