Biology Notes – RP Year 3 2013

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Topic 1 –Biotechnology

Definition:

Biotechnology is the industrial, medical, environmental and commercial applications of biological materials, mainly using micro-organisms, enzymes and genetic engineering, and it can be beneficial or destructive.

History & Uses

Ancient Biotechnology

In ancient times, biotechnology was found in the forms of:

- Making of:
    - Cheese
    - Bread
    - Vinegar
    - Alcohol
- Cross-breeding of animals

Classical Biotechnology

The development of biotechnology in the 19th and 20th centuries led to the evolution of these biotechnologies.

- Discovery of genetics
- Antibiotics

Modern Biotechnology

In modern times, multiple subcategories of biotechnology have developed.

- Discover of structure of DNA
- Genetic engineering
- Cloning
- Diagnosing and treating diseases
- Increasing food supply

- Detergent
- DNA fingerprinting
- Cleaning oil spills

Enzyme Biotechnology

Enzymes are used as industrial catalysts as they are highly specific and efficient in small amounts, and they work at normal temperatures and pressure, thus less energy is needed to maintain the output. They are biological catalysts and proteins, and have an optimum pH and temperature.

Uses of Biotechnology

Diary Industry	Cheese manufacture to coagulate milk proteins	Rennin	Stomachs of calves
Brewing Industry	Reduce wine/beer cloudiness Breakdown of starch to glucose for fermentation by yeast	Protease Amylase	Bacteria Germinating Barley
Food Industry	Produce fructose syrup from glucose (fructose has the same energy content but is far sweeter to human tastebuds than glucose or sucrose, so less is needed for sweetening foods (lower calories) Fruit juice production – to increase volume of extracted juice and to remove cloudiness due to presence of pectins Pre-digestion of some baby foods Meat tenderization – proteases added to meat to break down tough and inelastic connective tissue and collagen Production of chocolate with soft centres by first having a solid centre with invertase and polysaccharides (insoluble, not sweet), which is covered with molten chocolate, then the centre is broken down into soluble monosaccharides which becomes runny.	Glucose isomerase Cellulase, hemicellulose, pectinase Trypsin Bromelain Papain Ficin Invertase	Bacteria Bacteria Bacteria Pineapple Papaya Fig Yeast
Textile Industry	Remove starch from fibres (which help to protect from mechanical damage during weaving) Biological washing powder contains protease, amylase and lipase, which remove blood, starch and grease stains.	Amylase Protease Amylase Lipase	Bacteria and Fungi Bacteria Germinating Barley Bacteria

	Caused hypersensitivity, thus now the enzyme is encapsulated in inert waxy coating, and thermostable enzyme is used.		
Forestry and Paper Industry	Removal of lignin from pulverized wood, prior to use of wood cellulose in manufacturing processes Partial breakdown of starch to produce smooth "quality" paper	Ligninases Amylase	Fungi Bacteria and Fungi
Medical / Pharmaceutical Uses	Removal of blood clots and in wound cleaning (blood is made of proteins) Used in biosensors (Glucose test in urine: contains glucose oxidase, which breaks down glucose to from H_2O_2, and peroxidase, which uses H_2O_2 to change the color of the patch, and the intensity of patch indicates amount of glucose.	Trypsin Various enzymes	Bacteria Bacteria

Enzymes in Detergent

- Detergent proteases convert coagulated protein → Soluble short chain peptides
- Detergent lipase converts fat or oil stains → Soluble fatty acids and glycerol
- Detergent amylase converts starch stains → Soluble shorter-chain polysaccharides and sugars

Enzymes in Nature

- Digestive system: Enzymes are needed to break down large insoluble food molecules into simple soluble molecules for absorption in the bloodstream.
- Respiratory system: Enzymes are needed to break down glucose to produce energy.
- Reproduction: Enzymes are needed for formation of sperms and eggs and for growth and development of foetus.
- Seed Germination: Enzymes are needed to break down store food such as starch and fats in seeds into soluble molecules for the absorption and growth of the embryo into a new plant.
- Growth: Enzymes are needed to make new cell membranes and cell protoplasm for increase in body mass.

Types of Enzymes

There are two types of enzymes; whole-cell/intracellular enzymes (endoenzymes) and extracellular/cell-free enzymes (exoenzymes).

Whole-cell/Intracellular Enzymes (Endoenzymes)

- An endoenzyme, or intracellular enzyme, is an enzyme that functions within the cell in which it was produced. Because the majority of enzymes fall within this category, the term is used primarily to differentiate a specific enzyme from an exoenzyme. It is possible for a single enzyme to have both endoenzymatic and exoenzymatic functions.
- Advantage: in cases where enzymes are expensive or difficult to extract from cells in an active form; or where a sequence of reactions is being catalyzed by a group of related enzyme within the cell.
- Disadvantage: substantial portion of the substrate is converted into bacterial biomass (used by bacterial cells for growth instead of conversion to desired products). Optimum conditions to produce the product may not be the optimum conditions for the growth of the cell as a whole.

