

Edexcel IAL Biology A-level

Topic 7: Respiration, Muscles and the Internal Environment

Definitions and Concepts

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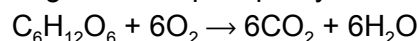


7.1-7.8: Respiration

Aerobic respiration: A form of cellular respiration that takes place in the presence of oxygen and produces carbon dioxide, water and ATP. It involves four main stages: glycolysis, link reaction, Krebs cycle, and the electron transport chain.

Anaerobic respiration - A form of cellular respiration that takes place in the absence of oxygen. In animals, lactate is produced. In plants and microorganisms, ethanol and carbon dioxide are produced. Less ATP is formed than in aerobic respiration.

ATP synthase: An enzyme found in the inner mitochondrial membrane which is used to harness the energy of the proton gradient to phosphorylate ADP to form ATP.



Chemiosmosis: The passive diffusion of protons from a high concentration to a lower concentration across a partially permeable membrane used in oxidative phosphorylation.

Coenzyme A: A coenzyme that binds an acetyl group to form acetyl coenzyme A during the link reaction of aerobic respiration.

Coenzymes: Molecules that help enzymes carry out their function e.g. NAD, FAD, coenzyme A and NADP.

Decarboxylation: The removal of a carbon dioxide molecule.

Dehydrogenation: The removal of a hydrogen atom.

Electron transport chain: A series of electron carrier proteins that transfer electrons in a chain of oxidation-reduction reactions.

FAD: A coenzyme that becomes reduced when it takes up hydrogen atoms during the Krebs cycle, forming reduced FAD.

Glycolysis: A series of reactions that occur in the cytoplasm and make up the first step in both aerobic and anaerobic respiration.

Hexose: A monosaccharide with six carbon atoms. It exists in two forms: open-chain and cyclic.

Intracellular enzyme: An enzyme that works within cells.

Krebs cycle: A series of steps used to oxidise Acetyl CoA and reduce the cofactors NAD and FAD for use in oxidative phosphorylation.

Lactate dehydrogenase: An enzyme that catalyses the conversion of pyruvate to lactate.

Lactate fermentation: A type of fermentation that takes place in animal cells and produces lactate.



Lactate: The molecule produced from glucose through the process of anaerobic respiration which is oxidised mainly in the liver to produce glucose.

Link reaction - The second stage of aerobic respiration (also known as 'oxidative decarboxylation') that takes place in the mitochondrial matrix and converts pyruvate into acetyl coenzyme A and carbon dioxide. Reduced NAD is also formed.

NAD: A coenzyme that becomes reduced when it takes up hydrogen atoms during aerobic respiration, forming reduced NAD.

Oxidation: The loss of electrons, gain of oxygen or loss of hydrogen in a substance.

Oxidative decarboxylation: See 'link reaction'.

Oxidative phosphorylation: The synthesis of ATP from reduced coenzymes and oxygen in the electron transport chain of aerobic respiration.

Phosphorylation: The addition of a phosphate group to a molecule often using ATP hydrolysis.



Pyruvate: A 3 carbon molecule which is produced by glycolysis at an output of two molecules of pyruvate per one molecule of glucose.

Reduction: The gain of electrons, loss of oxygen or gain of hydrogen in a substance.

Respiration: A set of metabolic reactions that take place in organisms and break down respiratory substances, such as glucose, into smaller inorganic molecules, like water and carbon dioxide. This is linked to the synthesis of ATP.

Respiratory quotient (RQ): The ratio of carbon dioxide produced to oxygen consumed during respiration. Calculated using the formula:

$$\text{RQ} = \frac{\text{CO}_2 \text{ produced}}{\text{O}_2 \text{ consumed}}$$

Respiratory substrate: An organic molecule that can be broken down via the respiratory pathways to produce ATP.

Respirometer: A device used to determine respiration rate in living organisms by measuring the change in volume of oxygen or carbon dioxide.

Substrate level phosphorylation: The direct addition of a phosphate group onto ADP to form ATP



Triose phosphate (TP): A three-carbon compound formed in glycolysis and the light-independent stage of photosynthesis. It may serve as a starting material for the formation of organic molecules or be used to regenerate RuBP.

7.9-7.13: Cardiac and Skeletal Muscle

A band: The section of a sarcomere consisting of both actin and myosin filaments between the I band and the H zone.

