

Organisation and maintenance of organisms: nutrients and diet

Typed version of the handwritten O Level Biology class notes (basic understanding of the topic). The original handwritten pages, with their structure diagrams, are on the same page of megalecture.com.

Nutrients (biological molecules)

- **Major nutrients:** carbohydrates, proteins, fats (lipids), nucleic acids, water.
- **Minor nutrients:** minerals, vitamins, inorganic chemicals.

Carbohydrates

- Organic chemicals made of carbon, hydrogen and oxygen in the ratio 1 : 2 : 1.
- General formula $(CH_2O)_n$. Example: glucose, $C_6H_{12}O_6$ ($n = 6$).
- The name comes from "hydrated carbon": $H_2O \rightarrow H-OH$, the presence of water (a hydroxyl group). Every carbon must have water.
- In Greek terminology carbohydrates are called saccharides: sweet to taste, also called sugar. (Sketch: the straight-chain form of glucose, $C=O$ then five $C-H/C-OH$ carbons, and the ring form, a hexagon of carbons with OH groups; the α and β forms differ in the position of one OH group.)
- Soluble in water; solubility depends on simplicity: glucose readily soluble, starch slightly soluble, cellulose insoluble in water.

Three basic types

1. **Monosaccharides** (one unit). Examples: glucose, $C_6H_{12}O_6$ (a hexagon ring); fructose, $C_6H_{12}O_6$ (a pentagon ring; reducing sugar).
2. **Disaccharides** (two units; contain double the energy compared to monosaccharides). Examples: **maltose** (glucose + glucose), a reducing sugar: the two rings undergo a chemical reaction (condensation) to remove one water molecule, forming an α 1–4 bond, the glycosidic bond. **Sucrose** (glucose + fructose): condensation forms an α 1–2 glycosidic bond; because the $-OH$ of fructose is unavailable, sucrose is a non-reducing sugar. To gain energy from disaccharides is more difficult than from monosaccharides.
3. **Polysaccharides** (multiple, more than two units).
 - **Starch** (repeating glucose units making a chain; a plant chemical): no matter how many units, the bond will be α 1–4. Used in plants as the storage carbohydrate; more bonds in polysaccharides = more storage space; the preferable form of storage as it would not finish its entity by dissolving in cytoplasm and disturbing its water potential. (Side note: glucose is converted to glycogen and stored in liver cells so that it will not disturb the water potential of the liver cells or cause continuous endosmosis resulting in cell bursting; it is insoluble and holds more energy because of its complex nature.)
 - **Glycogen** (repeating glucose units; "animal starch"): α 1–4 bonds, with branching chains



of glucose every 10–12 units. Because of the chain type it becomes a storage form for carbohydrates in animals. Insoluble in cytoplasm.

- **Cellulose** (repeating glucose units; a plant chemical): β 1–4 bonds, making it more complex and rigid and the cell wall harder. Humans cannot break the β 1–4 bond, so it remains undigested in humans; herbivores can digest it due to the presence of cellulase, the enzyme for breaking the β 1–4 bond. Can contain high levels of water due to the rigidity of the cell wall.

Proteins

- Long chains of molecules called amino acids; composed of carbon, hydrogen, oxygen and nitrogen.
- **Amino acids**: 22 different types universally present in living organisms, though there are species-specific changes: the sequence of amino acids and the number of amino acids. The general structure always remains the same: a central carbon with H, an amino group (NH_2), a carboxyl group (COOH) and a variable group R.
- R causes the variations. Examples: $\text{R} = \text{CH}_3$ gives alanine; $\text{R} = \text{CH}_2\text{--SH}$ gives cysteine; $\text{R} = \text{CH}_2\text{--benzene ring}$ gives phenylalanine.
- Whenever amino acids come side by side they form bonds: the COOH of one and the H--N of the next join by condensation (removing water) to give a **peptide bond**, --CO--NH-- .
- Two amino acids: a **dipeptide chain**. Many: a **polypeptide chain**, in which a number of amino acid bonds are present; the longer the chain, the more the number, the more energy is stored; the number can vary.
- The polypeptide chain is packaged, compacted or folded for storage and to make a mature protein (the packaged form is drawn as a coil).
- When folded they form hydrogen bonds: a positive charge on one end and negative on another; loose attractive bonds which can break very easily but keep the chain stabilised. High pH, temperature or concentration can loosen hydrogen bonds: enzyme denaturation.
- The folding causes the polypeptide to have a shape which can be different from others: an enzyme has an active site, a hormone a receptor or binding site, haemoglobin an oxygen-binding site.
- Folding is not only important for stabilising but also for binding shapes and for maturity of the protein. Proteins are hence forming a shape whose function is important to the body.

