

YEAR 11 ATAR HUMAN BIOLOGY

Semester 2 Exam Study Guide

UNITS 1 & 2 • FULL COURSE

HUMAN BIO MADE EASY

Science taught the way your brain learns best, made for WA students



Name: _____ Exam date: _____

Study plan: _____ to _____

THE RULES

- Phone off or in another room; no social media during study blocks
- Work in blocks of 45 minutes or less, with a 10-minute break between blocks
- Finish every session with a 10-minute retrieval quiz, from memory, no notes
- Draw diagrams regularly rather than just re-reading notes
- Use flashcards for definitions, such as hormones, enzymes and structures
- Can't answer a retrieval question without notes? That topic is first tomorrow

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How to Use This Guide

This guide breaks the entire Year 11 ATAR Human Biology course into **23 study sessions**, grouped by topic in the same order as your booklets, with space in the timetable to write in your own dates.

- Each session has **two work blocks of 45 minutes** or less, followed by a 10-minute retrieval quiz (with answers included so you can self-mark).
- Work backwards from your exam date to plan your dates. The plan runs one session per school day for Sessions 1–21, covering the whole course at a steady, sustainable pace, and the full plan takes roughly six weeks. **If you can start earlier, you should. More time = better preparation**
- Leave two or three days free after Session 21 as buffer/catch-up days. You can use them to redo any session you fell behind on or scored poorly in.
- If you have other exams in the lead-up to Human Biology, keep Human Biology revision light on those days (evenings only) and focus on whatever exam is next.
- Session 22 (full-course mixed retrieval) falls two days before your exam, and Session 23 (the full mock exam) on the day before the real exam. This timing is a guide only – if you can do the mock exam earlier, that would be even better.
- If you're starting later than planned, prioritise Unit 2 (Sessions 13–21, the most recently taught content) and the Priority List near the end of this guide, then use remaining time on Unit 1.
- Each session lists relevant resources from www.misstagore.com (Year 11 ATAR Human Biology library – quizzes, Quizlets, mind maps and videos). Search the resource name shown against the topic to find it quickly.
- In this guide you will also find textbook page references in every session, a Confidence & Spaced-Revision Tracker (straight after the timetable), a Common Mistakes to Avoid section, six blank labelling diagrams with an answer key.

Resource Library Quick Reference

All resources below are free at www.misstagore.com under the Year 11 ATAR Human Biology library ([Unit 1 & Unit 2 library page](#)).

Topic	Look for these on misstagore.com
Cell Structure, Membranes & Metabolism	Cell Organelles, Cell Membranes, Cells & Tissues, Enzymes, Respiration
Respiratory & Circulatory Systems	Respiration, Blood, Heart & Blood Vessels, Cardiac Cycle, Respiratory System
Digestive & Excretory Systems	Digestive System, Digestion Kahoot!, Chapters 7–9 Practice Test, Kidney
Musculoskeletal System	Bones & Cartilage, Muscles, Musculoskeletal System Quizlet
DNA & Cell Reproduction	DNA, Transcription, Translation, Mitosis & Meiosis, DNA Validation
Genetics & Inheritance	Genetic Crosses & Pedigrees, Variation, Mendelian Genetics Key Words Quizlet
Reproduction, ART & STIs	Reproductive Organs, Female Cycle, Stem Cells, Male Hormones, Changes in Baby & Mother, Contraception & STIs Quizlet
Exam Revision (all topics)	Exam Revision Quizzes 1–6; How to Answer Extended Response Questions (video)

Master Revision Timetable

Tick each session off as you complete it. Write your own dates in the Date column, working back from your exam date.

Day	Date	Topic	Notes and reflections	Done
1		Cell Structure & Organisation		☐
2		Cell Membrane & Transport		☐
3		Enzymes & Metabolism		☐
4		Respiratory System Structure		☐
5		Gas Exchange & the Heart		☐
6		Blood, Vessels & the Lymphatic System		☐
7		Digestive System I – Structure & Digestion		☐
8		Digestive Enzymes, Absorption & Excretion Intro		☐
9		Kidney & Excretory System		☐
10		Skeletal System		☐
11		Joints & Muscle Structure		☐
12		Muscle Action + Unit 1 Mixed Review		☐
13		DNA Structure, Replication & Epigenetics		☐
14		Protein Synthesis		☐
15		Mitosis & Meiosis		☐
16		Non-disjunction, Cancer & Unit 2 Cell Review		☐
17		Mendelian Genetics		☐
18		Pedigrees, Genetic Counselling & Variation		☐
19		Reproductive Systems & Gametogenesis		☐

Day	Date	Topic	Notes and reflections	Done
20		Hormones, Fertilisation & Early Development		☐
21		Pregnancy, Birth, Screening, Fertility Tech & STIs		☐
Buffer / catch-up days (2–3 days) — no new content, revisit any weak session				
Other exams before Human Bio? Keep Human Bio revision light on those days (evenings only)				
22		Full-Course Mixed Retrieval		☐
23		Mock Exam & Final Review		☐
EXAM DAY — ATAR HUMAN BIOLOGY SEMESTER 2 EXAM				

★ A-Grade Priority List ★

Short on time? Focus here first.

1. Mitosis & meiosis stages
2. Structure & direction of blood flow through the heart
3. Punnett squares & pedigree interpretation
4. Nephron structure and the 3 processes (filtration / reabsorption / secretion)
5. DNA replication enzymes (helicase, polymerase, ligase)
6. Sliding filament model of muscle contraction
7. Hormonal control of the menstrual cycle (FSH, LH, oestrogen, progesterone)
8. Gas exchange adaptations of the alveoli
9. Digestive enzymes (source, substrate, product)
10. Spermatogenesis & oogenesis
11. Placenta structure and foetal circulation shunts
12. Enzyme action & factors affecting enzyme function
13. Compact vs spongy bone, and the cartilage types
14. Crossing over, independent assortment & random fertilisation
15. Transcription & translation

🕒 Daily Retrieval Routine 🕒

10 minutes, every day, no notes.

- ☐ Name the four tissue types
- ☐ List the stages of mitosis in order
- ☐ Name the three processes of the nephron
- ☐ Name the hormone that triggers ovulation
- ☐ Define genotype and phenotype
- ☐ Name the three foetal shunts
- ☐ State the three components of a nucleotide
- ☐ Name the three sources of variation from meiosis/fertilisation
- ☐ Name the four chambers of the heart

Rule for the weeks ahead: *if you cannot answer a retrieval question without notes, that topic becomes the first thing you revise tomorrow. This turns revision into a focused improvement cycle and builds real confidence before the exam. Good luck!*

Confidence & Spaced-Revision Tracker

Retrieving information after a gap is what makes it stick, so each session's 5-question retrieval quiz is repeated twice: about 3 days and 7 days after you first studied it. Each repeat takes 10 minutes. Dates that fall on a weekend move to the Monday.

- After each session, rate the topic: **R (red)** = you couldn't answer most retrieval questions; **A (amber)** = you got some; **G (green)** = you got 4 or 5 out of 5.
- On each redo date, redo that session's quiz from memory and write your score. **4–5 = green**. **2–3 = amber** (re-read the study points and redraw the diagram, then redo the quiz again). **0–1 = red** (repeat the session or ask your teacher).
- If time is short, do the first redo for every session before you do any second redo. Use your buffer days for red and amber topics.
- If a redo date falls on a day when you have other exams, keep it to the 10-minute quiz only.

Session	Topic	Confidence after first study	Redo quiz 1 (3 days later)	Redo quiz 2 (7 days later)	Exam-ready?
1	Cell Structure & Organisation <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
2	Cell Membrane & Transport <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
3	Enzymes & Metabolism <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
4	Respiratory System Structure <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
5	Gas Exchange & the Heart <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
6	Blood, Vessels & the Lymphatic System <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
7	Digestive System I – Structure & Digestion <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
8	Digestive Enzymes, Absorption & Excretion Intro <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
9	Kidney & Excretory System <i>Studied:</i> _____	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐

Session	Topic	Confidence after first study	Redo quiz 1 (3 days later)	Redo quiz 2 (7 days later)	Exam-ready?
10	Skeletal System <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
11	Joints & Muscle Structure <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
12	Muscle Action + Unit 1 Mixed Review <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
13	DNA Structure, Replication & Epigenetics <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
14	Protein Synthesis <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
15	Mitosis & Meiosis <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
16	Non-disjunction, Cancer & Unit 2 Cell Review <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
17	Mendelian Genetics <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
18	Pedigrees, Genetic Counselling & Variation <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
19	Reproductive Systems & Gametogenesis <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
20	Hormones, Fertilisation & Early Development <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐
21	Pregnancy, Birth, Screening, Fertility Tech & STIs <i>Studied: _____</i>	☐ R ☐ A ☐ G	Date: _____ Score: ____ / 5	Date: _____ Score: ____ / 5	☐

Daily Study Sessions

Session 1 — Cell Structure & Organisation

Resources: *Cell Organelles quiz & mind map; Cells & Tissues quiz; video: Cell Ultrastructure – Organelles*

Textbook: *Ch 2, pp. 26–31 (cell structure) and pp. 43–48 (tissues). Chapter summary: p. 56.*

Watch out for: *common mistakes for this topic are listed under “Cells & Metabolism” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Levels of Organisation & Tissue Types

Study:

- **Cell theory:** A cell is the smallest structure that can perform the functions of life. All organisms are made of cells, cells are the basic structural and functional units of life, and new cells arise from pre-existing cells. Everything the body does results from the combined, coordinated activities of its cells, but each cell is also an individual unit with requirements that must be met if it is to survive.
- **Four levels of organisation:** Cells (the lowest level) are specialised for different jobs, e.g. muscle cells shorten and red blood cells carry oxygen. Cells with a similar specialisation form a tissue. An organ is made of two or more tissues working together (the stomach has epithelial tissue on the inside and muscular tissue in the wall). A system is a group of organs with a common purpose (the respiratory system: nose, trachea, lungs, diaphragm and intercostal muscles). All the systems are integrated into the one organism.
- **Systems depend on each other:** No system works in isolation. Heart muscle needs oxygen supplied by the respiratory system, and brain cells need nutrients absorbed by the digestive system and delivered by the circulatory system. Some organs belong to more than one system (the pancreas is part of both the digestive and endocrine systems), and large organs such as the skin contain smaller organs (sweat glands, nerves, hair and nails).
- **Epithelial tissue:** A covering or lining tissue: the outer layer of the skin, the covering of organs such as the heart, kidneys and lungs, and the lining of hollow organs such as the stomach and intestines. The cells are very closely joined, which makes epithelium a continuous protective barrier. Cell shape varies from thin and flat (e.g. the cells lining the mouth) to taller column shapes, depending on the job of the tissue.
- **Connective tissue:** Supports the body and holds parts together. Unlike epithelium, the cells are not close together: they are separated by large amounts of non-cellular material called the matrix. Examples are bone, cartilage, tendons, ligaments, fat (adipose) tissue and blood, whose matrix is the liquid plasma.
- **Muscular tissue:** Made of long, thin cells (muscle fibres) that can contract and become shorter. Skeletal muscle is attached to bones, is under voluntary control and looks striped (striated). Smooth muscle has no striations, is involuntary and is found in the walls of the stomach, intestines and blood vessels, the iris and the uterus. Cardiac muscle makes up most of the heart, is involuntary and pumps the blood.
- **Nervous tissue:** Made of specialised cells called neurons, which have long projections. When part of a neuron is stimulated, messages travel along the projections from one part of the body to another. Nervous tissue is found in the brain, spinal cord and nerves.

→ **Then complete:**

- Sketch the 4 levels of organisation with one human example at each level
- Write one sentence linking structure to function for each tissue type

Block 2 (45 min): The Generalised Human Cell

Study:

- **The parts of a cell:** Every human cell has a cell membrane (outer boundary), cytoplasm (everything inside the membrane except the nucleus, including the fluid and the organelles), organelles (structures that carry out particular functions), a cytoskeleton (an internal scaffold of protein fibres) and inclusions (granules or droplets such as haemoglobin and melanin that are not part of the cell structure). A cell diagram is a model: no real cell looks exactly like it.
- **Cell membrane and cytoplasm:** The membrane separates the cell from its surroundings and controls what enters and leaves. The cytoplasm is the jelly-like material between the nucleus and the membrane. Its liquid part, the cytosol, is 75–90% water with dissolved salts and carbohydrates, and it is where most metabolic reactions occur.
- **Nucleus:** The largest organelle, usually oval or spherical and separated from the cytoplasm by a double nuclear membrane with pores. It contains the DNA (loosely coiled chromatin when the cell is not dividing) and the nucleolus, where ribosomes are produced. Most cells have one nucleus, liver cells can have two or more, and mature red blood cells have none.
- **Ribosomes, ER and Golgi body work as a team:** Ribosomes are tiny spheres where amino acids are joined to make proteins; they lie free in the cytoplasm or attached to the endoplasmic reticulum (ER). The ER is a network of membrane channels running from the nuclear membrane to the cell membrane: rough ER has ribosomes attached, smooth ER does not. Proteins made at ribosomes travel through the ER channels to the Golgi body, a stack of flattened membranes that modifies the proteins and packages them into vesicles for secretion from the cell.
- **Lysosomes:** Small membrane-bound spheres formed from the Golgi body. They contain digestive enzymes that break down large molecules. A lysosome can join with a vesicle containing food particles or worn-out organelles and digest the contents.
- **Mitochondria:** Spherical or sausage-shaped organelles with a double membrane. The inner membrane is folded into cristae, which gives a very large surface area for the reactions of cellular respiration that make energy available as ATP. Cells with high energy demands, such as muscle cells, have many mitochondria, which is why mitochondria are called the powerhouses of the cell.
- **Cilia, flagella, cytoskeleton and centrioles:** Cilia are short, numerous projections that beat to move substances over a cell surface (e.g. mucus in the trachea). Flagella are longer, with only one or two per cell (the sperm cell is the only human cell with one). The cytoskeleton (microtubules and microfilaments) gives shape, holds organelles in place and moves materials around. Centrioles are involved in cell division.
- **Why cells differ:** Cell size and shape vary because each cell type is specialised for a particular function, but all cells have the same basic parts. The structure of each organelle is linked to its function, which is a theme that runs through the whole course.

→ Then complete:

- Draw and label a generalised animal cell completely from memory

Retrieval Quiz (10 min) - answer without notes

1. What are the four levels of biological organisation in the human body?
2. Name the four tissue types.
3. What is an organelle?
4. Which organelle is the site of aerobic respiration?
5. Which organelle produces ribosomes?

Check your answers:

1. Cells, tissues, organs, systems.
2. Epithelial, connective, muscular, nervous.
3. A specialised structure within a cell that performs a specific function.
4. The mitochondria.
5. The nucleolus.

Session 2 — Cell Membrane & Transport

Resources: *Cell Membranes quiz; Transport Across the Cell Membrane mind map & videos; Surface Area to Volume Ratio video*

Textbook: *Ch 2, pp. 32–42 (cell requirements: diffusion, osmosis, active transport, bulk transport, surface area to volume). Chapter summary: p. 56.*

Watch out for: *common mistakes for this topic are listed under “Cells & Metabolism” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Membrane Structure & Passive Transport

Study:

- **Cells need a stable environment:** The immediate environment of every cell is the tissue (extracellular) fluid. Body systems work together to keep it constant in temperature and composition, which is called homeostasis. Cells take in glucose and oxygen and produce carbon dioxide, water and other wastes, and many cells also make products such as hormones and enzymes for use elsewhere. Everything that enters or leaves a cell must cross its membrane.
- **The fluid mosaic model:** The membrane is a bilayer of phospholipids with the hydrophilic (water-loving) heads on the outside and the hydrophobic (water-hating) tails on the inside. It is fluid because the molecules keep changing position, and mosaic because it contains many different molecules, including proteins that act as channels, carriers and receptors. The membrane forms a physical barrier, regulates the passage of materials, is sensitive to changes (through receptors) and helps support the cell (it is attached to the cytoskeleton).
- **Selectively permeable:** Membranes let some ions and molecules pass while restricting others. Passive processes use no energy, whereas active processes use ATP. The three basic types of transport are simple diffusion (including osmosis), facilitated transport through proteins, and vesicular transport.
- **Diffusion:** Molecules of liquids and gases move randomly, so they spread out until evenly distributed. The difference in concentration is the concentration gradient. The net movement is from high to low concentration, and the steeper the gradient the faster the diffusion. When concentrations are equal, molecules still move randomly but there is no net movement. Oxygen, carbon dioxide, alcohol and steroids can diffuse directly through the lipid bilayer (simple diffusion). Oxygen diffuses into cells because it is continually used up in respiration, and carbon dioxide diffuses out because it is continually produced.
- **Osmosis:** A special type of diffusion: the movement of water (the solvent) across a selectively permeable membrane. Water moves from the side with a lower solute concentration (higher water concentration) to the side with a higher solute concentration (lower water concentration), because the solute cannot cross. This dilutes the more concentrated solution and produces an osmotic pressure. A cell placed in a very dilute solution takes in water by osmosis and swells.
- **Facilitated transport (passive):** Water-soluble molecules such as glucose and ions are repelled by the hydrophobic tails, so they cross through proteins. Channel proteins form a pathway that ions and water can pass through. Carrier proteins are open to only one side at a time: a specific substance binds, the protein changes shape and releases it on the other side. Carriers are specific, can become saturated (so the rate stops increasing), and are regulated by hormones. Facilitated diffusion moves substances down their concentration gradient and needs no energy.

→ **Then complete:**

- Draw & label the fluid mosaic model of the membrane
- Explain in one paragraph why osmosis is a special case of diffusion

Block 2 (45 min): Active Transport, Bulk Transport & SA: V

Study:

- **Active transport:** Carrier proteins move substances against their concentration gradient, from low to high concentration, using energy from ATP. Its big advantage is that it does not depend on a gradient: the cell can take in or pass out a substance whatever its concentration. An example in humans is the sodium–potassium pump.
- **Vesicular (bulk) transport:** An active process, because energy is needed to form the vesicles. In endocytosis the membrane folds around liquid droplets or solid particles and pinches off a vesicle: pinocytosis takes in liquids and phagocytosis takes in solids. In exocytosis a vesicle from inside the cell fuses with the membrane and pushes its contents out into the extracellular fluid.
- **Movement inside the cell:** Molecules move within the cytoplasm mostly by diffusion: as oxygen is used up by the mitochondria, more diffuses in to replace it. Some substances are moved by structures, e.g. proteins made by the cell are transported through the endoplasmic reticulum to the Golgi body.
- **Keeping the concentration gradient:** Gradients across the membrane are maintained because the cell keeps using up some substances (oxygen, glucose) and keeps producing others (carbon dioxide, wastes), while the body keeps supplying and removing them through its transport systems.
- **Surface area to volume ratio:** Everything a cell needs and produces must cross its surface, so the surface area to volume ratio matters. If a cube-shaped cell doubles its side length, its volume increases eight times but its surface area only four times, so the ratio falls as the cell grows. A large cell could not absorb enough nutrients or remove enough wastes for its volume, which is why most cells are microscopic and why small cells exchange materials more efficiently.
- **Factors affecting exchange:** The rate at which materials cross the membrane depends on the surface area to volume ratio, the concentration gradient, and the physical and chemical properties of the substance (size, charge, and whether it dissolves in lipid or water).

→ Then complete:

- Construct a table comparing diffusion, osmosis, active transport and endo-/exocytosis (energy? direction? example(s)?)
- Explain why small cells are more metabolically efficient than large ones

Retrieval Quiz (10 min) — answer without notes

1. What model describes the cell membrane?
2. Does active transport require ATP?
3. What is the difference between phagocytosis and pinocytosis?
4. Why does SA:V ratio matter for cells?
5. What is osmosis?