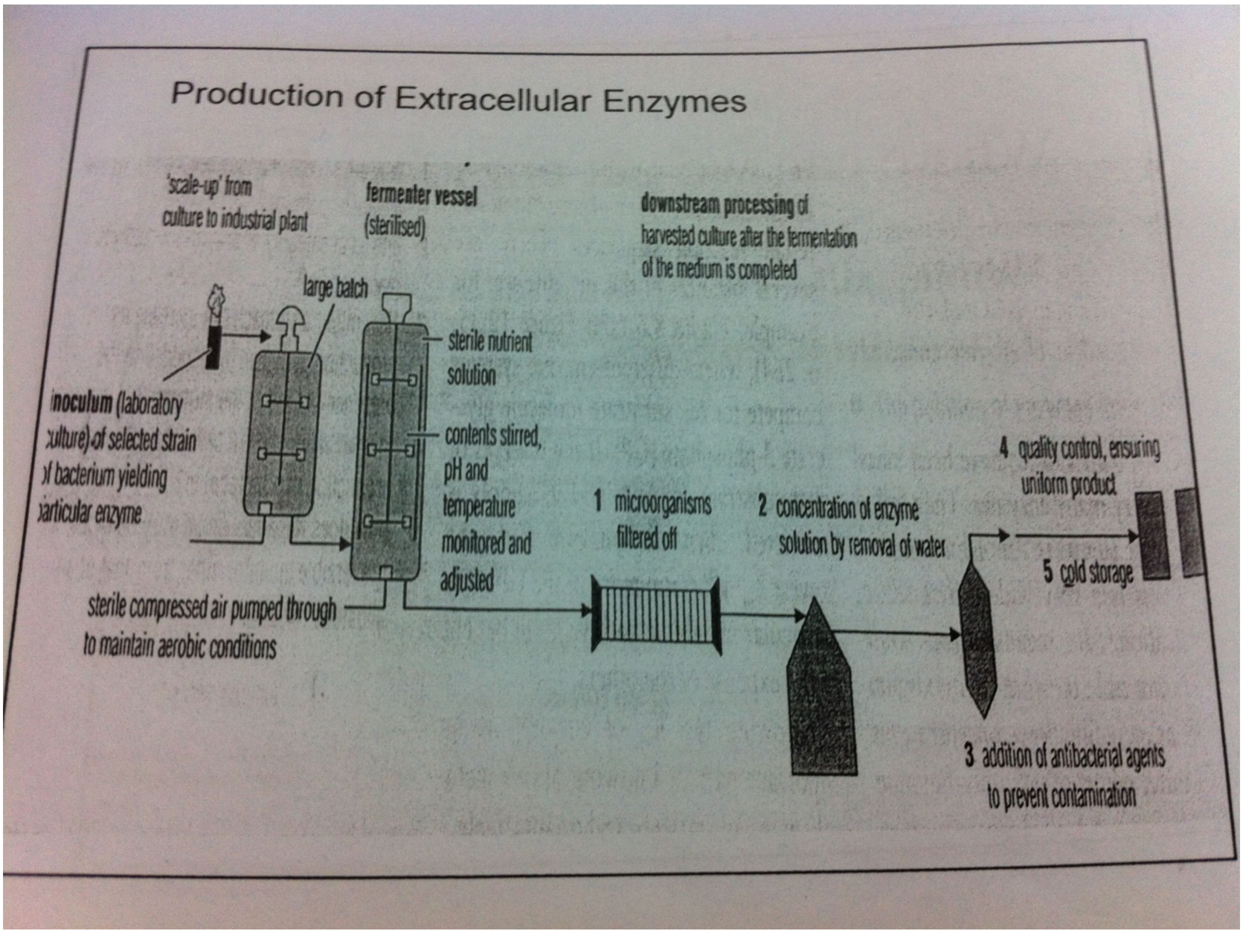
Cell-free/Extracellular Enzymes (Exoenzymes)

1. Most of the enzymes used on an industrial scale are secreted by microorganisms and naturally act on their substrate outside the cell. It is usually used for breaking up large molecules that would not be able to enter the cell otherwise.
2. Advantage: relatively easy to obtain in bulk. No 'wasteful' side reactions occur since other enzymes are not present.
3. Disadvantage: some enzymes may be difficult or expensive to extract.

Extraction of Extracellular Enzymes: Why Microorganisms?

- Microorganisms possess high growth rates and produce a greater enzymes per body mass compared to animals or plants.
- They can be cultured economically using low cost substrates for their nutrition.
- Microorganisms especially bacteria can be genetically engineered to contain genes from plant or animal sources, which encode for a particular protein. (Genetic modification)
- Some bacteria can grow at extremes of temperature and pH, hence their enzymes are fully functional at these extreme conditions (useful in certain industrial conditions)

Production of Extracellular Enxymes



Steps:

1. Inoculum (Laboratory culture of selected strain of bacterium yielding particular enzyme) – To check to see if inserted gene disrupts other gene sequences
2. 'Scale up' from small culture to industrial plant – Large batch of strain of bacterium is tested to ensure bacterium can survive and remain stable in such conditions
3. Fermenter vessel (Sterilised) – Contains sterile nutrient solutions, with contents stirred, pH and temperature monitored and adjusted to ensure that bacteria can thrive and multiply
4. After a certain time, contents are removed from fermenter vessel, and microorganisms are filtered off
5. Enzyme solution is then made to become concentrated through the removal of water
6. Antibacterial agents are then added to the concentrated enzyme solution to prevent contamination of the solution
7. Enzyme solution is then sent to cold storage

Immobilized Enzymes

- Immobilized enzymes are attached to, or retained within, an insoluble support material.
- Reaction mixture on which the enzyme acts is then passed through this support material.
- Enzyme can be **re-used**.
- **Product is enzyme free** (not contaminatedz)
- Saves cost if the enzyme was expensive to extract.
- Prevents the product from being degraded or destroyed by the normal methods of extracting free enzymes from the product.
- Methods of Immobilization
    - Immobilization by physical absorption or entrapment
        - Collagen Matrix: Enzyme absorbed
        - Silica Gel Lattice: Enzyme entrapped
        - Polymer Microspheres of Alginate Beads: Enzymes entrapped
    - Immobilization by chemical reaction
        - Matrix of Cellulose Fibres: Enzyme covalently bonded

Isolated Enzymes versus Immobilized Enzymes

Isolated free enzymes are added to the reaction mixture with no attempt made to reclaim the enzyme at the end of the reaction, such as enzymes in domestic detergents. However, an advantage is that there is much higher level of enzymatic activity compared to immobilized enzymes.

Lactose-free Milk

Certain people have lactose-intolerance, thus lactose-free milk is produced by having skimmed milk run though a pasteurisation process, before passed through a column of immobilized lactase, and when the amount is reduced to an appropriate extent, the milk is packaged.

Topic 2 – Chemicals of Life

Definition of Biological Molecules: Large complex molecules produced by living organisms

Carbohydrates

Definitions

Monosaccharide: Simplest sugar

Disaccharide: 2 monosaccharide molecules chemically joined together (due to hydrolysis)

Polysaccharide: Many monosaccharide molecules chemically joined together (due to hydrolysis)

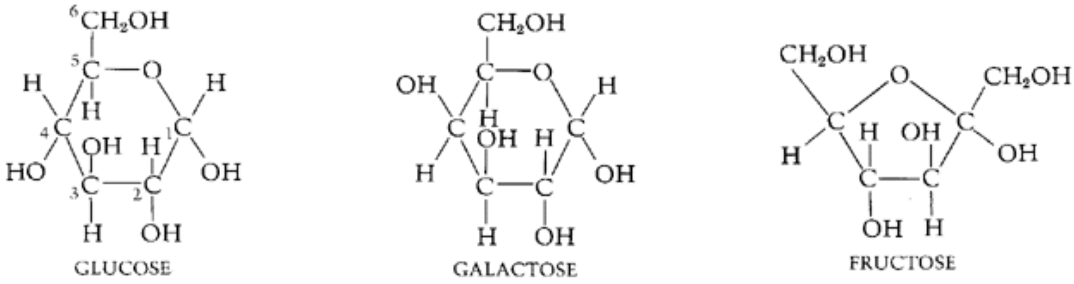
General formula for molecular formula of monosaccharides: $C_x(H_2O)_{2x}$

Hence, ratio of H : O = 2 : 1

Types of Sugars and Examples

Type	Example	Notes
Monosaccharides	Glucose, Fructose, Galactose	$C_6H_{12}0_6$, Structural Isomers
Disaccharides	Sucrose(non-reducing sugar, glucose + fructose), Lactose(glucose + galactose), Maltose(glucose + glucose)	$C_{12}H_{22}0_{11}$ Can be broken down by hydrolysis reaction
Polysaccharides	Starch(Energy storage in plant), Glycogen(Energy storage in animals), Cellulose(Structural Support)	Formed in enzyme-mediated dehydration synthesis. Used for energy storage and structural support

