ATP synthase, water turbines, and the transport of potential energy

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Rules-to-Build-By

Professor Morris and I created a new Rule-to-Build-By and it states that in order to store energy for later use, turbine like structures convert potential energy to kinetic energy, making another form of energy from the potential energy, and controls the transport of potential energy.

What

This is demonstrated by ATP synthases that passes energy stored in protons down a concentration gradient and the cell membrane to synthesize ATP (Alberts et al., 2010) and the energy stored in water turbines of a hydroelectric generator for dams such as the Hoover Dam to make electricity (Morris, 2012).

How

ATP synthase is a molecular complex that is found in the membrane of the mitochondria. Its purpose is to convert the energy of their protons moving down their concentration gradient into the synthesis of ATP. It takes about 3 or 4 protons to move down the ATP synthase to convert a molecule of ADP and the inorganic phosphate into ATP. ATP synthase can be broken down into two parts, the F_0 which is found in the inner mitochondria membrane and the F_1 – ATPase which is pointing toward the matrix of the mitochondria. F_1 – ATPase catalyzes the hydrolysis of ATP to the inorganic phosphate (Kimball, 2010)

There are three ATP synthase catalytic cites that have been seen in X-ray structures in the F_1 region. Of each subunit pair, one subunit arranges pseudo-symmetrically about the center shaft. Relative to the F_1 center shaft, the F_0-driven rotation surrounding the subunits is thought to pass through at least three conformational states for each rotation, while each site synthesizes one ATP for each rotation. The reaction can also happen in reverse. For instance, through the hydrolysis of ATP by F_1, the center shaft spins while cyclic changes in F_1 are producing the necessary torque (or pivot) rotation. Conformation changes also occur with coupling the transmission between neighboring pairs and through the center shaft (Israelewitz, 2006).

ATP synthase works as a turbine to convert energy stored in a proton gradient into chemical energy (kinetic energy) found in the bond energy of ATP. In an ATP synthase molecular machine, protons flow down an electrochemical gradient and drive a rotator found in the membrane. It is said that protons flow down an entry channel

which is going down the side of the membrane and binds rotor subunits to it. The subunits have to be protonated. After the subunits have been protonated and have completed almost a full circle around the membrane, an exit channel forms and allows protons to leave through the other side of the membrane. During this process, energy that is stored in the proton gradient converts potential energy into mechanical energy, or more specifically in a rotational fashion. This occurs due to a shaft in the rotator and this shaft forms in the center of what is known as the F_1 ATPase. F_1 ATPase catalyzes and forms ATP. F_1 can also crystalize. The center shaft also influences the conformation of subunits. Conformation changes can initiate the synthesis of ATP from ADP (Masasuke et al., 2009).

The rotation of ATP synthase depends on the concentration of ATP and the protons. For instances, a high ATP concentration and a low proton concentration will reverse the rotation because it hydrolyzes ATP and pumps protons up the membrane while a high proton concentration and a low ATP concentration pumps the protons down the membrane (Masasuke et al., 2009).

Furthermore, the center shaft of ATP synthase was discovered by the fluorescence of filaments. Under a microscope, scientists looked at fluorescent filaments and found when ATP was added to the ATP synthase, the filaments where shown to rotate (Masasuke et al., 2009).

Correspondingly to ATP synthase, man-made turbines are used to create electricity similar to the way ATP synthase converts energy in molecules. This is due to hydroelectric power which is "the production of power using the gravitational force of falling or flowing water" (http://www.top-alternative-energy-sources.com/hydroelectric-power.html). Water turbines were developed in the 19th century and they were used for industrial power. Turbine is used as a clean, renewable source of energy (http://www.top-alternative-energy-sources.com/hydroelectric-power.html).

It functions by water flow. Water flows from a high level location into a pipe known as a penstock and then carries it down to a lower level location to a turbine water wheel. The water level increases as it flows down a penstock and this pressure drives the turbine which is connected to the generator. In the generator, there is a rotor that is spun by the turbine. There are electromagnets that are connected to a stator (part of the rotor) that are spun by the generator. The flow of electrons are connected to the stator. Electricity production happens when the electrons exist the generator and return the water back into the river (http://www.youtube.com/watch?feature=player_embedded&v=cEL7yc8R42k#!).

Why

ATP synthase is an important molecular machine in which cells gain energy through mechanisms that are membrane based. ATP is the most predominant way in which cells obtain energy. ATP is made in a few ways such as through glycolysis in the cytosol and by the oxidation of phosphorylation which is found in the mitochondria. Oxidation phosphorylation differs from glycolysis because it requires electron transport in the mitochondria and the passage of ions through it as well. This is also similar to how ATP generation occurs in the plasma membrane of bacteria. The history of membrane-based mechanism for making ATP has been important for discovering the production of ATP. For instance, in photosynthetic bacteria, plants and algae, they all have a similar mechanism for producing ATP during the process of photosynthesis (Alberts et al., 2010).