Check your answers:

1. *The fluid mosaic model.*
2. *Yes – it moves substances against their concentration gradient.*
3. *Phagocytosis engulfs solids ('cell eating'); pinocytosis engulfs liquids ('cell drinking').*
4. *A high SA:V allows efficient diffusion of nutrients/wastes; as cells grow, volume increases faster than surface area, limiting size.*
5. *The diffusion of water molecules across a selectively permeable membrane from high to low water concentration.*

Session 3 — Enzymes & Metabolism

Resources: *Enzymes quiz, mind map & video; Respiration quiz, mind map & video; Metabolism video*

Textbook: *Ch 3, pp. 63–75 (metabolism pp. 63–66; enzymes pp. 67–69; cellular respiration pp. 69–73; energy use in the cell pp. 74–75). Chapter summary: p. 80.*

Watch out for: *common mistakes for this topic are listed under “Cells & Metabolism” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Enzyme Action

Study:

- **Metabolism:** All the chemical reactions in the cells of an organism. Catabolic reactions break large molecules into smaller ones and release energy (digestion is an example). Anabolic reactions build small molecules into larger ones and need energy (protein synthesis is an example). Metabolism is about balancing energy release with energy use.
- **Nutrients and organic compounds:** There are six nutrient groups: water, carbohydrates, lipids, proteins, minerals and vitamins. Organic compounds have a carbon chain: carbohydrates are the main energy source (simple sugars such as glucose, disaccharides and polysaccharides such as starch), lipids are made of glycerol and fatty acids (triglycerides, phospholipids, steroids), proteins are chains of amino acids joined by peptide bonds and folded into specific shapes, and nucleic acids (DNA and RNA) are chains of nucleotides. Water, minerals and vitamins are inorganic: water is the solvent for reactions, minerals form part of enzymes, cofactors and ATP, and vitamins act as coenzymes.
- **Enzymes lower activation energy:** For a reaction to happen, particles must collide with enough energy to break bonds (the activation energy). Catalysts lower the activation energy, so more particles react and the reaction is faster, and they are not consumed. Enzymes are the protein catalysts of living things. Without them, reactions would be too slow at body temperature.
- **Specificity and models of enzyme action:** The molecule an enzyme acts on is its substrate, and the part of the enzyme that binds it is the active site. Enzyme and substrate have complementary shapes, so each enzyme acts on only one substrate and one reaction, forming an enzyme–substrate complex. In the lock-and-key model the active site is always the exact shape of the substrate. In the induced-fit model, weak bonds form when the substrate joins and the enzyme changes shape to fit it. The products are released and the enzyme is reused.
- **Concentration and temperature:** More enzyme means a faster reaction, because there are more active sites. More substrate also increases the rate until all the active sites are occupied (saturation), after which adding more substrate has no effect. Products must be removed or the rate slows. The rate rises with temperature up to the optimum (30–40°C for most human enzymes), but above about 45–50°C the enzyme is denatured: its shape, including the active site, changes and it becomes inactive.
- **pH, cofactors, coenzymes and inhibitors:** Each enzyme has an optimum pH. Many enzymes need a cofactor (an ion or non-protein molecule) that changes the shape of the active site so the enzyme can bind its substrate. Cofactors that are non-protein organic molecules are coenzymes, and many vitamins work this way. Enzyme inhibitors slow or stop an enzyme; cells use them to control reactions, and many drugs are inhibitors (penicillin inhibits a bacterial enzyme involved in building the cell wall).

→ **Then complete:**

- Sketch a lock-and-key diagram with labels
- Explain what happens to enzyme activity as temperature rises past the optimum

Block 2 (45 min): Cellular Respiration & ATP

Study:

- **Cellular respiration:** The process in every cell that breaks down organic molecules from food to release energy for cell activities. Glucose is the main fuel. The summary equation is glucose + oxygen → carbon dioxide + water + energy (ATP and heat). In reality it involves more than 20 reactions in sequence, each catalysed by a different enzyme, so energy is released gradually and under control. Only about 40% of the energy goes into ATP; about 60% is released as heat, which helps maintain body temperature.
- **ATP and ADP:** ATP (adenosine triphosphate) is made of adenosine (adenine plus ribose) and three phosphate groups. It is formed when a phosphate group joins ADP (adenosine diphosphate), storing energy in the bond to the third phosphate. That bond is easily broken, releasing energy where it is needed, and the ADP can be reused. ATP transfers energy from catabolic reactions (respiration) to anabolic and other cell processes.
- **Glycolysis:** The first phase, in the cytosol, does not need oxygen. One glucose molecule is broken down in 10 steps to two molecules of pyruvate, releasing enough energy to make 2 ATP.
- **Anaerobic respiration:** If oxygen is not available, pyruvate is converted to lactic acid by fermentation in the cytosol. No further ATP is made, but the 2 ATP from glycolysis allow cells to keep working, for example muscles during vigorous exercise when the respiratory and circulatory systems cannot supply enough oxygen. Lactic acid can cause muscle pain. It is carried to the liver and converted back to glucose and glycogen using oxygen, so the body incurs an oxygen debt that is repaid (recovery oxygen), which is why we keep breathing heavily after exercise.
- **Aerobic respiration:** With oxygen, pyruvate enters the mitochondria and is completely broken down. It is first converted to acetyl CoA (a CO₂ molecule is removed; no ATP is made). Acetyl CoA enters the citric acid (Krebs) cycle, where carbon is released as CO₂ and 2 ATP are produced per glucose. The electron transport system (oxidative phosphorylation) is the only stage that uses oxygen: electrons are passed between molecules and finally combine with oxygen to form water, producing up to about 34 ATP. The theoretical maximum is 38 ATP per glucose (some sources give 36), and the actual yield is usually lower.
- **Where and why:** Aerobic respiration takes place in the mitochondria, whose folded inner membrane (cristae) carries the enzymes and provides a large surface area. It releases about 95% of the energy a cell needs, so cells that need a lot of energy contain many mitochondria.
- **What ATP energy is used for:** Building complex molecules, cell division and growth, movement of organelles and of whole cells, maintaining cell organisation, active transport and transmission of nerve impulses. Because only 40% of the energy is captured in ATP and the rest is lost as heat, energy must be continually taken in as food.

→ Then complete:

- Draw a table comparing aerobic vs anaerobic respiration (location, oxygen, products, energy yield)
- Flashcards: enzyme, active site, denaturation, aerobic, anaerobic, ATP, ADP

Retrieval Quiz (10 min) — answer without notes

1. What model explains enzyme-substrate binding?
2. What happens to an enzyme at very high temperatures?
3. Where does aerobic respiration occur in the cell?
4. What is produced in humans during anaerobic respiration?
5. What happens when ATP is converted to ADP?

Check your answers:

1. The lock-and-key model.
2. It denatures – its active site changes shape and can no longer bind its substrate.
3. The mitochondria.
4. Lactic acid (and a small amount of ATP).
5. A phosphate group is released, releasing energy for cell processes.

Session 4 — Respiratory System Structure

Resources: *Respiratory System quiz & video; Ventilation video*

Textbook: *Ch 4, pp. 86–90 (structure of the respiratory system and mechanics of breathing). Chapter summary: p. 97.*

Watch out for: *common mistakes for this topic are listed under “Respiratory & Circulatory Systems” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Structures & the Airflow Pathway

Study:

- **Why we need a respiratory system:** All cells need oxygen for cellular respiration and must get rid of the carbon dioxide they produce. In the lungs, oxygen moves from the air into the blood, which carries it to the cells; in the tissues, the blood picks up carbon dioxide and takes it to the lungs. The circulatory and respiratory systems work together to keep oxygen and carbon dioxide levels in the tissues relatively constant.
- **Nose, pharynx, epiglottis and larynx:** Air enters through the nose and mouth. The convoluted, mucus-lined nasal cavity warms and humidifies the air, and hairs and mucus trap debris. The pharynx (throat) runs from the nasal cavity to the top of the trachea and oesophagus. The epiglottis, a flap of elastic cartilage, covers the larynx when swallowing so food cannot enter the airway. The larynx is a cartilage structure containing the vocal cords (mucous membranes that vibrate to make sound).
- **Trachea:** The windpipe carries air to and from the lungs. C-shaped rings of cartilage hold it open so air can always pass. Its epithelial lining produces mucus that traps dust and debris, and cilia beat in a wave-like motion to move the mucus up to the pharynx to be swallowed.
- **Bronchi and bronchioles:** The trachea divides into two primary bronchi (one per lung), which divide into secondary bronchi (one per lobe) and then tertiary bronchi. Bronchi have C-shaped cartilage that becomes more spread out as they get smaller, with more smooth muscle and elastin. Bronchioles have no cartilage; their smooth muscle and elastin let them control airflow, and they end in millions of terminal bronchioles that open into clusters of alveoli. Cilia and mucus continue to protect the lungs from contaminants.
- **Lungs, pleura and alveoli:** The lungs fill the chest cavity except the mediastinum (heart and blood vessels). The left lung has two lobes and the right has three. A double-layered membrane, the pleura, covers the lungs (visceral pleura) and lines the chest wall (parietal pleura); pleural fluid between the layers holds the lungs against the chest wall while letting them slide during breathing. Alveoli are the air sacs at the ends of the airways: each has a wall one cell thick surrounded by capillaries, so they are the functional units of the lungs.

Then complete:

- Draw & label the respiratory pathway from nose to alveoli
- Trace the pathway of a breath of air out loud without notes

Block 2 (45 min): Tissue-Function Links & Ventilation

Study:

- **Ventilation depends on pressure differences:** Ventilation (breathing) moves air into and out of the lungs. Air flows from places of higher pressure to places of lower pressure, so the lungs must change pressure by changing volume.
- **Inspiration:** The diaphragm and external intercostal muscles contract. The diaphragm flattens and the rib cage moves up and out, increasing the volume of the chest cavity. The pleura adheres to the chest wall, so the lungs expand too. The larger volume makes the air pressure inside the lungs slightly lower than atmospheric pressure, so air flows in through the nose and trachea until the pressures are equal. In quiet breathing the diaphragm does most of the work.
- **Expiration:** The diaphragm and external intercostals relax, so the diaphragm bulges up into the chest cavity and the rib cage moves down and in. Volume decreases, pressure in the lungs becomes greater than outside, and air flows out. At rest expiration is passive. In heavier breathing it is more forceful: the intercostal muscles contract to actively lower the rib cage, as when blowing up a balloon.
- **Structure–function links in the airways:** Cartilage rings keep the trachea and bronchi open but flexible. Ciliated, mucus-producing epithelium traps and removes dust and pathogens. Mucous membranes in the nose warm and moisten air. Smooth muscle and elastin in the bronchioles control the amount of air reaching the alveoli. Pleural fluid lets the lungs slide smoothly against the chest wall.
- **Breathing versus cellular respiration:** Breathing (ventilation) is the mechanical movement of air into and out of the lungs. Cellular respiration is the chemical process in cells that releases energy from glucose. Do not use the word respiration for breathing in an exam answer.

→ Then complete:

- Explain, using pressure/volume language, what happens during inspiration
- Quiz yourself: what tissue feature protects the trachea from collapsing?

Retrieval Quiz (10 min) — answer without notes

1. Give the pathway of air from the nose to the alveoli.
2. What is the function of the epiglottis?
3. What does ciliated epithelium in the trachea do?
4. What happens to thoracic volume during inspiration?
5. What is the difference between breathing and ventilation?

Check your answers:

1. *Nose → pharynx → larynx → trachea → bronchi → bronchioles → alveoli.*
2. *It closes over the trachea during swallowing to prevent food/drink entering the airway.*
3. *Sweeps mucus and trapped debris/pathogens up and away from the lungs.*
4. *It increases as the diaphragm and external intercostal muscles contract, decreasing pressure so air flows in.*
5. *Breathing is the mechanical process of moving air in and out; ventilation refers to the flow of air into and out of the alveoli.*

Session 5 — Gas Exchange & the Heart

Resources: *Gas Exchange video; Structure of the Heart video; Heart & Blood Flow mind map*

Textbook: *Ch 4, pp. 91–93 (gas exchange); Ch 5, pp. 109–112 (heart structure and blood flow). Chapter summaries: p. 97 and p. 136.*

Blank labelling diagram: *Diagram 1 (The Human Heart) — see the Blank Labelling Diagrams section.*

Watch out for: *common mistakes for this topic are listed under “Respiratory & Circulatory Systems” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Efficient Gas Exchange

Study:

- **Alveoli are built for gas exchange:** There are hundreds of millions of alveoli with a total surface area of about 50–80 m² (roughly a third of a tennis court), so large amounts of gas can be exchanged quickly. Each alveolus has a rich supply of blood capillaries. Its wall is one cell thick (about 1 µm), so gases have a very short distance to diffuse. It is lined by a thin film of moisture, because gases can only diffuse into and out of the blood when dissolved. The lungs are deep inside the body to prevent excessive evaporation of this fluid.
- **The process of gas exchange:** Deoxygenated blood reaches the alveolar capillaries through the pulmonary arteries. It has a lower oxygen concentration and a higher carbon dioxide concentration than the air in the alveolus. Oxygen dissolves in the moisture and diffuses through the alveolar wall and capillary wall into the blood, and carbon dioxide diffuses out of the blood into the alveolar air. As a result expired air has less oxygen and more carbon dioxide than inspired air (about 15.8% versus 20.95% O₂, and 4.3% versus 0.04% CO₂).
- **Maintaining the concentration gradient:** Diffusion needs a concentration gradient. It is maintained by (1) the constant flow of blood, which removes oxygenated blood and replaces it with blood that is low in oxygen and high in carbon dioxide, and (2) ventilation, which replaces the air in the alveoli with fresh air that is high in oxygen and low in carbon dioxide.
- **Why the direction reverses in the tissues:** Gases always diffuse down their own concentration gradients. In the lungs the gradients favour oxygen entering the blood and carbon dioxide leaving. In the body tissues cells are using oxygen and producing carbon dioxide, so oxygen diffuses out of the blood and carbon dioxide diffuses into it.
- **Lifestyle and the respiratory system:** Emphysema (long-term exposure to irritants such as tobacco smoke or dust) damages alveoli, which lose elasticity and break down, reducing surface area, so the person has difficulty exhaling and gas exchange is inadequate. Lung cancer is uncontrolled cell division forming a tumour; tobacco smoking is by far the greatest risk, and asbestos adds to it. Pneumonia and tuberculosis are infections that fill the alveoli with fluid and mucus, reducing surface area and air volume. Asthma narrows the airways through smooth muscle contraction, inflammation and mucus.

→ **Then complete:**

- List all four alveolar adaptations and explain how each increases diffusion rate
- Draw a labelled diagram of an alveolus and surrounding capillary showing gas movement

Block 2 (45 min): Circulatory System & Heart Structure

Study:

- **The circulatory system:** Blood is the transport link between all body systems. It transports oxygen, nutrients, carbon dioxide, wastes and hormones, distributes heat, helps maintain water and ion balance, protects against micro-organisms and clots to prevent blood loss. It circulates through arteries, capillaries and veins pumped by the heart.
- **Structure of the heart:** The heart is about the size of a fist, lies between the lungs in the mediastinum and is enclosed in a membrane, the pericardium, which holds it in place and prevents overstretching. Its wall is made of cardiac muscle. The septum separates the two sides. The right side collects blood from the body and pumps it to the lungs; the left side receives blood from the lungs and pumps it to the body. Each side has an upper atrium, which receives blood, and a lower ventricle, which pumps it out. The left ventricle has a thicker wall because it must pump blood around the whole body.
- **Valves:** The atrioventricular valves (tricuspid on the right, bicuspid or mitral on the left) are thin flaps held by tendons (chordae tendineae) attached to papillary muscles. When the ventricles contract, blood catches behind the flaps and they billow out and seal the opening, so blood leaves through the arteries instead of flowing back into the atria. The semilunar valves (pulmonary and aortic), with three cusps each, sit at the exits from the ventricles and stop blood flowing back when the ventricles relax. Their closing gives the heart sounds 'lub dub'.
- **Vessels entering and leaving the heart:** The superior and inferior vena cava bring blood from the body to the right atrium. The pulmonary artery takes blood from the right ventricle to the lungs. Four pulmonary veins bring blood from the lungs to the left atrium. The aorta, the largest artery, takes blood from the left ventricle to the body. The pulmonary artery carries deoxygenated blood and the pulmonary veins carry oxygenated blood, the reverse of the usual pattern for arteries and veins.
- **Path of blood:** Body → vena cavae → right atrium → tricuspid valve → right ventricle → pulmonary valve → pulmonary artery → lungs → pulmonary veins → left atrium → mitral (bicuspid) valve → left ventricle → aortic valve → aorta → body. The same blood flows continuously round this double circuit.
- **The cardiac cycle and cardiac output:** Systole is the pumping (contraction) phase and diastole is the filling (relaxation) phase. In diastole both atria and ventricles fill; atrial systole pushes the remaining blood into the ventricles; ventricular systole then forces blood into the arteries. Both atria contract together, then both ventricles. Cardiac output (mL/min) = stroke volume (mL) × heart rate (beats/min); for example 70 mL × 58 beats/min = 4060 mL/min.

→ Then complete:

- Label a blank heart diagram from memory, including all valves
- Trace the direction of blood flow out loud, starting from the vena cava

Retrieval Quiz (10 min) — answer without notes

1. Name four features of alveoli that make gas exchange efficient.
2. Which heart chamber pumps blood to the lungs?
3. What valve sits between the left atrium and left ventricle?
4. Which vessel carries oxygenated blood away from the heart to the body?
5. What structure separates the left and right sides of the heart?

Check your answers:

1. Large surface area, thin (one-cell-thick) moist walls, extensive capillary network, large SA:V ratio.
2. The right ventricle (via the pulmonary artery).
3. The bicuspid (mitral) valve.
4. The aorta.
5. The septum.

Session 6 — Blood, Vessels & the Lymphatic System

Resources: *Blood quiz, mind map & video; Blood Vessels, Blood Clots, Blood Groups & Transfusions, Lymphatic System videos*

Textbook: *Ch 5, pp. 103–108 (blood), pp. 113–115 (blood vessels), pp. 119–122 (blood groups and transfusions), pp. 123–126 (lymphatic system). Chapter summary: p. 136.*

Watch out for: *common mistakes for this topic are listed under “Respiratory & Circulatory Systems” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Blood Vessels & Blood Composition

Study:

- **Composition of blood:** An adult has about 4–6 L of blood. Plasma (about 55%) is water with dissolved sugars, salts, proteins, nutrients, wastes and hormones, and it transports the blood components. The formed elements (about 45%) are erythrocytes, leucocytes and thrombocytes.
- **Erythrocytes (red blood cells):** The most abundant cells (haematocrit 40–45%). They are biconcave discs with no nucleus, which gives more room for haemoglobin and makes them flexible enough to squeeze through capillaries. The trade-off is a short life span of about 120 days. The biconcave shape increases surface area for oxygen exchange.
- **Leucocytes and thrombocytes:** Leucocytes (white blood cells) make up only about 1% of blood and protect against infection. Neutrophils are the most common and digest pathogens; monocytes form macrophages that engulf pathogens and damaged cells; lymphocytes (T and B) carry out the immune response; basophils release histamine and heparin in allergic reactions; eosinophils respond to parasites and inflammation. Thrombocytes (platelets) are cell fragments that stick to injured vessel walls and start clotting.
- **Transport of oxygen:** About 3% of oxygen dissolves in plasma and 97% is carried by haemoglobin in red blood cells as oxyhaemoglobin. The combination is loose: haemoglobin combines with oxygen where oxygen concentration is high (lung capillaries) and releases it where oxygen concentration is low (tissues, where cells continually use oxygen). Oxygenated blood is bright red; deoxygenated blood is dark red.
- **Transport of carbon dioxide:** About 7–8% is dissolved in plasma, about 22% combines with haemoglobin as carbaminohaemoglobin, and about 70% is carried as bicarbonate ions (CO_2 reacts with water to form carbonic acid, which ionises to hydrogen and bicarbonate ions). In the lungs these reactions reverse and the carbon dioxide diffuses into the alveoli. Plasma also carries ions (Na^+ , K^+ , Ca^{2+} , Cl^-), glucose, amino acids, vitamins, fatty acids and wastes such as urea, creatinine and uric acid.
- **Blood vessels:** Arteries carry blood away from the heart; their walls have smooth muscle and elastic fibres, so they stretch when the ventricles contract and recoil when they relax, which keeps the blood moving and maintains pressure. Vasoconstriction narrows and vasodilation widens vessels to control blood flow; arterioles are important in this. Capillaries are microscopic with walls one cell thick, so materials pass easily between blood and cells. Veins carry blood towards the heart; blood pressure is low, so their walls are thin and inelastic and many have valves to prevent backflow.

→ **Then complete:**

- Draw a table comparing artery, capillary and vein structure & function
- Explain why red blood cells lack a nucleus

Block 2 (45 min): Clotting, the Lymphatic System & Blood Groups

Study:

- **Blood clotting:** When a vessel is damaged: (1) vasoconstriction reduces blood flow; (2) platelets stick to the rough damaged surface and to each other to form a platelet plug, and release chemicals that prolong the constriction; (3) for more serious injuries, coagulation: clotting factors in the plasma trigger a series of reactions that produce threads of the insoluble protein fibrin, forming a mesh that traps blood cells, platelets and plasma to make the clot (thrombus). Clot retraction then pulls the vessel edges together, squeezing out serum, and the clot dries to form a scab that blocks entry of micro-organisms.
- **ABO and Rhesus blood groups:** Red blood cells carry antigens (sugars and proteins) that can stimulate the immune system, and antibodies are the proteins made in response. ABO groups depend on antigens A and B: group A has antigen A, group B has antigen B, AB has both and O has neither. A person makes antibodies against the antigens they do not have (A makes anti-B, B makes anti-A, AB makes neither, O makes both). Blood group is determined by DNA. Rhesus (Rh) antigens are proteins: Rh-positive people have them, Rh-negative people do not and can make anti-Rh antibodies after exposure.
- **Transfusions:** If incompatible blood is mixed, the recipient's antibodies make the donor's red cells clump together (agglutinate) and break down, so ABO and Rh groups are matched. The first Rh-positive transfusion to an Rh-negative person usually causes no problem, but it sensitises them, so later exposure causes rapid antibody production. Group O is the universal donor because its red cells carry neither A nor B antigen. Transfusions may use whole blood, red cell concentrates (the most widely used), plasma, platelet concentrates, cryoprecipitate, immunoglobulins or the patient's own stored blood (autologous). In Australia blood is donated freely through the Red Cross.
- **Lymphatic system:** At the arterial end of capillaries, high pressure forces fluid into the tissues; some returns to the capillary but the excess is collected by the lymphatic system and returned to the blood as lymph. Lymph flows one way only, from blind-ended lymph capillaries to larger lymph vessels and then into large veins; there is no pump.
- **Lymph nodes and defence:** Lymph nodes are bean-shaped structures along lymph vessels (most numerous in the neck, armpits, groin and around the alimentary canal). Lymph filters through a fibre meshwork inside, where macrophages engulf bacteria and debris by phagocytosis and lymphocytes take part in the immune response. During infection more lymphocytes are made and the nodes swell and become sore. The lymphatic system therefore both returns fluid and forms part of the body's internal defence.