*Note: Glucose, fructose, galactose are all structural isomers of one another. While all 3 have the same chemical formula $C_6H_{12}O_6$, their structural formulas are all different from one another



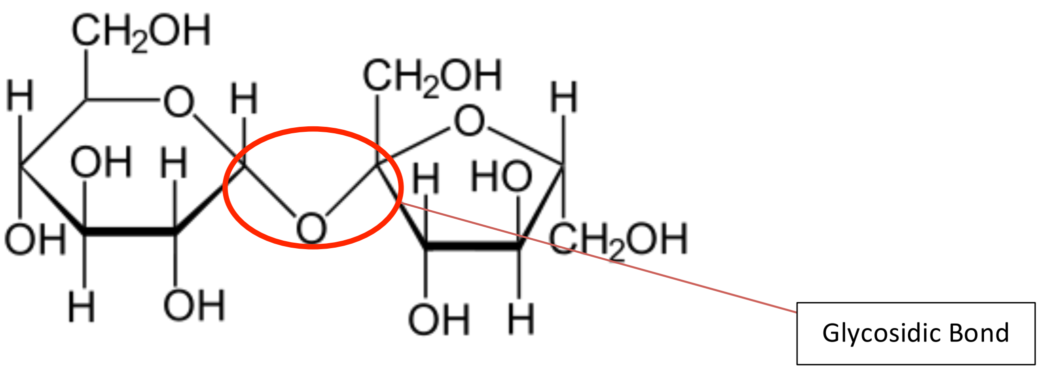
The above figure shows the different structural formulas of the 3 different structural isomers.

Dehydration Synthesis & Hydrolysis

Definition: Formation of a complex molecule from the bonding of 2 simpler molecules with the removal of a molecule of water. It is also known as a "condensation reaction".

Chemical Equation: $C_{12}H_{22}O_{11} + H_2O \leftrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$

Word Equation: $Sucrose + Water \leftrightarrow Glucose + Fructose$



The above picture is a representation of a sucrose molecule. The bond formed between the glucose and fructose molecules is known as a glycosidic bond.

*Note: Hydrolysis is the reverse of dehydration synthesis, hence the two-sided arrow in the formula, which indicates a reversible reaction.

Polysaccharides

	Starch	Glycogen	Cellulose

Monomer	Alpha glucose (α-glucose)	Alpha glucose (α-glucose)	beta glucose (β-glucose)
Length of chain	Very long	Long chain, Short branches	Very long
Branching	Straight+ Branching	Branching	No branching

*Note: The ideal storage material would be:

1. Reasonably compact (store more than if it were stored as glucose) and inert (Unreactive; stable)
2. Mobilised quickly (can be easily hydrolysed to form sucrose) when food materials are unavailable from the environment

These are the reasons why energy is stored as starch in plants and energy is stored as glycogen in animals.

Essentially, these polysaccharides are convenient storage molecule because their large size makes them more or less insoluble (they do not oxidise) in water, so they exert no osmotic or chemical influence in the cell. They also fold up into compact shapes, and are easily converted back to sugars by hydrolysis when required.

Energy Value of Carbohydrates

1 g of carbohydrates will yield 16 kJ of energy.

Its sources are bread, potato, sweets, sugar, cereals, and flour.

Functions of Carbohydrates

- Source of energy
- To form supporting structures (e.g.: cellulose cell walls)
- Formation of nucleic acids (DNA and RNA)
- To synthesize lubricants, e.g.: mucus (carbohydrates and protein)
- To produce nectar in flowers to attract insects for pollination

Tests for Carbohydrates

Tests for reducing sugars

Definition of Benedict's test for reducing sugars: Tests for ability to reduce Cu^{2+} ions in Benedict's solution to Cu^{+} ions, forming brick-red precipitate of copper (I) solution.

Steps:

1. To a test sample of an unknown solution, add an equal volume of Benedict's solution. Shake. Heat in a boiling water bath.

2. Positive test: A coloured precipitate is seen, with different colours indicating different concentrations of reducing sugars. [green ppt → yellow ppt → orange ppt → red ppt → brick-red ppt (in increasing amount of reducing sugars)]
3. All monosaccharides and disaccharides are reducing sugars EXCEPT sucrose (testing of sucrose will involve the addition of sucrase to catalyse the breakdown of sucrose into glucose and fructose and then test for these reducing sugars)

Test for starch

Steps for iodine test:

1. Add a few drops of iodine solution to unknown sample
2. Positive test: blue-black mixture is seen
3. Negative test: mixture remains yellowish-brown (colour of iodine solution)

Dangers of Carbohydrates

Overconsumption of carbohydrates leads to obesity as excess carbohydrates can be converted into fats and stored in adipose tissues beneath the skin and around internal organs.

Lipids

Characteristics

Made up of elements: C, H, O

However, unlike carbohydrates:

- No fixed molecular formula
- No fixed ratio of H : O (general rule-of-thumb: Lipids contain much more H atoms than O atoms)
- Energy value – 1g of fat yields 38 kJ of energy

Types of Lipids

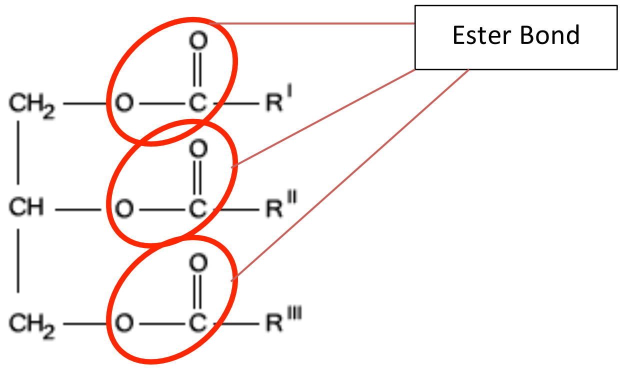
1. Animal and vegetable fats (triglycerides)
2. Phospholipids (2 fatty acids on 1 phosphate head)
3. Steroids (Complex hydrocarbons – e.g.: Cholesterol)

Triglyceride Molecule

Formation: Via dehydration synthesis

Breakdown: Via hydrolysis

Linkage: 3 fatty acid chains are bonded to a glycerol backbone, thus forming a triglyceride. The bond formed between the fatty acid chains and the glycerol backbone is known as an ester bond.



Saturated Fats versus Unsaturated Fats

Saturated fats – contain no double bonds within fatty acid chain

Monounsaturated fats – Presence of 1 double bond in fatty acid chain

Polyunsaturated fats – Presence of 2 or more double bonds in fatty acid chain

Sources

Saturated fats: Can be obtained from animal fats such as pork fat, beef fat

Monounsaturated fats: Can be obtained from olive oil, peanut oil, avocado, cold-water fist such as salmon, mackerel and trout.