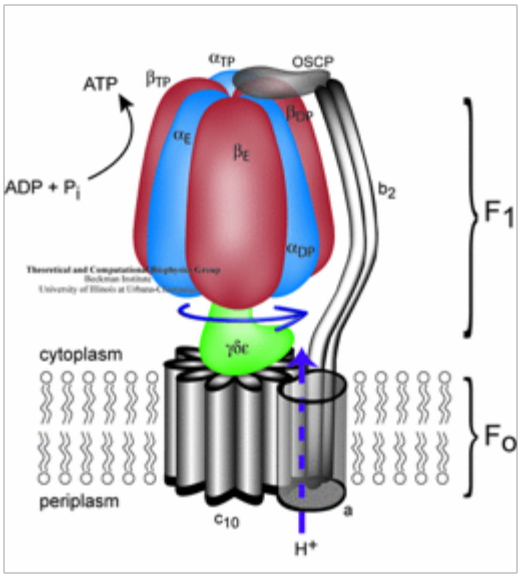
ATP production for membrane-based processes occurs in two steps. First, the electrons that come from the oxidation of food molecules are moved along a series of electron carriers known as the electron transport chain which is found in the membrane. This releases energy that is necessary for protons that come from water in the cell and is pumped across the membrane which creates an electrochemical proton gradient. The next step is when the protons flow back down its electrochemical gradient through the ATP synthase. An ATP synthase catalyzes the energy that is necessary for the synthesis of ATP from ADP and inorganic phosphate. This acts like a turbine which allows the proton gradient to initiate the production of ATP (Alberts et al., 2010).

Cells have evolutionary systems that obtain the energy that is necessary for life. In order for this process to occur, there must be a membrane that is embedded in a pump protein, an ATP synthase and a high source of electron energy and protons (Alberts et al., 2010). "The pump harness the energy of electron transfer to pump protons derived from water, creating a proton gradient across the membrane" (Alberts et al., 2010). Furthermore, the "proton gradient is harnessed by ATP synthase to make ATP (Alberts et al., 2010).

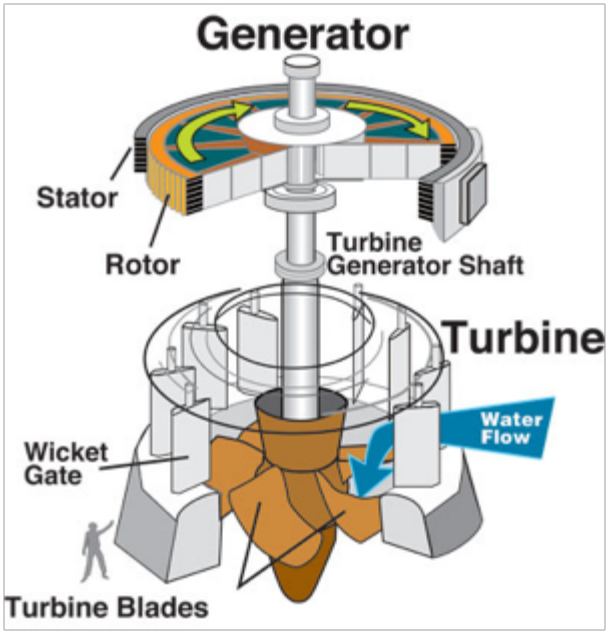
As for water turbines, there are two types of turbines, reaction turbines and impulse turbines. Reaction turbines work by the water that changes it pressure as it goes through the turbine. Impulse turbines work by changing the velocity of water jets. Water pressure is then converted to kinetic energy before hitting the turbine blade. Usually, reaction turbines are used for lower location head sites while impulse turbines are used for high location head sites (http://www.top-alternative-energy-sources.com/water-turbine.html).

Water turbines are useful because they are a "clean power producer" (http://www.top-alternative-energy-sources.com/water-turbine.html) because the energy is unchanged when it is put into the turbine (despite there are some negative effects such as the alteration of rivers' ecology, the killing of fish, restricting ,migration, etc.) (http://www.top-alternative-energy-sources.com/water-turbine.html).

Figures



F_0 converts electrochemical potential energy into mechanical energy through the rotation of the central shaft. This rotation produces cyclic conformation changes in the F_1 region which catalyze binding sites and allow ATP synthesis to occur (Davis et al., 2005).



Water turbines vary for different locations. There are three types of turbines, they include: Francis turbines, Kaplan turbines (propeller turbine) and impulse turbines. The parts of the water turbine include: stator, a rotor, turbine

generator shaft, and turbine blades (http://www.top-alternative-energy-sources.com/water-turbine.html).

Hydroelectricity comes from water released by dams that drive water turbines and generators. Hydro power is a way of producing a clean and a renewable source of energy because it produces low levels of greenhouse gases (http://www.top-alternative-energy-sources.com/hydroelectric-power.html).

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