→ Then complete:

- Sequence the steps of blood clotting from memory
- Complete a blood-group compatibility table (who can donate to whom)

Retrieval Quiz (10 min) — answer without notes

1. Which blood vessel type has valves to prevent backflow?
2. What is the role of platelets (thrombocytes)?
3. What does the lymphatic system return to the circulatory system?
4. What determines a person's ABO blood group?
5. What protein forms the mesh of a blood clot?

Check your answers:

1. Veins.
2. They are involved in blood clotting.
3. Excess tissue fluid.
4. The antigens present on the surface of their red blood cells.
5. Fibrin.

Session 7 — Digestive System I – Structure & Digestion

Resources: *Digestive System quiz & mind maps; Digestion Mouth to Stomach / Small & Large Intestine videos*

Textbook: *Ch 6, pp. 142–148 (types of digestion and the alimentary canal). Chapter summary: p. 163.*

Watch out for: *common mistakes for this topic are listed under “Digestive & Excretory Systems” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Structure of the Digestive System

Study:

- **Why we digest food:** All cells need nutrients for energy and for materials for growth, reproduction and secretion. The digestive system extracts nutrients from food and absorbs them for use by cells. Its functions are ingestion, mechanical digestion, chemical digestion, movement of food along the canal, absorption into the blood and lymph, and elimination of undigested material. Digestion is breaking food into particles small enough to be absorbed.
- **The alimentary canal:** A continuous tube from the mouth to the anus. Together with associated organs (salivary glands, pancreas, liver and gall bladder) it forms the digestive system. The lining of the canal is the surface through which nutrients are absorbed.
- **Mechanical digestion:** The physical breakdown of food into smaller pieces, which increases the surface area for enzymes to act on. It includes chewing by the teeth, churning in the stomach, segmentation in the small intestine and emulsification of fats by bile salts. Peristalsis moves the food along.
- **Chemical digestion:** Enzymes break large, complex molecules into small, simple molecules that can cross cell membranes: carbohydrates are split into monosaccharides such as glucose, proteins into peptides and amino acids, and lipids into fatty acids and glycerol.
- **Mouth and teeth:** Food is ingested and chewed (mastication) and mixed with saliva from three pairs of salivary glands. Saliva contains mucus to lubricate the food and salivary amylase, which begins the digestion of starch into the disaccharide maltose. Incisors are chisel-shaped for biting and cutting, canines are conical for tearing, and premolars and molars have broad crowns with cusps for crushing and grinding. The tongue shapes the food into a bolus and pushes it into the pharynx to be swallowed.
- **Oesophagus and peristalsis:** A muscular tube about 23–25 cm long connecting the pharynx to the stomach. Its wall has a circular and a longitudinal muscle layer. Successive bands of circular muscle contract behind the bolus, producing a wave called peristalsis that pushes the food along, helped by lubricating mucus.
- **Stomach:** A J-shaped enlargement of the canal that has an extra oblique muscle layer, so it can contract in many directions to churn the food and mix it with gastric juice into a thick liquid called chyme. The pyloric sphincter at the lower end regulates the flow of chyme into the duodenum, and food usually stays 2–8 hours.

→ **Then complete:**

- Label a full digestive-system diagram
- List the four tooth types in order around the jaw with one function each

Block 2 (45 min): Tissue Adaptations & Chemical Digestion

Study:

- **Gastric juice:** Secreted by gastric glands in the gastric pits of the stomach lining (the mucosa). It contains hydrochloric acid, mucus and enzymes, each made by a different type of cell. The pH of the stomach is about 2–3.
- **Role of acid, pepsin and mucus:** Hydrochloric acid activates pepsinogen, converting it to the active enzyme pepsin, provides the acidic conditions in which pepsin works, and kills many bacteria. Pepsin breaks proteins into shorter peptides (polypeptides). A layer of mucus protects the stomach lining from the acid. Nutrients are not absorbed through the stomach because of its thick mucus layer, although some alcohol and drugs such as aspirin are.
- **Small intestine:** The longest part of the canal (about 6–7 m), named for its narrow diameter. It has three sections: the duodenum (25 cm, where most chemical digestion occurs), the jejunum and the ileum. Digestion continues under the influence of pancreatic juice, bile and intestinal juice.
- **Pancreatic juice:** Secreted by the pancreas through the pancreatic duct into the duodenum. It helps neutralise the acid arriving from the stomach and contains pancreatic amylase (starch to maltose), trypsin or pancreatic protease (proteins to peptides), pancreatic lipases (fats to fatty acids and glycerol), and ribonuclease and deoxyribonuclease (digest RNA and DNA).
- **Bile:** Produced by the liver, stored in the gall bladder and released into the small intestine through the common bile duct. Bile contains no digestive enzymes. Bile salts act like a detergent and emulsify fat into tiny droplets. This is mechanical digestion because it increases the surface area on which lipases can act. (People without a gall bladder cannot control the release of bile.)
- **Intestinal juice and segmentation:** Glands in the lining of the small intestine secrete intestinal juice containing peptidase (peptides to amino acids), sucrase, lactase and maltase (sucrose, lactose and maltose to simple sugars) and lipases. This completes digestion. Segmentation, contractions of the circular muscle that narrow the intestine, mixes the contents and continues mechanical digestion.

→ Then complete:

- Explain why bile is not classified as an enzyme
- Draw a villus and label its adaptations for absorption

Retrieval Quiz (10 min) — answer without notes

1. Which organ produces bile?
2. What is the function of rugae and villi in the small intestine?
3. Why does the stomach produce mucus?
4. What is the difference between mechanical and chemical digestion?
5. Which teeth are used for tearing food?

Check your answers:

1. The liver (stored in the gall bladder).
2. They increase surface area for absorption of digested nutrients.
3. To protect the stomach lining from digestion by its own HCl and enzymes.
4. Mechanical digestion physically breaks food into smaller pieces; chemical digestion uses enzymes to break down molecules.
5. Canines.

Session 8 — Digestive Enzymes, Absorption & Excretion Intro

Resources: *Digestion Kahoot!*; *Chapters 7–9 Practice Test*; *Excretion video*

Textbook: Ch 6, pp. 148–155 (small and large intestine, digestive enzymes and absorption); Ch 7, pp. 168–171 (excretion, liver and skin). Chapter summaries: p. 163 and p. 188.

Watch out for: common mistakes for this topic are listed under “Digestive & Excretory Systems” in the Common Mistakes to Avoid section.

Block 1 (45 min): Digestive Enzymes & Absorption

Study:

- **End products of digestion:** When chemical digestion is complete, carbohydrates have been broken down into simple sugars, proteins into amino acids, and fats into fatty acids and glycerol. These small molecules, together with vitamins, minerals and water, are absorbed through the wall of the small intestine.
- **Digestive enzymes summary:** Salivary amylase (mouth): starch → maltose. Pepsin (stomach): protein → shorter peptides. Pancreatic amylase: starch → maltose. Trypsin (pancreatic protease): proteins → peptides. Pancreatic lipase: fats → fatty acids and glycerol. Intestinal peptidase: peptides → amino acids. Maltase, sucrase and lactase: maltose, sucrose and lactose → simple sugars. Intestinal lipase: fats → fatty acids and glycerol. Enzymes work under distinctive conditions in different parts of the system, e.g. pepsin in acid and the pancreatic enzymes in the near-neutral small intestine.
- **Adaptations for absorption:** Efficient absorption needs a large internal surface area. The small intestine is very long (6–7 m), its lining (mucosa) is folded, the folds carry finger-like villi (about 1 mm long), and the cells covering the villi have microscopic microvilli. Each villus contains a lymph capillary called a lacteal, surrounded by a network of blood capillaries, and muscular movements help absorption. Nutrients can be absorbed by active transport against a concentration gradient.
- **Where the products go:** Simple sugars, amino acids, water and water-soluble vitamins are absorbed into the blood capillaries and carried by the hepatic portal vein to the liver, where they may be processed or passed on to other cells. Fatty acids and glycerol recombine into fats in the cells of the villi and, with fat-soluble vitamins, enter the lacteals; the lymph system then empties them into the blood through veins in the upper chest.
- **Large intestine:** About 1.5 m long and wider than the small intestine, made up of the caecum, colon, rectum and anus (the appendix attaches to the caecum). It has no villi and secretes no digestive juices, only mucus. Material moves slowly (18–24 hours), during which most remaining water and some mineral salts are absorbed. Bacteria break down some remaining organic compounds and produce some vitamins, which are absorbed.
- **Faeces and elimination:** Faeces are made of water, undigested food (particularly cellulose), bacteria, bile pigments and cells shed from the lining. Except for the bile pigments they are not metabolic waste, so defecation is elimination, not excretion. Digestive health: low fibre can cause constipation and increase the risk of bowel cancer, diarrhoea causes water loss, and people with coeliac disease have villi damaged by gluten so cannot absorb nutrients.

→ **Then complete:**

- Draw a table: enzyme | source | substrate | product for all digestive enzymes
- Explain the role of the lacteal in fat absorption

Block 2 (45 min): Large Intestine & Introduction to Excretion

Study:

- **What excretion is:** Chemical processes in cells produce by-products, and many are toxic wastes that would be harmful if they accumulated. Every cell produces waste, so removing the wastes of metabolism (excretion) is essential. Excretion is different from elimination, which is removal of undigested material.
- **Organs of excretion:** The lungs excrete carbon dioxide from cellular respiration. Sweat glands in the skin lose water for cooling and also excrete some salts, urea and lactic acid. The liver processes wastes and toxins so they can be excreted. The alimentary canal passes out bile pigments, which are breakdown products of haemoglobin. The kidneys are the principal excretory organs, removing urea, uric acid and creatinine and maintaining the constant composition of body fluids.
- **Nitrogenous wastes:** Urea is made in the liver from the breakdown of amino acids (protein metabolism). Uric acid comes from the metabolism of purines, which come from breakdown of nucleic acids such as DNA and from food. Creatinine is produced in muscle from the breakdown of creatine phosphate, an energy-rich compound.
- **Liver:** The liver and skin are the two heaviest organs. The liver prepares materials for excretion: it deaminates excess amino acids and makes urea, detoxifies alcohol and drugs such as antibiotics, deactivates hormones so the kidneys can excrete them, and breaks down haemoglobin from dead red blood cells to make bile pigments.
- **Regulating body fluids:** The excretory system regulates the chemical composition of body fluids by removing metabolic wastes and retaining the correct amounts of water, salts and nutrients. The kidneys, liver, lungs, skin and alimentary canal all contribute.

→ Then complete:

- Match each excretory organ to the waste(s) it removes
- Write one sentence distinguishing excretion from elimination

Retrieval Quiz (10 min) — answer without notes

1. What does pancreatic lipase break down?
2. What structure absorbs fats into the lymphatic system?
3. What are the main functions of the large intestine?
4. Name the four organs of excretion.
5. What is the difference between excretion and elimination?

Check your answers:

1. *Lipids into fatty acids and glycerol.*
2. *The lacteal (within a villus).*
3. *Reabsorbing water/ions and forming & storing faeces.*
4. *Kidneys, liver, lungs, skin.*
5. *Excretion is the removal of metabolic waste products; elimination is the removal of undigested food (faeces).*

Session 9 — Kidney & Excretory System

Resources: *Kidney quiz; Kidney/Nephron mind maps; Kidney & Nephron Structure video; Formation of Urine video*

Textbook: *Ch 7, p. 170 (liver) and pp. 172–182 (kidneys, nephron, kidney stones and kidney failure). Chapter summary: p. 188.*

Blank labelling diagram: *Diagram 2 (The Nephron) — see the Blank Labelling Diagrams section.*

Watch out for: *common mistakes for this topic are listed under “Digestive & Excretory Systems” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Urinary System & Nephron Structure

Study:

- **Kidneys and the urinary system:** The kidneys are a pair of reddish-brown organs about 11 cm long in the abdomen. Each is covered by the renal capsule and has an outer cortex, an inner medulla (with renal pyramids) and a renal pelvis; vessels enter and leave at the hilum. Together the two kidneys receive about a quarter of the blood pumped by the heart. Urine drains from the collecting ducts into the renal pelvis, then through the ureters (25–30 cm, pushed by muscle waves) to the bladder, a hollow muscular organ that stores urine, and out through the urethra.
- **The nephron:** The nephron is the microscopic functional unit of the kidney, with about 1.2 million in each kidney. It has a renal corpuscle (the glomerulus, a knot of arterial capillaries, enclosed in the double-walled glomerular capsule) and a renal tubule about 5 cm long: proximal convoluted tubule, loop of Henle, distal convoluted tubule. Several distal tubules join a collecting duct that opens into the renal pelvis.
- **Blood supply:** Blood enters the corpuscle by the afferent arteriole, is filtered in the glomerulus and leaves by the efferent arteriole, which then breaks into the peritubular capillaries surrounding the tubules, the loop of Henle and the collecting duct.
- **Filtration:** The efferent arteriole is narrower than the afferent arteriole, which raises the pressure in the glomerulus. Only two thin cell layers (the capillary wall and the capsule wall) separate blood from the capsule, so water and dissolved substances are forced through. The filtrate contains everything in blood except blood cells and plasma proteins, which are too large. About 20% of the plasma is filtered, roughly 125 mL/min or 180 L/day, yet only about 1% leaves the body as urine. Filtration is not selective.
- **Selective reabsorption:** Useful materials are returned to the blood in the peritubular capillaries by the cells lining the tubule: water, glucose, amino acids and ions such as sodium, potassium, calcium, chloride and bicarbonate; urea is partly reabsorbed. Tubule length (two coiled sections and the loop of Henle) and the huge number of nephrons give a large surface area. The amount of water reabsorbed is regulated under hormonal control according to the body's needs. About 99% of the water entering the nephron is reabsorbed.
- **Tubular secretion:** The third process adds materials from the blood to the filtrate: potassium and hydrogen ions, creatinine and drugs such as penicillin. It maintains blood pH (7.4–7.5) and urine pH. Overall: excretion = filtration – reabsorption + secretion.
- **Normal urine:** About 1.5 L a day, mainly water with urea, ions, uric acid and creatinine, with no significant protein or glucose. Its amber colour comes from bile pigments. About half a litre of water must be lost each day just to remove wastes, and if body fluids are low in water the urine is concentrated.

→ **Then complete:**

- Label a full nephron diagram
- Explain what happens to a glucose molecule as it passes through the nephron (filtered, then fully reabsorbed)

Block 2 (45 min): Liver, Waste Toxicity & Kidney Disease

Study:

- **Deamination and urea:** Excess amino acids cannot be stored. In the liver, enzymes remove the amino group (NH_2) from the amino acid in a process called deamination. The amino group is converted to ammonia (NH_3) and then to urea. The rest of the amino acid, mostly carbon and hydrogen, is converted into a carbohydrate that cells can use for energy.
- **Why ammonia is converted to urea:** Ammonia is very soluble and highly toxic; a thousandth of a milligram per litre of blood is enough to kill a person. Liver cells rapidly convert it to urea, which is much less toxic, harmless in moderate amounts and easily excreted by the kidneys in urine (small amounts also in sweat).
- **Kidney stones:** Solid crystals that build up in the kidneys, usually when urine becomes too concentrated (often from too little fluid). Small crystals pass unnoticed; crystals can combine into stones that lodge in the ureter, bladder or urethra and cause intense pain. Smaller stones may pass with fluids, pain relief and muscle relaxants; larger stones are broken up with sound waves or removed by surgery.
- **Kidney disease and failure:** Most kidney diseases affect the glomeruli, so protein and sometimes red blood cells leak into the urine, blood protein falls and fluid builds up in the tissues (swelling of hands, feet or face). A person can lose up to 90% of kidney function without realising. Diabetes, high blood pressure and kidney disease slowly destroy nephrons, and in kidney failure the kidneys can no longer excrete waste or control fluid levels, so the only treatments are dialysis or a kidney transplant.
- **Dialysis:** Peritoneal dialysis uses the peritoneum as the membrane: 2–3 L of fluid with glucose and other substances at blood concentrations but no wastes is put into the abdomen through a catheter, wastes diffuse into it, and it is then drained. Haemodialysis passes blood through a dialysis machine containing thousands of fine tubes of differentially permeable membrane in a bath of fluid with no waste; wastes diffuse out and the patient spends 4–5 hours attached. In both, useful substances stay in the blood because there is no concentration difference.
- **Lifestyle and the kidneys and liver:** Kidney health is helped by a healthy weight (to avoid diabetes and high blood pressure), not smoking, drinking water instead of sugary drinks, moderate alcohol and avoiding performance-enhancing drugs such as anabolic steroids. Liver disease (infection, alcohol, fatty diet and other causes) allows toxins to build up, causing jaundice, abdominal swelling, dark urine and pale faeces.

→ Then complete:

- Explain why the liver converts ammonia to urea before excretion
- Compare the causes/treatment of kidney stones vs kidney failure in a table

Retrieval Quiz (10 min) — answer without notes

1. What is the functional unit of the kidney?
2. Name the three processes that occur in the nephron.
3. Which organ converts ammonia to urea?
4. Why is urea preferred over ammonia for excretion?
5. Name two treatments for kidney failure.

Check your answers:

1. The nephron.
2. Filtration, reabsorption, secretion.
3. The liver.
4. Urea is far less toxic than ammonia, so it can be concentrated and requires less water to excrete safely.
5. Dialysis and kidney transplant.

Session 10 — Skeletal System

Resources: *Bones & Cartilage quiz; Bones mind maps; Bones / Compact & Spongy Bone / Types of Cartilage videos*

Textbook: *Ch 8, pp. 202–210 (skeletal system, bone and cartilage). Chapter summary: p. 222.*

Watch out for: *common mistakes for this topic are listed under “Musculoskeletal System” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Skeleton Structure

Study:

- **The musculoskeletal system:** It is made up of the skeletal system (bones and associated structures such as tendons, ligaments and cartilage) and the muscular system, which work together. The skeleton gives the body shape and form and stops the soft tissues collapsing. Muscles attached to bones move them or hold them steady.
- **Functions of the skeleton:** (1) Support: a scaffold that carries the weight of the body. (2) Movement: bones are attachment points for muscles, and where bones meet and can move (articulate) the skeleton determines the extent of movement. (3) Protection: the cranium protects the brain, the vertebrae the spinal cord, the rib cage the heart and lungs, and the pelvis the reproductive organs and bladder. (4) Blood cell production: red bone marrow contains stem cells that can become red blood cells, white blood cells or platelets. (5) Storage of minerals (calcium, phosphorus, sodium, potassium) and fat, which can be released to other parts of the body when needed, e.g. calcium for a developing foetus.
- **Axial and appendicular skeleton:** There are normally 206 bones in the adult skeleton, some fused (as in the skull). The axial skeleton lies around the central axis: skull, vertebral column, ribs and sternum (and the ear ossicles). It supports erect posture and protects the central nervous system and thoracic organs. The appendicular skeleton is the bones of the upper and lower limbs plus the pectoral (shoulder) girdle and pelvic (hip) girdle, which allow the limbs to articulate with the axial skeleton.
- **Structure of a long bone:** Bones are living organs with living cells, capable of growth and repair. The diaphysis is the shaft, a hollow cylinder of compact bone surrounding the medullary cavity, which stores fat (yellow marrow). The epiphyses are the enlarged ends, covered by a thin layer of articular cartilage, with compact bone outside and spongy (cancellous) bone inside; in some bones the spaces hold red marrow where blood cells are made. The periosteum is the dense, white, fibrous outer covering (absent at joints, where articular cartilage covers the bone).