Polyunsaturated fats: Can be obtained from vegetable oils such as sunflower, corn and soybean, as well as from many nuts and seeds such as almonds, cashews, walnuts, macadamia nuts.

Functions of Lipids

- Source and store of energy
- Insulating material (especially beneath the skin) to prevent excessive heat loss
- Solvent for fat-soluble vitamins (Vitamins A, D, E, K) and hormones (e.g.: sex hormones)
- Constituent of cell membranes (Phospholipids)
- Layer of oil on skin surface helps in restricting water loss from skin surface
- Production of sex hormones and growth hormones from cholesterol

Tests for Lipids

Ethanol Emulsion Test

Steps:

1. Add 2 cm^3 of ethanol to a drop of oil in a test tube
2. Shake mixture thoroughly (oil will be seen to dissolve in ethanol to form a clear solution)
3. Add 2 cm^3 of water to the mixture and shake.
4. Positive test: A white emulsion is formed and heat is evolved (test tube feels warm)
5. Negative test: No white emulsion seen on shaking with water

Explanation: The oil is first placed in ethanol as oil can dissolve in alcohols. After this, the mixture of oil and ethanol is then mixed with water, as water and ethanol are miscible. When the ethanol and water mix, the oil itself does not mix but is left as minute droplets dispersed throughout water. Light passing through is scattered in all directions and gives the suspension a milky white appearance.

Dangers of Lipids

Overconsumption of fats (Especially saturated fats) leads to:

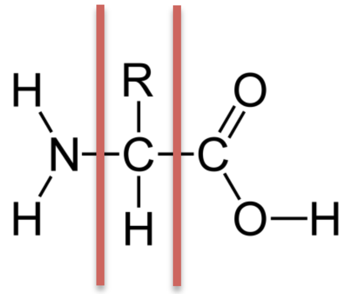
- Increase in blood levels of cholesterol
- Excess cholesterol deposits on inner walls of arteries leading to hardening and narrowing of arteries → atherosclerosis
- Results in high blood pressure and blood clot formation
- Blood clot gets swept into coronary arteries supplying oxygenated blood to the heart muscles → blockage in these arteries → heart attack

Proteins

Definition

- Made up of the elements C, H, O, N (*Note that some proteins may also contain sulfur (S) and phosphorus (P))
- Basic unit of protein: Amino acid (Likened to a monosaccharide in sugars)
- By dehydration synthesis, amino acids can be chemically joined to form larger structures like dipeptides, oligopeptides , polypeptides
- Proteins/peptides can be broken down to their respective amino acids by hydrolysis
- 1g of protein yields 17 kJ of energy

Structural Formula of Amino Acids

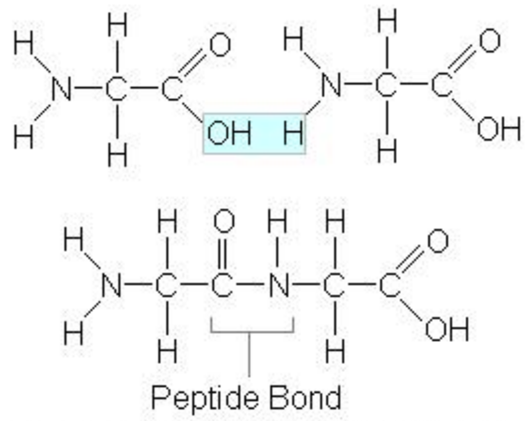


An amino acid can be broken up into various groups.

The group on the left is called the amino group. There is a hydrogen atom bonded to the central carbon atom of the amino acid. On the right is the carboxyl group. These three groups are present in ALL amino acids.

However, the R-group is the variant that results in the 20 amino acids that our body possesses.

During dehydration synthesis, the carboxyl group of one amino acid interacts with the amino group of another amino acid in order to form an amide bond. The reverse occurs in hydrolysis.



A molecule of water is removed from two glycine amino acids to form a peptide bond.

The parts highlighted in blue in the diagram above are then removed to form a peptide/amide bond.

Types of Protein

1. Globular Proteins
    - Include transport protein – haemoglobin, which transports oxygen from lungs to all parts of the body, and membrane pumps, which transport molecules across cell membranes
    - Enzymes – Protein that speeds up (catalyses) rate of chemical reactions in the body
    - Antibodies – Protein involved in immunity, by combating disease by destroying bacteria that invades the body
2. Structural Proteins
    - Keratin – Found in hair and nails

- Collagen – Component of bone, tendon, teeth and skin

Sources of Protein

- Animal sources:
  - Meat
  - Eggs
  - Milk
  - Seafood
  - Liver
- Plant sources:
  - Peas
  - Beans
  - Nuts

Functions of Proteins

3. For synthesis of protoplasm (nucleus, cytoplasm and cell membrane)
4. Hence, in essence, proteins are necessary for growth and repair of worn out body cells
5. Synthesis of enzymes and some hormones (e.g.: insulin)
6. Formation of antibodies to combat diseases
7. Source of energy

Test for Proteins

<u>Biuret Test</u>

Steps:

1. To 2 cm^3 of protein solution in a test tube, add 1 cm^3 of sodium hydroxide solution
2. Shake mixture thoroughly
3. Add copper (II) sulphate solution to the mixture, drop by drop, shaking after each drop
4. Positive test: A violet/purple colouration is seen
5. Negative test: Solution remains blue (Colour of copper (II) sulfate solution)

*Note: This test CANNOT be used for amino acids because it tests for the presence of amide/peptide bonds.

Importance of Water

Note that water may be the single most important molecule in our body.

- 70-80% of cell contents are comprised of water

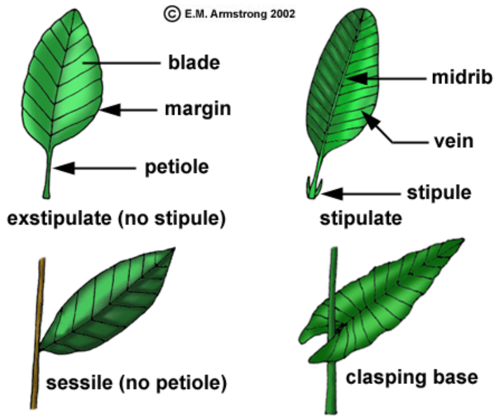
- Universal solvent, hence it is the medium in which many chemical reactions of an organism occur, e.g.: hydrolytic reactions of digestion
- Transporting agent for digested food substances, hormones and excretory products from one part of the body to another
- Essential component of lubricant found in the joints, blood and digestive juices
- Raw material (reactant) of photosynthesis
- Temperature-regulation – Excess body heat remove via evaporation of sweat from skin surface

Topic 3 – Plant Nutrition

Structure of a Leaf

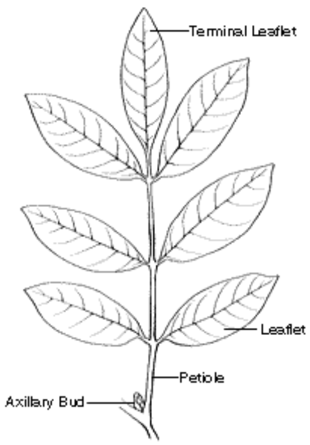
Parts of a leaf

- Leaf blade (lamina)
- Leaf stalk (petiole)
- Leaf base



*Note: Ignore the two diagrams on the right. The leaf in the top left hand corner is called a petiole leaf.

