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Nobel Prize in Chemistry 1978

Peter D. Mitchell

The Nobel Prize in Chemistry 1978 was awarded to Peter Mitchell *"for his contribution to the understanding of biological energy transfer through the formulation of the chemiosmotic theory"*

Information about winners:

Dr **Peter Mitchell**,

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RESEARCH INFORMATION:

NOBEL PRIZE IN CHEMISTRY FOR BIOLOGICAL ENERGY TRANSFER

Mitchell's research has been carried out within an area of biochemistry often referred to in recent years as 'bioenergetics', which is the study of those chemical processes responsible for the energy supply of living cells. Life processes, as all events that involve work, require energy, and it is quite natural that such activities as muscle contraction, nerve conduction, active transport, growth, reproduction, as well as the synthesis of all the substances that are necessary for carrying out and regulating these activities, could not take place without an adequate supply of energy.

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It is now well established that the cell is the smallest biological entity capable of handling energy. Common to all living cells is the ability, by means of suitable enzymes, to derive energy from their environment, to convert it into a biologically useful form, and to utilize it for driving various energy requiring processes. Cells of green plants as well as certain bacteria and algae can capture energy by means of chlorophyll directly from sunlight - the ultimate source of energy for all life on Earth - and utilize it, through photosynthesis, to convert carbon dioxide and water into organic compounds. Other cells, including those of all animals and many bacteria, are entirely dependent for their existence on organic compounds which they take up as nutrients from their environment. Through a process called cell respiration, these compounds are oxidized by atmospheric oxygen to carbon dioxide and water.

During both photosynthesis and respiration, energy is conserved in a compound called adenosine triphosphate, abbreviated as ATP. When ATP is split into adenosine diphosphate (ADP) and inorganic phosphate (Pi), a relatively large amount of energy is liberated, which can be utilized, in the presence of specific enzymes, to drive various energy-requiring processes. Thus, ATP may be regarded as the universal 'energy currency' of living cells. The processes by which ATP is formed from ADP and Pi during photosynthesis and respiration are usually called 'photophosphorylation' and 'oxidative phosphorylation', respectively. The two processes have several features in common, both in their enzyme composition - both involve an interaction between oxidizing (electron-transferring) and phosphorylating enzymes - and in their association with cellular membranes. In higher cells, photophosphorylation and oxidative phosphorylation occur in specific membrane-enclosed organelles, chloroplasts and mitochondria, respectively; in bacteria, both these processes are associated with the cell membrane.

The above concepts had been broadly outlined by about the beginning of the 1960s, but the exact mechanisms by which electron transfer is coupled to ATP synthesis in oxidative phosphorylation and in photophosphorylation remained unknown. Many hypotheses were formulated, especially with regard to the mechanism of oxidative

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phosphorylation; most of these postulated a *direct* chemical interaction between oxidizing and phosphorylating enzymes. Despite intensive research in many laboratories, however, no experimental evidence could be obtained for any of these hypotheses. At this stage, in 1961, Mitchell proposed an alternative mechanism for the coupling of electron transfer to ATP synthesis, based on an *indirect* interaction between oxidizing and phosphorylating enzymes. He suggested that the flow of electrons through the enzymes of the respiratory or photosynthetic electron-transfer chains drives positively charged hydrogen ions, or protons, across the membranes of mitochondria, chloroplasts and bacterial cells. As a result, an electrochemical proton gradient is created across the membrane. The gradient consists of two components: a difference in hydrogen ion concentration, or pH, and a difference in electric potential; the two together form what Mitchell calls the 'protonmotive force'. The synthesis of ATP is driven by a reverse flow of protons down the gradient. Mitchell's proposal has been called the 'chemiosmotic theory'.

This theory was first received with scepticism; but, over the past 15 years, work in both Mitchell's and many other laboratories have shown that the basic postulates of his theory are correct. Even though important details of the underlying molecular mechanisms are still unclear, the chemiosmotic theory is now generally accepted as a fundamental principle in bioenergetics. This theory provides a rational basis for future work on the detailed mechanisms of oxidative phosphorylation and photophosphorylation. In addition, this concept of biological power transmission by protonmotive force (or 'proticity', as Mitchell has recently began to call it in an analogy with electricity) has already been shown to be applicable to other energy-requiring cellular processes. These include the uptake of nutrients by bacterial cells, cellular and intracellular transport of ions and metabolites, biological heat production, bacterial motion, etc. In addition, the chloroplasts of plants, which harvest the light-energy of the sun, and the mitochondria of animal cells, which are the main converters of energy from respiration, are remarkably like miniaturized solar- and fuel-cell systems. Mitchell's discoveries are therefore both interesting and potentially

valuable, not only for the understanding of biological energy-transfer systems but also in relation to the technology of energy conversion.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1978/press.html