→ **Then complete:**

- Label the axial and appendicular skeleton on a diagram
- Label a long bone cross-section fully from memory

Block 2 (45 min): Bone Tissue & Cartilage

Study:

- **Bone as a connective tissue:** Bone is a connective tissue in which inorganic salts of calcium and phosphate are deposited in the non-cellular matrix. This makes it the hardest connective tissue, giving rigidity and strength. Bone mass continues to grow until about age 30 and then gradually declines.
- **Compact bone:** Made of many similar units called osteons (Haversian systems) that run parallel to the long axis of the bone, giving it maximum strength. Each osteon has a central (Haversian) canal containing blood capillaries (and possibly nerves and lymph capillaries), concentric layers of matrix called lamellae, small spaces called lacunae between the lamellae each holding an osteocyte (bone cell), and tiny canals (canaliculi) linking the lacunae so bone cells can pass materials from cell to cell.
- **Spongy bone:** Also called cancellous bone. It is not organised into osteons but into an irregular arrangement of thin bony plates called trabeculae. Bone cells occupy spaces in the trabeculae, and blood vessels and nerves pass through irregular spaces. It is lighter and more porous than compact bone and its spaces contain marrow. The two structures suit different roles: compact bone for strength in the shaft, spongy bone at the ends of long bones.
- **Cartilage:** Also a connective tissue. It has collagen fibres embedded in a firm matrix of a protein–carbohydrate complex called chondrin, giving support with some flexibility. Chondroblasts produce the matrix and become trapped in spaces (lacunae) once surrounded by it; at that stage they are mature cells called chondrocytes. Cartilage is found at joint surfaces, in the trachea and bronchi, and in the nose, larynx and ear.
- **Three types of cartilage:** Hyaline cartilage has many closely packed, very fine collagen fibres, giving strength with flexibility; it forms the rings of the trachea and bronchi and the articular cartilage at the ends of bones. Elastic cartilage has conspicuous elastic fibres and gives flexible support, e.g. the external ear. Fibrocartilage has coarse parallel bundles of thick collagen fibres, is slightly compressible and withstands heavy pressure; it is found in the intervertebral discs, the meniscus of the knee and the pubic symphysis.
- **Why cartilage heals slowly:** Cartilage has no blood vessels, so nutrition and waste removal depend on slow diffusion through the matrix. Chondrocytes therefore have a slow metabolic rate and slow cell division, so injured cartilage takes much longer to heal than bone.

→ Then complete:

- Draw a comparison table: compact bone vs spongy bone (structure, location, function)
- Draw a comparison table: elastic vs hyaline vs fibrocartilage (structure, location)

Retrieval Quiz (10 min) — answer without notes

1. What are the two divisions of the skeleton?
2. Where is spongy bone found and why is it suited to that location?
3. What cells build new bone?
4. What type of cartilage is found at the ends of bones in joints?
5. What are mature cartilage cells called?

Check your answers:

1. Axial and appendicular.
2. At the epiphyses (ends) of long bones – its honeycomb structure absorbs stress and houses red marrow.
3. Osteoblasts.
4. Hyaline cartilage.
5. Chondrocytes.

Session 11 — Joints & Muscle Structure

Resources: *Muscles quiz; Musculoskeletal Quizlet; Types of Joints / Movement of a Joint videos*

Textbook: Ch 8, pp. 194–198 (*muscle types and structure*) and pp. 211–218 (*joints, movement, osteoporosis and osteoarthritis*). Chapter summary: p. 222.

Blank labelling diagram: *Diagram 3 (A Synovial Joint); Diagram 4 (A Sarcomere (relaxed))* — see the *Blank Labelling Diagrams* section.

Watch out for: *common mistakes for this topic are listed under “Musculoskeletal System” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Joints & Movement

Study:

- **Joints:** A joint is where two or more bones meet. Tightly fitting joints are strong with little movement; loosely fitting joints allow a great range of movement but are weaker and more prone to dislocation. Joints are classified by their range of movement: fibrous (fixed), cartilaginous (slightly movable) and synovial (freely movable).
- **Fibrous and cartilaginous joints:** Fibrous (fixed) joints hold the bones in place with fibrous connective tissue, e.g. the sutures of the skull; they are very strong. Cartilaginous joints are held by cartilage and allow slight movement, e.g. the pubic symphysis, joints between adjacent vertebrae and the joints between the ribs and sternum.
- **Synovial joints:** Most joints are freely movable. They occur at the shoulder, elbow, wrist, fingers, hip, knee, ankle and toes, and are the most commonly injured joints. They are categorised by the movement they allow: ball-and-socket (shoulder, hip: wide range of movement), hinge (elbow, knee: movement in one plane), pivot (atlas and axis, allowing the head to rotate), gliding (carpals, tarsals), saddle (the thumb: side-to-side and back-and-forth) and condyloid (the finger joints: two directions).
- **Structure of a synovial joint:** A synovial cavity separates the bones. The articular capsule has an outer fibrous capsule (strong, flexible, resists dislocation) and an inner synovial membrane, which secretes synovial fluid. The fluid lubricates the joint, keeps surfaces apart, nourishes the articular cartilage and contains phagocytic cells that remove debris. Articular cartilage covers the bone surfaces, ligaments hold the bones together, articular discs (menisci in the knee, made of fibrocartilage) direct synovial fluid to areas of greatest friction, and bursae (small sacs of synovial fluid) reduce friction. The surfaces are held together by the fit of the bones, the strength of the ligaments and the tension of the muscles around the joint.
- **Movements at joints:** Flexion decreases the angle between bones (bending) and extension increases it (straightening). Abduction is movement away from the midline of the body and adduction is movement towards it. Rotation is movement of a bone around its long axis (turning the head from side to side), and circumduction is the circular movement of a limb. Tendons join muscle to bone; ligaments join bone to bone.
- **Osteoporosis and osteoarthritis:** In osteoporosis, bone density falls (bones lose calcium and minerals, especially in women after menopause) until fractures occur from minor falls, most often in the vertebrae, ribs, pelvis and wrist. Prevention and treatment involve adequate calcium, vitamin D and exercise, not smoking, and sometimes medication. In osteoarthritis the joint cartilage deteriorates with age, wear and irritation, exposing bone that wears away and forms bony spurs, causing pain, stiffness and a grating sound; there is no cure, and treatment includes pain relief, physiotherapy and, in severe cases, joint replacement.

→ **Then complete:**

- Label a synovial joint diagram fully
- Demonstrate/describe each joint movement using your own arm or leg

Block 2 (45 min): Muscle Types & Microstructure

Study:

- **Three types of muscle:** Skeletal muscle is attached to bones, is under voluntary control, moves the skeleton, maintains posture and gives the body its form; it is striated. Smooth muscle (involuntary, not striated) is in the walls of organs such as the stomach, intestines and blood vessels. Cardiac muscle is in the heart, is involuntary and striated, and pumps blood.
- **Properties of muscle:** Muscle has excitability (responds to a stimulus), contractility (can shorten), extensibility (can be stretched) and elasticity (returns to its shape). Muscle is the only tissue that can contract.
- **Structure of skeletal muscle:** Muscle cells are held in bundles surrounded by a connective tissue sheath called the perimysium; epimysium holds the bundles together and blends into the tendon. Each muscle cell is a muscle fibre: a long cylinder with many nuclei, surrounded by a plasma membrane (sarcolemma) enclosing cytoplasm (sarcoplasm). Inside are hundreds to thousands of thread-like myofibrils, surrounded by the sarcoplasmic reticulum, which stores the calcium ions released during contraction. Order from largest to smallest: muscle → bundle → fibre → myofibril → myofilament.
- **Myofilaments:** Each myofibril is made of protein myofilaments: thick filaments made mainly of myosin and thin filaments made mainly of actin. Their arrangement gives skeletal and cardiac muscle a banded (striated) appearance.
- **The sarcomere:** The repeating unit of a myofibril is the sarcomere, the distance between successive Z lines. The A band is the length of the thick (myosin) filaments; the I band contains only thin filaments; the H zone is the lighter middle of the A band that contains only thick filaments.
- **Ageing:** The amount of connective tissue in muscle increases with age, which contributes to the gradual decrease in muscle strength.

→ Then complete:

- Draw & label the hierarchy: muscle → fascicle → fibre → myofibril → sarcomere
- Flashcards: sarcolemma, sarcoplasm, myofibril, actin, myosin, sarcomere

Retrieval Quiz (10 min) — answer without notes

1. Name two pairs of movement permitted at synovial joints.
2. What produces synovial fluid?
3. Which muscle type is involuntary and striated?
4. What is a fascicle?
5. What are the two main proteins that make up myofilaments?

Check your answers:

1. Flexion/extension and abduction/adduction (also rotation and circumduction).
2. The synovial membrane.
3. Cardiac muscle.
4. A bundle of muscle fibres wrapped in connective tissue.
5. Actin and myosin.

Session 12 — Muscle Action + Unit 1 Mixed Review

Resources: Revisit any misstagore.com Unit 1 quiz scored under 80%

Textbook: Ch 8, pp. 198–201 (how muscles work: sliding filament model and antagonistic muscles). Chapter summary: p. 222.

Blank labelling diagram: Diagram 4 (A Sarcomere (relaxed)) — see the Blank Labelling Diagrams section.

Watch out for: common mistakes for this topic are listed under “Musculoskeletal System” in the Common Mistakes to Avoid section.

Block 1 (45 min): Sliding Filament Model & Muscle Groups

Study:

- **Sliding filament theory:** During contraction the actin and myosin filaments slide over one another and the sarcomeres shorten. The Z lines are drawn closer together, the fibre shortens and so the muscle shortens. The myofilaments are the same length as before; the fibril shortens because the filaments overlap more (so the I band and H zone get narrower while the A band stays the same). When the muscle relaxes the filaments are pulled back in the opposite direction.
- **Energy for contraction:** Muscle fibres need ATP and are activated by a nerve impulse, which causes calcium to be released from the sarcoplasmic reticulum. Energy is released when ATP breaks down to ADP and a phosphate group, and ATP is re-formed using energy from cellular respiration. At any time some fibres are contracted while others are relaxed.
- **Muscles, tendons and bones:** Muscles are attached to bones by tendons (fibrous, inelastic connective tissue) that bridge the joints. Muscles can only contract, so they can pull bones together but cannot push them apart. Movement in the opposite direction needs a second muscle to pull the other way.
- **Antagonistic pairs:** To move the forearm about the elbow the biceps and triceps cooperate: when the biceps contracts to bend the arm the triceps relaxes, and the reverse when the arm straightens. The hamstrings and quadriceps in the leg are another pair. The end of a muscle attached to the stationary bone is the origin, the attachment to the movable bone is the insertion, and the fleshy part between is the belly.
- **Agonist, antagonist, synergist and fixator:** The muscle that causes the desired action is the agonist (prime mover); the muscle with the opposite effect, which yields to the movement, is the antagonist. When the arm bends, the biceps is the agonist and the triceps the antagonist; when it straightens, the roles reverse. Synergists help the prime mover, by producing the same movement or by steadying a joint so unwanted movement is prevented. A synergist that stabilises one part of the body while another moves is a fixator (e.g. muscles that hold the scapula against the chest).
- **Muscle tone and posture:** Muscle tone is the partial contraction of skeletal muscles, with different fibres taking turns to contract so it can be kept up for long periods without fatigue. It holds body parts in position (the head is held up by tone in the neck muscles) and determines posture.

→ **Then complete:**

- Explain, using the sliding filament model, how a sarcomere shortens
- Using biceps/triceps as an example, explain antagonistic action during arm flexion and extension

Block 2 (45 min): Unit 1 Mixed Retrieval

Study:

- **Linking Unit 1 into one story:** Food is digested and absorbed in the small intestine (villi); glucose and other nutrients travel in the blood to cells. Air is ventilated into the alveoli, and oxygen diffuses into the blood and is carried by haemoglobin. Cells use glucose and oxygen in the mitochondria to make ATP, and produce carbon dioxide, water, heat and urea, which the blood carries to the lungs and kidneys for excretion. Muscles use that ATP to contract, and the skeleton and joints turn contraction into movement. Every system depends on the others.
- **Cross-topic questions:** Many exam questions combine topics. For example, 'why does breathing rate increase during exercise?' links muscle contraction, ATP demand, aerobic and anaerobic respiration, carbon dioxide and lactic acid production, blood flow (cardiac output and vasodilation), ventilation, and oxygen debt. Practise writing answers that connect two or three systems.
- **How to use this block:** Sit the Unit 1 practice section under timed conditions with no notes, then mark it yourself and list every mistake by topic (cells, respiratory, circulatory, digestive, excretory, musculoskeletal). Redo the misstagore.com quiz for any topic where you scored under 80% and put those topics at the top of your Priority List.

→ Then complete:

- Complete a full past-paper Unit 1 practice section under timed conditions and self-mark
- Redo any misstagore.com Unit 1 quiz you scored under 80% on

Retrieval Quiz (10 min) — answer without notes

1. What shortens during muscle contraction – the filaments or the sarcomere?
2. What is the 'origin' of a muscle?
3. During arm flexion, which muscle is the agonist and which is the antagonist?
4. What ion is required for muscle contraction?
5. What is the role of a synergist muscle?

Check your answers:

1. *The sarcomere shortens (the filaments slide past each other but do not change length).*
2. *The fixed attachment point that does not move during contraction.*
3. *Biceps brachii is the agonist (contracts); triceps brachii is the antagonist (relaxes).*
4. *Calcium.*
5. *It assists or stabilises the movement produced by the prime mover.*

Session 13 — DNA Structure, Replication & Epigenetics

Resources: DNA quiz; DNA Replication mind map & video; Epigenetics video

Textbook: Ch 9, pp. 230–233 (DNA, genes, chromosomes and replication) and pp. 240–241 (epigenetics). Chapter summary: p. 244.

Watch out for: common mistakes for this topic are listed under “DNA & Cell Reproduction” in the Common Mistakes to Avoid section.

Block 1 (45 min): DNA Structure

Study:

- **DNA stores genetic information:** DNA (deoxyribonucleic acid) is found in the cells of all organisms and contains the genetic information that determines the structure of the cell and the way it functions. Most DNA is in the nucleus (nuclear DNA), but a small amount (less than 1% of the total in humans) is in the mitochondria (mtDNA) and is important for mitochondrial function.
- **Nucleotides and the double helix:** DNA is a polymer made of repeating units called nucleotides. Each nucleotide has a deoxyribose sugar, a phosphate group and a nitrogenous base: adenine (A), thymine (T), cytosine (C) or guanine (G). The sugar of one nucleotide bonds to the phosphate of the next, forming a chain of alternating sugars and phosphates (the backbone). Two chains are joined by weak hydrogen bonds between bases, with adenine always pairing with thymine and cytosine with guanine (complementary base pairing). The two strands twist into a double helix.
- **The genetic code:** The order of the bases along the DNA molecule is the genetic code. Although there are only four bases, a gene can have up to 2 million base pairs, so the number of possible sequences is enormous. A sequence of three bases (a triplet) codes for one amino acid. The DNA in one human cell would be 2–3 m long in total if stretched out, yet it is only about two-millionths of a millimetre wide, and it is divided into 46 molecules (one per chromosome).
- **Genes, histones, chromatin and chromosomes:** A gene is a section of DNA that codes for a particular protein. To fit inside the nucleus, DNA is wrapped around groups of eight histone proteins to form nucleosomes. In a cell that is not dividing, the coiled DNA and histones form a tangled network called chromatin. When a cell divides, the chromatin becomes super-coiled into chromosomes, which are large enough to see with a light microscope. There are 46 chromosomes in a normal human cell, and the DNA molecule in one chromosome has about 140 million base pairs.
- **Nuclear DNA compared with mitochondrial DNA:** Nuclear DNA is in very long strands bound to histone proteins. Mitochondrial DNA is in small circular molecules that are not bound to proteins, with about five to ten molecules per mitochondrion. Human mtDNA has 37 genes, all essential for normal mitochondrial function: 24 code for RNA molecules used in protein synthesis and 13 carry instructions for enzymes needed for cellular respiration.

→ **Then complete:**

- Draw & label a nucleotide, then two paired nucleotides showing base pairing
- Explain the relationship between DNA, gene, chromatin and chromosome in one paragraph

Block 2 (45 min): DNA Replication & Epigenetics

Study:

- **Why DNA must be replicated.** In every cell division the DNA must make an exact copy of itself, so that each daughter cell gets the same genetic information. This is DNA replication, and it is possible because of the double-stranded structure and the weak hydrogen bonds between complementary bases.
- **Steps of replication:** (1) The enzyme helicase separates the two strands of the DNA molecule by breaking the weak hydrogen bonds between the base pairs. (2) Each separated strand contains half of the original information and acts as a template. (3) DNA polymerase adds new nucleotides to the new strand; because A pairs only with T and C only with G, the new strand is complementary to the template. (4) DNA ligase joins short sections of DNA together. The result is two identical DNA molecules, each with one original strand and one new strand.
- **DNA compared with RNA:** RNA is also a chain of nucleotides but its sugar is ribose (one more oxygen than deoxyribose), it is single stranded (and can fold back on itself, forming hydrogen bonds between complementary bases), and it has uracil in place of thymine. Uracil pairs with adenine.
- **What epigenetics is:** 'Epi' means on top of. Epigenetics is the study of changes in gene expression caused by mechanisms other than changes in the DNA sequence. A person's genome is the hereditary information in their DNA; their epigenome is the sum of all the factors that determine when, where and which genes are switched on. The epigenome tells muscle cells to behave like muscle cells and nerve cells like nerve cells, and if it is abnormal, disease may result. Danielle Reed's summary: things written in pen (DNA) cannot be changed; things written in pencil (epigenetics) can.
- **Chromatin remodelling:** Modifying histone shape (by changing some of their amino acids) can be copied each time DNA is replicated, which helps a differentiated cell stay the type of cell it is. Acetylation, adding an acetyl group to histones, reduces the attraction between histones and DNA, relaxes the chromatin and lets RNA polymerase reach the gene, so it enhances gene expression. Methylation, adding methyl groups to DNA (usually at CpG sites, where a cytosine is next to a guanine), restricts access for RNA polymerase and inhibits gene expression. Histone methylation may increase or decrease transcription, depending on where the methyl groups attach.
- **Environment and the epigenome:** Severe stress, nutrition, toxins and drugs can change the epigenome without changing the DNA. Some epigenetic changes can be inherited by offspring, which has changed the older idea that only genes could be passed on. The number of epigenetic changes in our cells increases with age, and identical twins (who have the same DNA) are studied to separate genetic from epigenetic effects.

→ Then complete:

- Sequence the roles of helicase → DNA polymerase → ligase from memory
- Explain how an environmental factor could alter gene expression via methylation

Retrieval Quiz (10 min) — answer without notes

1. What are the three components of a nucleotide?
2. Which bases pair together in DNA?
3. What enzyme unwinds the DNA double helix?
4. What is the key structural difference between nuclear and mitochondrial DNA?
5. What effect does DNA methylation generally have on gene expression?

Check your answers:

1. A phosphate group, a deoxyribose sugar, and a nitrogenous base.
2. Adenine with thymine; cytosine with guanine.
3. Helicase.
4. Nuclear DNA is linear and inherited from both parents; mitochondrial DNA is circular and inherited only from the mother.
5. It generally suppresses/switches off gene expression.

Session 14 — Protein Synthesis

Resources: *Transcription & Translation quizzes; Translation and Transcription mind map; Introduction to DNA video*

Textbook: *Ch 9, pp. 234–239 (RNA, transcription, translation and gene expression). Chapter summary: p. 244.*

Watch out for: *common mistakes for this topic are listed under “DNA & Cell Reproduction” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Transcription

Study:

- **Why protein synthesis matters:** The sequence of bases in DNA controls the order of amino acids, and therefore the type of protein made. Proteins include haemoglobin, actin and myosin, collagen, insulin, antibodies and amylase, and all enzymes are proteins. DNA also controls lipid and carbohydrate synthesis indirectly, because the enzymes that make them are proteins.
- **Three types of RNA:** Messenger RNA (mRNA) is made in the nucleus and carries the genetic code into the cytoplasm so ribosomes can read it. Ribosomal RNA (rRNA) makes up about 60% of the mass of a ribosome, aligns the mRNA, tRNA and ribosome, and helps form the peptide bonds between amino acids. Transfer RNA (tRNA) is a small molecule (70–90 nucleotides) that carries one specific amino acid and has an anticodon.
- **Triplet, codon and anticodon:** A sequence of three bases coding for an amino acid is called a triplet on DNA, a codon on mRNA and an anticodon on tRNA. Learn this trio, as it is often examined.
- **Transcription:** Transcription copies the genetic instructions from DNA to mRNA in the nucleus. It is triggered by chemical messengers that enter the nucleus and bind to the gene. Helicase separates the DNA strands (about 17 base pairs at a time), then RNA polymerase copies one strand, the template strand, to make a complementary mRNA: where the DNA has C, G is added to the mRNA; DNA G gives C; DNA T gives A; and DNA A gives uracil (U). At the end of the gene a sequence of bases signals RNA polymerase to stop and the mRNA is released. Many mRNA copies can be made from one gene, and mRNA leaves the nucleus through a nuclear pore.
- **Template and coding strands:** Only one of the DNA strands, the template strand, is copied. The other is the coding strand. Because of base pairing, the mRNA has the same base sequence as the coding strand except that uracil replaces thymine.