<u>Compound Leaf</u>



Types of Leaves

- Simple leaf
- Compound leaf

Leaf Blade (lamina)

Adaptations

- Has a large, flat surface
    - To maximise exposure to sunlight
- Thin
    - CO_2 can diffuse throughout leaves to increase rate of photosynthesis

Leaf Stalk (Petiole)

Adaptations

- Hold lamina away from the stem
    - Absorb maximum amount of sunlight
- Petiole continues into the midrib of the leaf

*Note: Sessile leaves have no petiole

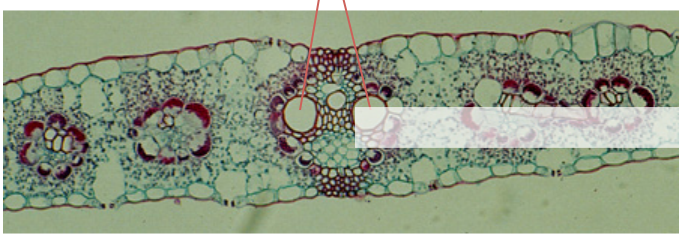
Veins

Adaptations

- Carry water and mineral salts to the cells in the leaf blade
- Carry manufactured from the leaf blade to other parts of the plant
- In dicot plants, there is a main vein (the midrib) giving off branches repeatedly forming a network of fine veins
- In monocot plants, veins run parallel to each other

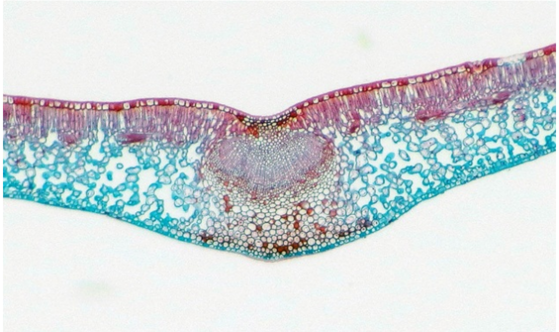
Cross Section of Leaves

Monocot Leaves



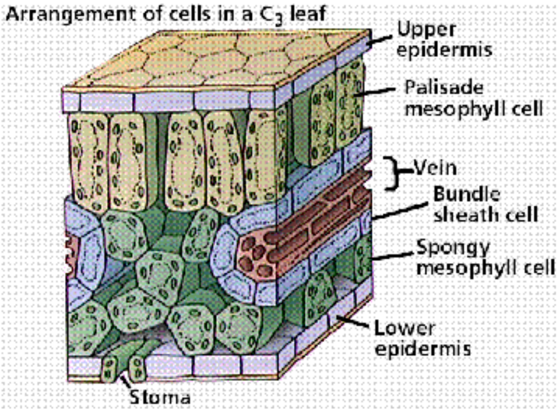
Cross section of monocot leaf

Dicot Leaves



Cross section of dicot leaf

Internal Structure



*Note: Remember the structure (REMEMBER)

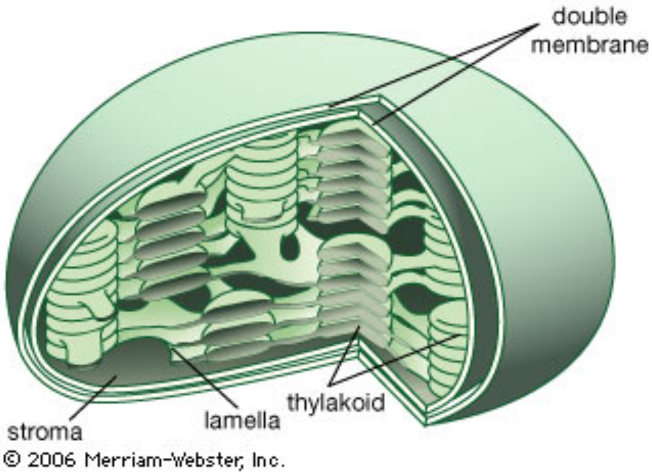
Epidermis

- Single layer of closely packed cells
- On BOTH upper and lower surface of the leaf
- Help to keep the leaf's shape.
- Reduce evaporation from the leaf, prevent bacteria and fungi from getting in.
- Focuses the light on mesophyll layers
- Thin waxy layer called "cuticle" to reduce water loss

Mesophyll

- Lies below epidermis
- Site of photosynthesis
- Two regions:
    - Palisade tissue and Spongy tissue
- Palisade cells long and contain many chloroplasts

- The chloroplasts absorb sunlight and the energy is used to make carbohydrates from carbon dioxide and water
- Spongy mesophyll cells are irregularly shaped
- Loosely arranged so that numerous intercellular air spaces occur among them
- Also contain chloroplasts



  - Chloroplasts are oval shaped organelles that contain chlorophyll

<u>Definitions of important parts of the chloroplasts</u>

Definition of stroma: The enzymes of the light independent stage are found here.

Definition of grana: Stacks of membranes called thylakoids. The chlorophyll molecules and the enzymes of the light dependent stages are sited here. On average, a chloroplast contains about 60 grana, and each granum is made up of about 50 thylakoids, so the resultant surface area available for the light-dependent reactions of photosynthesis is substantial.

Internal Structure – Chloroplasts

A typical mesophyll cell has about 30 to 40 chloroplasts, each organelle measuring about 2-4 µm by 4-7µm.

Stomata

- Structures that are present in the leaf epidermis
- Are more abundant in the lower epidermis of the leaf in most dicots
- Consists of a pair of guard cells surrounding an opening (stomata pore)
- Guard cells are bean-shaped in surface view
- Guard cells contain chloroplasts (EPIDERMAL CELLS DO NOT)
- Amongst all the cells in the lower epidermis, only guard cells can make sugar

Stomata Regulation by Guard Cells

Opening of Stomata Pore

- During sunlight hours, photosynthesis occurs in guard cells
- Sugar produced causes water potential in guard cells to drop
- Water enters the guard cells by osmosis
- Guard cells swell up and become turgid
- Opens up stomata pore

Closing of Stomata Pore

- At night, sugar is used up. Water potential in guard cells increase.
- Water leaves the guard cells.
- Guard cells become flaccid, straighten up
- Stomata pore closes

*Note: Control of the size of the stomata pore is necessary to prevent excessive water loss through transpiration, as well as to regulate the amount of CO_2 entering the cell, in order to maximise the rate of photosynthesis.

