Cells use water in nano-rotors to power energy conversion

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Researchers from the Max Planck Institute of Biophysics in Frankfurt, and Mount Sinai School of Medicine in New York have provided the first atomic-level glimpse of the proton-driven motor from a major group of ATP synthases, enzymes that are central to cellular energy conversion.

The study, by Dr. Thomas Meier, his PhD student Laura Preiss and Dr. Ozkan Yildiz of the Max-Planck Institute, and Drs. Terry Krulwich and David Hicks of Mount Sinai, revealed a water molecule in the critical rotor element of a bacterial nano-motor that shares common features with the rotors of ATP synthases from human mitochondria and from diverse bacteria, including pathogens such as Mycobacterium tuberculosis, in which the ATP synthase is a drug target. The paper publishes next week in the online, open access journal PLoS Biology.

ATP synthases are among the most abundant and important proteins in living cells. These rotating nano-machines produce the central chemical form of cellular energy currency, ATP (adenosine triphosphate), which is used to meet the energy needs of cells. For example, human adults synthesize up to 75 kg of ATP each day under resting conditions and need a lot more to keep pace with energy needs during strenuous exercise or work. The turbine of the ATP synthase is the rotor element, called the c-ring. This ring is 63 A in diameter (6.3 nm, or 6.3 millionths of a millimeter) and completes over 500 rotations per second during ATP production.

The researchers from Frankfurt and New York were able to grow three-dimensional protein crystals of the unusually stable rotor ring from a Bacillus that can grow under extremely low-proton (alkaline) conditions. The molecular architecture of this turbine was determined using X-ray crystallography.

The researchers were surprised by the results and excited by the promise they hold for future mechanistic insights into the structure and function of ATP synthases. Dr. Meier states: "We did not expect a water molecule to be a key player in this group of rotors. This atomic structure gives us a new and much better framework for understanding how these proton-driven nano-machines work, how they capture the protons that fuel rotation and how they hold on to them through rotation.

The results join other recent examples of the usefulness of unusual organisms, such as this 'extremophilic' bacillus, in providing insights into fundamental life processes and we look forward to further collaborative work on different forms of this rotor. Further basic research into the structural and mechanistic details of ATP synthase nano-machines will impact both nanotechnology and medicine and, perhaps, areas in which nanotechnology converges with medicine."

More information: Preiss L, Yildiz O, Hicks DB, Krulwich TA, Meier T (2010) A New Type of Proton Coordination in an F1Fo-ATP Synthase Rotor Ring. PLoS Biol 8(8): e1000443. doi:10.1371/journal.pbio.1000443

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