→ **Then complete:**

- Explain why RNA polymerase uses only one DNA strand as a template
- Flashcards: mRNA, tRNA, rRNA, RNA polymerase, codon, anticodon

Block 2 (45 min): Translation

Study:

- **Translation:** Translation is the production of a protein using the information in the mRNA, at a ribosome in the cytosol. The ribosome attaches at the start codon (AUG), which also codes for methionine, so every protein begins with methionine (it may be removed later). The ribosome then moves along the mRNA three bases at a time, reading each codon.
- **The role of tRNA:** A tRNA molecule with the complementary anticodon pairs with each codon, bringing its specific amino acid. The amino acids are joined by peptide bonds into a polypeptide in the sequence specified by the mRNA; each bond needs the energy from the breakdown of one ATP. After delivering its amino acid, the tRNA detaches and can pick up another. Translation ends when a stop codon is reached and the finished protein is released.
- **Speed and efficiency:** One ribosome can make a protein of 400 amino acids in about 20 seconds, and several ribosomes can read the same mRNA at the same time. A cell may have 300 000 identical mRNA molecules, so it could produce over 150 000 protein molecules per second.
- **Gene expression:** Gene expression is the process of copying information from DNA to mRNA and translating it into a protein. At any time a cell makes mRNA from only a fraction of its genes: for example, the insulin gene is switched on in some pancreas cells but not in bone or muscle cells. Whether a gene is on or off depends on factors including the age of the cell, the time of day, signals from other cells, the cell's environment and whether the cell is dividing.
- **Worked example:** Template strand CTC CCC TTA GTC GAT AGT. Coding strand (complementary): GAG GGG AAT CAG CTA TCA. mRNA (copy of the template with U for T, same as the coding strand): GAG GGG AAU CAG CUA UCA. The anticodons on tRNA would then be CUC CCC UUA GUC GAU AGU. A protein of 250 amino acids needs at least 750 mRNA bases (3 per amino acid). Use the codon chart supplied in the exam to convert codons to amino acids.

→ Then complete:

- Use a codon chart to translate a short mRNA sequence into an amino acid sequence
- Explain, step by step, the journey from DNA to a finished protein

Retrieval Quiz (10 min) — answer without notes

1. Where does transcription occur?
2. Where does translation occur?
3. What does a tRNA molecule carry?
4. What is a codon?
5. What ends the process of translation?

Check your answers:

1. In the nucleus.
2. At the ribosome, in the cytoplasm.
3. A specific amino acid.
4. A three-base sequence on mRNA that codes for a specific amino acid.
5. A stop codon.

Session 15 — Mitosis & Meiosis

Resources: *Mitosis & Meiosis quiz; Mitosis/Meiosis mind maps; Meiosis video; Sources of Genetic Variation video*

Textbook: *Ch 10, pp. 249–260 (cell cycle, mitosis, meiosis and variation in daughter cells). Chapter summary: p. 269.*

Watch out for: *common mistakes for this topic are listed under “DNA & Cell Reproduction” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Mitosis

Study:

- **Why cells divide:** Organisms grow because they have more cells, not because their cells get larger. New cells are also needed to replace old, dead or damaged cells. Life spans vary: the cells lining the intestine live less than two days, liver cells about 450 days, and many brain nerve cells last a lifetime. Generally, the more wear and tear on a cell, the shorter its life.
- **The cell cycle:** The events from one cell division to the next. The cell grows and produces new proteins in G1, the DNA molecules are copied in the S phase, and the cell prepares for division in G2 (G1, S and G2 together are interphase). In the M (mitotic) phase the cell divides into two. After division, cells may re-enter G1 or leave the cycle and stop dividing for days, years or the rest of the person's life.
- **Purpose of mitosis:** DNA controls the structure and actions of cells, so each new cell must receive exactly the same DNA as the parent. Mitosis is the division of the nucleus that achieves this, giving two genetically identical diploid daughter cells (46 chromosomes in humans) for growth and repair. Mitosis is continuous, but it is described in four stages.
- **Interphase, prophase and metaphase:** In interphase (S phase) each chromosome is copied, so the quantity of DNA doubles. In prophase the centrioles move to opposite poles and microtubules radiate from them, the nucleolus disappears and the nuclear membrane breaks down, and the chromatin coils into visible chromosomes, each made of two identical chromatids joined at a centromere. A spindle of fibres forms. In metaphase the chromatid pairs line up on the equator of the spindle.
- **Anaphase, telophase and cytokinesis:** In anaphase the centromeres divide and the chromatids, now called chromosomes, are pulled to opposite poles. In telophase the chromosomes form tight groups at the poles, nuclear membranes and nucleoli re-form, the spindle disappears and the chromosomes uncoil to chromatin. Cytokinesis, division of the cytoplasm, usually begins during telophase: a furrow deepens until the cytoplasm is cut in two, giving two daughter cells each with the same number and type of chromosomes as the parent cell.
- **Stem cells and differentiation:** Stem cells are unspecialised and can divide repeatedly by mitosis; their daughter cells may be new stem cells (proliferation) or differentiate into specialised cells. Specialised cells generally cannot divide, so they must be replaced. Totipotent stem cells can form any cell needed for embryonic development, including the embryo and all its membranes (the cells from the first few divisions after fertilisation). Pluripotent stem cells can give rise to any cell of the body (embryonic stem cells). Multipotent stem cells form a limited range of cell types, e.g. blood stem cells give red cells, white cells and platelets, and skin stem cells give the different skin cells.

→ **Then complete:**

- Identify the mitotic stage from unlabelled diagrams
- Draw the four mitotic stages + cytokinesis from memory with one-line descriptions

Block 2 (45 min): Meiosis & Variation

Study:

- **Why meiosis is needed:** Gametes (sperm and ova) are made by meiosis in the testes and ovaries. If gametes were made by mitosis they would have 46 chromosomes, and fertilisation would double the number each generation (92, then 184). Meiosis halves the number: gametes are haploid ($n = 23$) while body cells are diploid ($2n = 46$). In diploid cells the chromosomes exist in homologous pairs, which are the same shape and carry genes for the same characteristics.
- **Overview of meiosis:** The DNA is replicated once in interphase, but there are two nuclear divisions. In the first division the homologous pairs separate, giving two cells with 23 chromosomes (each still made of two chromatids). In the second division the chromatids separate, giving four cells with 23 chromosomes each.
- **First division:** In prophase I the replicated chromosomes become visible as long threads and the homologous chromosomes come to lie alongside each other along their whole length, so each pair looks like four strands. Crossing over happens here. The pairs line up at the equator in metaphase I and, in anaphase I, one member of each pair goes to each pole; the cell then divides.
- **Second division:** A new spindle forms, usually at right angles to the first. The chromosomes line up on the equator in metaphase II, the centromeres divide and the chromatids (now chromosomes) move to opposite poles in anaphase II, and the nuclei re-form and the cytoplasm divides in telophase II. The result is four haploid daughter cells.
- **Mitosis compared with meiosis:** Both begin with DNA replication. Mitosis: one division, two daughter cells, diploid, genetically identical to the parent, for growth and repair. Meiosis: two divisions, four daughter cells, haploid, genetically different, for sexual reproduction. In mitosis chromatids separate; in meiosis I homologous chromosomes separate and in meiosis II chromatids separate. Meiosis has two divisions so that the chromosome number is halved once (from $2n$ to n) while the DNA is copied only once.
- **Sources of variation:** Crossing over: in prophase I the chromatids of homologous chromosomes cross at points called chiasmata, break and exchange segments, producing new combinations of alleles (recombination). Independent assortment: the homologous pairs separate randomly and independently, so each of the 23 pairs sorts independently and one egg can be any of 2^{23} (about 8.4 million) combinations of chromosomes. Random fertilisation: any sperm can fertilise any egg, so each zygote has a combination of genes that has probably never occurred before. Non-disjunction is covered in the next session.

→ Then complete:

- Make a mitosis vs meiosis comparison table (divisions, daughter cells, chromosome number, genetic identity)
- Write a short response: 'Explain how meiosis leads to genetic variation'

Retrieval Quiz (10 min) — answer without notes

1. How many daughter cells does mitosis produce, and are they identical?
2. How many daughter cells does meiosis produce, and what is their chromosome number relative to the parent?
3. In which phase does crossing over occur?
4. Name the three sources of genetic variation from meiosis/fertilisation.
5. What happens during anaphase of mitosis?

Check your answers:

1. Two, genetically identical.
2. Four, haploid (half the parent's chromosome number).
3. Prophase I.
4. Crossing over, independent assortment, random fertilisation.
5. Sister chromatids separate and are pulled to opposite poles of the cell.

Session 16 — Non-disjunction, Cancer & Unit 2 Cell Review

Resources: *DNA Validation quiz; redo Mitosis & Meiosis quiz*

Textbook: *Ch 10, pp. 259–266 (non-disjunction and cancer). Chapter summary: p. 269.*

Watch out for: *common mistakes for this topic are listed under “DNA & Cell Reproduction” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Non-disjunction & Cancer

Study:

- **Non-disjunction:** In the first meiotic division a homologous pair may fail to separate, or in the second division chromatids may fail to separate. This is non-disjunction. One daughter cell receives an extra chromosome, and another is missing one, so the gametes have 24 or 22 chromosomes instead of 23. After fertilisation by a normal gamete the zygote has 47 or 45 chromosomes. Such changes usually cause severe and distinctive birth defects, and miscarriage often occurs early in pregnancy.
- **Trisomy and monosomy:** Trisomy is having three copies of a chromosome instead of two. Trisomy 21 is Down syndrome (an extra chromosome 21), which occurs relatively often, especially in children of older mothers, and causes a characteristic facial appearance and variable intellectual disability. Trisomy 13 is Patau syndrome and trisomy 18 is Edwards syndrome. Monosomy is having only one copy of a chromosome; it also usually causes severe malformations. Partial trisomy and partial monosomy involve only part of a chromosome.
- **What cancer is:** Normally cell division is controlled. In cancer this control is lost and cells divide uncontrollably, producing a mass called a tumour. Cancer cells do not differentiate into the normal tissue cells around them. A malignant tumour can invade other tissues and spread to other parts of the body (metastasis), forming secondary tumours. A benign tumour cannot invade or spread, and is often surrounded by a capsule, but it can be dangerous if it presses on vital organs such as the brain.
- **Carcinogens:** Environmental factors called carcinogens can trigger malignant tumours; cancer usually appears only after long exposure and may develop years after exposure has ended. Examples: ultraviolet radiation (skin cancer), X-rays and ionising radiation, viruses (human papillomavirus causes cervical cancer), and chemicals such as tobacco tar, asbestos, soot, organic solvents and excessive alcohol. Genetics and lifestyle also affect the likelihood of cancer.
- **Reducing cancer risk:** Education (e.g. Slip! Slop! Slap! Seek! Slide!) and legislation (smoking bans, tobacco plain packaging and health warnings, the asbestos ban, standards for X-ray machines) have reduced cancer rates, but each person is still responsible for minimising their own risks: sunscreen, hats and shade (especially 10 a.m.–3 p.m.), protective clothing when handling chemicals, not smoking, and a healthy lifestyle.
- **Screening and early detection:** Early detection greatly improves treatment. The Cervical Screening Test looks for early changes in cervical cells caused by HPV (it does not diagnose cancer), and regular screening can prevent up to 90% of the most common cervical cancers. Mammography (BreastScreen Australia) can detect tumours about 1 cm across. The faecal occult blood test (bowel screening) checks for blood from polyps or bowel cancer, and a positive result leads to a colonoscopy. There is no screening program for prostate cancer, because tests (digital rectal examination, PSA blood test, biopsy) have limitations and many prostate cancers grow so slowly that they never need treatment.

→ **Then complete:**

- Explain how non-disjunction during meiosis I differs from during meiosis II
- List individual and government responsibilities in limiting carcinogen exposure

Block 2 (45 min): DNA & Cell Division Rapid Retrieval

Study:

- **Putting Unit 2 cell content together:** DNA replicates in the S phase of the cell cycle so that mitosis can give two identical cells. DNA is transcribed and translated into proteins, and gene expression (controlled by epigenetic changes) decides which cell type a cell becomes. Meiosis halves the chromosome number to make gametes and, with crossing over and independent assortment, creates variation. Fertilisation restores the diploid number. Errors such as non-disjunction, or loss of control of the cell cycle, cause chromosome disorders and cancer.
- **Identifying stages from diagrams:** Ask: are the chromosomes in homologous pairs (four strands) or single? Are they at the equator, at the poles, or still coiling? Mitosis has no pairing of homologous chromosomes. In prophase I the homologous chromosomes pair up; in anaphase I whole chromosomes (each still of two chromatids) move apart; in anaphase II and in mitotic anaphase the chromatids separate. Cells at the end of meiosis are haploid, and at the end of mitosis diploid. State how you decided, using the features you can see.
- **Chromosome number practice:** Human diploid number 46, haploid 23. A species with a diploid number of 14 (Tasmanian devil) has a haploid number of 7. Trisomy gives 47 chromosomes and monosomy gives 45 in a human zygote. There are 2^{23} possible chromosome combinations in a human gamete, before crossing over is taken into account.
- **Command words:** Compare means describe similarities and differences; a Venn diagram or table works well for mitosis and meiosis. Explain why meiosis has two stages by linking the two divisions to halving the chromosome number and separating first homologous chromosomes, then chromatids.

→ Then complete:

- Complete DNA & cell-division multiple-choice practice questions and self-mark
- Redo the misstagore.com Mitosis & Meiosis quiz and DNA Validation quiz

Retrieval Quiz (10 min) — answer without notes

1. What is non-disjunction?
2. What is trisomy 21 also known as?
3. What causes cancer at the cellular level?
4. Give one example of a carcinogen.
5. What is the outcome of monosomy?

Check your answers:

1. The failure of chromosomes to separate properly during meiosis.
2. Down syndrome.
3. Uncontrolled cell division due to damage to genes that regulate the cell cycle.
4. UV radiation (or tobacco smoke/asbestos).
5. A gamete/individual with one fewer chromosome than normal, e.g. Turner syndrome.

Session 17 — Mendelian Genetics

Resources: *Genetic Crosses & Pedigrees quiz; Mendelian Genetics Key Words Quizlet; Monohybrid/Sex-linked/Co-dominance videos*

Textbook: Ch 15, pp. 385–390 (Mendelian inheritance and Punnett squares) and pp. 396–405 (genetic disorders, sex-linked and co-dominant inheritance). Chapter summary: p. 415.

Watch out for: common mistakes for this topic are listed under “Genetics & Inheritance” in the Common Mistakes to Avoid section.

Block 1 (45 min): Genetics Terminology & Sex Determination

Study:

- **Mendel’s discoveries:** Gregor Mendel, an Austrian monk, worked with garden peas and in 1865 gave the first clear explanation of inheritance (before this many people thought offspring were a blend of both parents). He used pure-breeding plants (which always produce the same trait when bred together) and crossed plants with contrasting traits. The offspring (hybrids) all showed only one of the traits, which he called dominant; the hidden trait was recessive. When the hybrids were self-pollinated, the recessive trait reappeared in the next generation in a ratio of about 3 dominant : 1 recessive.
- **Principle of segregation:** Mendel concluded that each plant has two hereditary factors (genes) for each characteristic, which are unchanged as they pass between generations. During gamete formation the two factors separate (segregate), so each gamete gets only one, and at fertilisation each offspring receives one from each parent. In 1903 Walter Sutton linked this to the behaviour of chromosomes in meiosis and proposed that genes are located on chromosomes.
- **Key terms:** A gene is the factor that determines an inherited characteristic and lies on a chromosome. Alleles are alternative forms of a gene. A dominant allele masks the effect of the other allele; a recessive allele is masked when a dominant allele is present. Homozygous (pure-breeding) means two identical alleles; heterozygous (hybrid) means two different alleles. The genotype is the combination of alleles and the phenotype is the physical appearance produced by the genotype. P is the parental generation, F1 the first filial generation and F2 the second. A carrier is a heterozygous person who has a recessive allele but does not show the trait, and a male with an X-linked allele is hemizygous because he has no second allele.
- **Writing genotypes:** Use a capital letter for the dominant allele and the same letter in lower case for the recessive allele (green pod G, yellow pod g). Avoid letters such as Ww, Ss or Cc, where the upper- and lower-case forms are hard to tell apart. Co-dominant alleles use capital letters with different superscripts, and sex-linked alleles are written as superscripts on X and Y.
- **Sex determination:** Humans have 46 chromosomes: 22 pairs of autosomes and one pair of sex chromosomes. Females are XX and males are XY (the Y is much smaller than the X and carries fewer genes). All eggs carry an X, but half the sperm carry X and half carry Y, so the father’s sperm determines the sex of the child: an X-bearing sperm gives a female and a Y-bearing sperm gives a male, each with a 50% chance.

→ **Then complete:**

- Define all eight key terms from memory without notes
- Explain why the father’s sperm determines the sex of a child

Block 2 (45 min): Punnett Squares & Inheritance Patterns

Study:

- **Using a Punnett square:** A Punnett square models a cross and shows the probability of each genotype and phenotype. Write one parent's gametes across the top and the other's down the side, fill each box with the combination of alleles, then count. For $Hh \times Hh$ the offspring are $\frac{1}{4} HH$, $\frac{1}{2} Hh$ and $\frac{1}{4} hh$, which gives $\frac{3}{4}$ dominant phenotype and $\frac{1}{4}$ recessive (3:1). These are probabilities, not guarantees: each child is an independent event. Example: a heterozygous long-eyelash mother $\times$ short-eyelash father gives a $\frac{1}{2}$ chance of long eyelashes.
- **Autosomal dominant disorders:** Only one dominant allele is needed to show the disorder. Examples are Huntington's disease, achondroplasia (a form of dwarfism), neurofibromatosis and facioscapulohumeral muscular dystrophy. Dominant alleles causing severe defects are rarely passed on because people often die before reproducing, but Huntington's disease (5–10 per 100 000 people) usually shows after age 40, so the allele may be passed on before the parent knows. It is incurable, but genetic screening can tell people at risk so they can decide whether to have children.
- **Autosomal recessive disorders:** A heterozygous person is a carrier. If both parents are carriers, each child has a 25% chance of being affected (homozygous recessive), 50% of being a carrier and 25% of being unaffected and not a carrier. Phenylketonuria (PKU, about 1 in 10 000) is caused by lack of the enzyme phenylalanine hydroxylase, so phenylalanine builds up and damages the brain; a heel-prick test in the first days after birth allows early treatment with a special diet. Cystic fibrosis (1 in 3700 people, 1 in 25 carriers in Australia) causes chest infections, lack of digestive enzymes and salt loss; it is also screened at birth and managed with diet and pancreatic extract. Consanguineous parents are more likely to both be carriers of the same recessive allele.
- **Sex-linked (X-linked) inheritance:** Genes on the X chromosome show a different pattern in males and females, because males have only one X and are hemizygous. Recessive X-linked traits such as red–green colour blindness and haemophilia are more common in males. Write genotypes like $X^H X^h$ (carrier female) and $X^h Y$ (affected male), with H and h as superscripts on the X. Rules: a son's X comes from his mother, so a father cannot pass a sex-linked trait to a son; a father passes his X to all his daughters; if a daughter has a recessive sex-linked trait, her father must have it too; carrier mothers pass the allele to half their sons (affected) and half their daughters (carriers); two unaffected parents can have an affected son but not an affected daughter. Sex-linked dominant conditions (e.g. Rett syndrome) are much rarer.
- **Co-dominance and multiple alleles:** In co-dominance both alleles are fully expressed in the heterozygote (e.g. the M and N blood antigens). The ABO system has three alleles at one gene on chromosome 9: I^A , I^B and i . I^A and I^B are co-dominant and i is recessive to both. $I^A I^A$ or $I^A i$ gives group A, $I^B I^B$ or $I^B i$ gives group B, $I^A I^B$ gives group AB and ii gives group O. So a child with group AB cannot have parents who are A and O, because neither parent has an I^B allele.

→ Then complete:

- Complete a monohybrid cross and a sex-linked cross using Punnett squares, stating phenotype ratios
- Flashcards: each named condition + its mode of inheritance

Retrieval Quiz (10 min) — answer without notes

1. What is the difference between genotype and phenotype?
2. Which parent determines the biological sex of a child, and why?
3. What is co-dominance?
4. What is the mode of inheritance of red-green colour blindness?
5. Is Huntington's disease dominant or recessive?

Check your answers:

1. Genotype is an organism's genetic makeup; phenotype is its observable characteristics.
2. The father – only sperm can carry either an X or a Y chromosome (the egg always carries an X).
3. A pattern of inheritance where both alleles are fully and separately expressed in the phenotype (e.g. AB blood type).
4. X-linked recessive.
5. Dominant (autosomal dominant).

Session 18 — Pedigrees, Genetic Counselling & Variation

Resources: Variation quiz, mind map & Quizlet; Pedigrees video

Textbook: Ch 15, pp. 391–395 (pedigrees) and pp. 406–409 (genetic counselling); Ch 10, pp. 258–260 (variation). Chapter summaries: p. 415 and p. 269.

