

The importance of energy transfers within and between organisms

I would recommend 5 paragraphs.

6 are included here to give you an extra example of a relevant paragraph that could be included in this essay.

1. ATP, or adenosine triphosphate, is the molecule that transfers energy for energy-requiring processes of the cell, and its structure is well suited to this role. It is a phosphorylated nucleotide made up of the nitrogenous base adenine, the pentose sugar ribose and a chain of three phosphate groups, and the bonds between these phosphate groups are relatively unstable so that they are easily broken and release energy. ATP is hydrolysed by the enzyme ATP hydrolase into ADP and an inorganic phosphate, a reaction that releases a small and readily usable quantity of energy, and the inorganic phosphate that is released can itself be added to other molecules to make them more reactive. The reaction is reversible, so ATP is continually rebuilt from ADP and inorganic phosphate during respiration and photosynthesis. ATP is an effective energy donor because each molecule releases a small and therefore manageable amount of energy in a single, rapid step, so that little is wasted. It is a universal energy donor used in the same way in all cells and for all processes and is rapidly hydrolysed and resynthesised, which keeps the transfer of energy immediate and responsive. The importance of energy transfer from ATP is clearly seen in active transport, where the energy from the hydrolysis of ATP allows carrier proteins to move ions or molecules against their concentration gradient. In the ileum, energy from ATP hydrolysis is used by the sodium-potassium pump to actively transport sodium ions out of the epithelial cells. This maintains the low concentration of sodium ions inside the epithelial cells that drives sodium-glucose co-transport, so that glucose can be absorbed from the gut against its own concentration gradient. Without the energy transferred by ATP, this absorption, and therefore the uptake of glucose from food, could not take place, meaning tissues would not receive sufficient glucose for glycolysis and the following stages of respiration.

2. Photosynthesis is the process by which light energy is transferred into the chemical energy of organic molecules. In the light-dependent reactions, which occur on the thylakoid membranes of the chloroplast, light energy is absorbed by chlorophyll and used to excite electrons to a higher energy level, and as these electrons pass along a chain of electron carrier proteins the energy they release is used to pump protons into the thylakoid space; as the protons diffuse back through the enzyme ATP synthase, ATP is generated by chemiosmosis in a process called photophosphorylation. Light energy also splits water by photolysis, providing electrons, protons and oxygen, and reduced NADP is formed. In the light-independent reactions in the stroma, the chemical energy carried by ATP and reduced NADP is used to reduce GP to triose phosphate, some of which is converted into glucose- a store of chemical energy. The importance of this energy transfer is that it converts light, which cannot be used directly to drive metabolic reactions, into a stable chemical form that organisms can use and store. It is the point at which almost all of the energy in living systems first enters, because the glucose made by producers becomes the respiratory substrate and building material not only for the plant itself but, through feeding, for the consumers and decomposers of an entire ecosystem. Only a very small proportion of the light energy reaching a leaf is actually transferred into chemical energy, because much is reflected, transmitted or of an unusable wavelength, and this low efficiency ultimately limits the amount of energy available to support all the organisms in a food chain.

3. Aerobic respiration transfers the chemical energy stored in glucose into the more immediately usable chemical energy of ATP. In glycolysis, which takes place in the cytoplasm, glucose is phosphorylated and split into two molecules of pyruvate, yielding a small net amount of ATP by substrate-level phosphorylation along with reduced NAD. The pyruvate then enters the mitochondrial matrix, where the link reaction and the Krebs cycle release carbon dioxide and, more importantly, produce reduced NAD and reduced FAD together with a little more ATP from substrate-level phosphorylation. The greatest energy transfer occurs in oxidative phosphorylation on the inner mitochondrial membrane, where the reduced coenzymes donate electrons to an electron transport chain; the energy released is used to pump protons across the membrane, and the protons then diffuse back through ATP synthase to generate the bulk of the cell's ATP by chemiosmosis, with oxygen acting as the final electron acceptor. This energy transfer is of fundamental importance because ATP is the energy currency that powers nearly every energy-requiring process in the organism, from active transport and protein synthesis to muscle contraction. By releasing the energy of glucose gradually in many small, enzyme-controlled steps rather than all at once, the cell is able to capture much of it as ATP instead of losing it as heat. The dependence on oxygen as the final electron acceptor explains why aerobic respiration yields so much more ATP than anaerobic pathways, allowing organisms with high energy demands to sustain their activity, while the heat that is inevitably lost during these transfers is itself put to use by warm blooded organisms in maintaining a constant body temperature.