Entry of CO_2 into the Leaf

- CO2 is used in photosynthesis (DUH)
- CO2 concentration in the leaf becomes lower than the atmospheric air
- Diffusion gradient exists
- CO2 diffuses through the stomata into the system of air spaces in the leaf
- CO2 dissolves in thin film of water on the mesophyll layer of cells
- Dissolved CO_2 then diffuses in solution into the cells

Entry of Water and Mineral Salts into the Leaf

- Water and mineral salts enter the plant via the roots
- Xylem tissue brings water and dissolved mineral salts to the leaf from the roots
- Veins contain xylem and phloem tissue
- One out of the veins, water and dissolved mineral salts diffuse from cell to cell (via osmosis) to the mesophyll cells of the leaf

Importance of Photosynthesis

- Converts light energy from the sun to chemical energy
- Stored in carbohydrates
- From carbohydrates, proteins, fats and other organic compounds formed. Directly and indirectly fills all of our food requirements

- Energy in coal, petroleum and natural gas all come from the sun via photosynthesis
- Helps to "purify" the air by removing CO_2 and release O_2

Autotrophs

- Organisms that make their own organic matter from inorganic matter
- Photoautotrophs use energy from light for this process (Essentially anything with chloroplasts)

Heterotrophs

- Unable to make their own food, they live on compounds produced by other organisms (hetero means "other")
- Some heterotrophs consume the remains of dead organisms by decomposing and feeding on organic litter such as carcasses, feces and fallen leaves; they are known as decomposers
- Most fungi and many types of prokaryotes get their nourishment this way
- Almost all heterotrophs, including humans, are completely dependent on photoautotrophs for food – and also fo oxygen, a by-product of photosynthesis

Conditions of Photosynthesis

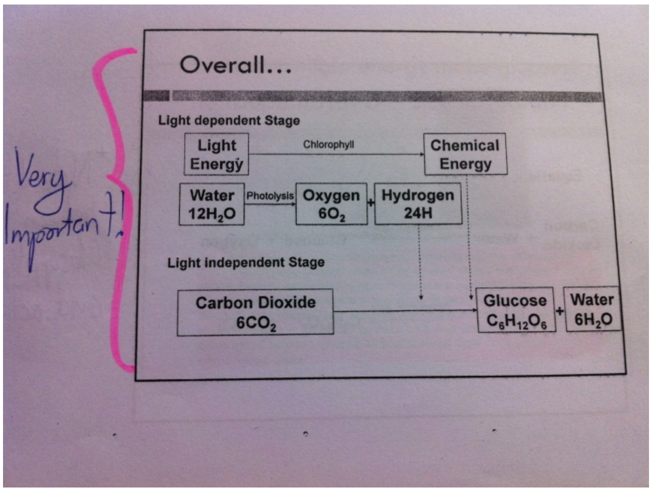
- Chlorophyll
- Light
- Carbon Dioxide
- Water
- Temperature (Enzymes are involved in the temperature)

Two Stages of Photosynthesis

Definition: Light energy absorbed by chlorophyll and transformed into chemical energy used in the synthesis of carbohydrates from water and carbon dioxide. Oxygen gas is liberated in the process.

- Light Dependent Stage
  - Energy from sun absorbed by chlorophyll and converted to chemical energy
  - Light energy splits the water molecules to oxygen and hydrogen – Photolysis
    - $Light\ energy \xrightarrow{chlorophyll} Chemical\ energy\ (H^+ Electron\ and\ protons)$
  - Equation of light-dependent stage: $12H_2O \xrightarrow{Photolysis} 6O_2 + 24H$
- Light Independent Stage
  - Hydrogen used to reduce CO_2 to carbohydrates (glucose)
  - Energy required for this comes from the light stage
  - Equation of light-independent stage: $6CO_2 + 24H \rightarrow C_6H_{12}O_6 + 6H_2O$

Overall:

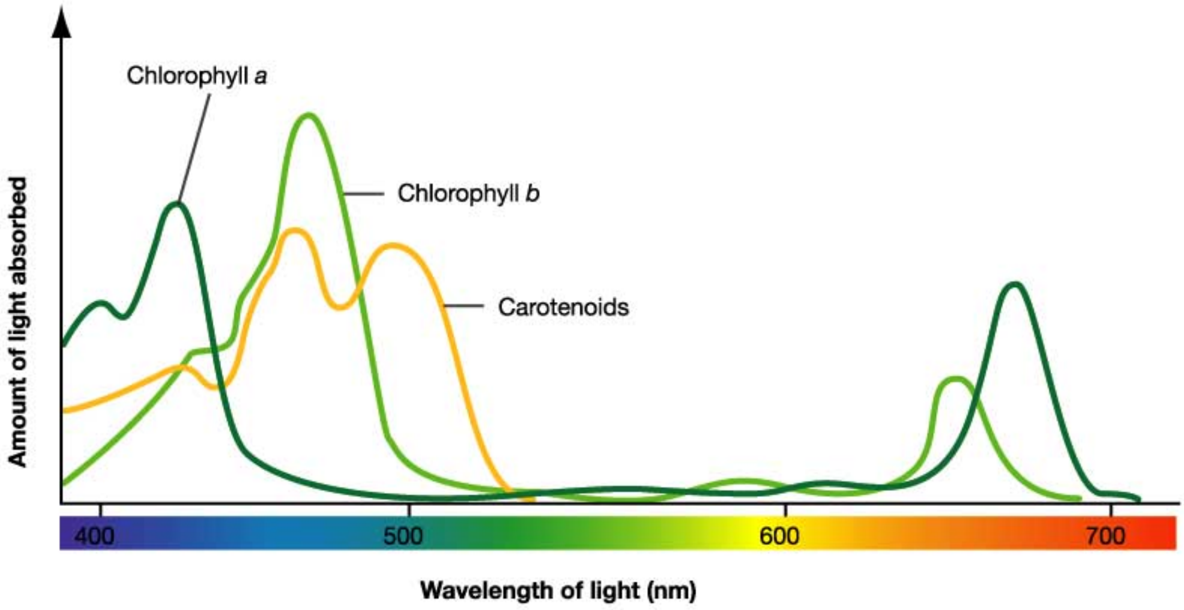


Overall equation: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Effects of Different Wavelengths of light on Rate of Photosynthesis

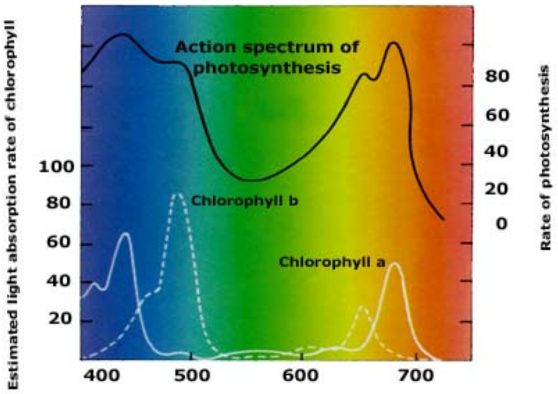
Absorption Spectrum

The absorption spectrum is a graph of relative absorbance of different wavelengths of light by a photosynthetic pigment.