Watch out for: common mistakes for this topic are listed under “Genetics & Inheritance” in the Common Mistakes to Avoid section.

Block 1 (45 min): Pedigree Analysis

Study:

- **What a pedigree shows.** A Punnett square models one possible cross, whereas a pedigree (family tree) shows which family members show a trait over generations, so patterns of inheritance can be investigated.
- **Pedigree symbols.** Squares are males and circles are females. Shaded symbols have the characteristic being studied. A horizontal line joins a union (a double line indicates a consanguineous union between close relatives), and a vertical line drops from it to the children. Twins come from the same point, and a horizontal line between them means they are identical. A diagonal line through a symbol shows the person has died. Generations are numbered with Roman numerals on the left and individuals within each generation are numbered from left to right.
- **Rules for dominant traits:** Every person showing a dominant trait has at least one dominant allele, and must have at least one parent with the trait (it cannot skip a generation). Two people with the trait can have a child without it (if both are heterozygous). Two people without the trait cannot have a child with it.
- **Rules for recessive traits:** Every person showing a recessive trait has two recessive alleles. It can skip a generation and a person can have it without either parent having it. Two people without the trait can have a child with it (if both are carriers), but two people with the trait cannot have a child without it.
- **Working out genotypes:** (1) Shaded individuals showing a recessive trait must be homozygous recessive (aa). (2) Unaffected parents of an affected child must both be heterozygous (Aa). (3) An unaffected individual with an unknown second allele is written A? (AA or Aa) unless the pedigree gives more information. (4) For a dominant trait, an unaffected person must be homozygous recessive; a parent with the trait who has an unaffected child must be heterozygous. In the albinism example, the third-generation cousins had two albino children so both were heterozygous, which means their parents (brother and sister) were heterozygous and a grandmother was an albino.
- **Sex-linked pedigrees:** For a recessive X-linked trait, affected males are X^hY , and all other males are X^HY . The mother of an affected male must carry the allele (X^HX^h or X^hX^h), and unaffected daughters of an affected male must be carriers (X^HX^h). Other females carry at least one dominant allele, but it is not possible to tell whether they are X^HX^H or X^HX^h without more information. The trait typically appears mostly in males and passes through carrier females.

→ **Then complete:**

- Analyse a practice pedigree and determine dominant/recessive and autosomal/sex-linked
- Deduce the genotype of three individuals on a practice pedigree

Block 2 (45 min): Genetic Technology, Ethics & Epigenetics Recap

Study:

- **Genetic counselling:** Couples who already have a child with a birth defect, or who have a family history of an inherited condition, may seek genetic counselling. By examining how often a disorder occurs in the family tree, a counsellor can calculate the probability that a condition will occur. For example, a couple with no family history who have a child with an autosomal recessive condition such as thalassaemia have a one-in-four chance for each later child. The decision about whether to risk having an affected child, or to use prenatal testing, must rest with the individuals concerned.
- **DNA profiling:** A person's DNA is distinctive enough to identify them. Special enzymes cut DNA at specific base sequences, leaving fragments whose lengths vary from person to person. The fragments are placed on a gel and an electric current is passed through it (gel electrophoresis): DNA is negatively charged and moves towards the positive electrode, with smaller pieces moving faster than larger ones. This produces a banding pattern like a barcode, the DNA fingerprint or DNA profile.
- **Markers and uses:** Profiling compares DNA markers, non-coding segments with repeated sequences whose number of repeats is inherited; 20 - 40 markers may be examined, and with 10 markers on different chromosomes there is about a one-in-a-million chance of two people matching (except identical twins). A child has bands matching each parent, and a mismatch excludes a possible father, while a match does not prove paternity. Profiling is used in forensic science, tracing ancestry and identifying carriers of hereditary disease (e.g. cystic fibrosis, Huntington's disease).
- **Ethical issues:** Who owns a person's genome, and who may see it? How is privacy protected, and what happens if data is stolen or misused? Testing may predict a disease that cannot be prevented or treated, and cannot say when it will start or how severe it will be, so it may cause anxiety or stigma. Many diseases (diabetes, heart disease, many cancers) have multiple interacting causes, and the environment can change gene expression (epigenetics), so results may be unreliable. Paternity testing raises consent and family issues, and misuse could lead to discrimination in insurance or employment. Benefits include early intervention, informing relatives and more personal involvement in health decisions. Present both sides in an extended answer.
- **Variation and epigenetics recap:** Variation between related individuals comes from crossing over, independent assortment, non-disjunction and random fertilisation, and gene expression is further modified by epigenetic changes (acetylation and methylation) responding to the environment. Together, genotype, epigenetics and environment produce the phenotype.

→ Then complete:

- Explain, in 2–3 sentences, how gel electrophoresis is used for DNA profiling
- Discuss one ethical issue around genetic testing and one counterargument

Retrieval Quiz (10 min) — answer without notes

1. On a pedigree, what does a shaded shape represent?
2. How can you tell a trait is likely X-linked from a pedigree?
3. What technique separates DNA fragments by size?
4. What is DNA profiling used for?
5. Name one ethical issue associated with genetic testing.

Check your answers:

1. An individual affected by the trait/condition.
2. It predominantly affects males and is passed from carrier mothers to sons.
3. Gel electrophoresis.
4. Identifying individuals or determining paternity from unique DNA patterns.
5. Potential discrimination (e.g. by insurers or employers) based on genetic results.

Session 19 — Reproductive Systems & Gametogenesis

Resources: *Reproductive Organs quiz; Spermatogenesis/Oogenesis diagrams & videos*

Textbook: Ch 11, pp. 275–284 (structure of the male and female reproductive systems, spermatogenesis and oogenesis). Chapter summary: p. 296.

Blank labelling diagram: Diagram 5 (The Male Reproductive System); Diagram 6 (The Female Reproductive System) — see the Blank Labelling Diagrams section.

Watch out for: common mistakes for this topic are listed under “Reproduction, Pregnancy & Technology” in the Common Mistakes to Avoid section.

Block 1 (45 min): Male Reproductive System & Spermatogenesis

Study:

- **Sexual reproduction and the gonads:** In sexual reproduction male and female sex cells join to form a zygote that develops into a new individual. The gonads (testes and ovaries) are the primary sex organs and make the gametes. Other organs store the gametes, bring them together for fertilisation and support the developing offspring. Unlike other body systems, the reproductive organs of the male and female are quite different.
- **Testes and scrotum:** The two testes (testicles) produce the male gametes (spermatozoa, or sperm). They are held in the scrotum, a skin-covered pouch that is divided internally into two sacs. Sperm production needs a temperature about 2°C lower than body temperature, so the testes lie outside the body cavity; smooth muscle in the scrotal wall moves the testes closer to the body when it is cold and relaxes to move them away to keep them cool.
- **Inside the testis:** Each oval testis (about 4.5 cm long) is divided into 200–300 lobules filled with fine seminiferous tubules, which are lined with cells that produce sperm. Between the tubules, interstitial cells secrete the hormone testosterone. The tubules join to form ducts that leave the testis and enter the epididymis.
- **Epididymis, vas deferens and urethra:** The epididymis is a highly folded tubule (5–6 m if unravelled) against the rear surface of each testis, where sperm are stored for up to a month while they mature. It continues as the vas deferens (sperm duct), which rises into the abdominal cavity, crosses the top of the bladder and loops down behind it, where the two vasa deferentia join the urethra. The urethra runs from the bladder through the penis to the exterior and is a duct for both urine and semen.
- **Accessory glands and semen:** Sperm must be in a liquid to reach the egg. Semen (seminal fluid) nourishes sperm and aids their transport and is a mixture of secretions from three glands. The seminal vesicles (behind the bladder) secrete a thick, sugar-rich fluid making up about 60% of the semen. The prostate gland surrounds the urethra just below the bladder (where the vasa deferentia join it) and secretes a thin, milky, alkaline fluid. The two pea-sized bulbo-urethral (Cowper’s) glands beneath the prostate secrete a clear mucus that lubricates the urethra.
- **Penis:** The penis transfers sperm to the vagina. It contains erectile tissue with many sponge-like spaces that fill with blood during arousal, so the penis enlarges, stiffens and becomes erect; only when erect can it be inserted successfully.
- **Spermatogenesis:** Occurs in the seminiferous tubules. Spermatogonia (diploid, 46 chromosomes) divide by mitosis from puberty, giving a continuous supply of cells. Some daughter cells grow to become primary spermatocytes (diploid), which undergo meiosis I to form haploid secondary spermatocytes (23 chromosomes). Meiosis II divides each into two spermatids, so four haploid spermatids form from one spermatogonium. The spermatids mature into spermatozoa, losing most of their cytoplasm and growing a tail, while being nourished by special cells in the tubule. The whole process takes about 72 days.
- **Structure of a sperm:** About 0.06 mm long. The head is almost all nucleus, with an acrosome at the tip containing enzymes that break down the layer of cells around the egg. The neck lies between the head and middle piece. The middle piece contains mitochondria for the respiration that powers movement. The tail contracts to propel the cell. Sperm have very little cytoplasm, so they survive only briefly and get nourishment from the semen.

→ **Then complete:**

- Label the full male reproductive system diagram from memory
- Draw & label a sperm cell, then sequence the stages of spermatogenesis

Block 2 (45 min): Female Reproductive System & Oogenesis

Study:

- **Ovaries:** The two ovaries are almond-shaped glands about 3 cm long, located entirely inside the body. Each is made of connective tissue (stroma) surrounded by a layer containing many germ cells, each enclosed in a follicle. Follicles are at different stages of development; as one matures it moves to the surface of the ovary and ruptures, releasing the egg.
- **Uterine tubes:** The egg is expelled into the funnel-like opening of the uterine tube (Fallopian tube or oviduct). The opening is fringed with finger-like fimbriae that help guide the egg in. Cilia in the tube lining and contractions of smooth muscle in its wall carry the egg towards the uterus.
- **Uterus and cervix:** The uterus is a single, hollow, pear-shaped organ behind the bladder and in front of the rectum, held in place by broad ligaments. Its wall is mainly smooth muscle, lined by a soft mucous membrane called the endometrium. Its role is to protect and nourish the developing foetus. The cervix is the neck of the uterus, which protrudes into the vagina.
- **Vagina and vulva:** The vagina is a stretchy muscular canal about 10 cm long, lined with mucous membrane. It receives the penis during intercourse and enlarges to become the birth canal. The vulva is the external genital organs: the labia majora (fleshy folds with oil-secreting glands), the labia minora (smaller pink folds surrounding the openings of the urethra and vagina) and the clitoris (erectile tissue with many nerves, equivalent to the penis).
- **Oogenesis:** Occurs in the ovaries. Before birth, oogonia (diploid) multiply by mitosis and grow into primary oocytes (several hundred thousand at birth), which begin prophase of meiosis I and stop there, each surrounded by a layer of cells forming a primary follicle. From puberty, as a follicle matures, its primary oocyte completes meiosis I, producing two haploid cells of unequal size: the large secondary oocyte (with almost all the cytoplasm) and the tiny first polar body. The secondary oocyte starts meiosis II and stops at metaphase; ovulation releases it. Meiosis II is completed only if a sperm penetrates it, giving an ovum and a second polar body. All polar bodies disintegrate.
- **Comparing gametogenesis:** Both involve mitosis, growth and two meiotic divisions and produce haploid gametes. Spermatogenesis occurs in the testes, begins at puberty and produces four functional sperm from each spermatogonium continuously. Oogenesis occurs in the ovaries, starts before birth (and pauses until puberty) and produces only one ovum (plus polar bodies) from each primary oocyte; the cytoplasm is unequally shared so the ovum has plenty of stored nutrients. About 400 of a female's 400 000 potential eggs reach maturity.

→ Then complete:

- Label the full female reproductive system diagram from memory
- Compare spermatogenesis and oogenesis in a table (gametes produced, timing, location)

Retrieval Quiz (10 min) — answer without notes

1. Where does spermatogenesis occur?
2. What is the function of the epididymis?
3. What structure sweeps the egg into the fallopian tube?
4. How many functional gametes does oogenesis typically produce from one primary oocyte?
5. What are the three parts of a sperm cell?

Check your answers:

1. In the seminiferous tubules of the testes.
2. Sperm maturation and storage.
3. The fimbriae.
4. One (the ovum); the polar bodies are not functional gametes.
5. Head, midpiece, and tail.

Session 20 — Hormones, Fertilisation & Early Development

Resources: *Female Cycle & Male Hormones quizzes; Stem Cells quiz & Quizlet; Sexual Reproduction to Implantation video*

Textbook: *Ch 11, pp. 285–291 (hormones); Ch 12, pp. 303–312 (fertilisation, implantation, stem cells and germ layers). Chapter summaries: p. 296 and p. 329.*

Watch out for: *common mistakes for this topic are listed under “Reproduction, Pregnancy & Technology” in the Common Mistakes to Avoid section.*

Block 1 (45 min): Hormonal Regulation

Study:

- **Hormones and the pituitary gland:** The reproductive system is controlled by endocrine glands, which release hormones into the fluid around their cells; the hormones travel in the blood to their target organs (the testes in males and the ovaries and uterus in females). The pituitary gland, below the brain, releases two gonadotropic hormones, follicle-stimulating hormone (FSH) and luteinising hormone (LH), as well as prolactin and oxytocin.
- **Hormones in females:** FSH stimulates the development and maturation of an ovarian follicle; the developing follicle secretes oestrogen, and as oestrogen rises the secretion of FSH falls. LH promotes maturation of the follicle, ovulation and formation of the corpus luteum, which secretes progesterone (and oestrogen); as progesterone rises, LH production falls. Prolactin acts on the breasts to prepare and maintain milk production. Oxytocin causes uterine contractions and promotes the movement of milk in the breast. Human chorionic gonadotropin (hCG), made by the developing placenta, maintains the corpus luteum in early pregnancy.
- **Hormones in males:** The same gonadotropic hormones are made. FSH stimulates the seminiferous tubules to produce sperm. LH stimulates the interstitial cells of the testes to secrete testosterone, which is needed for immature sperm to develop into mature spermatozoa, maintains the male reproductive organs and sex drive, and (at puberty) drives development of the body to sexual maturity and secondary sexual characteristics such as facial hair and a deeper voice.
- **Ovarian cycle:** The series of events in the ovaries. The cycle is variable (20–40 days) but averages about 28 days. In the first half FSH and LH slowly rise, so follicles grow over 10–14 days (primary → secondary → mature follicle); usually only one completes development and the others break down. As the follicles grow they release oestrogen, and at about day 14 the oestrogen level is high enough to trigger a surge in LH (and FSH), which causes ovulation of the most mature follicle. After ovulation the collapsed follicle becomes the corpus luteum (‘yellow body’), which secretes progesterone and oestrogen; these prepare the uterine lining for implantation and inhibit the release of FSH and LH, so no other follicles develop.
- **Fate of the corpus luteum:** If fertilisation does not occur, the corpus luteum reaches its maximum about 8–10 days after ovulation and then degenerates into a fibrous scar, the corpus albicans; oestrogen and progesterone fall and a new cycle begins. If fertilisation does occur, hCG from the developing placenta keeps the corpus luteum going and the ovarian cycles stop; the placenta takes over oestrogen and progesterone production after about 8–12 weeks.
- **Menstrual cycle:** The changes in the uterus (endometrium) that prepare for a possible embryo, occurring alongside the ovarian cycle. In the first half, while the follicle matures, the endometrium thickens, with more blood vessels and mucus glands; after ovulation it thickens further and its glands secrete a watery mucus rich in glycogen (oestrogen dominates the first half, and progesterone maintains the lining after ovulation). If the egg is not fertilised, the corpus luteum degenerates, progesterone falls and the endometrium breaks down: about 14 days after ovulation blood, mucus and cell debris are lost through the vagina (menstruation). The first day of menstruation is day 1 of the cycle. Menarche is a girl’s first period, and menopause (usually between 45 and 55) is when cycles stop; only about 400 of the initial 400 000 potential eggs reach maturity.

→ **Then complete:**

- Draw a hormone table: hormone | source | function, for all hormones studied
- Explain the hormonal events that trigger ovulation

Block 2 (45 min): Fertilisation, Implantation & Early Development

Study:

- **Insemination:** During ejaculation, rhythmic contractions of the epididymis, vasa deferentia, seminal vesicles and prostate push semen into the urethra and out of the body. An ejaculation is about 3 mL and contains 250 - 300 million sperm. Semen nourishes the sperm, gives them a fluid to swim in, neutralises the acidity of the male urethra and female vagina and contains enzymes that activate the sperm. Insemination is the release of sperm at the entrance to the uterus.
- **Journey of the sperm:** Sperm move through the cervix, uterus and into the uterine tubes, often within minutes. This is too fast for swimming alone, so muscle contractions of the uterus and tubes probably help. Of hundreds of millions of sperm only a few thousand reach the uterine tubes, because sperm mortality is high; this is why so many sperm are needed. Fertilisation normally occurs in the uterine tube when the ovum is about one-third of the way down.
- **Fertilisation:** The secondary oocyte released at ovulation is at metaphase II. It is surrounded by the corona radiata (follicle cells) and the zona pellucida (a glycoprotein layer). When a sperm reaches the zona pellucida, the acrosomal reaction releases digestive enzymes from the acrosome that break down the layer so the sperm can reach the oocyte's plasma membrane. The membranes fuse and the sperm nucleus enters. A fertilisation membrane forms around the oocyte to block other sperm, so only one haploid set of chromosomes is added. The oocyte completes meiosis II, and its haploid (female) pronucleus fuses with the male pronucleus to form a diploid zygote.
- **From zygote to blastocyst:** The zygote travels down the uterine tube, dividing by mitosis into 2, 4, 8, 16 cells and so on. By about six days it reaches the uterus as a blastocyst: a hollow ball of cells around a fluid-filled cavity, with a group of about 30 cells at one side, the inner cell mass (stem cells that will form the body). The outer cells form the placenta and support tissues. The blastocyst floats free for 2–3 days, then sinks into the soft endometrium and attaches (implantation), gaining nourishment from the uterine glands and blood vessels. High oestrogen and progesterone (from the corpus luteum, later the placenta) maintain the endometrium so menstruation stops. The first two months are the embryonic period; after that the developing individual is a foetus.
- **Stem cell potency in development:** The zygote and its first few daughter cells are totipotent: each can form any cell type, including the embryo and all its membranes (identical twins form when two totipotent cells separate). The inner cell mass cells are pluripotent (can form any body cell but not the placenta), and they specialise further into multipotent stem cells such as blood stem cells and skin stem cells. Differentiation is triggered by internal signals (controlled by genes) and external signals (chemicals from other cells, contact with neighbouring cells and the microenvironment).
- **Primary germ layers:** During implantation (third week) the inner cell mass forms three layers: ectoderm, mesoderm and endoderm. Ectoderm forms the epidermis of the skin, hair, nails, skin glands, the whole nervous system, sense-organ receptors and the lens and cornea of the eye. Mesoderm forms muscle (skeletal, smooth, cardiac), bone, cartilage, blood and other connective tissue, the lining of blood vessels, the dermis, and the kidneys, ureters and gonads. Endoderm forms the lining of the alimentary canal and respiratory system, the bladder and urethra, and glands such as the thyroid, thymus and gall bladder.

→ Then complete:

- Sequence zygote → morula → blastocyst → implantation, with approximate timing
- Match each germ layer to two structures it forms

Retrieval Quiz (10 min) — answer without notes

1. Which hormone triggers ovulation?
2. What structures does the sperm penetrate during fertilisation?
3. What is a blastocyst?
4. What is the difference between totipotent and pluripotent stem cells?
5. Which germ layer gives rise to the nervous system?

Check your answers:

1. Luteinising hormone (LH).
2. The corona radiata, then the zona pellucida.
3. A fluid-filled ball of cells that develops from the morula and implants into the endometrium.
4. Totipotent cells can form any cell type including placental tissue; pluripotent cells can form any body cell type but not placental tissue.
5. Ectoderm.

Session 21 — Pregnancy, Birth, Screening, Fertility Tech & STIs

Resources: *Changes in Baby & Mother quiz; Placenta/Stages of Birth/Foetal Circulation videos; Contraception & STIs Quizlet*

Textbook: Ch 12, pp. 311–327 (placenta, pregnancy, birth and a healthy pregnancy); Ch 13, pp. 335–355 (contraception and STIs); Ch 14, pp. 365–378 (fertility treatments and foetal screening). Chapter summaries: p. 329, p. 357 and p. 380.

Watch out for: common mistakes for this topic are listed under “Reproduction, Pregnancy & Technology” in the Common Mistakes to Avoid section.

