Organic and inorganic compounds

ELEMENTS FOUND IN LIVING ORGANISMS

Living organisms contain many chemical elements, some in large quantities and some in very small amounts. The three commonest chemical elements of life are carbon, hydrogen and oxygen. They are part of all the main organic compounds in living organisms. Examples of other elements that are needed are shown in the table opposite.

ORGANIC AND INORGANIC COMPOUNDS

Living organisms contain many chemical compounds. Some of them are organic and some are inorganic. Organic compounds are defined as compounds containing carbon that are found in living organisms.

There are a few carbon compounds that are inorganic even though they can be found in living organisms. These are all simple carbon compounds that are also widely found in the environment. Carbon dioxide, carbonates and hydrogen carbonates are three examples of inorganic carbon compounds. Three types of organic compound are found in large amounts in living organisms – carbohydrates, lipids and proteins.

THE SUBUNITS OF ORGANIC COMPOUNDS

The molecules of many organic compounds are large and may seem complex, but they are built up using small and relatively simple subunits. Some important subunits are shown below.

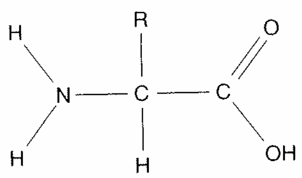
EXAMPLES OF CHEMICAL ELEMENTS AND THEIR ROLES

Element	Role in plants or animals
Nitrogen	Part of the amine groups of amino acids and therefore proteins
Calcium	Needed to make the mineral that strengthens bones and teeth.
Phosphorus	Part of the phosphate groups in ATP and DNA molecules
Iron	Needed to make hemoglobin and thus to carry oxygen in blood
Sodium	Used in neurons (nerve cells) for the transmission of nerve impulses

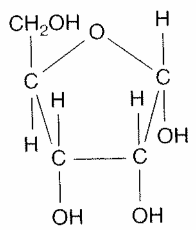
ATOMS AND IONS

An atom is a single particle of a chemical element. If an atom either gains or loses electrons it becomes an ion. Atoms are uncharged particles and ions are charged – they have either positive or negative charges. For example, if a sodium atom (Na) loses an electron, it becomes a sodium ion (Na^+).

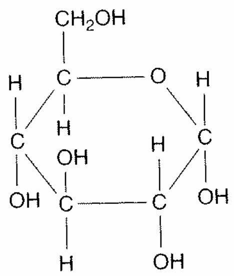
Subunits of proteins, carbohydrates and lipids



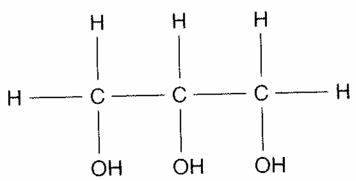
amino acids
(general structure)



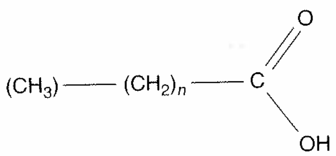
ribose
(a monosaccharide)



glucose
(a monosaccharide)



glycerol



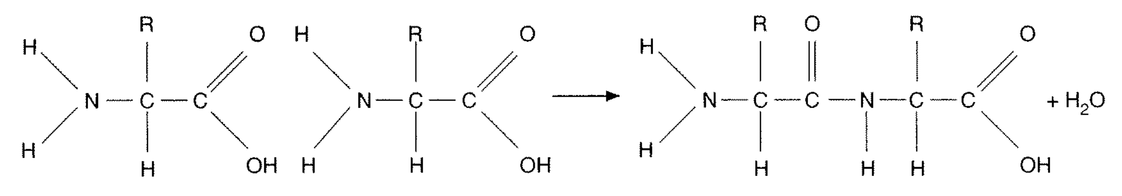
fatty acids
(general structure)

Building macromolecules

CONDENSATION REACTIONS

In a condensation reaction two molecules are joined together to form a larger molecule. Water is also formed in the reaction. For example, two amino acids can be joined together to form a dipeptide by a condensation reaction. The new bond formed is a **peptide linkage**.

Condensation of two amino acids to form a dipeptide and water



Further condensation reactions can link amino acids to either end of the dipeptide, eventually forming a chain of many amino acids This is called a **polypeptide**.

