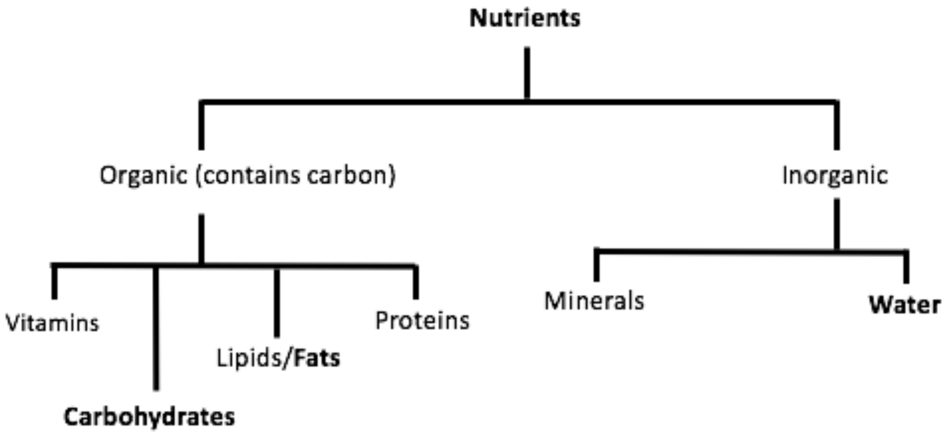
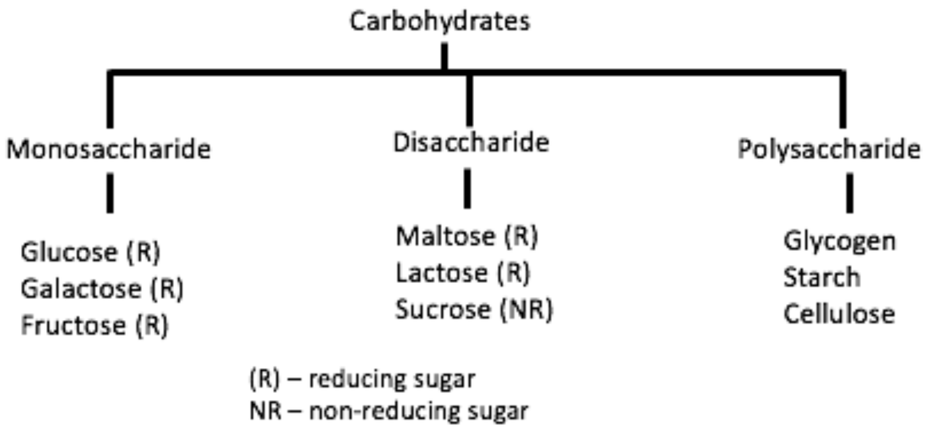
<u>Biomolecules Notes</u>

Why is there a need for food?
- Food provides energy for vital activities.
- Food provides raw materials to make new cells / substances
- Food helps organisms stay healthy.



Carbon Compounds
- Organic compounds: Compounds built from Carbon (C) and Hydrogen (H).
- In living mass, carbon is the third most abundant element by mass, after oxygen.
- Carbon has a unique collection of properties that make life possible
  - Can form stable bonds with many elements due to their 4 valence electrons.
  - Can form long chains, which are used for storage of energy.
    - C-C-C-C-C-C



Macromolecules
- Polysaccharides and proteins are the macromolecules that have been introduced in this topic.
- Chemically described as polymers
- Made by linking together similar building blocks called monomers
  - Proteins (polymers) are built from amino acids (monomers)
  - Polysaccharides (polymers) are built from monosaccharide sugars (monomers)

<u>Properties (Structures, Properties, Functions)</u>

- The type of macromolecule depends upon the type of monomer from which it is built.
- The order in which the monomers are combined decides the shape of the macromolecule.
- The shape of the macromolecule decides its biological properties and determines its role in cells.

- Monomers are linked together by **condensation reactions,** a reaction in which the elements of water are removed.
- **Hydrolysis reactions** are the reverse reactions that require water and results in the release of individual monomers again.

