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Biological and Pop Culture Relevance of an Intramitochondrial Lifestyle

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Introduction:

All bacteria live in environments that allow them to successfully live and reproduce. Some such as helicobacter pylori require the highly acidic environment of the stomach to live while others live in less extreme environments. A particular interesting case in living environments is in regards to the organism Candidatus Midichloria mitochondrii (hereafter M. mitochodrii). This bacteria has been discovered to colonize the mitochondria of certain tick species. In this paper, I plan to explore the organism itself and how evolution may have allowed such a lifestyle, the pop culture relevance surrounding this organism, and the potential advances to be gained from the study of such an organism

Mitochondria:

As one of the most important organelles in the eukaryotic cell, mitochondria are responsible for processes vital to the cell such as cellular respiration as well as the intrinsic pathway of apoptosis. Being an extremely conserved organelle, there is little variation in the structure or function between eukaryotic organisms. The widely accepted view of the origins of mitochondria are that they arose from a prokaryotic bacteria entering into a symbiotic relationship with an early eukaryotic cell. In this relationship, the prokaryote receives protection while giving the eukaryotic cell energy in the form of Adenosine Triphosphate (ATP). One of the biggest pieces of evidence to these claims that mitochondria possess their own DNA and means to replicate it during the S phase of the cell cycle. Since it is known that DNA contains the genetic material of the organism, it follows that mitochondria used to be its own organism before forming this symbiotic relationship which resulted in early eukaryotes. The intrinsic pathway of apoptosis is the mitochondrial process in which the cell ultimately dies. This could be due to a variety of stimulants and each results in the release of cytochrome c into the cytoplasm. Due to the importance of the processes mitochondria perform, it is a growing target for pathogens and researchers alike.

Discovery and Description of M. mitochondrii:

In 2006, examination of the oocytes of Ixodes ricinus (hereafter I. ricinus) showed there is an organism with the unique ability to live in not only the cytoplasm of a cell, but also inside the mitochondria. Its prevalence was 100% in females, but significantly less than males. This unique organism is classified as a Gram negative bacterium from the order Rickettsiales. Upon analysis of this organism's 16S rRNA and *gyrB* gene sequences, there were close relatives among the species in the order Rickettsiales which was where this organism was ultimately classified promptly after discovery (1). There is also evidence of M. mitochondrii existence in the salivary glands of I. ricinus and suggests the possibility of transmission to the vertebrate host during a blood meal (2). The extension of habitat beyond the oocytes to other specialized organs such as the salivary glands has been suggested to be evidence of a mutualistic

relationship. In such a relationship, M. mitochondrii is proposed to improve the overall fitness of its host (3).

While entry into the cytoplasm of a cell has been extensively researched, entry into the mitochondria has significantly less research associated with it. Due to the discovery of M. mitochondrii and its lifestyle in mitochondria, its research may prove useful for learning more about the interactions that take place on the outer membrane. Since this is a relatively new organism for study, its entry into mitochondria is not entirely known. In the genome of M. mitochondrii contains a sequence that is known to code for a flagellum. In electron micrographs showing this organism with an intact flagellum which leads us to believe the flagellum serves a purpose other than movement. It has been proposed that this flagellum is used to gain access into the cell and possibly the mitochondria. Two possible modes of entry into the mitochondria have been proposed. The first being that M. mitochondrii sheds its vesicle after entry into the cell and enters the intermembrane space without the use of a vesicle. The second theory is that this organism does not shed the vesicle after entry into the cell and uses it to gain entry into the mitochondria. (5.) Both are valid hypotheses, but more research is needed to learn which route is used for entry into the mitochondria.

Advantage of an Intramitochondrial lifestyle:

Living in the mitochondria of another organism in and of itself begs many questions such as “What led to this lifestyle?” and “What are the advantages to living there?” There is currently no evolutionary evidence for the origin of this lifestyle shown by M. mitochondrii, but there are three theories that have been proposed that may explain why an organism may evolve to colonize a mitochondria. This bacterium is able to avoid host immune systems by living in the mitochondria, living in the mitochondria allows this organism to use some of the energy in the form of ATP produced by the mitochondria for their own use, and living in the mitochondria allows for transovarial transmission. (5.)

Avoiding the host's immune system:

Since M. mitochondrii resides in the intermembrane space of mitochondria in oocytes, it has the unique ability to alter significant pathways for the cell. Specifically, the intrinsic pathway for apoptosis potentially can be slowed or halted. There is also evidence of M. mitochondrii blocks the release of mitochondrial DNA which is known to induce an innate immune response. This allows M. mitochondrii to evade the host’s immune system by blocking the process of apoptosis caused by immune cells interacting with the oocyte. Blocking or slowing the process of apoptosis also allows M. mitochondrii to persist within its host. (5.)

Using the hosts chemical energy:

Living in the intermembrane space of a mitochondria comes with its share of benefits in regards to chemical energy such as ATP. The intermembrane space plays host to the products as well

as reactants of cellular respiration from its host such as ATP. There is evidence to support the hypothesis that there is a certain amount of exchange between M. mitochondrii and its host in regards to reactants and products for various cellular processes. An example is the presence of an ATP-ADP translocase in this organism which implies there is some exchange of metabolites between the two organisms. It is also hypothesized that M. mitochondrii has still retained its ability to produce ATP through cellular respiration which leads us to believe there is a possibility that both methods are used to acquire ATP. (5.)

Using the mitochondria as security into the next generation:

Since M. mitochondrii inhabits the mitochondria of oocytes, the reproductive cells of the tick, the host's offspring will also have these organisms in its mitochondria. This is possible due to the concept of maternal inheritance. The female reproductive cells provide the cytoplasm including the organelles for the next generation in addition to the DNA which merges with the male counterpart. Since the female provides the organelles, specifically the mitochondria for the next generation, M. mitochondrii is able to all but confirm its position in the next generation. While the invasion of female reproductive cells is not a new topic, this organism takes it a step further. Colonizing the mitochondria as well adds another layer to secure the passage into the next generation of its host. (5.)

Links to Pop Culture:

This organism's name owes itself as a peculiar, but fitting pop culture reference. The name Midichloria is a reference to the Star Wars universe's own intraspecies life form, midichlorians. Midichlorians are described as symbiotic life forms that reside in all living cells. These symbiotes are able to communicate with themselves as well as other organisms. This intercommunication is the basis for the energy field called "the Force" that is a prominent pillar of the Star Wars universe. Since M. mitochondrii has an intermitochondrial lifestyle that is similar to the midichlorians in the Star Wars universe, the researchers who discovered this organism deemed it sufficient to name it after midichlorians.

Potential Advances from study of M. mitochondrii:

Since mitochondria are a highly conserved organelle across all eukaryotic cells, the study of mitochondria in I. ricinus colonized with M. mitochondrii may give us insight into some functions in our own mitochondria. Even though mitochondria are widely studied, many aspects of its biology are unknown and around 30% of mitochondrial proteins still have an unknown function. (5.) Studying M. mitochondrii and how it interacts with the mitochondrial membrane may improve our understanding of mitochondrial biology by learning the function of some proteins that otherwise have an unknown function.

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