In a similar way, condensation reactions can be used to build up carbohydrates and lipids. The basic subunits of lipids are monosaccharides. Two monosaccharides can be linked to form a disaccharide and more monosaccharides can be linked to a disaccharide to form a large molecule called a **polysaccharide**. Fatty acids can be linked to glycerol by condensation reactions to produce lipids called **glycerides**. A maximum of three fatty acids can be linked to each glycerol, producing a triglyceride.

HYDROLYSIS REACTIONS

Large molecules such as polypeptides, polysaccharides and triglycerides can be broken down into smaller molecules by hydrolysis reactions. Water molecules are used up in hydrolysis reactions. Hydrolysis reactions are the reverse of condensation reactions.

Polypeptides + Water → Dipeptides or Amino acids

Polysaccharides + Water → Disaccharides or Monosaccharides

Glycerides + Water → Fatty acids + Glycerol

EXAMPLES OF CARBOHYDRATES

Monosaccharides	Glucose, fructose and ribose
Disaccharides	Sucrose (glucose + fructose) Maltose (glucose + glucose)
Polysacharides	Starch (made of glucose subunits) Glycogen (made of glucose subunits, but linked differently from starch)

FUNCTIONS OF LIPIDS

- **Energy storage** – in the form of fat in humans and oil in plants
- **Heat insulation** – a layer of fat under the skin reduces heat loss
- **Buoyancy** – lipids are less dense than water so help animals to float

FUNCTIONS OF CARBOHYDRATES

- **Transport** – glucose is carried by the blood to transport energy to cells throughout the body
- **Energy storage** – energy is stored in the form of glycogen in liver cells

USING CARBOHYDRATES AND LIPIDS IN ENERGY STORAGE

Both lipids and carbohydrates can be used for energy storage in living organisms. Both types of storage compound have advantages. Carbohydrates are usually used for energy storage over short periods and lipids for long-term storage.

Advantages of lipids	**Advantages of carbohydrates**
1. Lipids contain more energy per gram than carbohydrates so stores of lipid are lighter than stores of carbohydrate that contain the same amount of energy	1. Carbohydrates are more easily digested than lipids so the energy stored by them can be released more rapidly
2. Lipids are insoluble in water, so they do not cause problems with osmosis in cells	2. Carbohydrates are soluble in water so are easier to transport to and from the store

Enzymes and substrates

INTRODUCING ENZYMES

Catalysts speed up chemical reactions without being changed themselves. Living organisms make biological catalysts called **enzymes**. *Enzymes are globular proteins which act as catalysts of chemical reactions.*

Without enzymes to catalyse them, many chemical processes happen at a very slow rate in living organisms. By making some enzymes and not others, cells can control what chemical reactions happen in their cytoplasm.

The structure of enzymes is quite delicate and can be damaged by various substances and conditions. This is called **denaturation**. *Denaturation is changing the structure of an enzyme (or other protein) so that it can no longer carry out its function.* Denaturation is usually permanent.

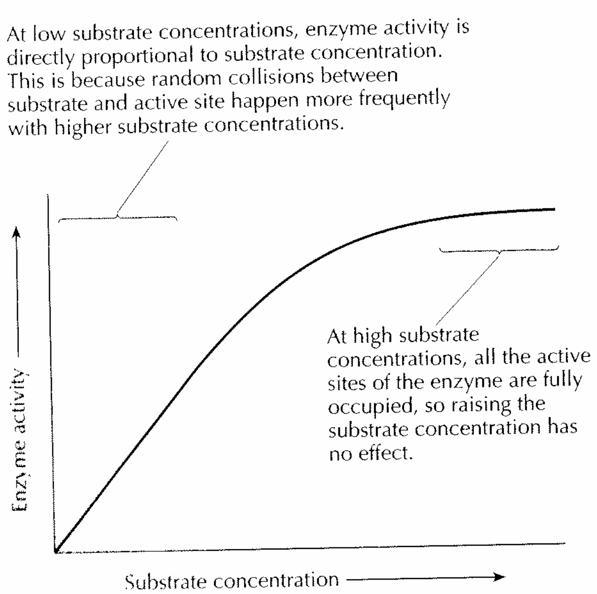
In chemical reactions, one or more reactants are converted into one or more products. In reactions catalysed by enzymes, the reactants are called **substrates**.