Carbohydrates (hydrated Carbon)
- largest group of organic compounds
- General Formula: $C_x(H_2O)_y$
- Carbohydrates are needed:
    - as a **substrate for respiration** (to provide energy)
    - to form supporting structures (e.g. cell wall in plants)
    - to be converted into other organic compounds such as amino acids & fats
    - for the formation of nucleic acids in DNA
    - to synthesize **lubricants** (e.g. mucus)
    - to synthesize **nectar** in some flowers
- contains three main elements: Carbon, Hydrogen, Oxygen

Monosaccharides
- Monosaccharides are carbohydrates with relatively small molecules.
- Properties:
    - All monosaccharides are **reducing sugars**.
    - Monosaccharides **taste sweet** and are **soluble in water**.
- Examples:
    - Glucose
        - especially important
        - all cells use glucose in respiration
        - our bodies transport glucose in blood
    - Fructose
        - also found in cells
        - sweetest common sugar
    - Galactose
        - forms part of glycolipids and glycoproteins

Disaccharides
- Disaccharides are carbohydrates made of two monosaccharides combined together.
- A molecule of water is removed when two monosaccharides combine, so the reaction is called a **condensation reaction.**
    - Remove a molecule of water from glycosidic bond
        - The bond formed between the monosaccharides is called a **glycosidic bond.**

- Properties:
  - **soluble** in water
- Examples:
  - Sucrose: made up of glucose and fructose
    - An important sugar
    - transported in the phloem tissue to stems, roots or carbohydrate storage sites in the plant
    - the "sugar" that humans prefer to use in food and drinks
    - mostly extracted and purified from sugar cane
  - Maltose (<u>2</u> alpha-<u>glucose</u>): found in germinating barley
  - Lactose (beta-<u>galactose</u> and <u>glucose</u>): found in milk

<u>Polysaccharides</u>
- Polysaccharides are built from many monosaccharide molecules condensed together.
- Properties:
  - **insoluble** in water
- Polysaccharides, like **cellulose** and **glycogen** contain only one type of monomer.
  - Cellulose: beta-glucose
  - Glycogen: alpha-glucose
- **Starch** is a mixture of 2 polysaccharides
  - amylose chain and amylopectin chain
  - has 2 types of glycosidic bond
  - forms helix structure
  - Starch is the major storage carbohydrate of most plants (stored in leucoplasts)
    - The molecule is compact and insoluble.

<u>Name of Polymer formed</u>	<u>Structure</u>	<u>Role in Organisms</u>	<u>Occurrence</u>
Starch	Made up of several thousand glucose molecules (amylopectin and amylose chain joined together)	Form of storage in plants. When needed, starch can be digested to glucose to provide energy.	Found in storage organs of plants (potato tubers and tapioca)
Cellulose	Made up of many glucose molecules but glycosidic bonds formed between glucose units are different from starch.	Cellulose cell wall protect plant cells from bursting or damage. It cannot be digested in our intestines and serve as dietary fibre that prevents constipation.	Present in cell walls of plants

Glycogen	Is a highly branched molecule made up of many glucose molecules	Form of storage in mammals. When needed can be digested to glucose to provide energy.	Stored in the liver and muscles of mammals

<u>Lipids</u>

- Contain the elements carbon, hydrogen and oxygen but have no general formula
- Insoluble in water
- Lipids are soluble only in organic solvents such as alcohol, propanone and ether
- Examples:
    - occur in animal fats (solid) and plant oils (liquid)
    - found in phospholipids of cell membranes
    - steroids from which many growth and sex hormones are produced
    - waxes found in plants and animals

<u>Triglycerides</u>

- Formed by condensation reaction that occurs between fatty acids and glycerol
    - 3 fatty acid molecules combine with 1 glycerol molecule to form a triglyceride
- Fats and oils are the same structurally, except oils are liquids and fats are solid.
- Triglycerides are large molecules, but are smaller than macromolecules like glycogen and starch.
- Their hydrophobic properties make them clump together and appear to be macromolecules.
- Ester bonds are formed in the production of triglycerides.
    - double bond O and simple bond O
- Phospholipids have a similar chemical structure to triglyceride, except that one of the fatty acids is replaced by a phosphate group. The phosphate group is ionized and therefore water soluble.

	Structure	Role in Cells
Triglyceride	High proportion of carbon and hydrogen to oxygen per unit mass, thus making it <u>highly reduced</u>. It is <u>hydrophobic</u>.	Upon oxidation, these bonds release large amounts of energy and hence is a <u>good energy store</u>. • It releases water when oxidised during cellular respiration. This water is called metabolic water, which is extremely important to desert animals like camels. Does not affect water potential of cell when stored in large amounts.
Phospholipid	Hydrophobic fatty acid "tails" and a charged hydrophilic phosphate "head"	Form a selectively permeable membrane where hydrophilic heads are exposed to the aqueous medium while

		hydrophobic tails are excluded from aqueous medium in bilayer.

