Energy transfers which take place in living organisms

Science, Chemistry

Energy transfers which take place in living organisms The nucleotide ATP (adenosine triphosphate) maintains both catabolic and anabolic reactions. Catabolic reactions e. g. respiration are where larger molecules are broken down into smaller ones with energy being released, and anabolic reactions e. g. photosynthesis are where smaller molecules are built up into larger ones which require energy. Catabolism provides the energy for organisms to synthesise larger molecules in its anabolic reactions. To release energy, ATP is hydrolysed into ADP and Pi (an inorganic phosphate) which releases energy that can be used for energy requiring reactions such as photosynthesis. However to maintain the organisms anabolic reactions, ATP must be continually synthesised by condensation reactions where ADP is added onto a phosphate molecule. This process is helped by energy transferred from catabolic reactions such as respiration and occurs in three ways: photophosphorylation, oxidative phosphorylation and substrate-level phosphorylation. Photophosphorylation takes place in chlorophyll- containing plant cells during photosynthesis, oxidative phosphorylation occurs in the mitochondria and animal cells during electron transport, and substrate- level phosphorylation occurs in plant and animal cells when phosphate groups are transferred from donor molecules to ADP to make ATP e. g. when pyruvate is formed at the end of glycolysis. Photosynthesis is an anabolic process where plants produce sugars from carbon dioxide, light energy and water. The sugars are used for other anabolic reactions e. g. protein synthesis and the energy required for these reactions comes from ATP which is synthesised from chemical energy into ATP during respiration. The ATP used in plants is made from the conversion of light energy from the sun, to chemical energy by plants, into the form of organic molecules during respiration in all cells. The ATP produced can then be used by cells to perform useful work e. g. metabolism and active transport which shall be discussed later on. Photosynthesis is a process of energy transformation and includes three stages: the capturing of light energy by chloroplast pigments e. g. chlorophyll, the light- dependent reaction and the light- independent reaction. In the light- dependent reaction, light is captured and the energy is used to add an inorganic phosphate molecule to ADP to make ATP, and water is split into H+ ions and OH- ions, a process known as photolysis. As the chlorophyll molecule absorbs light energy, electrons are excited to a higher energy level gaining enough energy to leave the chlorophyll molecule, and to be taken up by an electron- carrier molecule. Through a series of oxidation- reduction reactions, the electrons are passed down electron carriers which are of slightly lower energy level than the previous one, and the energy is then used to combine an inorganic phosphate molecule in order to make ATP. To maintain this absorption of light energy, the lost electrons must be replaced. This is done when water molecules are split using light energy during photolysis, while also producing hydrogen ions which are taken up by electron carriers called NADP to form reduced NADP. This reduced NADP is used as a source of chemical energy for the plant in the light- independent reaction. ATP and reduced NADP are used to reduce carbon dioxide to produce sugars and other organic molecules in the light- independent reaction. In the stroma, as the carbon dioxide diffuses into the plant through the stomata it combines with the 5- carbon compound ribulose bisphosphate (RuBP) using an enzyme, to produce two 3- carbon glycerate 3-

phosphate (GP). ATP and reduced NADP reduce GP into triose phosphate, (TP) which is converted into organic substances e. g. glucose and carbohydrates, or to regenerate ribulose bisphosphate using ATP from the light- dependent reaction. The chloroplast are adapted to host these energy transfers in many ways, mainly through particular adaptations for both the light dependent reaction in the thylakoids and for the light- independent reaction in the stroma of the chloroplasts. In the thylakoids the chloroplasts have large thylakoid membranes which provide a large surface area for the attachment of chlorophyll and enzymes that carry out the light dependent reaction. Furthermore, the grana has a network of proteins which hold the chlorophyll in a very precise manner that allows for maximum absorption of light. In the stroma of the chloroplasts, the fluid contains all of the enzymes needed to carry out the light-independent reaction, and the fluid also surrounds the grana allowing the products of the light- independent reaction to diffuse readily into the stroma. ATP is an immediate energy source of a cell as has unstable phosphate bonds which can easily be broken down to release energy. This energy is used in various ways in cells, and without this source of energy, cell’s natural processes would break down and processes would become disordered. Metabolic processes rely on ATP to provide the energy for the build up of macromolecules from their basic units e. g. DNA synthesis from nucleotides. ATP is further needed for movement as it provides the energy for muscle contraction e. g. filaments need energy for the filaments of muscle to slide past one another and therefore shorten the overall length of a muscle fibre. ATP is also the main source of energy for active transport where molecules and ions are moved against their concentration gradient, due to ATP changing the shape of carrier proteins in plasma membranes.