ENZYME–SUBSTRATE SPECIFICITY

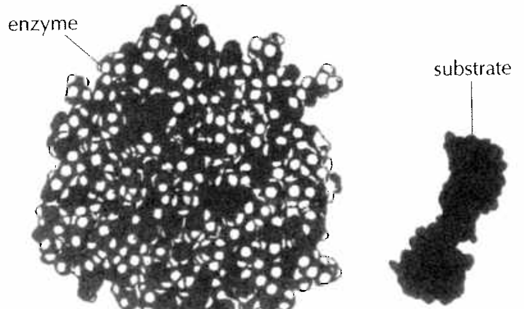
Most enzymes are specific – they catalyse very few different reactions. They therefore only have a very small number of possible substrates. This is called enzyme–substrate specificity. The substrates bind to a special region on the surface of the enzyme called the **active site**. *An active site is a region on the surface of an enzyme to which substrates bind and which catalyses a chemical reaction involving the substrates.*

The active site of an enzyme has a very intricate and precise shape. It also has distinctive chemical properties. Active sites match the shape and chemical properties of their substrates. Molecules of substrate fit the active site and are chemically attracted to it (right). Other molecules either do not fit or are not chemically attracted. They do not therefore bind to the active site. This is how enzymes are substrate-specific. The way in which the enzyme and substrate fit together is similar to the way in which a key fits a lock. The enzyme is like the lock and the substrate is like the key that fits it.

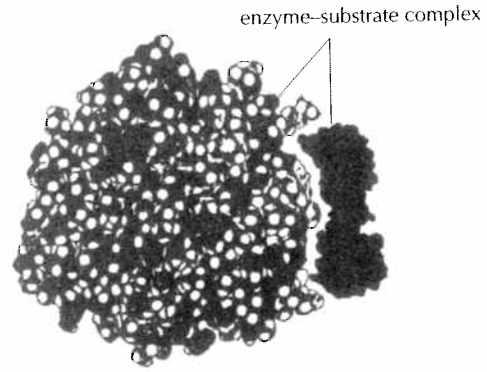
EFFECT OF SUBSTRATE CONCENTRATION ON ENZYME ACTIVITY



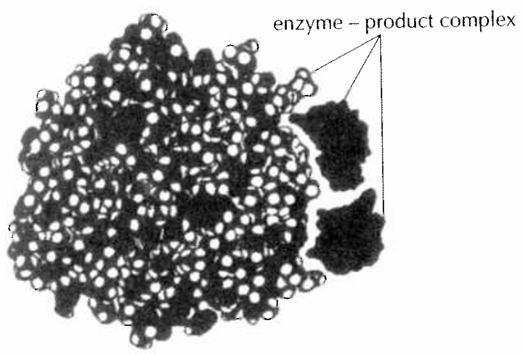
Stages in enzyme catalysis



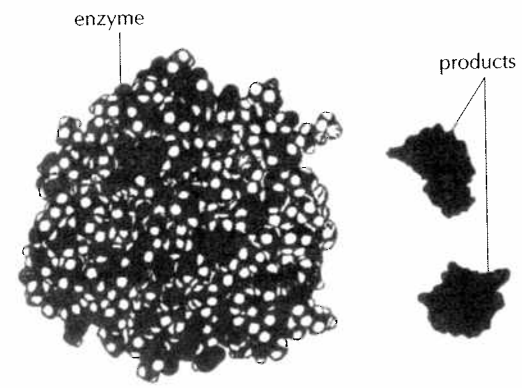
Substrate molecules are in continual random motion. If one collides with the active site it can bind to it.



The substrate fits the active site. If other molecules collide with the active site they do not fit and fail to bind.



The active site catalyses a chemical reaction. The substrates are turned into products.



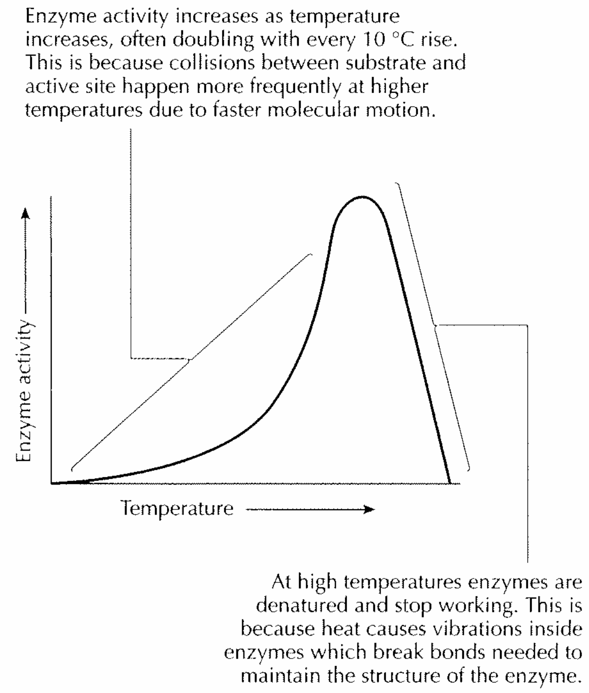
The products detach from the active site, leaving it free for more substrate to bind.