Block 1 (45 min): Placenta, Circulation & Birth

Study:

- **Embryonic membranes:** The amnion is the first to develop (surrounding the embryo by day 8). It secretes amniotic fluid, which acts as a shock absorber, keeps the temperature constant and lets the embryo and foetus move freely; it usually ruptures just before birth (‘breaking of the waters’). The chorion, formed from the outer cells of the blastocyst, surrounds the embryo and the other membranes and becomes the main foetal part of the placenta. The yolk sac and allantois form the outer structure of the umbilical cord.
- **The placenta:** An organ formed from both foetal and maternal tissue in the first three months. It supplies oxygen, glucose, amino acids, fatty acids, vitamins and minerals to the foetus; removes carbon dioxide and nitrogenous wastes (urea, uric acid, ammonia, creatinine) for the mother to excrete; transfers antibodies from mother to foetus; and secretes hormones that maintain pregnancy. Finger-like chorionic villi grow from the chorion into the endometrium and are bathed in pools of maternal blood. Foetal and maternal blood do not normally mix, because layers of cells separate them; exchange occurs by diffusion and active transport across a large surface area (about 16 m² in a mature placenta).
- **Umbilical cord:** Two umbilical arteries carry blood from the foetus to the capillaries of the chorionic villi, and one umbilical vein carries blood (oxygen and nutrient rich) from the placenta back to the foetus. On the maternal side, blood enters the placenta through the uterine arteries and leaves through the uterine veins.
- **Growth during gestation:** Gestation is about 280 days, measured from the start of the last menstrual period. After one month the embryo is under 4 mm long. By the end of week 8 it is about 3 cm and 1 g, with a human form and all organs present (although not yet functioning fully). Then the foetus grows: week 16 about 18 cm and 100 g; week 20 about 25 cm and 300 g; week 28 about 38 cm and over 1000 g; week 36 about 2700 g with the circulatory system fully developed but the digestive system still maturing; week 40 (full term) about 50 cm and 3400 g. Late in pregnancy maternal antibodies cross the placenta, giving the newborn temporary immunity.
- **Changes in the mother:** The uterus grows and pushes other abdominal organs up and out, the breasts enlarge and milk-secreting tissue develops, the heart enlarges and blood volume increases (by about 40% by the end of pregnancy), so more blood flows through the kidneys and more urine is produced (the growing uterus also presses on the bladder early and late in pregnancy). Her digestive system slows, so constipation is common, and hormonal changes can affect her emotions.
- **A healthy pregnancy:** A pregnant woman needs about 850 kJ more energy a day and at least 65 g of protein. Folic acid (from at least one month before pregnancy and for the first three months) helps prevent neural tube defects such as spina bifida; calcium is needed for bones and teeth; pregnant women should avoid listeria risks (soft cheeses, pâté, salad bars, raw or smoked seafood), gain about 0.5 kg a week in the second half of pregnancy and keep up regular exercise. A teratogen is any agent that causes physical defects in the embryo: alcohol (foetal alcohol syndrome), tobacco smoke (low birth weight, miscarriage, SIDS), thalidomide (limb malformations), methyl mercury, illegal and some medicinal drugs, and the rubella virus (deafness, blindness, heart defects). Drugs do most harm early in pregnancy, when a woman may not know she is pregnant.
- **Birth:** Labour is preceded by hormonal changes that soften the pelvic ligaments and make the uterus more responsive. Stage 1 (dilation): contractions shorten and open the cervix; about 8–9 hours for a first child and about 4 hours for later children. Stage 2 (expulsion): often begins with rupture of the amnion; uterine and abdominal muscle contractions push the foetus through the vagina, usually headfirst (over 90% of births), taking 20 minutes to 2 hours. The cord is clamped and cut. Stage 3 (placental stage): about five minutes after delivery the placenta, membranes and cord (the afterbirth) are expelled; placental vessels constrict, uterine contractions squeeze shut the uterine vessels and clots form, so little blood is lost.

- **Foetal circulation:** The foetus gets oxygen and nutrients from the placenta, not its own lungs or gut, so three shunts bypass non-functioning organs. The ductus venosus lets about 30% of the blood from the umbilical vein bypass the liver and enter the inferior vena cava. The foramen ovale is an opening between the right and left atria so most blood goes straight across, avoiding the collapsed lungs. The ductus arteriosus connects the pulmonary artery to the aorta, so most blood from the right ventricle bypasses the lungs.
- **Changes at birth:** The first breath expands the lungs, which then offer little resistance, so blood flow through the ductus arteriosus falls and it becomes fibrous tissue within a few weeks. More blood returning from the lungs increases the pressure in the left atrium, which pushes the flap of the foramen ovale shut. Once the cord is cut the ductus venosus constricts and closes. If the foramen ovale does not close the baby has a 'hole in the heart', is blue from too little oxygen and needs surgery. The newborn breathes fast and has a high heart rate to meet its own oxygen needs and keep warm.

→ **Then complete:**

- Label a placenta diagram including chorionic villi and umbilical vessels
- Explain why the foetal shunts must close at birth

Block 2 (45 min): Screening, Reproductive Technology & STIs

Study:

- **Infertility:** Defined as being unable to achieve pregnancy despite frequent unprotected sex for at least a year; it affects about one in six Australian couples. About 40% is due to sperm problems, 40% to the female reproductive system and 20% to a combination.
- **Male causes:** Sperm must be produced in sufficient numbers, swim forward (motility), have normal structure (morphology) and be able to penetrate the corona radiata and zona pellucida. Other causes include semen flowing into the bladder, antibodies against the man's own sperm, blockages of the vas deferens and hormone imbalances.
- **Female causes:** Fewer healthy eggs with age (especially after 36); polycystic ovarian syndrome (many follicles fail to mature so no egg is released); high prolactin; early menopause (primary ovarian insufficiency), including from cancer treatment; endometriosis (endometrial cells growing outside the uterus, affecting about 10% of women); fibroids (benign muscle growths that may distort the uterus or block the tubes); blocked uterine tubes (from infection such as gonorrhoea or chlamydia, or ectopic pregnancy); and menstrual or hormonal problems that stop implantation.
- **Treatments that allow natural fertilisation:** Microsurgery can open blocked tubes and remove fibroids or endometriosis. Ovulation tracking uses blood tests for the LH surge (sperm survive 2–3 days but the egg only 24 hours, so the best time is just before ovulation). Ovulation induction uses clomiphene (stimulates FSH) or FSH injections, with hCG to trigger ovulation. Artificial (intrauterine) insemination places prepared sperm in the uterus through a catheter (10–20% success per cycle, about 80% over 3–6 cycles); it can use the partner's or donor sperm.
- **Assisted reproductive technologies:** GIFT: eggs and sperm are collected, mixed in the laboratory and injected into the uterine tube by laparoscopic surgery, so fertilisation occurs naturally; lower success and needs surgery, but is acceptable to some for religious or ethical reasons. IVF: hormones stimulate multiple follicles, eggs are collected with a needle through the vagina, mixed with sperm at 37°C, and 2–6 days later an embryo is placed in the uterus through a catheter; the number of embryos is regulated and spare embryos are frozen. ICSI: a single sperm is injected into an egg (for sperm problems), with a concern that a genetic cause of male infertility may be passed on. Other options are surgical sperm retrieval, donor eggs, sperm or embryos, and surrogacy (traditional using the father's sperm, or gestational using IVF; surrogates cannot be paid beyond expenses, and the agreement is not legally binding).
- **Ethical, religious and cost issues:** The fate of unused embryos (over 100 000 frozen in Australia in 2019; typically stored for five years; options are to dispose, donate to others or donate for research), religious objections (third parties, excess embryos, separating procreation from sex) and cost (e.g. about \$9828 per IVF cycle, with about \$4991 out of pocket in 2020, and most couples need several cycles).
- **Screening and diagnosis of foetal health:** Ultrasound (sound waves) confirms pregnancy, dates it, shows the number of foetuses, growth, anatomy, placenta and position. Amniocentesis (16–20 weeks) takes 10–20 mL of amniotic fluid to examine foetal cells; it carries a small risk of infection or miscarriage and detects Down syndrome, cystic fibrosis, spina bifida and other disorders. Chorionic villus sampling (9–19 weeks) takes cells from the chorion, gives faster results but has about a 2% miscarriage risk and cannot diagnose spina bifida. A maternal blood test (from about 10 weeks) uses foetal DNA in the mother's blood to screen (not diagnose) for Down, Edwards, Patau and Turner syndromes; a high-risk result is confirmed by amniocentesis or CVS. Foetal monitoring records heart rate (ECG); fetoscopy views the foetus but is risky; foetal blood sampling gives results within days but has a 1–2% miscarriage risk; newborn heel-prick tests detect PKU, and AFP in amniotic fluid indicates spina bifida; DNA probes detect disorders such as Duchenne muscular dystrophy.
- **Contraception:** Abstinence is the only method with no risk of pregnancy or STIs. Periodic abstinence (rhythm, cervical mucus and symptothermal methods) and lactational amenorrhoea are not very reliable; withdrawal is highly unreliable. Barrier methods: condom (also protects against STIs), diaphragm and cervical cap (used with spermicide) and the female condom (which also protects). Spermicides alone are unreliable. Hormonal methods (combined pill with oestrogen and progesterone substitutes, mini pill, vaginal ring, injections, implants) prevent ovulation, thicken cervical mucus and make the uterine lining unsuitable for implantation; they are very reliable but give no STI protection and can have side effects such as a small increased risk of blood clots. IUDs (copper or hormonal) are over 99% effective and reversible. The emergency contraceptive pill works best within 72 hours,

and a copper IUD can be used as emergency contraception within five days. Sterilisation (vasectomy, tubal ligation) is permanent. Ethical views differ, e.g. some object to methods that prevent implantation.

- **Sexually transmitted infections:** STIs are caused by viruses, bacteria, fungi or parasites passed on by close body contact; three-quarters of cases in Australia are in people aged 15–29 and there is no vaccine for most. Chlamydia (bacterium *Chlamydia trachomatis*) is the most common, often silent; untreated it can cause epididymitis in men, pelvic inflammatory disease, infertility and ectopic pregnancy in women, and can infect a baby at birth; antibiotics treat it. Gonorrhoea (*Neisseria gonorrhoeae*) causes burning and pus in males and often no recognised symptoms in females; it can cause infertility and blindness in newborns, and antibiotic-resistant strains exist. Syphilis (*Treponema pallidum*) passes through primary (chancre), secondary (rash, highly infectious), latent and tertiary stages, can cross the placenta, and is treated with antibiotics. Genital herpes (Herpes simplex virus type 2) stays in the nervous system for life and recurs; it can be passed on even without symptoms and antivirals reduce but do not cure it. Genital warts are caused by some types of human papillomavirus (HPV); other HPV types cause cervical cancer, and the Gardasil vaccine (since 2007) protects against some. HIV, a retrovirus with an RNA core, infects helper T-lymphocytes, uses reverse transcriptase to make DNA copies and gradually destroys the immune system, leading to AIDS; it spreads through unprotected sex, shared needles, infected blood and unsterilised equipment, and from mother to baby. Bacterial STIs are treatable with antibiotics; viral STIs are not curable.

→ **Then complete:**

- Complete a table comparing IVF, AI, GIFT and ICSI (procedure, success rate, ethical consideration)
- Complete an STI summary table (pathogen type, symptoms, treatable/curable?)

Retrieval Quiz (10 min) — answer without notes

1. What structures increase surface area for exchange in the placenta?
2. Why don't maternal and foetal blood mix?
3. Name the three foetal shunts that close after birth.
4. What is ICSI?
5. Which studied STIs are caused by bacteria rather than a virus?

Check your answers:

1. Chorionic villi.
2. Exchange occurs by diffusion across the placental membrane, keeping the two blood supplies separate.
3. Ductus venosus, ductus arteriosus, foramen ovale.
4. Intracytoplasmic sperm injection – a single sperm is injected directly into an egg, used to treat male infertility.
5. Chlamydia, syphilis and gonorrhoea (herpes, genital warts and HIV are viral).

Session 22 — Full-Course Mixed Retrieval

Full Course Review

Resources: Exam Revision Quizzes 1–6; ‘How to Answer Extended Response Questions’ video

Textbook: Chapter summaries (pp. 56, 80, 97, 136, 163, 188, 222, 244, 269, 296, 329, 357, 380, 415) and the review questions at the end of each chapter (see the Textbook Review Question Bank).

Blank labelling diagram: Diagram 1 (The Human Heart); Diagram 2 (The Nephron); Diagram 3 (A Synovial Joint); Diagram 4 (A Sarcomere (relaxed)); Diagram 5 (The Male Reproductive System); Diagram 6 (The Female Reproductive System) — see the Blank Labelling Diagrams section.

Block 1 (45 min): Rapid Recall Across the Whole Course

Study:

- Draw from memory, no notes: a generalised cell, the heart, the nephron, a sarcomere, a nucleotide, mitosis vs meiosis stages, male & female reproductive systems, a pedigree

→ **Then complete:**

- Time yourself: 2 minutes per diagram, then self-mark against your booklets
- Note any diagram you couldn’t complete – revisit that topic today, not tomorrow

Block 2 (45 min): Full Mixed Practice

Study:

- Complete a mixed past-paper style section covering both Unit 1 and Unit 2 topics under timed conditions

→ **Then complete:**

- Complete misstagore.com Exam Revision Quizzes 1–6 and self-mark
- Watch ‘How to Answer Extended Response Questions’ and rewrite one weaker response using the technique

Retrieval Quiz (10 min) — answer without notes

1. What is the site of aerobic respiration?
2. What valve is between the right atrium and right ventricle?
3. What are the three processes occurring in a nephron?
4. What produces new bone tissue?
5. What are the three sources of genetic variation from meiosis and fertilisation?

Check your answers:

1. The mitochondria.
2. The tricuspid valve.
3. Filtration, reabsorption, secretion.
4. Osteoblasts.
5. Crossing over, independent assortment, random fertilisation.

Session 23 — Mock Exam & Final Review

Full Course Review

Resources: *Full mock exam (teacher-provided or past paper) + marking key*

Textbook: *Re-read the chapter summaries for the topics you got wrong in the mock exam.*

Block 1 (45 min): Full Mock Exam

Study:

- Sit a full mock exam under timed, test-like conditions – no notes, no phone

→ **Then complete:**

- Complete the mock exam in one sitting, then mark immediately using the answer/marking key
- Log every error by topic in your Priority List below

Block 2 (45 min): Targeted Final Review

Study:

- Revisit only the specific topics/questions you got wrong in the mock exam

→ **Then complete:**

- Re-do the Final A-Grade Self-Assessment Checklist below and tick off every item you can answer without notes
- Get an early night – no new content the day before the exam

Note

No retrieval quiz today – today is for targeted revision of your own weak spots, identified from the mock exam.

Final A-Grade Self-Assessment Checklist

You should be able to answer every statement below without notes.

Cell Structure & Metabolism

- ☐ I can label a generalised cell and state the function of each organelle
- ☐ I can explain diffusion, osmosis, and active transport
- ☐ I can explain the lock-and-key model and the factors affecting enzyme activity
- ☐ I can compare aerobic and anaerobic respiration

Respiratory & Circulatory Systems

- ☐ I can trace the pathway of air from the nose to the alveoli
- ☐ I can explain how alveoli are adapted for gas exchange
- ☐ I can label the heart and trace the direction of blood flow
- ☐ I can describe the composition and function of blood, and the role of the lymphatic system
- ☐ I can explain ABO/Rhesus blood groups and transfusion compatibility

Digestive & Excretory Systems

- ☐ I can label the digestive system and describe the function of each organ
- ☐ I can list the digestive enzymes, their sources, substrates and products
- ☐ I can label the nephron and explain filtration, reabsorption and secretion
- ☐ I can explain the difference between excretion and elimination
- ☐ I can explain the causes and treatment of kidney stones and kidney failure

Musculoskeletal System

- ☐ I can compare compact and spongy bone, and the three cartilage types
- ☐ I can label a synovial joint and describe each type of joint movement
- ☐ I can describe the sliding filament model of muscle contraction
- ☐ I can explain antagonistic muscle pairs using an example

DNA & Cell Reproduction

- ☐ I can explain DNA replication step-by-step
- ☐ I can explain transcription and translation
- ☐ I can identify every stage of mitosis and meiosis
- ☐ I can explain crossing over, independent assortment and random fertilisation
- ☐ I can explain how non-disjunction leads to trisomy/monosomy

Genetics & Inheritance

- ☐ I can define gene, allele, genotype, phenotype, dominant and recessive
- ☐ I can complete Punnett squares for monohybrid, sex-linked and co-dominant crosses
- ☐ I can interpret a pedigree to determine mode of inheritance
- ☐ I can explain DNA profiling and gel electrophoresis

Reproduction, Pregnancy & Technology

- ☐ I can label the male and female reproductive systems
- ☐ I can describe spermatogenesis and oogenesis
- ☐ I can explain the hormonal control of the menstrual cycle
- ☐ I can describe fertilisation, implantation and early development
- ☐ I can explain placental exchange and the closure of the foetal shunts at birth
- ☐ I can compare IVF, AI, GIFT and ICSI, and describe contraception methods and STIs

Exam Technique

- ☐ I can answer a short-answer question in the exact number of distinct points requested
- ☐ I can structure a longer extended response using clear scientific terminology
- ☐ I have completed at least one full mock exam under timed conditions

Common Mistakes to Avoid

These are the errors that lose students the most marks. Read the left-hand column, make sure you would never write it, then check you can state the right-hand column from memory.

Cells & Metabolism (Sessions 1–3)

Common mistake	Correct idea
Diffusion and osmosis need energy.	Both are passive – no ATP is used. Active transport is the one that needs ATP.
Osmosis is the movement of particles (solute).	Osmosis is the movement of water only, across a selectively permeable membrane, from a high to a low water concentration.
Respiration means breathing.	Cellular respiration is the release of energy from glucose inside cells. Breathing (ventilation) just moves air in and out of the lungs.
High temperature 'kills' enzymes.	Enzymes are not alive. High temperature (or extreme pH) denatures them – the active site changes shape and can no longer bind the substrate.
Enzymes are used up in the reaction.	Enzymes are not consumed or altered – they can be reused many times.
Anaerobic respiration makes no ATP.	It makes a small amount (2 ATP from glycolysis) compared with aerobic respiration (up to about 38 ATP).
ATP is energy / mitochondria make energy.	Energy is not created. Respiration releases energy from glucose and transfers it to ATP, which stores it in the bond to the third phosphate group.
Catabolism builds molecules up.	Catabolism breaks large molecules down and releases energy; anabolism builds molecules up and needs energy.

Respiratory & Circulatory Systems (Sessions 4–6)

Common mistake	Correct idea
The diaphragm relaxes when we breathe in.	During inspiration the diaphragm contracts and flattens; the external intercostals contract and lift the rib cage.
Air is sucked in by the lungs.	Air flows from high to low pressure. Volume of the chest cavity increases, pressure falls below atmospheric, and air flows in.
Oxygen enters the blood because the body needs it.	Oxygen diffuses down its concentration gradient. The gradient is maintained by ventilation (fresh air) and constant blood flow.
Arteries carry oxygenated blood and veins carry deoxygenated blood.	Arteries carry blood away from the heart, veins carry it towards the heart. The pulmonary artery is deoxygenated and the pulmonary veins are oxygenated.
Veins have thicker walls than arteries.	Arteries have thick, elastic, muscular walls (high pressure). Veins have thinner walls, a wider lumen and valves.

Common mistake	Correct idea
Left and right sides of the heart mixed up on the diagram.	The heart is drawn as if facing the patient: the right side of the heart is on the left of the page.
Red blood cells have a nucleus.	Mature human red blood cells have no nucleus, leaving more room for haemoglobin.
Blood groups are determined by antibodies.	ABO groups are determined by the antigens on the surface of red blood cells. The plasma antibodies are the ones that do not match.
The lymphatic system is just another blood circulation.	It returns excess tissue fluid to the blood and filters pathogens at lymph nodes. It has no pump.

Digestive & Excretory Systems (Sessions 7–9)

Common mistake	Correct idea
Bile is an enzyme.	Bile contains no enzymes. It emulsifies fats, increasing their surface area for lipase.
Most nutrient absorption happens in the stomach or large intestine.	The small intestine (villi and microvilli) is the main site of absorption. The large intestine mainly reabsorbs water and ions.
All digestion starts in the mouth.	Only starch digestion starts in the mouth (salivary amylase). Protein digestion begins in the stomach and lipid digestion in the small intestine.
Excretion and elimination (defecation) are the same.	Excretion is removal of metabolic wastes (urea, CO ₂ , bile pigments). Faeces are undigested food and are eliminated, not excreted.
The kidneys make urea.	The liver makes urea from ammonia (from deamination of amino acids). The kidneys remove it from the blood.
Filtration in the glomerulus is selective.	Filtration is non-selective (it depends on molecular size and pressure). Selectivity comes from reabsorption.
Glucose is normally found in urine.	All glucose is reabsorbed in the proximal convoluted tubule, so it should not appear in urine.
Ammonia is excreted because it is safe.	Ammonia is very toxic, so the liver converts it to urea, which is far less toxic.