Saturated and Unsaturated Triglycerides

- Saturated: **no C=C double bonds** between the carbon atoms in their hydrocarbon tails
- Unsaturated: **one or more double bonds** present in the hydrocarbon tails
- When several double bonds occur the resulting fat is called **polyunsaturated** fat.
- C=C double bonds will result in kinks (bends) in the hydrocarbon tails. Such kinks have biological significance in the structure of the cell surface membrane. The kinks ensure membrane fluidity by preventing hydrocarbon tails of phospholipids from aggregating too closely.

Role of Fats and Oils in Living Things

- Comparing mass for mass, fats and oils release more than twice as much energy as carbohydrates.
    - This means that in 1g of fat and 1g of carbohydrates, the fat is higher in calories and releases higher amounts of energy when burnt.
- Fat forms a concentrated, insoluble energy store.
- [check] Fats and oil do not affect water potential of cells when stored in large amounts.
- Concentrated reserves of food for long unfavourable seasons.
    - Complete oxidation of fats and oils produce large amounts of metabolic water.
        - Helps animals to survive when there is no drinking water.
        - Development of embryos of birds and reptiles.
    - Buoyancy aid
        - Presence of adipose tissues function as a heat insulation layer.
    - Waterproofing for hair and feathers
        - Oil acts as water repellent for fur/hair/feathers.
    - Electrical insulation – in nerve cells (the myelin shafts)

Proteins

- contain the element nitrogen and sulfur
- formed from many amino acids combined in a long chain
    - amino acids contain a basic amino group ($-NH_2$) and an acidic carboxyl group ($-COOH$) and a variable R-group
        - variable R-group: defines the amino acid
            - If R = H, glycine is formed etc.
- peptide bond is formed when 2 amino acids react together (removal of water molecule) → condensation reaction

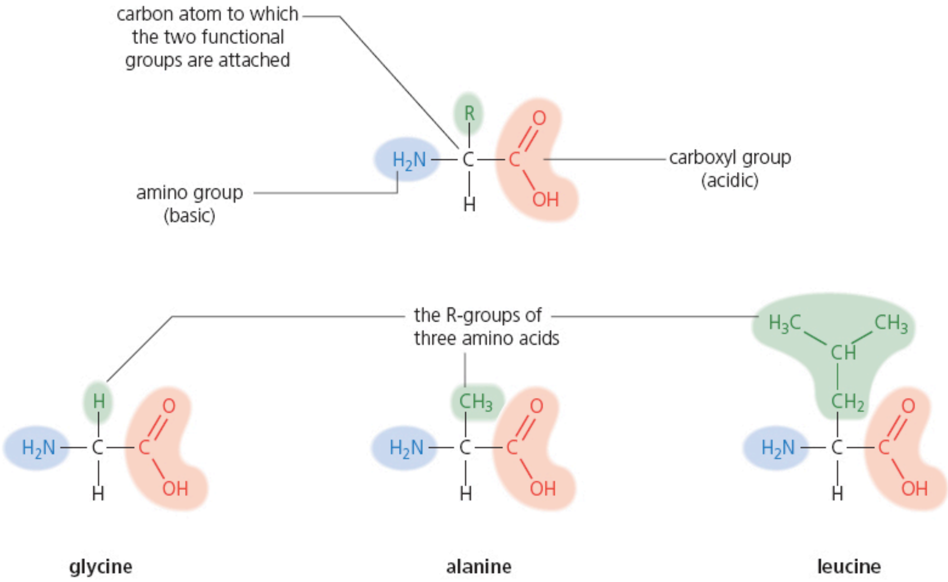


Figure 2.18 The structure of amino acids

Structure of Proteins

- Primary structure of a protein is the long chain of amino acids
  - sequence of amino acids in the polypeptide chain is controlled by DNA in the nucleus
  - shapes are permanent and held together by hydrogen bonds
- Secondary structure is when primary structure takes up a particular shape immediately after formation at the ribosome.
  - 2 major structural forms – α-helix and β-sheets
- Tertiary structure is the precise, compact structure unique to that protein that arises when the molecule is further folded and held in a particular complex shape.
- Quarternary structure – when 2 or more proteins become held together, forming a complex, biologically active molecule

To hold the tertiary structure of the protein, certain bonds (namely hydrophobic interactions, hydrogen bond, ionic bond, disulfide bond) are required.