Reversal (breakage) of bonds

- **Glycosidic bond**: two glucose rings joined by --O-- plus $\text{H}_2\text{O} \rightarrow$ two separate rings with OH groups. This is hydrolysis, releasing energy. Starch $\rightarrow$ maltose $\rightarrow$ glucose by breaking the chain.
- **Hydrolysis**: breakage of bonds; releases energy.
- **Condensation**: bonds are made; energy is stored.

Fats

- Storage chemibiological molecules, energy reserves for future use.
- Made of carbon, hydrogen and oxygen.
- A combination of one glycerol and three fatty acids: glycerol has three -OH groups; each joins with the HO-C(=O)-R of a fatty acid, losing 3 H_2O by condensation, to give the basic structure of a fat with three **ester bonds** ($\text{-C-O-C(=O)-R}_1, \text{R}_2, \text{R}_3$). E.g. R_1 is a chain of carbons, -C-C-C- .
- Called lipids and oil as well.
- Complex (more than others); difficult to break down; conserve more energy.
- The human body favours storing energy in the form of fats; the lower abdomen has more fat deposition.
- **Saturated fats:** single bonds in the carbon R chains (H-C-C-C with all H). Not advised, as it moves as a semi-solid and makes a disturbance to the walls of vessels, increasing blood pressure; also would disturb the contents of blood plasma, making clots which can block vessels.
- **Unsaturated fats:** double or triple bonds in the carbon R chains (-C-C=C-C-C-), oil. Advised to use oil as it moves as a liquid and is more convenient for blood vessels. Unsaturated $\rightarrow$ saturated by hydrogenation (adding hydrogens).
- Larger in size than glucose and amino acids.

Food tests

Test	Observation	Result
1. Iodine test (starch): 2 cm ³ of starch solution + 3–4 drops of (yellowish-brown) iodine	Blue-black colour Brown colour	Positive starch test Negative starch test
2. Reducing sugar test: 2 cm ³ of glucose solution + 2 cm ³ Benedict's reagent (turquoise blue; does not act in acidic medium, only in neutral) + heat in a water bath for 3–5 minutes (for indirect heat). E.g. glucose, fructose, maltose, lactose.	Green $\rightarrow$ yellow $\rightarrow$ brown $\rightarrow$ orange $\rightarrow$ brick red (mild appearance if the concentration is less) Blue colour remains the same	Positive sugar test Negative test
3. Non-reducing sugar test: 2 cm ³ of sucrose solution + 2 cm ³ dilute HCl (can perform hydrolysis in the presence of enzymes) + heat for 3–4 minutes, cool at room temperature + one pellet of sodium hydroxide (solid) + Benedict's reagent + heat again for 3–4 min in a water bath. E.g. sucrose.	Blue $\rightarrow$ green $\rightarrow$ yellow $\rightarrow$ brown $\rightarrow$ orange $\rightarrow$ brick red	Positive non-reducing sugar
4. Biuret test (protein): 2 cm ³ of egg albumin + 2 cm ³ of sodium hydroxide + 3–4 drops of CuSO_4 , in a stand	Violet-coloured ring Blue	Positive protein test Negative protein test

5. Emulsion test (fats): 1 cm ³ of sample oil + 1 cm ³ of alcohol, ethanol or ether (organic chemical) + shake + distilled water 1 cm ³	White emulsion or suspension appears at the top Clear solution	Positive fats test Negative fats test
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Provided things: 5 test tubes, one stand, all the chemicals. Water is an inorganic solvent.

Minor nutrients

Minerals

- Not produced by the living organs; chemicals which are required, absorbed by plants through their roots; by the intake of plants they enter the organism's body.
- **Nitrogen** (present in the form of salts: nitrates NO₃⁻, nitrites NO₂⁻): absorbed into the blood and becomes proteins → growth. Lack causes stunted growth.
- **Magnesium** (the central chemical of chlorophyll): its presence affects photosynthesis. Lack results in chlorosis (yellow leaves).
- **Iron** (the central chemical of haemoglobin; e.g. liver, red meat, beans and nuts, dried fruit): increases the oxygen-carrying capacity of blood. Deficiency results in decreased oxygen in blood: anaemia. Deficiencies can be recovered by increasing the intake.
- **Phosphates** (PO₄³⁻): used to make nucleic acids, the genetic molecules DNA and RNA.
- **Calcium** (e.g. cheese, eggs, milk, leafy green vegetables): Ca deposits in bones and teeth and makes them strong; specifically required by animals at different levels; also important for muscle contraction and for nerve impulses.
- All are required in minor quantities but at a regular level. Their lack can cause deficiency and can result in diseases.