Accelerans nerve: A sympathetic nerve which connects the medulla oblongata with the sinoatrial nerve and causes an increase in heart rate using the neurotransmitter noradrenaline.

Actin: A protein which makes up large filaments that play important roles in muscle contraction along with myosin.

Adenosine triphosphate (ATP): A molecule that acts as the energy currency of cells formed from a molecule of ribose, a molecule of adenine and three phosphate groups.

Antagonistic muscle pairs: Two muscles which have opposing effects.

ATPase: A group of enzymes which catalyse ATP hydrolysis into ADP and inorganic phosphate (P_i).

Atrioventricular node (AVN): A group of cells located between the atria that slow down the wave of excitation and pass it between the ventricles along the bundle of His.

Bradycardia: An abnormally slow heartbeat which is often characterised by a heart rate of below 60 BPM.

Bundle of His: A collection of Purkyne fibres which run from the AVN down to the apex of the ventricles.

Calcium ions (Ca^{2+}): A key inorganic ion found in biological systems that helps to strengthen bones and plays a crucial role in muscle contraction and nerve impulse transmission.

Cardiac cycle: Describes the sequence of events involved in one complete contraction and relaxation of the heart. There are three stages: atrial systole, ventricular systole and diastole.

Cardiac muscle: Striated muscle found in the heart.

Cardiac output: The total amount of blood that the heart pumps per minute which can be calculated using the following equation:

$$\text{Cardiac output} = \text{Stroke volume} \times \text{Heart rate}$$



Cardiovascular control centre: The region of the medulla oblongata which controls the heart rate and blood pressure through hormones and nerve impulses.

Electrocardiogram (ECG): A recording which measures the electrical activity of the heart and can be used to aid the diagnosis of heart conditions.

Extensors: A muscle which increases the angle at a joint and acts to extend a limb.

Fast twitch muscle fibre: A type of muscle fibre which can produce a short burst of strong contraction.

Flexors: A muscle which decreases the angle at a joint and acts to bend a limb.

H zone: The section composed of just thick myosin in the middle of a sarcomere which shortens during muscle contraction.

I band: The section of a sarcomere consisting of just actin filaments which shortens during contraction and is located between the Z line and the start of the A band.

Intrinsic rhythm: The rate at which the heart beats with no interference from the Central Nervous System.

Ligament: A tough section of connective tissue that connects two bones together at a joint.

Medulla oblongata: A region of the brainstem which controls involuntary actions such as heart rate and breathing.

Muscle: A group of muscle tissues which contract together to produce a force. Mammals have three types of muscle: skeletal, smooth and cardiac.

Myogenic: Describes cardiac muscle tissue that initiates its own contraction without outside stimulation from nervous impulses.

Myosin: A protein molecule composed of a head and a tail which plays an important role in muscle contraction along with actin.

Purkyne fibres: Specialised cardiac muscle fibres which make up the bundle of His and conduct the wave of excitation through the septum from the AVN down to the apex of the ventricles.

Sarcolemma: The membrane which surrounds a muscle cell.

Sarcomere: A singular unit of muscle fibre between two different Z lines.

Sinoatrial node (SAN): A group of cells in the wall of the right atrium that generate electrical activity, causing the atria to contract. The SAN is often referred to as the heart's pacemaker.



Skeleton: The bony framework of the body in vertebrates (endoskeleton) or the hard outer envelope of insects (exoskeleton).

Sliding filament theory: A theory that explains muscle contraction through the sliding of actin and myosin filaments.

Slow twitch muscle fibre: A type of muscle fibre which is able to contract slowly for longer periods of time but with less force than fast twitch fibres.

Smooth muscle (involuntary muscle): Non-striated muscle found in the gut and the blood vessels, which is under the control of the involuntary nervous system.

Striated muscle (skeletal muscle or voluntary muscle): The muscle attached to the skeleton.

Tachycardia: An abnormally fast heartbeat which is often characterised by a heart rate of over 100 BPM.

Tendon: A fibrous connective tissue which attaches muscle to bone.

Tropomyosin: A helical protein which blocks the myosin binding sites on the actin filament and works together with troponin to allow myosin to bind to actin during muscle stimulation.

Troponin: A protein complex which is attached to tropomyosin and binds Ca^{2+} ions which causes it to pull on tropomyosin to allow muscle contraction to take place.

