Mitochondria are well-known as the “powerhouse” of the cell – but these organelles have many other vital functions. Mitochondria are also heterogeneous, differing in structure and function. Dr Kasturi Mitra of the University of Alabama, Birmingham, Alabama, USA, leads a research team focused on understanding the relationship between structure and function of mitochondria, in both health and disease. Dr Mitra’s work has demonstrated that dynamic change in mitochondrial structure-function plays a key role in regulating the cell cycle, with important implications for diseases like cancer, as well as the natural process of ageing.

Mitochondria are diverse in shape and structure. Even within a single cell, mitochondria can be heterogeneous; that is, they vary in both structure and function. Further, mitochondria are not only heterogeneous at the level of the whole organelle. Recent research suggests that, within a single mitochondrion, there are multiple different regions that are responsible for very different functions.

As with other important pieces of biological apparatus, in mitochondria structure and function are likely to be intricately linked. The different levels of mitochondrial heterogeneity and their implications are the research focus of Dr Kasturi Mitra at the University of Alabama. Together with graduate student Brian Spurlock, the team aims to understand the relationship between structure and function in mitochondria, both in health and disease.

The structure of any individual mitochondrion, at any given time, depends on both the type of cell in which the mitochondrion resides, and the physiological state of that cell. The necessary variations in mitochondrial shape and structure, however, are created primarily by two opposing processes: fission and fusion.

Fission-fusion dynamics and shape change
Mitochondrial fission (splitting) and fusion (joining), collectively known as mitochondrial dynamics, are part of the complex of systems that keeps a cell in balance. During fission, one large mitochondrion splits to form smaller mitochondria. Conversely, during fusion, two mitochondria join together to form one large organelle, or to exchange their contents.

It is becoming increasingly clear that the fission and fusion dynamics of mitochondria serve to protect the cell. Fusion might allow damaged and undamaged mitochondria to join together, “diluting” the damage; on the other hand, fission could allow the organelle to dispose of a damaged part, which can then be broken down by the cell. In this way, fission and fusion act as “quality control” processes for mitochondria.

Control of mitochondrial dynamics is an intricate process. The balance of fusion and fission is maintained by specific molecules within the cell, particularly certain enzymes and other regulatory proteins. Interactions of mitochondria with other organelles and structures within the cell can also impact mitochondrial fission and fusion.

The cell cycle
Mitochondria appear to be influenced by the cell cycle: the process in which a cell grows and divides to form daughter cells. According to Dr Mitra, mitochondrial shape change is fastest in cells that are proliferating, i.e. growing and dividing to increase in number. In these cells, the cell cycle swiftly repeats over a short space of time. The progression of the cell cycle is regulated by a family of proteins called cyclins, which activate various enzymes at different stages of the cycle. Cyclins also regulate key mitochondrial functions, including energy release and fission-fusion dynamics.

Dr Mitra and her colleagues next aimed to understand the impact of mitochondrial shape change during the cell cycle. There is evidence that the amount of ATP produced by mitochondria varies according to the different energy demands of each stage of the cell cycle. Dr Mitra’s research revealed that ATP produced by mitochondria actively affect specific parts of the cell cycle. When mitochondrial ATP is depleted, the cell cycle may slow or stall. Her lab demonstrated that such slowing down of cell cycle is due to direct mitochondrial regulation of the cell cycle. Moreover, the cell produces proteins that activate or differentiate mitochondria in the process. As a mechanism, they have proposed that energetically active mitochondria recruit Cyclin E on the mitochondrial surface to prevent its destruction and is released to support cell proliferation. Importantly, they showed that the master regulator of the mitochondrial surface to prevent its destruction and is released to support cell proliferation. Importantly, they showed that the master regulator of

Dr Mitra’s work clearly suggests that regulation of mitochondrial dynamics is strongly integrated with regulation of the cell cycle.
Behind the Research

Dr Kasturi Mitra

Dr Brian Spurlock

The Mitra lab’s combinatorial approach involves quantitative cell biology, biochemical and genetic tools in various mammalian cells and tissues and in Drosophila melanogaster models.

Research Objectives


Tanjwar, DK, et al. 2016. Crosstalk between the mitochondrial fission protein, Drp1, and the cell cycle is identified across various cancer types and can impact survival of epithelial ovarian cancer patients. Oncotarget 7(37): 60021–60037.

Personal Response

Besides cancer, do we know of any other diseases in which mitochondrial dynamics might play an important role?

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References