What are proteins?

- Proteins must be folded into a complex and specific 3D shape in order to be functional.
- The synthesis of a polypeptide is not equivalent to the production of a functional protein.
- In many cases, multiple polypeptide chains must assemble into a functional complex.

Fibrous Proteins

- long strand
- examples of fibrous proteins are fibrin and keratin

Collagen

- made up of 3 helical chains wound together as a triple helix that is stretched out
- lies side by side, forming collagen fibres
- found in skin, tendons, cartilage, bone, teeth and in the walls of blood vessels and forms the cornea of the eye

Globular Proteins

- Enzymes, haemoglobin

Role of Proteins

- for growth and repair of worn-out body cells
- synthesis of enzymes and hormones
- synthesis of antibodies to combat diseases

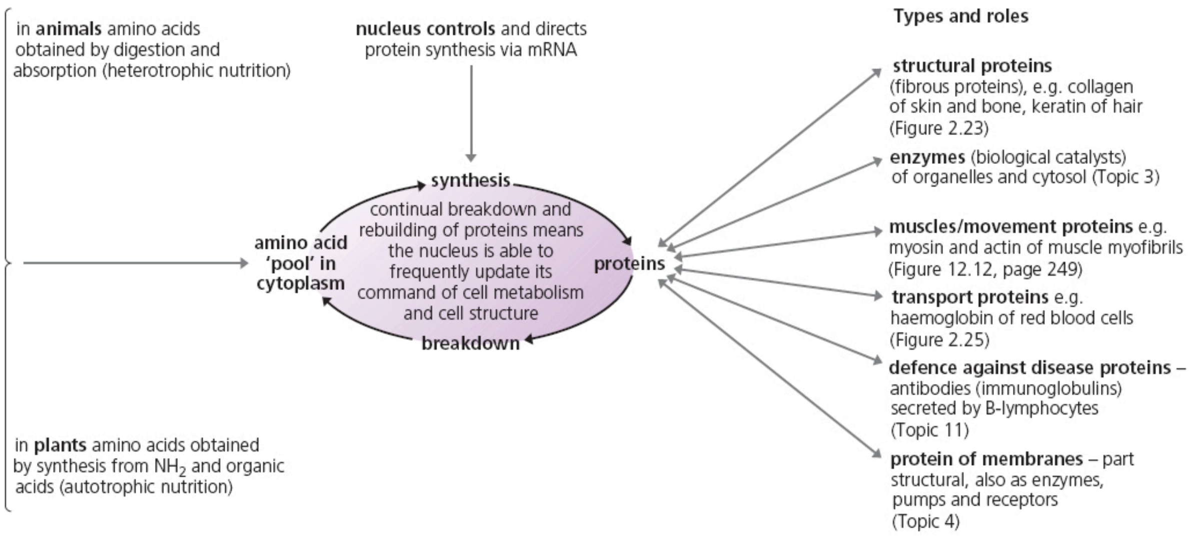


Figure 2.26 The dynamic state of cell proteins

Denaturation of Proteins

- Loss of the three-dimensional structure of a protein
- Bonds that maintain the three-dimensional shape of the protein molecules are changed
- Exposure to heat (or radiation) disrupts hydrogen and ionic bonds
- Small chains in the pH of the medium may alter the ionic charges
- However, the tertiary structure may spontaneously reform, given a favourable medium.

WS3.3 Water

*Important table

Properties of Water	Roles in Living Things
High specific heat capacity	• Allow for large/bulky organisms to have **stable** temperatures
High latent heat of vaporization	• Allows for cooling by **evaporation** as a mechanism of heat loss
Universal **solvent** in biological systems	• Allows for **chemical reactions** to take place • Is key component of tissues (tissue fluid, digestive juices, blood) • It also helps transport **dissolved substances**.

Highly cohesive water molecules	• Allows water to be drawn up narrow columns such as **<u>xylem vessels</u>**

Enzymes and their role in Metabolism

- Molecules involved are called metabolites.
- Anabolic reactions = building larger molecules from smaller ones
- Catabolic reactions = larger molecules are broken down
- Intracellular enzymes -- enzymes that work internally within cells.
- Extracellular enzymes -- enzymes that work externally

Enzymes as biological catalysts

- A catalyst is a molecule that speeds up a chemical reaction but remains unchanged at the end of the reaction.
- For a reaction between two molecules to occur there must be an effective collision between them. The molecules must collide with each other in the right way at the right speed.
- What is an enzyme?
    - Enzymes are proteins that function as biological catalysts.
    - Many enzymes have a name based on the name of their substrate, with the ending -*ase* added.

