ENZYMES

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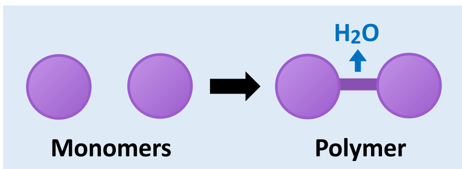
METABOLISM

Metabolism describes the **totality of chemical processes** that occur within a cell in order to maintain life. These reactions provide a source of energy and enable the synthesis and assimilation of cellular materials. Metabolic reactions are catalysed by **enzymes** and can be described as being either anabolic or catabolic:

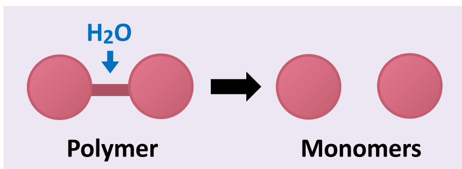
Anabolism:

- Smaller compounds are **combined** to form larger compounds
- In the case of organic compounds, this involves **condensation**
- Water is **released** as a by-product of condensation reactions



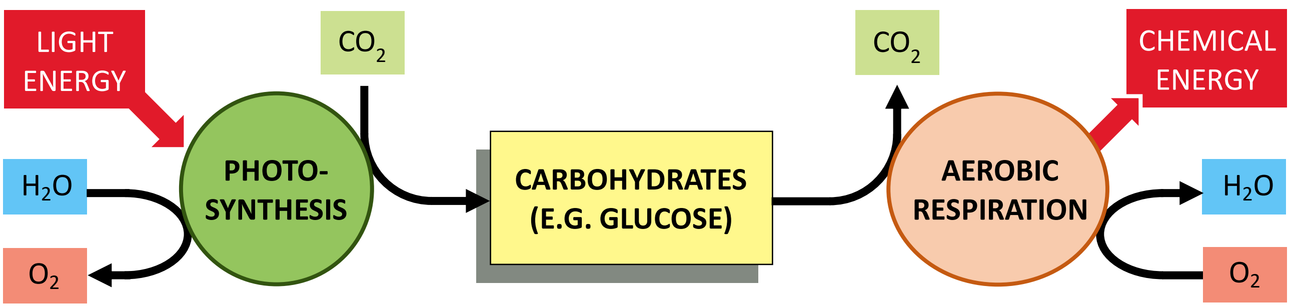
Catabolism:

- Large compounds are **broken down** into smaller compounds
- In the case of organic compounds, this involves **hydrolysis**
- Water is **required** as an input for hydrolysis reactions



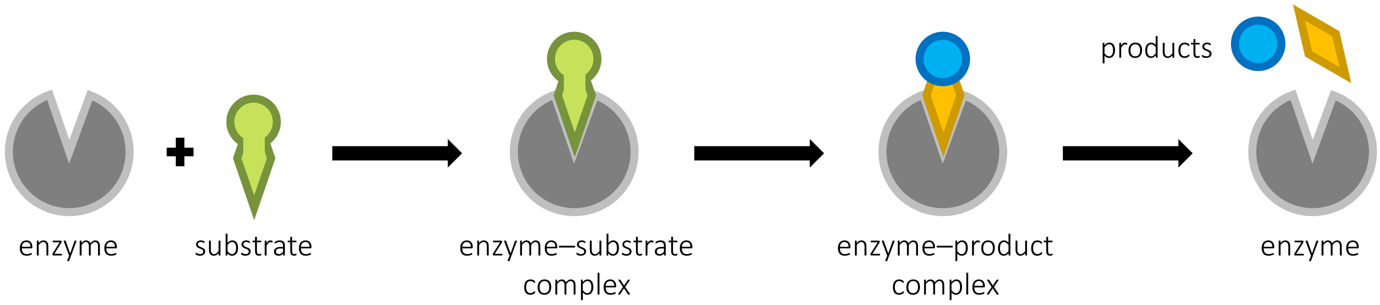
METABOLIC REACTIONS

Photosynthesis is an example of an anabolic reaction. It is an **endergonic** process that uses light energy to synthesise organic compounds from inorganic sources. Conversely, cell respiration is a catabolic reaction. It is an **exergonic** process that releases chemical energy (ATP) from the breakdown of organic compounds.