Musculoskeletal System (Sessions 10–12)

Common mistake	Correct idea
Ligaments join muscle to bone.	Tendons join muscle to bone. Ligaments join bone to bone.
Muscles push bones.	Muscles can only pull (contract). Antagonistic pairs work in opposite directions.

Common mistake	Correct idea
The filaments get shorter during contraction.	The filaments slide past each other and do not change length. The sarcomere shortens, the I band and H zone narrow, and the A band stays the same.
The origin is the moving end of the muscle.	The origin is the fixed attachment. The insertion is the attachment that moves.
Osteoporosis and osteoarthritis are the same.	Osteoporosis is loss of bone density. Osteoarthritis is breakdown of the articular cartilage in joints.
Bone is dead, hard tissue.	Bone is living tissue with cells (osteocytes), a blood supply and the ability to remodel.
All cartilage is the same.	Hyaline, elastic and fibrocartilage differ in structure and location (e.g. joint surfaces, ear, intervertebral discs).

DNA & Cell Reproduction (Sessions 13–16)

Common mistake	Correct idea
RNA contains thymine.	RNA contains uracil instead of thymine, ribose instead of deoxyribose, and is single stranded.
Transcription happens at the ribosome.	Transcription happens in the nucleus. Translation happens at the ribosome.
tRNA has a codon.	mRNA has codons. tRNA has anticodons. DNA has triplets.
The template strand and the mRNA have the same sequence.	The mRNA is complementary to the template strand and has the same sequence as the coding strand (with U in place of T).
Epigenetics changes the DNA sequence.	Epigenetic changes (e.g. methylation, acetylation, histone changes) change gene expression, not the sequence of bases.
Mitosis makes gametes.	Mitosis makes two identical diploid cells for growth and repair. Meiosis makes four genetically different haploid gametes.
Sister chromatids separate in meiosis I.	Homologous chromosomes separate in meiosis I. Sister chromatids separate in meiosis II.
Crossing over happens in mitosis.	Crossing over happens in prophase I of meiosis and increases variation.
Cancer is caused only by carcinogens.	Cancer is uncontrolled cell division caused by damage to genes that control the cell cycle. Carcinogens (e.g. tobacco smoke, UV, asbestos) increase the risk, but other factors also play a part.

Genetics & Inheritance (Sessions 17–18)

Common mistake	Correct idea
Dominant means the most common allele.	Dominant means the allele is expressed when present in a heterozygote. It is not necessarily the most common.
Genotype is what you look like.	Genotype is the alleles you carry. Phenotype is the observable trait.
Sex-linked conditions only affect males.	They are more common in males (one X chromosome) but females can be affected if they have two copies of the recessive allele.
The mother determines the sex of the baby.	The egg always carries an X. The sperm carries an X or a Y, so the father's sperm determines the sex.
Recessive conditions cannot appear if neither parent is affected.	Two unaffected carrier parents can have an affected child.
Punnett squares show what will happen in each family.	They show probabilities. Each pregnancy is an independent event.
Shaded pedigree symbols mean carrier.	Shaded means affected. Squares are males and circles are females.
Carriers of an X-linked recessive condition can be male.	A male with one X carrying the allele is affected (hemizygous). Only females can be carriers.

Reproduction, Pregnancy & Technology (Sessions 19–21)

Common mistake	Correct idea
Fertilisation happens in the uterus.	Fertilisation usually happens in the upper third of the uterine (Fallopian) tube. Implantation happens in the endometrium of the uterus.
Ovulation and menstruation are the same thing.	Ovulation is the release of a secondary oocyte. Menstruation is the shedding of the endometrium.
Sperm are made in the epididymis or prostate.	Sperm are produced in the seminiferous tubules. The epididymis stores and matures them.
The mother's and the foetus's blood mix in the placenta.	The two blood supplies stay separate. Exchange happens by diffusion across the placental membrane.
Zygote, embryo and foetus mean the same thing.	Zygote = fertilised egg. Embryo = the developing baby up to about 8 weeks. Foetus = from about 9 weeks until birth.
IVF, GIFT and ICSI are interchangeable.	IVF: fertilisation in a dish, embryo transferred to the uterus. GIFT: eggs and sperm placed in the uterine tube. ICSI: one sperm injected into an egg. IUI: sperm placed in the uterus.
A blood test can diagnose Down syndrome.	The maternal blood test is a screening test (it shows increased chance). Amniocentesis or CVS is needed to diagnose.

Common mistake	Correct idea
Contraceptives such as the pill protect against STIs.	Hormonal methods give no STI protection. Condoms reduce (but do not eliminate) the risk.
All STIs can be cured with antibiotics.	Chlamydia, gonorrhoea and syphilis are bacterial and treatable. HIV, herpes and genital warts are viral and cannot be cured.

Exam Technique (all topics)

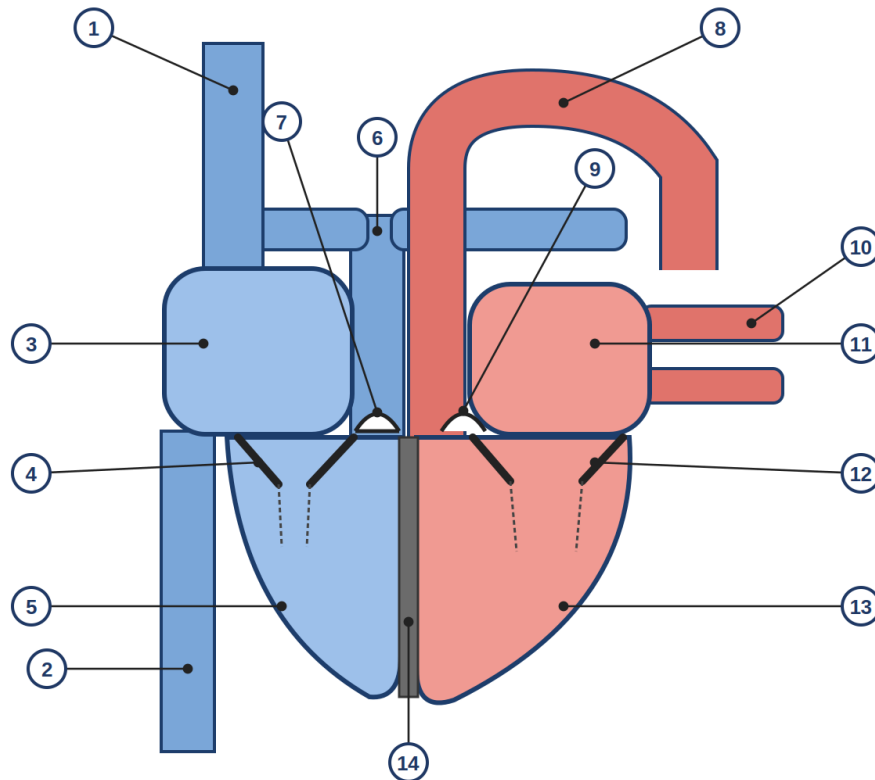
Common mistake	Correct idea
'This proves the hypothesis.'	Hypotheses can only be supported or not supported – avoid the word 'prove'.
Answering 'explain' with a description only.	'Describe' = say what happens. 'Explain' = say what happens and why or how (give the reason).
Giving one point for a 3-mark question.	Look at the marks. Give at least as many separate, correct points as marks available.
Vague words like 'it', 'stuff', 'gets rid of'.	Use the correct scientific term (e.g. 'denatured', 'concentration gradient', 'selectively permeable').
Diagram drawn without labels or labels not touching the structure.	Label lines should touch the structure, never cross each other, and use the correct term.

Blank Labelling Diagrams

Six diagrams to label from memory. Write the name of each numbered structure on the lines, check against the answer key at the end of this section, then redo any you got wrong the next day. Where a task asks you to draw a diagram from memory, these are also useful to copy and annotate.

Diagram 1: The Human Heart

The diagram is drawn as if facing the patient, so the right side of the heart is on the left of the page. Blue = deoxygenated blood, red = oxygenated blood.



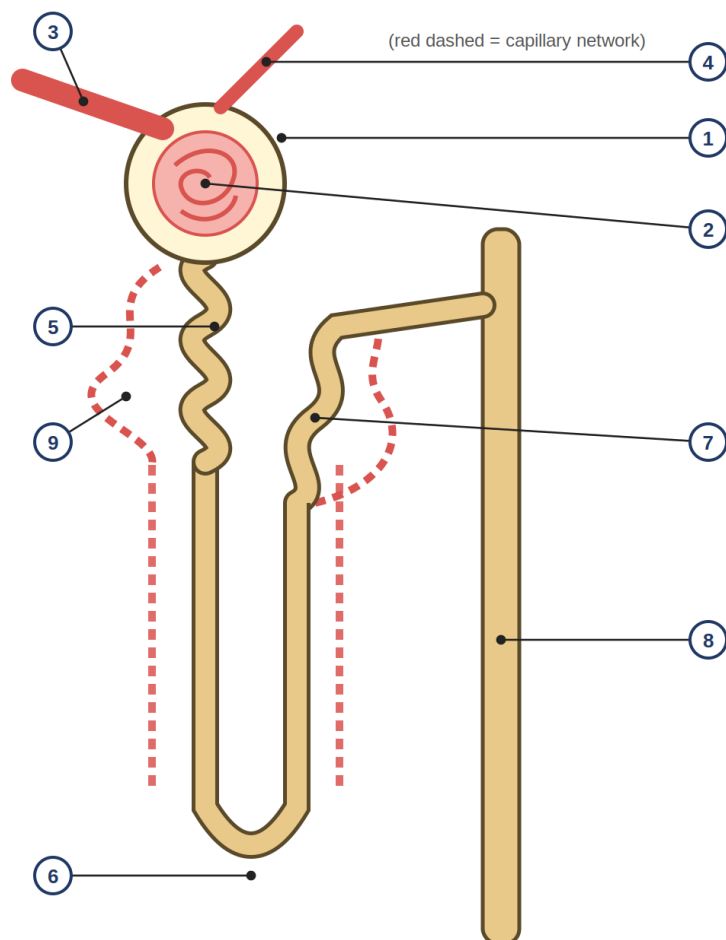
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____

Then trace the path of a red blood cell from the superior vena cava to the aorta, naming every chamber, valve and vessel it passes through.

Diagram 2: The Nephron

Red dashed lines show the capillary network around the tubule.



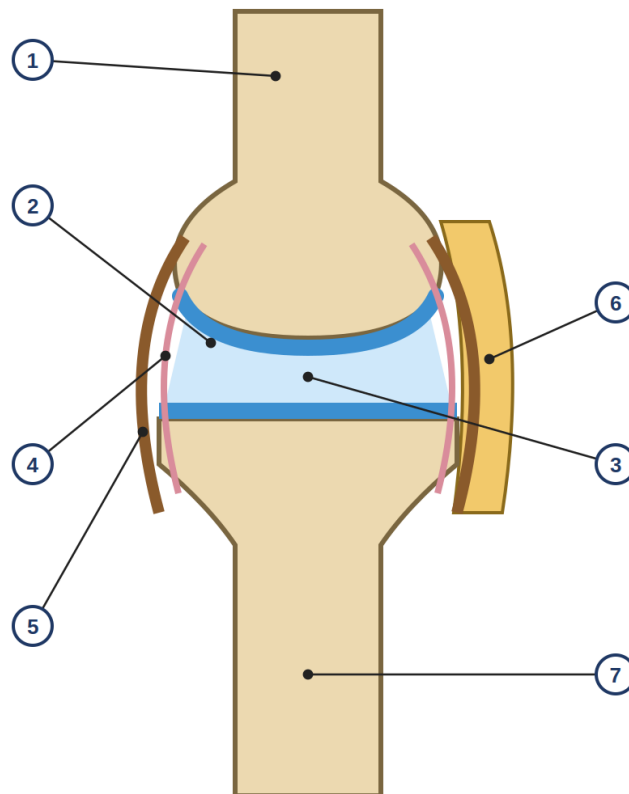
1. _____
2. _____
3. _____
4. _____
5. _____

6. _____
7. _____
8. _____
9. _____

Then mark where filtration, reabsorption and secretion occur.

Diagram 3: A Synovial Joint

Simplified diagram of a joint such as the knee.



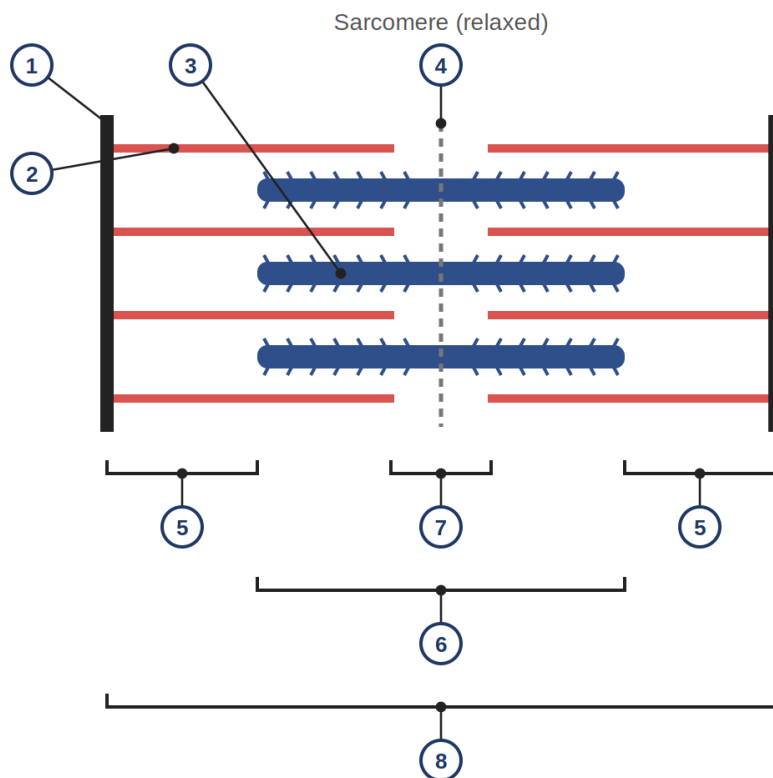
1. _____
2. _____
3. _____
4. _____

5. _____
6. _____
7. _____

Then state the function of each labelled structure.

Diagram 4: A Sarcomere (relaxed)

The two I-band brackets are both labelled 5.



1. _____
2. _____
3. _____
4. _____

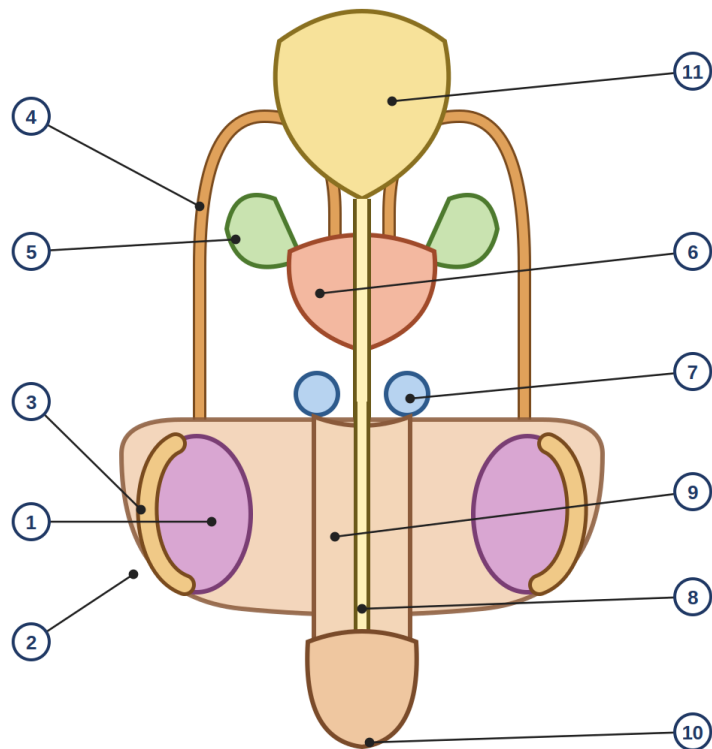
5. _____
6. _____
7. _____
8. _____

Then redraw the sarcomere as it would look when contracted, and state which of the bands and zones change width.

Diagram 5: The Male Reproductive System

Front view, simplified.

Male reproductive system (front view, schematic)



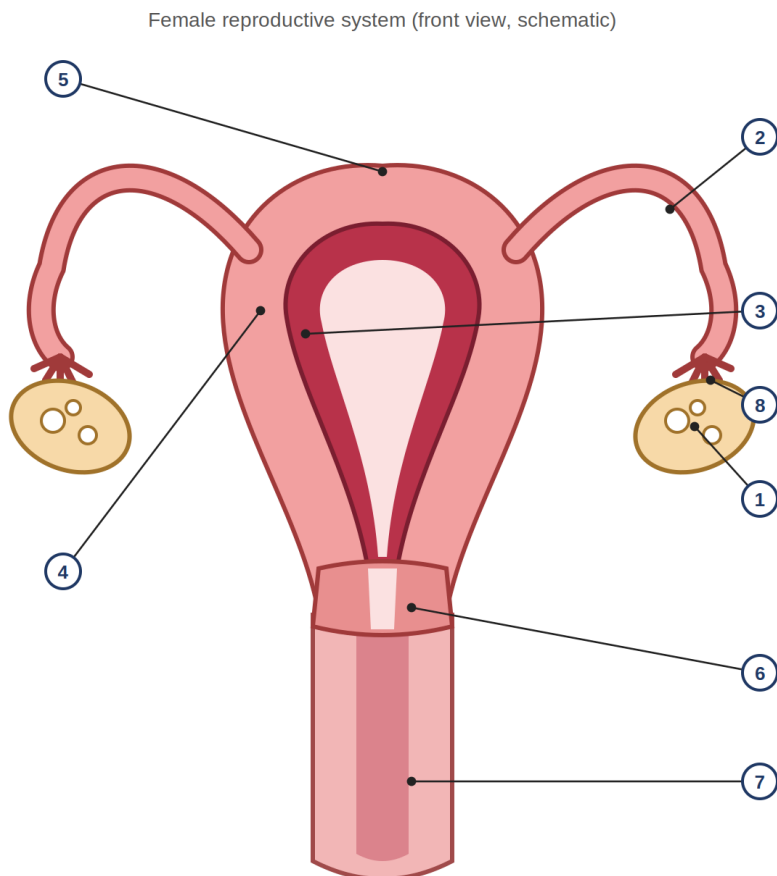
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

7. _____
8. _____
9. _____
10. _____
11. _____

Then draw the path taken by a sperm cell from the seminiferous tubules to the outside of the body.

Diagram 6: The Female Reproductive System

Front view, simplified.



1. _____
2. _____
3. _____
4. _____

5. _____
6. _____
7. _____
8. _____

Then mark where the egg is released, where fertilisation usually occurs and where implantation occurs.

Blank Diagram Answer Key

Diagram 1 — The Human Heart

- | | | |
|----------------------|-------------------------------|----------------------------|
| 1 Superior vena cava | 6 Pulmonary artery | 11 Left atrium |
| 2 Inferior vena cava | 7 Pulmonary (semilunar) valve | 12 Bicuspid (mitral) valve |
| 3 Right atrium | 8 Aorta | 13 Left ventricle |
| 4 Tricuspid valve | 9 Aortic (semilunar) valve | 14 Septum |
| 5 Right ventricle | 10 Pulmonary vein | |

Diagram 2 — The Nephron

- | | | |
|------------------------------|------------------------------|----------------------------|
| 1 Bowman's capsule | 4 Efferent arteriole | 7 Distal convoluted tubule |
| 2 Glomerulus/Renal Corpuscle | 5 Proximal convoluted tubule | 8 Collecting duct |
| 3 Afferent arteriole | 6 Loop of Henle | 9 Peritubular capillaries |

Diagram 3 — A Synovial Joint

- | | |
|---|--|
| 1 Bone (upper) | 5 Fibrous capsule (outer layer of the articular capsule) |
| 2 Articular cartilage | 6 Ligament |
| 3 Synovial cavity (contains synovial fluid) | 7 Bone (lower) |
| 4 Synovial membrane | |

Diagram 4 — A Sarcomere (relaxed)

- | | | |
|---------------------------|----------|--------------------------------|
| 1 Z line | 4 M line | 7 H zone |
| 2 Thin filament – actin | 5 I band | 8 Sarcomere (Z line to Z line) |
| 3 Thick filament – myosin | 6 A band | |

Diagram 5 — The Male Reproductive System

- | | | |
|----------------|------------------------|-------------|
| 1 Testis | 5 Seminal vesicle | 9 Penis |
| 2 Scrotum | 6 Prostate gland | 10 Foreskin |
| 3 Epididymis | 7 Bulbo-urethral gland | 11 Bladder |
| 4 Vas deferens | 8 Urethra | |

Diagram 6 — The Female Reproductive System

- | | | |
|----------------------------|--|------------|
| 1 Ovary | 4 Uterus (muscular wall of the uterus) | 6 Cervix |
| 2 Uterine (Fallopian) tube | 5 Uterus | 7 Vagina |
| 3 Endometrium | | 8 Fimbriae |