Enzymes control Metabolism

- Some enzymes are produced only under particular conditions or at certain stages.
- By making some enzymes and not others, cells can control what chemical reactions happen in the cytoplasm.

<u>Characteristics of Enzymes</u>

1. They are catalysts (i.e. speed up chemical reactions).
2. They are required in small amounts.
3. They remain unchanged at the end of the reactions.
4. They are specific in action.
5. They are affected by temperature and pH.

<u>Enzyme Specificity</u>

- Enzymes are highly specific in their action.
- Each chemical reaction inside a cell is catalysed by a unique enzyme.
- An enzyme is specific due to the unique 3D shape at the active side.
- Active sites are depressions on the surface of an enzyme that fits the shape of specific substrate molecule(s).
- Active sites have specific shapes and distinctive chemical properties.

<u>Mode of Action</u>

- [1] The shape of active site of the enzyme is specific and complementary to the shape of the substrate.
- Upon [2] <u>effective collisions</u> between enzyme and substrate, the [3] <u>enzyme substrate complex</u> is formed.

- [4] Interactions between enzyme and substrate molecules strain/weaken chemical bonds within substrates. Thus, [5] lowering activation energy.
- [6] When reaction between substrates finished, product(s) no longer fit into active site and are released. Enzymes are released.
    - numbered/highlighted ones are keywords.

Enzymes lower the activation energy (EA)

- As molecules react, they become unstable, high energy intermediates (momentarily).
- Products have a lower energy level than the substrate molecules.
- Energy is needed to raise molecules to a transition state and the minimum amount of energy needed to do so is activation energy.
- Enzymes are able to lower the activation energy required to activate the reacting molecules.

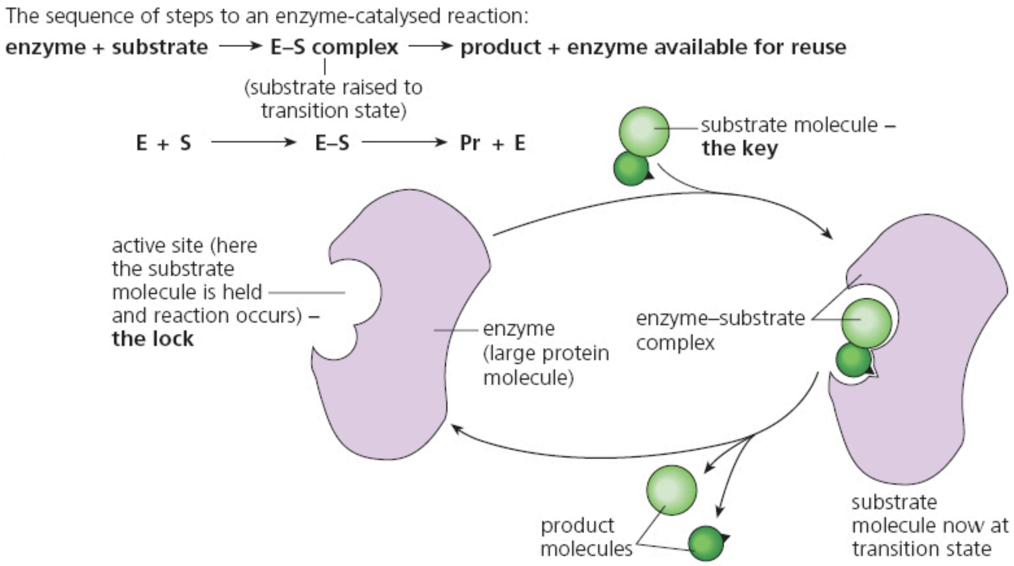


Figure 3.4 The lock and key hypothesis of enzyme action

Lock and Key Hypothesis

Enzymes + Substrate --> Enzyme-Substrate Complex --> Enzymes + Products

- Enzymes are large globular proteins while most substrates are small.
- The substrate binds to the enzyme at the active site (of the enzyme)。
- Substrate = "Key", Enzymes = "Lock"