ENZYMES

Enzymes control the metabolism of a cell. An enzyme is a globular protein that acts as a **biological catalyst**. It speeds up the rate of a chemical reaction by lowering the **activation energy** threshold required for the reaction to proceed. Enzymes are not changed or consumed by the reactions they catalyse and thus can be reused. Enzymes are commonly named after the molecules they react with (called the **substrate**) and end with the suffix '-ase' (e.g. lipase is an enzyme that breaks down lipids, whereas proteases digest proteins).



SPECIFICITY

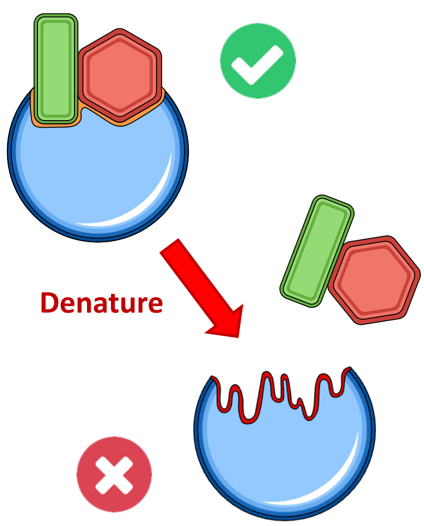
All enzymes possess an indentation or cavity to which a substrate can bind – this is called the **active site**. The shape and chemical properties of the active site are complementary to a particular substrate. Thus, an enzyme demonstrates **specificity** for a given substrate. Some enzymes are *highly* specific and have an active site that precisely fits one distinct substrate (the 'lock and key' model), while other enzymes may be *broadly* specific and recognise a class of related molecules (e.g. proteases can digest a variety of proteins). In these instances, the active site undergoes a conformational change to improve bonding (the '**induce fit**' model). This stresses the bonds in the substrate and increases reactivity (lowers activation energy hurdle).

MOLECULAR MOTION

Enzyme reactions occur in aqueous solutions (such as the cytoplasm or interstitial fluid), with the substrate and enzyme moving randomly in Brownian motion. For enzyme reactions to occur, a substrate and enzyme must physically collide in the correct orientation to facilitate binding to the active site. The frequency of the successful collisions can be improved by increasing the **molecular motion** of the particles or increasing the **concentration of particles** (either substrate or enzyme). Thermal energy can be introduced to increase the kinetic energy of the particles, while the enzyme or substrate may occasionally be fixed in a static position (e.g. membrane-bound) to localise reactions to particular sites and increase the likelihood of catalysis.

DENATURATION

The shape and chemical properties of the active site are highly dependent on the **tertiary structure** of the enzyme. This structure can be modified by external factors such as temperature and pH. These factors may disrupt the chemical bonds needed to maintain the tertiary structure, potentially leading to a change in the shape of the active site. This will result in **denaturation** (loss of biological activity) as the enzyme will no longer be able to interact with the substrate. In most cases, denaturation results in an *irreversible* loss of biological activity. However, some enzymes may be able to return to a functional state if restored to their native conditions. In these instances, denaturation is considered to be *reversible*.