4. The transfer of energy between organisms can be followed as it passes along a food chain from producers to consumers. Producers capture light energy and convert it to chemical energy, and the total amount they fix is the gross primary production; because some of this is used by the plant in respiration, the energy that remains stored in plant biomass and available to the next trophic level is the net primary production, given by $NPP = GPP - R$. When a primary consumer eats the plant, only part of the ingested energy is built into its own tissues to form new biomass, and its net production is described by $N = I - (F + R)$, where I is the chemical energy ingested, F is the energy lost in faeces and urine, and R is the energy lost in respiration. The importance of these energy transfers is that they reveal how inefficient the movement of energy between trophic levels is, since typically only around ten per cent passes from one level to the next, with the remainder lost in respiration, in egestion and excretion, and in the parts of the organism that are not eaten. This inefficiency explains why food chains rarely have more than four or five trophic levels and why there is progressively less energy and biomass at each higher level. Understanding exactly where this energy is lost is of great importance in agriculture, because reducing respiratory losses, for example by limiting the movement of livestock or by keeping them warm, allows a greater proportion of the ingested energy to be converted into biomass, and it also explains why a given area of land can feed far more people when used to grow crops than when used to rear animals.

5. The Pacinian corpuscle is a mechanoreceptor in the skin that transfers the mechanical energy of a stimulus (pressure) into the electrical energy of an action potential. It consists of the ending of a sensory neurone surrounded by layers of connective tissue called lamellae. When pressure is applied to the skin, these lamellae are deformed and press on the neurone's cell-surface membrane, deforming the stretch-mediated sodium ion channels it contains; this causes the channels to open, so that sodium ions diffuse into the neurone and depolarise the membrane, producing a generator potential. If the pressure is great enough, the generator potential reaches the threshold value and triggers an action potential that is then transmitted along the sensory neurone towards the central nervous system. The importance of this energy

transfer is that it is an act of transduction, converting a physical stimulus from the environment into the only form of information the nervous system can carry, an electrical impulse; without it the organism would have no way of detecting pressure or touch and so could not respond appropriately to its surroundings. In addition, a stronger stimulus produces a higher frequency of action potentials, allowing the organism to judge not only that a stimulus is present but how intense it is.

6. Muscle contraction transfers the electrical energy of an action potential into the kinetic energy of movement. When an action potential arrives at the neuromuscular junction it depolarises the sarcolemma and spreads down the transverse tubules, causing the sarcoplasmic reticulum to release calcium ions into the sarcoplasm. These calcium ions bind to troponin, causing tropomyosin to shift and expose the myosin-binding sites on the actin filaments. Myosin heads then attach to actin to form cross-bridges and, using energy released by the hydrolysis of ATP, they flex in a power stroke that pulls the actin filaments past the myosin and shortens the sarcomere; further ATP is needed to break the cross-bridges so that the cycle can repeat, and to actively transport the calcium ions back into the sarcoplasmic reticulum afterwards. The importance of this energy transfer is that it allows an organism to turn a nerve impulse into muscle contraction, which is essential for movement, for the ventilation movements that draw air into the lungs, for the beating of the heart and for moving food through the digestive system. The need for ATP to detach the myosin heads is demonstrated by rigor mortis, in which the muscles of a dead organism become rigid because no ATP is available to break the cross-bridges. During intense exercise the molecule phosphocreatine acts as a store that can regenerate ATP almost instantly, ensuring that the transfer of energy into movement can continue even when demand is very high.