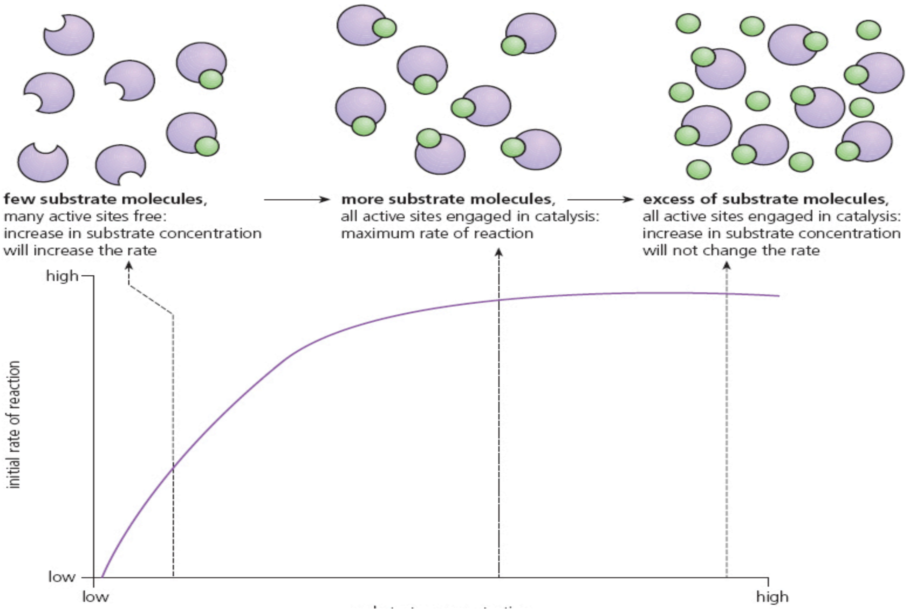
Catalysis by Induced Fit

- 1 difference only
- Arrangement of amino acids matches groupings on substrate, allowing E-S complex to form.
- An essential, critical change of shape is caused in the enzyme.
- This momentary change of shape is important in allowing a reaction to occur.

Factors affecting Enzyme Action

- Substrate Concentration

- At lower concentrations the rate increases in direct proportion to the substrate concentration.
    - All molecules can find an active site without delay.
    - The rate of reaction is set by how much substrate is present.
- At higher substrate concentrations, rate of reaction becomes constant, showing no increase.
    - There are more substrate molecules than enzyme molecules.



- Enzyme Concentration
    - The more enzymes added, the faster the rate of reaction → more active sites are made available.

- Effect of Temperature
    - [D] For every 10 degrees rise in temperature, the rate of enzyme reaction is <u>doubled</u> until the optimum temperature is reached.
        - [E] Enzymes are inactive at low temperatures due to low kinetic energy, therefore the effective collisions are low.
        - [E] As temperature increases, kinetic energy of the substrate and enzyme molecules increases, thereby <u>increasing frequency of effective collision</u> between substrates and enzyme active sites, which increases the rate of formation of <u>enzyme-substrate complex</u> and increases the rate of reaction/products formed.

    - [D] Enzyme activity is highest at its <u>optimum temperature of ______. [specify]</u>
        - [E] All enzyme active sites are occupied / saturated.

    - [D] When temperature is increased beyond optimum temperature of ___,
        - [E] High temperatures <u>break the bonds</u> that keep the enzyme protein in its specific shape.
        - The active site loses its original shape and is <u>no longer complementary to the substrate.</u>
        - The enzyme is denatured and loses its catalytic function.

Every enzyme has an optimum temperature at which it is most active. Not all enzymes have the same optimum temperature. The rate of denaturation increases at higher temperatures.

- Effect of pH
  - [D] All enzymes have an optimum pH at which they will work most efficiently. Rate of reaction is at a maximum.
    - [E] Enzyme maintains its specific 3D conformation and so the enzyme active site is complementary to the substrate.
    - Enzyme binds the substrate(s) to form the enzyme-substrate complex. Substrate is converted to products.
  - [D] Changes in pH [specify if it's increase or lowered pH] can affect enzyme activity.
    - [E] Structure of a protein is maintained by various bonds within the 3D structure.
    - Change in pH alters the bonding pattern, thereby altering the 3D conformation / shape of the active site of the enzyme.
    - Hence, the substrate is no longer complementary to the active site.
    - No enzyme-substrate complex can be formed.
    - No products are formed.
    - The enzyme is denatured and loses its catalytic function.
    - Effects of pH on active sites are normally reversible, unlike temperature changes (provided it is not too extreme).

Enzymes function best at the pH at which they are found, and will denature if surroundings become too acidic or alkaline.