FACTORS AFFECTING ENZYME ACTIVITY

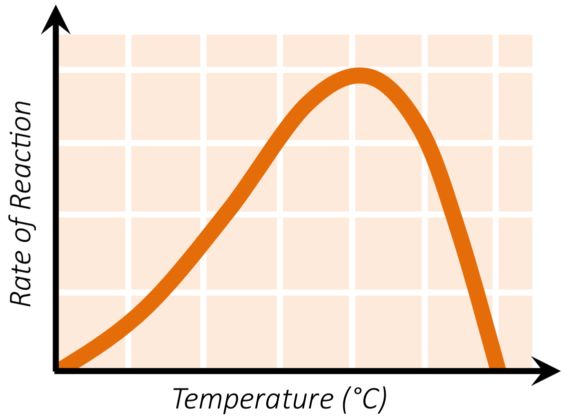
The efficiency of an enzyme-catalysed reaction will be influenced by two key factors:

- The frequency of successful enzyme-substrate collisions (due to more particles or more kinetic motion)
- The capacity for the enzyme and substrate to interact upon collision (will be impacted by denaturation)

Factors that affect enzyme activity include: temperature, pH, substrate concentration or enzyme levels

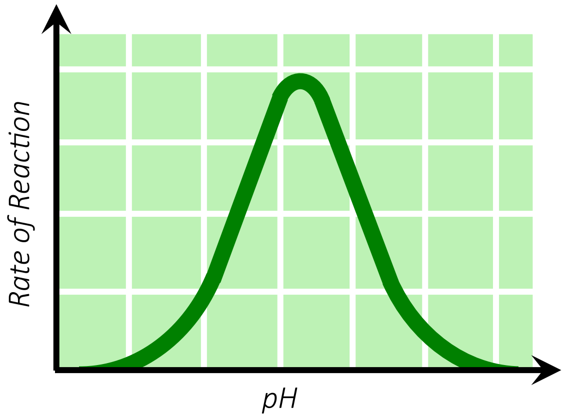
TEMPERATURE

Low temperatures result in insufficient thermal energy for the activation energy threshold to be reached. As temperature increases, particles gain **kinetic energy**, resulting in more frequent enzyme-substrate collisions. At an optimal temperature, enzyme activity will peak, because higher temperatures will disrupt the bonding within the enzyme, causing a loss of tertiary structure and a resulting loss of biological activity (denaturation).



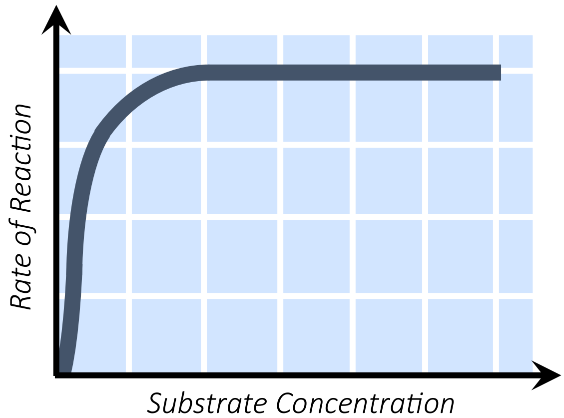
pH

All enzymes have an optimal pH, at which the activity of the enzyme is at its highest. Outside of this optimal range, enzyme activity will diminish. Amino acids are **zwitterions** (have both a positive and negative charge), and changing the pH alters the charge of the enzyme (which in turn alters both solubility and overall shape). Enzymes will denature outside of an optimal pH range, leading to a characteristic bell-shaped activity curve.



SUBSTRATE CONCENTRATION

Increasing substrate concentration will increase the activity of a corresponding enzyme. Higher substrate levels will result in increased frequency of collisions with the enzyme in a given period of time. Above a certain substrate concentration, the enzyme activity will **plateau**. This is because the environment is now saturated with substrate and all enzyme active sites are occupied (reaction is now at maximum catalysis).



ENZYME CONCENTRATION

Increasing enzyme concentration will result in a **linear** increase in activity. This is because the rate of reaction will be proportional to the amount of enzyme available for reaction (more enzymes will result in more frequent enzyme-substrate collisions, leading to a higher rate of activity). Enzymes will typically exist in low concentrations within living organisms. This is because enzymes are not consumed by the reactions that they catalyse and can continually be reused. Enzymes are generally only used in higher amounts in industrialised settings (e.g. in certain household products or in the generation of chemicals or biofuels).