Vitamins

- Organic chemicals; not produced by animals, produced by plants; required by animals though.
- **Vitamin A** (source: carrot and citrus fruits): produces retinol, important for improvement of vision. Lack (extreme) results in night blindness, weak eyesight.
- **Vitamin C** (source: egg, milk and meat, leafy green vegetables and citrus fruits): also called ascorbic acid; important for our normal gums and skin. Lack of vitamin C causes bleeding gums, pale skin: scurvy.
- **Vitamin D** (source: liver, fish liver oil (cod-liver oil), eggs and fish, and sunlight; direct exposure of skin to the sunlight): also known as calciferol; important for movement of Ca and PO₄: it makes bones stronger. No vitamin D and the presence of Ca and PO₄ is of no use. Lack in infants will cause (reversible) weaker, soft and bending bones: rickets.
- Animal bodies cannot store vitamins: a fresh supply of vitamins is needed.

Fibre

- Also termed roughage; undigested waste material (plant food); undigested cellulose.
- The presence of water in plants makes faeces soft, which lets it pass through the last part of the digestive system; it can absorb water from the digestive tract, which makes it soft.

- Lack of plant intake: constipation (damages the wall of the last part; also blood).
- Minor quantity, e.g. fruit, vegetables and cellulose. Herbivores at the level of the appendix have certain bacteria that digest cellulose; it produces the enzyme cellulase.

Water

- Important for all living organisms and single cells.
- A polar molecule: H—O—H sharing two electrons; the oxygen is much more strongly positive and has more attraction force, making the electrons of hydrogen tilt towards it, so oxygen carries a partial δ^- charge; the H—O—H angle is 104° .
- Its polar characteristic makes it a universal solvent: it can dissolve the maximum of solutes (except fats and oils, which are only dissolved by organic chemicals). $\text{NaCl} + \text{H}_2\text{O} \rightarrow \text{Na}^+$ and Cl^- each surrounded by water molecules; water does not let them combine.
- Required for all metabolic reactions in cells; to transport materials in and out of cells; to transport materials within the body of a multi-cellular organism (e.g. minerals from roots to leaves, nutrients from the digestive system to all cells); to maintain body temperature (e.g. sweating in animals, transpiration in plants).
- Acts as a reactant for photosynthesis; maintains the shape of plant cells and in turn the whole of the plant body (known as the hydroskeleton); is involved in the movement of parts of the plant (e.g. opening and closing of flowers, leaves turning towards the sunlight).
- Sources of water: food and drinks; metabolic processes, e.g. aerobic respiration.

Food and energy

Living cells $\rightarrow$ mitochondria (for the formation of ATP; the energy released here is enough): $\text{glucose} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{energy (ATP, an energy-conserving chemical)}$. With reference to energy do not use "production" of energy, only "release".

- All food materials should be brought to the level of glucose. Carbohydrates carry less energy than proteins and fats because of their simple nature; fats carry the maximum energy; proteins carry less energy than fats.
- ATP: adenosine triphosphate (required at the level of active transport). $\text{ADP} + \text{P} \rightarrow \text{ATP}$ (adenosine diphosphate + phosphate): the bond is broken to consume energy. $\text{ADP} + \text{P} \rightleftharpoons \text{ATP}$: release downwards, conservation upwards.
- Fats are energy-storing molecules (not a ready source of energy). Proteins are taken to form living structures (to add new cells, for muscles etc.; not a ready source of energy). Carbohydrates are a ready source of energy: $\text{glucose} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{energy}$. Priority is given to carbohydrates $\rightarrow$ fats $\rightarrow$ proteins.
- In a condition of prolonged starvation, a body requires regular intake of energy, hence the carbohydrate stored is used; after carbohydrates we use fats; after fats we use proteins.

Requirements for living organisms

- **Carbohydrates:** a ready source of energy; extra carbohydrates are stored in energy reserves in the form of starch (in plants) and glycogen (in animals). E.g. pasta, rice, potatoes, sugar, vegetables.

- **Proteins:** energy-carrying molecules; involved in the formation of biomass, e.g. muscles in animals, chemicals in the body (enzymes, hormones, receptors); used as the last priority in the absence of carbohydrates and fats available for cellular respiration. E.g. meat, fish, eggs, peas, beans, lentils, soya.
- **Fats:** energy storage molecules; extra fats are stored either in the form of glycogen or as adipose tissue underneath the skin; they provide us insulation (extra heat remains inside the body against extremely low temperatures outside); protective cushions around delicate organs, e.g. kidneys, ovaries; plants store fats in the form of reserved food in their seeds. E.g. cheese, butter, margarine, oils, nuts.

Test for the amount of energy

- Take a specific food material on a spatula and heat it. The heat energy released is calculated by placing a beaker (of water) and thermometer above it: the rise in temperature is the amount.
- More chance of error, because gaps between the spatula and beaker will not give us the exact amount of energy: so a calorimeter (joule meter) is used. The calorimeter is also called a bomb calorimeter; used to measure the energy value of foods. (Sketch: a sealed vessel of water with a thermometer; the food sample sits on a heating element below, with oxygen fed in.)
- Energy level of food = (rise in temperature (°C) × volume of water (cm³)) ÷ amount of food sample (g), in calories per gram or joules per gram. 1 calorie = 4.2 joules. Energy value of food in kJ = A/100 × 4.2.
- The Recommended Daily Allowance (on wrappers) gives us a condition of a balanced diet.

