Similarities between mitochondria and bacteria biology essay

Bacteria are believed to be among the oldest cells on Earth, fossils indicate bacteria-like organisms were around almost 3. 5 billion years ago. They are unicellular micro-organisms that lack a membrane bound nucleus and contain no organelles. Many people consider them to be the cause of many diseases, which they are, but the human body contains trillions of bacteria, aiding processes such as digestion and growth. Mitochondria on the other hand are organelles found in the majority of eukaryotic cells, they produce energy in the form of adenosine triphosphate (ATP). What could these organelles found in eukaryotes have in common with bacteria, which are prokaryotes? Hopefully this essay will address that question and attempt to answer it. To achieve this in the first section of this essay I will consider the structural similarities between them both. I will then go on to compare the functional similarities in the second section of this essay which will then be followed by a section outlining and explaining the endosymbiotic theory which should help to clarify the previous sections. Finally I will summarise the similarities between mitochondria and bacteria and the causes of these similarities and the validity of the theory explaining them.

Structure

At first glance bacteria and mitochondria look to have a very different internal structure and can also have a radically different external shape, but inside they do share some similarities. The internal structure of bacteria is very simple, it contains no membrane bound organelles, but instead it contains a nucleoid which is the central part of the cell and it is where the DNA is generally confined to. Ribosomes are present in the cytoplasm of the bacteria as well as storage granules. All bacteria have a plasma membrane, most also have a cell wall and while some have a capsule, others do not (1). Some bacteria also have flagella which are tiny whip-like structures often located at one end of the cell. Although they vary in size greatly, common bacteria such as Escherichia coli are about 2µm in length, when comparing this to mitochondria they are very similar in length but like bacteria, the shapes and sizes of mitochondria vary significantly depending on what species or cell they are found in (2).

Mitochondria are located in the cytoplasm of both animal and plant cells; they are cylindrical structures that consist of an outer membrane, inner membrane and matrix. Like bacteria, mitochondria also have their own circular DNA genome which is separate from the nucleus of the cell which is located in the matrix. The membrane of the mitochondria is also very similar to the membrane found around the bacteria; it is double layered and is made up from lipids, just like a prokaryotes membrane. This is interesting as it shows no similarities with a eukaryotic cell’s cytoplasm, but instead it is very similar to the composition of a bacterial membrane. The inner folds of the mitochondrial membrane, cristae, are very similar to mesosomes found in bacteria. Mitochondria also contain ribosomes similar to those found in bacteria; this will be explained further in the next section.

Function

The main function of bacteria, like any organism, is to reproduce, and while mitochondria’s main function is to produce energy in the form of ATP it also needs to reproduce. Mitochondria are formed by a process very similar to binary fission, the method by which bacteria divide. When a bacterium reaches a certain size, it splits down the middle to create two organisms. In a mitochondrion the nucleus signals the cell to produce more organelles, but only the mitochondria actually replicate themselves while other organelles have to be made up from substances present within the cell. There is an electron transport chain found in both the plasma membrane around a prokaryote as well as in the membrane around the mitochondria but it is absent in membrane of eukaryotic cells.

Proteins are required in a cell to perform all functions and all synthesis of these proteins takes place in ribosome; these ribosomes are present throughout the cell but mitochondria have their own ribosomes to produce the proteins they need. Chemical and microscopic analysis shows how the structures of mitochondrial and bacterial ribosomes share more similarities with each other than with ribosomes in eukaryotic cells. Ribosomes found in the cytoplasm of eukaryotic cells are 80S in size while ribosomes found in bacteria and mitochondria are 70S in size (3). One experiment carried out by Margulis showed that the protein synthesis of both mitochondria and bacteria are sensitive to erythromycin and chloramphenicol and insensitive to cyclohexamide and emetine whilst cytoribosomal protein synthesis is insensitive to erythromycin and chloramphenicol and is usually sensitive to cyclohexamide and emetine, suggesting that mitochondrial ribosomes are different from those found in the cytoplasm of eukaryotic cells, and are similar to those found in bacteria. This experiment among other structural and functional similarities lead to Margulis to formulate the theory of endosymbiosis.

Endosymbiosis

The theory of endosymbiosis had been around before the evidence published by Lynn Margulis, but it was her work that made it a widely accepted theory among biologists. Included in her hypothesis was the thought that mitochondria are the result of endocytosis of aerobic bacteria. This would explain the similarities between mitochondria and bacteria, and why mitochondria differ from what would be expected from a typical eukaryotic organelle. The theory purposes that a proto-eukaryotic cell ingested an aerobic bacterium but it failed to digest it. The aerobic cell then thrived due to the cell’s cytoplasm being full of partially digested food molecules, and some of the ATP may have leaked into the cell’s cytoplasm. This occurred around a time where the concentration of oxygen in the atmosphere was increasing and aerobic respiration was advantageous to survive (3). An increase in ATP must have caused a growth advantage to the proto-eukaryote, enabling it to dominate over other cells that lacked cell walls and endosymbionts. The endosymbiont, originally the aerobic bacterium, eventually became dependent on the host for both protection and nutrients, meaning there was little need for genes involved in these processes. On the other hand, due to the endosymbiont only being permitted to remain if it continued to capture and store energy, there was a strong selective pressure to retain the genes involved in energy capture and storage. Eventually genes whose products were of no use to the host eroded and were ultimately lost. Finally as the genome reduction continued, the endosymbiont evolved into an energy-providing organelle. However, some more recent research suggests that the endosymbiont may have been an anaerobic bacterium with a fermentative metabolism (4). The bacterium that was originally engulfed is believed to have evolved into a mitochondrion that enabled the evolution of larger organisms.

The endosymbiotic theory is well supported, although there are many different variations of it there is strong evidence that suggests mitochondria did originate from bacteria. The similarities in the previous sections are all evidence pointing towards endosymbiosis and this theory explains why bacteria and mitochondria have much in common, and why the mitochondria’s function and structure often defies what would be expected from a eukaryotic organelle.

Conclusion

The similarities between bacteria and mitochondria are easy to see despite belonging to different domains. When a mitochondrion is looked at in detail there are obvious differences to a eukaryotic cell and other organelles present in the eukaryotic cytoplasm, the biggest of these is perhaps the presence of mitochondrial DNA, but there are similarities in many other aspects of a mitochondrion. Their primary functions may be different but bacteria and mitochondria still share process such as binary fission. All this evidence leads to the endosymbiotic theory which offers an explanation for these similarities, although many parts of it are still being debated. This theory allows us to understand how single cell organisms developed into the vast array of complex organisms that are present 3. 5 billion years after the first bacteria are thought to have existed.