Chlorophyll a
Chlorophyll b
Carotenoids
Amount of light absorbed
400
500
600
700
Wavelength of light (nm)

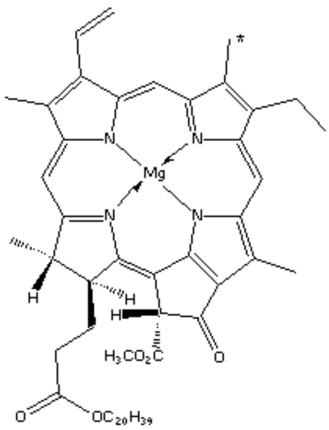
Action Spectrum

Action spectrum is a graph of relative photosynthetic rates at different wavelengths of light.



*Note: Violet-blue and red light is absorbed most by chlorophyll (absorption spectrum), and they are also the most effective wavelengths for photosynthesis (action spectrum).

Structure of Chlorophyll



*Note: All you need to know is that Mg^{2+} ions are necessary for the formation of the chlorophyll pigment.

**If there is no magnesium, no chlorophyll can be formed, and thus no food can be produced. This means that the plant will die.

Limiting factors

Definition of a limiting factor: Any factor that directly affects a process if its quantity is changed.

Limiting factors of Photosynthesis

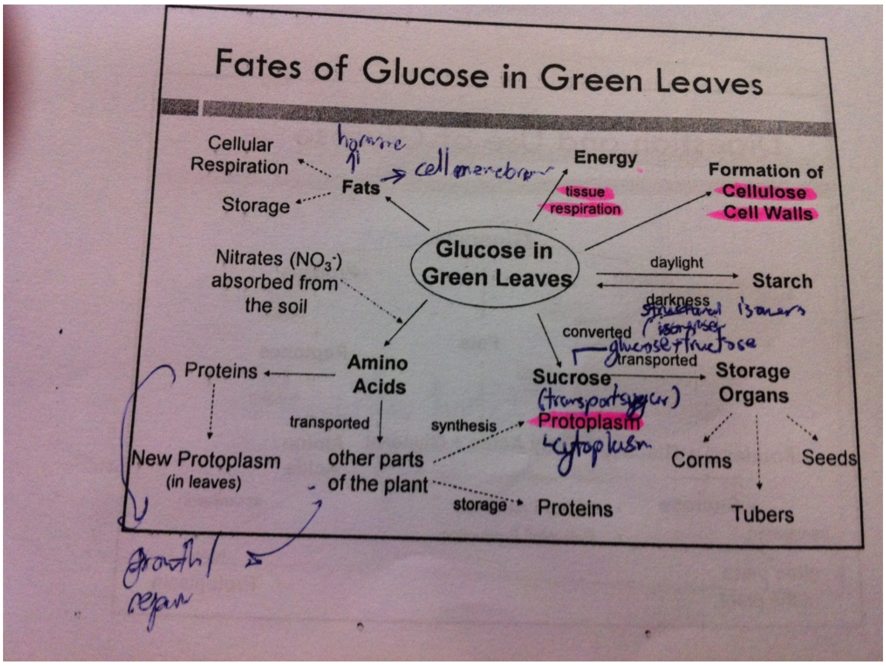
1. Concentration of CO_2 (generally greatest limiting factor)
2. Light intensity
3. Temperature

*Remember how to describe limiting factors. Always quote values.

Adaptations of Leaf to Photosynthesis

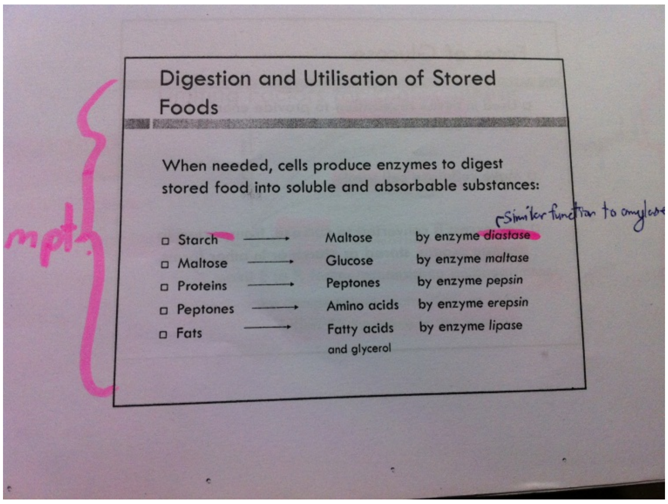
Physical Adaptation	Benefit
Veins contain xylem and phloem	Xylem transports water and mineral salts to mesophyll cells Phloem transports sugars away from leaf
Petiole present	Holds leaf in position to absorb maximum sunlight
Large flat surface	Absorb maximum light energy
Thin lamina	Allows CO_2 to reach inner cells rapidly Enables light energy to reach all mesophyll rapidly
Chloroplast contains chlorophyll All mesophyll cells have chloroplasts	Chlorophyll is necessary for photosynthesis. Absorbs and transforms light energy to chemical energy during photosynthesis
Chloroplasts are found in greater abundance in upper palisade tissue	More light energy can be absorbed near the leaf surface
Intercellular air spaces in mesophyll	Allows rapid diffusion of CO_2 to mesophyll cells
Stomata present in epidermal layers	Allows CO_2 to diffuse in and out of the leaf