Enzymes in action

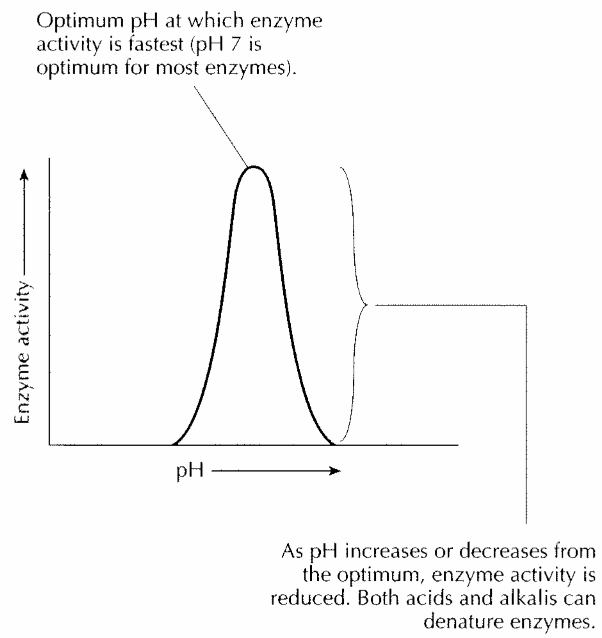
FACTORS AFFECTING ENZYME ACTIVITY

Wherever enzymes are used, it is important that they have the conditions that they need to work effectively. Temperature, pH and substrate concentration all affect the rate at which enzymes catalyse chemical reactions. The figures on page 14 and below show the relationships between enzyme activity and substrate concentration, temperature and pH.

EFFECT OF TEMPERATURE



EFFECT OF pH



USING ENZYMES IN BIOTECHNOLOGY

Biotechnology is the use of organisms or parts of organisms to produce things or to carry out useful processes. There are many ways in which enzymes, obtained from living organisms, can be used in biotechnology. Two examples are described below.

The use of pectinase in fruit juice production

Pectin is a complex polysaccharide, found in the cell walls of plants. Pectinase is an enzyme that breaks down pectin by hydrolysis reactions.

Source of enzyme

Pectinase is obtained by artificially culturing a fungus (*Aspergillus niger*). The fungus grows naturally on fruits, where it uses pectinase to soften the cell walls of the fruit so that it can grow through it.

Use of pectinase in biotechnology

Fruit juices are produced by crushing ripe fruits to separate liquid juice from solid pulp. When ripe fruits are crushed, pectin forms links between the cell wall and the cytoplasm of the fruit cells, making the juice viscous and more difficult to separate from the pulp. Pectinase is added during crushing of fruit to break down the pectin.

Advantages

Pectinase makes juice more fluid and easy to separate from the pulp. It therefore increases the volume of juice that is obtained. It also makes the juice less cloudy by helping solids suspended in the juice to settle and be separated from the fluid.

The use of protease in biological washing powder

Protease enzymes break down proteins into soluble peptides and amino acids. Laundry washing powders that contain protease are called biological washing powders.

Source of enzyme

Protease is obtained by culturing a bacterium, *Bacillus licheniformis*, that is adapted to grow in alkaline conditions. This bacterium feeds on proteins in its habitat by secreting protease. The protease has a high pH optimum of between 9 and 10.

Use of protease in biotechnology

Detergents in laundry washing powders remove fats and oils during the washing of clothes, but much of the dirt on clothing is made of protein, not lipids. If protease is added to the washing powder, this protein is digested during the wash. The high pH optimum of the protease allows it to remain active, despite the high pH caused by alkalis in the washing powder.

Advantages

If protease is not used, protein stains on clothes can only removed by using a very high temperature wash. Protease allows much lower temperatures to be used, with lower energy use and less risk of shrinkage of garments or loss of coloured dyes.