Factors affecting a balanced diet

1. **Age:** infants need more ready source of energy (carbohydrates + proteins + minerals) for rapid growth; middle-aged less ready source of energy (physical activity only, no cell division); old-aged least, because resting.
2. **Gender:** males of the same age require more energy as compared to a girl of the same age because of a larger-sized body.
3. **Occupation** (amount of physical energy): an office worker less energy, a labourer requires more.
4. **Physiological condition** (physical disorder): a diabetic requires a diet with less carbohydrates; high blood pressure → less fats; anaemic condition → iron-rich diet.

Balanced diet = basal metabolic rate + physical exercise + food action.

- **Basal metabolic rate:** the amount of energy required to perform basic functions (metabolic activity), e.g. circulatory system, respiratory system, excretory system.
- **Physical exercise:** daily work, exercise evident to us.
- **Food action:** the amount of energy required for digestion of food.

1 gram of	Energy
fats	39 kJ
protein	20 kJ
carbohydrates	17 kJ

The higher the person's mass, the more energy they need; children require a comparatively lesser amount.

Improving foods (modification of food)

- **Fortification:** adding any one nutrient to increase the food value. E.g. fortified milk (Nido), wheat (+ fluoride), water (+ fluoride, which strengthens the outer layer of teeth), mineral water (+ salts, which stay down during distillation).
- **Additives:** adding different chemicals to improve different conditions of food that do not lead to enough nutrient level. E.g. colouring agents (improving colour: tartrazine, β -carotene); flavouring agents (give flavour: vanilla essence, monosodium glutamate, MSG); preservatives (improving decomposition: antioxidants, sulphur dioxide); thickeners (improving texture: cellulose, cornflour, xanthan).
- Not always beneficial; with excessive use they cause side-by-side harms: tartrazine; sulphur dioxide (sensitivity in asthmatic conditions); monosodium glutamate (nausea, vomiting); freshwater + fertiliser (unfit for drinking; we still have an indirect use); pesticides are absorbed by plants (toxic chemicals, not readily degraded, converted to less harmful and excreted; decrease the population of animals at the end of the food chain; thinning eggshells of birds, which break before hatching; mental and nervous condition is affected).

Balanced diet and malnutrition

Malnutrition (bad nutrition): (i) more food consumption than required; (ii) very much less food consumption than required; (iii) unbalanced food consumption (one nutrient more than required).

- (i) Extra food beyond the immediate need is stored in the body at different levels: extra carbohydrates $\rightarrow$ glycogen $\rightarrow$ liver cells; extra proteins $\rightarrow$ amino acids $\rightarrow$ (degraded) deamination $\rightarrow$ more urea $\rightarrow$ urine $\rightarrow$ out of the body, or forming muscles and storing; extra fats $\rightarrow$ fatty acids and lipids $\rightarrow$ adipose tissue under the skin. An overweight condition: **obesity**.
- (ii) Leads to deficiencies of certain specific nutrients, e.g. vitamin C $\rightarrow$ scurvy; vitamin D $\rightarrow$ rickets; iron $\rightarrow$ anaemia.
- **Kwashiorkor:** protein deficiency, less use of mother's food (infants); they are consuming a more carbohydrate diet; lack of muscles as a result; very thin arms and thin legs and the lower body enlarges.
- **Marasmus:** overall diet deficiency (all nutrients), less amount of food; only staying alive; very lean body. One of the causes is overpopulation, uneven distribution of food, advancement in medicine (decreased death rate), pollution (dry conditions, less rainfall, low water table), flooding (fresh water reserves should be conserved), global warming causing abrupt melting.

Checked by Mega Lecture

This typed version follows the handwritten notes. Corrections: fructose and glucose formulae written $C_6H_{12}O_6$ (the notes have $C_6H_{12}C_6$); "glycogen bond" under reversal of bonds written as glycosidic bond; ATP expanded as adenosine triphosphate (the notes say "adamin"); "BMI" written as basal metabolic rate; vitamin C and D functions kept as written. Two points to be aware of: the syllabus counts 20 standard amino acids, not 22; and the usual O Level sources of vitamin C are citrus fruits and green vegetables (egg, milk and meat are better known as vitamin D and protein sources). The structure diagrams (glucose ring, glycosidic and peptide bonds, fats, the water molecule, the calorimeter) are described in words. Spotted a mistake? Tell us on WhatsApp: +92 336 780 1123.