Fates of Glucose

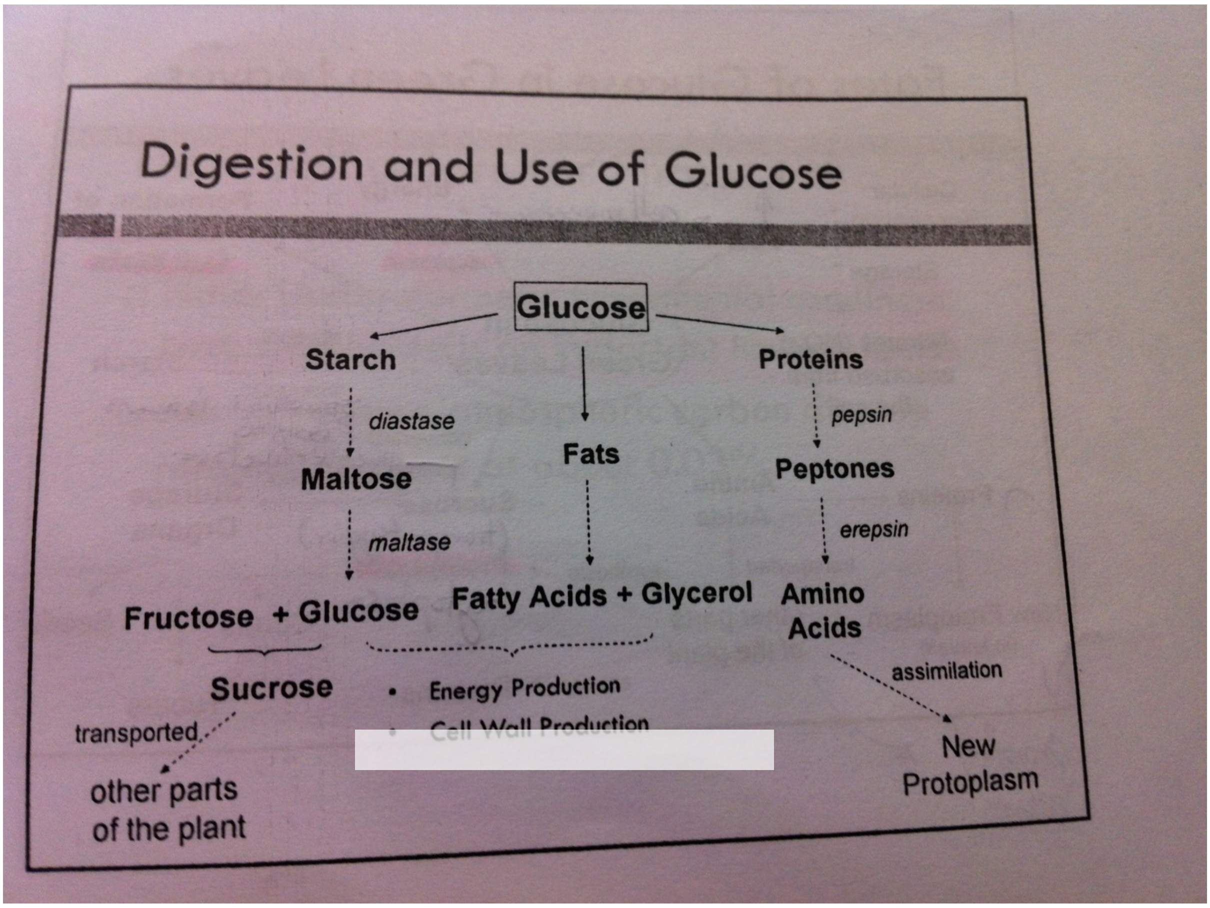


- Used in tissue respiration to provide energy for cellular activities
- Makes cellulose cell walls
- Excess glucose undergoes hydrolysis to become sucrose, transported to storage organs, stored as starch (or in other forms), depending on the plant
- If large amount accumulates, stored as starch in leaves
- In darkness, photosynthesis stops and starch is hydrolysed to simple sugars
- Fats are formed from glucose
- Reacts with nitrates and other mineral salts to form amino acids, which then combine to form protein
- Excess amino acids stored as proteins in leave to build new protoplasm or carried to growing parts of the plant, where they are used to build new protoplasm or stored as proteins.

Digestion and Utilisation of Stored Foods



Digestion and Use of Glucose



Topic 4 – Cellular Respiration

Definition

Respiration is the oxidation of food substances with the release of energy. It occurs in all living cells.

Uses of Energy

1. Synthesis – formation of new substances for growth and repair
2. Transport – Transport of materials by active transport, and movement of materials across cell membranes
3. Movement – Contraction of muscles
4. Electrochemical Activity – Generation of nerve impulses
5. Heat Production – Maintaining constant body temperature in warm-blooded animals

Aerobic Respiration

Definition: Breakdown of food substances in the presence of oxygen. It occurs in the mitochondria of cells

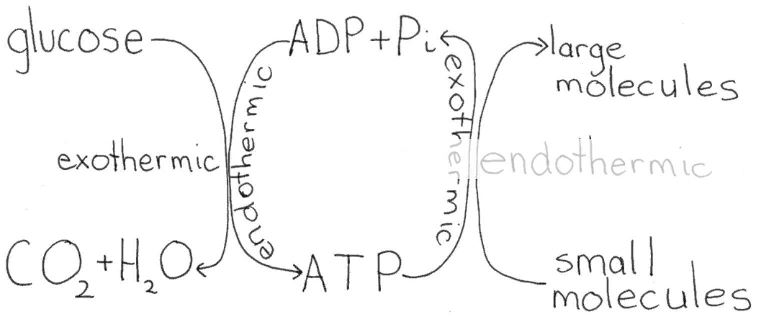
*Note: Aerobic respiration releases about 32-34 ATP worth of energy from one glucose molecule – considered a lot

Equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + lots\ of\ energy$

ATP Cycle (Adenosine Triphosphate)

Energy is stored within the high-energy phosphate bond between a phosphate ion and ADP.

Energy produced from respiration is used to phosphorylate ADP to ATP. Energy is temporarily stored in bonds until required. When necessary, ATP is hydrolysed to ADP and inorganic phosphates to produce energy for work.



Above is a diagram to refer to.

Formation of ATP

1. Respiration
2. Photosynthesis

Anaerobic Respiration

Definition

Anaerobic respiration is the breakdown of food substances in the absence of oxygen. Hence, it produces approximately 19x less energy compared to aerobic respiration

Where does it occur?

1. Yeast
   a. Can respire both aerobically and anerobically
   b. Products are ethanol and CO_2
   c. Process known as fermentation – used in wine (ethanol) and bread making (CO_2)
   d. Equation: $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH + small\ amount\ of\ energy$
2. Muscles
   a. Usually respire aerobically
   b. Only respire anaerobically during vigorous muscular activity
      i. Insufficient oxygen is transported to muscles
      ii. Anaerobic respiration occurs
      iii. Lactic acid builds up
   c. Equation: $C_6H_{12}O_6 \rightarrow 2CH_3CHOHCOOH + small\ amounts\ of\ energy$

*Note: During anaerobic respiration, only the 1^{st} stage of aerobic respiration occurs (glycolysis in the cell cytosol), so only 2 ATP produced per glucose molecule.

Muscle experiences fatigue due to lactic acid build up.

Oxygen Debt

During the period of rest immediately after vigorous exercise, oxygen debt occurs.

It is the amount of oxygen required to oxidize the lactic acid produced in muscles during anaerobic respiration.

Essentially,

1. Lactic acid is transported to live
2. Some oxidised to produce energy
   a. This is where oxygen debt comes in

3. Energy is used to convert remaining lactic acid to glucose
4. Glucose transported to muscles for usage/storage

Differences between Aerobic and Anaerobic Respiration

Aerobic Respiration	Anaerobic Respiration
Large amount of energy produced	Small amount of energy produced
Waste products are CO_2 and H_2O	Waste products are lactic acid and ethanol; contain a lot of unused energy
	Waste products are harmful to organisms if they accumulate
	Lactic acid can be converted back to sugar to be used for respiration Yeast cannot metabolise ethanol