7. Cell energy system – respiration.

During breathing we absorb oxygen and remove carbon dioxide from our bodies. This process which we call respiration is common to all life on Earth. During respiration energy is extracted from the stored chemical compounds. When sugar molecules are burnt by plants using oxygen, they produce ATP. During this process carbon dioxide and water are released into the environment and the recovered energy is used to power life. Animal cells require an outside source of glucose and oxygen, and like plants, also generate carbon dioxide and water.

Respiration in complex cells takes place in special cellular components called mitochondria. There can be thousands of them in a single cell where they use oxygen to burn up food. They are so small that a billion of them would fit onto a pinhead. All animals as well as plants contain at least some mitochondria. There are about 10 trillion mitochondria in the human body which constitutes about 10 percent of its mass. They could produce as much as 65 kg of ATP per day, although at any given moment only about 100 g of ATP is present in our body.

The main engine which drives production of ATP is the respiration system consisting of the electron transport system and ATP synthase. Without it life would be impossible and if the operation of the system came to a stop the cell would die. Each mitochondrion has thousands of electron transport system. Each system consists of four gigantic molecular complexes imbedded in the inner mitochondrion membrane. They use energy released by the flow of electrons along the system to pump protons across this membrane.

The intricacy of these four molecular supercomplexes is just incredible. Complex1 is built from about 140,000 atoms, and other complexes have similar mass. These complexes, at this moment, are subject to very intensive research and new information is published all the time.

The ultimate achievement of biological constructions is ATP synthase, built from about 86,000 atoms which produces ATP using protons generated by the electron transport system. Up to 30,000 ATP synthase complexes can be embedded in the inner mitochondrial membrane. ATP synthase is an ingenious example of nanotechnology. It is the smallest rotary motor built from protein molecules driven by a proton gradient or electric field gradient, so one could say that it is an electric motor. Schematic diagram of ATP synthase is shown in Figure 1.

The diameter of ATP synthase in bacteria is about 10 nanometers and its height is about 20 nanometers. The rotating parts are ring "c" and shaft "γ". It needs 10 protons for one revolution. The ATP synthase motor, when saturated with protons, can rotate up to 30,000 revolution per minute and is able to produce approximately 390 ATP molecules *per second.* With its near 100 percent efficiency, far surpassing human technology, ATP synthase shows clear evidence not merely of engineering but of exceptional design abilities. Scientists have been trying to uncover the "secret" behind this very efficient mode of operation for quite some time. Unfortunately, even after more than 40 years of research we still don't fully understand how ATP synthase really works.

The genes coding the respiration system are evolutionarily conserved genes. It means that these genes has remained essentially unchanged throughout evolution. Conservation of a gene indicates that it is unique and essential. Changes in the gene are likely to be lethal.

I have tried to show how extremely complex the respiration system is. When this system was proposed in 1961 scientists did not want to believe it. It took 20 years to be accepted by the scientific world.