Vagus nerve: A parasympathetic nerve which connects the medulla oblongata with the sinoatrial nerve and causes a decrease in heart rate using the neurotransmitter acetylcholine.

Ventilation centre: The region of the medulla oblongata which controls automatic breathing.

Z band: The line between two adjacent sarcomeres where the actin filaments are anchored.

7.14-7.17: Homeostatic Principles and Thermoregulation

Breathing rate: The number of breaths taken per minute.

Dynamic equilibrium: The steady state of a reversible reaction where the rate of the forward reaction is the same as the reaction rate in the backward direction. Homeostasis is often referred to as a dynamic equilibrium.

Expiratory reserve volume (ERV): The volume of air that can be expelled over and above the normal expired tidal volume, i.e., the extra air breathed out when you exhale as hard as possible after a normal expiration.

Homeostasis: Maintaining a constant internal environment around an optimum despite



external change.

Hypothalamus: A small region of the brain that has various functions, including regulating body temperature.

Inspiration: The process of moving air into the lungs. The contraction of the external intercostal muscles and diaphragm increase the volume in the thorax, thereby decreasing the pressure. Air flows in, down a pressure gradient.

Inspiratory capacity (IC): The volume that can be inspired beyond the end of a normal expiration. It is calculated by adding together the tidal volume and the inspiratory reserve volume.

Inspiratory reserve volume (IRV): The volume of air that can be taken in over and above the normal inspired tidal volume, i.e., the extra air that you can take in when you inhale as deeply as possible after a normal inspiration.

Negative feedback: The product of a process that counteracts change to maintain an equilibrium around a normal level.

Positive feedback: A process which causes an increase in change away from the normal level.

Residual volume (RV): The volume of air left in the lungs after the strongest possible expiration.

Respiratory minute ventilation (mL/min): The volume of gas inhaled or exhaled per minute. It is calculated by multiplying the tidal volume by the breathing rate.

Spirometer: An instrument used to find the vital capacity of an individual's lungs, or to measure their inspiratory or expiratory reserves.

Thermoregulation: The homeostatic process of maintaining a constant body temperature.

Tidal volume (VT): The volume of air moved in and out of the lungs in a resting breath.

Total lung capacity (TLC): The sum of the vital capacity and the residual volume.

Ventilation rate ($\text{dm}^3\text{min}^{-1}$): A measure of the volume of air breathed in a minute. It is calculated by multiplying the tidal volume by the frequency of inspiration.

Vital capacity (VC): The volume of air which can be breathed out by the most vigorous exhalation following the deepest possible inhalation. It can be calculated by adding together the tidal volume, the inspiratory reserve volume and the expiratory reserve volume.

7.18-7.22: The Kidneys, Osmoregulation and DNA Control



Adrenal glands: Glands which are located on the top of the kidneys and produce adrenaline and steroid hormones.

Antidiuretic hormone (ADH): A hormone released from the posterior pituitary gland that increases the reabsorption of water in the kidney tubules.

Bowman's capsule: A part of the nephron that forms a cup-like sack surrounding the glomerulus. It encloses a space called 'Bowman's space', which represents the beginning of the urinary space and is contiguous with the proximal convoluted tubule.

Countercurrent multiplication (kidneys): The process of using energy to generate an osmotic gradient that enables the reabsorption of water from the tubular fluid and the production of concentrated urine.

Deamination: Deaminase enzymes in the liver and, to a lesser extent, the kidneys remove an amino group (NH₂) from a molecule as part of the urea cycle.

Excretion: The process of removing metabolic waste from an organism.

Gene expression: The transcription (and often subsequent translation) of genes.

Gene regulation: The mechanisms that act to induce or repress the expression of a gene

Glomerular filtration rate (GFR): A method of measuring kidney function which assesses the amount of blood plasma filtered per unit of time and produces a value which should be above 90mL/min in healthy adults.

Glomerulus: The bundle of blood vessels at the beginning of a kidney nephron where ultrafiltration takes place.

Hormone: A regulatory substance produced in an organism and transported in tissue fluids such as blood or sap to stimulate specific cells or tissues into action.

Intracellular receptors: A class of ligand-dependent transcription factors that include receptors for both steroid and non-steroid hormones.

Kidney: Organ involved in blood filtration and urine excretion. It also produces some hormones.

Liver: The glandular organ that stores and metabolizes nutrients, detoxifies, and produces bile.