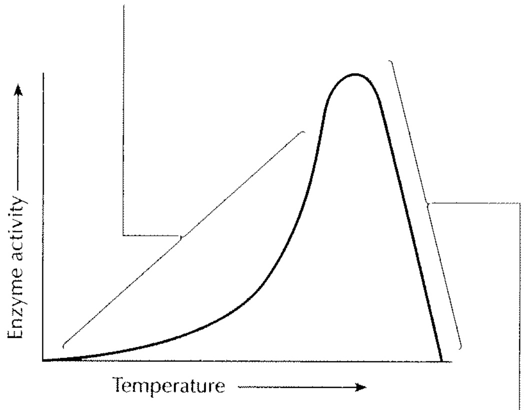
Enzymes in action

FACTORS AFFECTING ENZYME ACTIVITY

Wherever enzymes are used, it is important that they have the conditions that they need to work effectively. Temperature, pH and substrate concentration all affect the rate at which enzymes catalyse chemical reactions. The figures on page 14 and below show the relationships between enzyme activity and substrate concentration, temperature and pH.

EFFECT OF TEMPERATURE

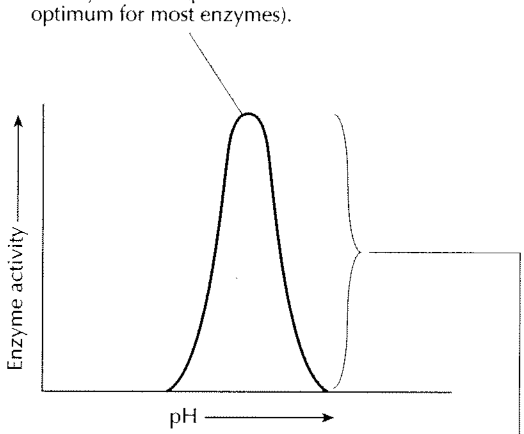
Enzyme activity increases as temperature increases, often doubling with every 10 °C rise. This is because collisions between substrate and active site happen more frequently at higher temperatures due to faster molecular motion.



At high temperatures enzymes are denatured and stop working. This is because heat causes vibrations inside enzymes which break bonds needed to maintain the structure of the enzyme.

EFFECT OF pH

Optimum pH at which enzyme activity is fastest (pH 7 is optimum for most enzymes).



As pH increases or decreases from the optimum, enzyme activity is reduced. Both acids and alkalis can denature enzymes.

USING ENZYMES IN BIOTECHNOLOGY

Biotechnology is the use of organisms or parts of organisms to produce things or to carry out useful processes. There are many ways in which enzymes, obtained from living organisms, can be used in biotechnology. Two examples are described below.

The use of pectinase in fruit juice production

Pectin is a complex polysaccharide, found in the cell walls of plants. Pectinase is an enzyme that breaks down pectin by hydrolysis reactions.

Source of enzyme

Pectinase is obtained by artificially culturing a fungus (*Aspergillus niger*). The fungus grows naturally on fruits, where it uses pectinase to soften the cell walls of the fruit so that it can grow through it.

Use of pectinase in biotechnology

Fruit juices are produced by crushing ripe fruits to separate liquid juice from solid pulp. When ripe fruits are crushed, pectin forms links between the cell wall and the cytoplasm of the fruit cells, making the juice viscous and more difficult to separate from the pulp. Pectinase is added during crushing of fruit to break down the pectin.

Advantages

Pectinase makes juice more fluid and easy to separate from the pulp. It therefore increases the volume of juice that is obtained. It also makes the juice less cloudy by helping solids suspended in the juice to settle and be separated from the fluid.

The use of protease in biological washing powder

Protease enzymes break down proteins into soluble peptides and amino acids. Laundry washing powders that contain protease are called biological washing powders.

Source of enzyme

Protease is obtained by culturing a bacterium, *Bacillus licheniformis*, that is adapted to grow in alkaline conditions. This bacterium feeds on proteins in its habitat by secreting protease. The protease has a high pH optimum of between 9 and 10.

Use of protease in biotechnology

Detergents in laundry washing powders remove fats and oils during the washing of clothes, but much of the dirt on clothing is made of protein, not lipids. If protease is added to the washing powder, this protein is digested during the wash. The high pH optimum of the protease allows it to remain active, despite the high pH caused by alkalis in the washing powder.

Advantages

If protease is not used, protein stains on clothes can only removed by using a very high temperature wash. Protease allows much lower temperatures to be used, with lower energy use and less risk of shrinkage of garments or loss of coloured dyes.