Loop of Henle: A large hairpin shaped loop found in the kidney tubule used to regulate the water and salt concentration of the blood.

Metabolic waste: Products produced in metabolic reactions which have no benefit to the



organism.

Nephron: The basic functional unit of the kidney.

Osmoreceptor: A type of receptor found in the hypothalamus which can detect the water concentration of blood plasma to maintain an appropriate water balance in the body.

Osmoregulation: The homeostatic regulation of the osmotic pressure of body fluids.

Perirenal fat capsule (adipose fat capsule): A layer of adipose tissue that surrounds the fibrous capsule. It helps anchor the kidneys in place.

Pituitary gland: A small, hormone-producing gland located at the base of the brain. It is divided into two regions, the anterior pituitary and the posterior pituitary.

Plasma: The main component of the blood that carries red blood cells. It is a yellow liquid that contains proteins, nutrients, mineral ions, hormones, dissolved gases and waste.

Polypeptide hormones: Polypeptide hormones, or protein hormones, consist of two peptide chains linked by a disulfide bridge. They are produced in the beta cells of the endocrine pancreas and released in response to elevated levels of blood glucose.

Posterior pituitary gland: The region of the pituitary gland that stores and secretes hormones produced by the hypothalamus.

Proximal convoluted tubule (PCT): Responsible for the most amount reabsorption of almost all filtered substances (sodium, glucose, amino acids, etc).

Proximal tubule: The segment of the nephron in kidneys which begins from the renal pole of the Bowman's capsule to the beginning of the loop of Henle. It can be further split into the proximal convoluted tubule (PCT) and the proximal straight tubule (PST).

Renal (adjective): Relating to the kidneys.

Renal arteries: Blood vessels that carry oxygenated blood from the heart to the kidneys. There are two renal arteries (left and right, connected to their respective kidneys), which normally branch off the aorta.

Renal capsule: A tough fibrous layer surrounding the kidney and covered in a layer of perirenal fat known as the adipose capsule of kidney. The adipose capsule is sometimes included in the structure of the renal capsule. It provides some protection from trauma and damage.

Renal cortex: The outer layer of kidney which contains the majority of the glomeruli in the renal corpuscles and major parts of the associated nephrons which produce urine.

Renal fascia: A layer of connective tissue encapsulating the kidneys and the adrenal glands. It can be divided into the anterior renal fascia and the posterior renal fascia. The renal fascia



is the outermost layer of the three layers surrounding the kidneys.

Renal hilum: The entry and exit site for structures servicing the kidneys: vessels, nerves, lymphatics, and ureters.

Renal medulla: The innermost part of the kidney, where the kidney's main functions are carried out. It contains the loop of Henle as well as renal pyramids.

Renal papilla: The tip of each renal pyramid which projects into a minor calyx where urine is collected from the tubes draining this portion of the medulla. It is covered by a stratified cuboidal epithelium.

Renal parenchyma: The functional tissue of the kidney, consisting of the nephrons.

Renal pyramids: The triangular masses of tubules in the renal medulla, consisting mainly of tubules that transport urine from the cortical, or outer, part of the kidney, where urine is produced, to the calyces (cup-shaped cavities) in which urine collects before it passes through the ureter to the bladder.

Renal tubule: The portion of the nephron containing the tubular fluid filtered through the glomerulus.

Renal veins: Blood vessels that drain oxygen-depleted blood from the kidney. There are two renal veins (left and right, connected to their respective kidneys), which branch off the inferior vena cava.

Selective reabsorption: The selective reuptake of useful substances along the kidney nephron using membrane transport proteins.

Steroid hormones: Steroids that act as hormones. They are secreted by three 'steroid glands' - the adrenal cortex, testes, and ovaries - and during pregnancy by the placenta.

Steroid: A class of natural or synthetic organic compounds characterised by a molecular structure of 17 carbon atoms arranged in four rings.

The Ornithine cycle (urea cycle): The cycle of reactions responsible for producing urea from ammonia for detoxification and excretion.

Transcription factors: Proteins which bind to regulatory regions of DNA and control DNA transcription.

Ultrafiltration: The removal of small substances from the blood through the pressure created by the structure of the kidney nephron.

Ureter: A tube that carries the urine from the kidney to the bladder. There are two ureters, one for each kidney. The ureters begin at the ureteropelvic junction (UPJ) of the kidneys,



which lie posteriorly to the renal vein and artery.

