

2 · Cells, Development, Biodiversity and Conservation

Pearson Edexcel · International A-Level · Biology

From one cell to a living world

You began as one fertilised egg cell. This unit explains how that cell divided, how the copies were shuffled and halved to make gametes, how identical genes became different tissues, and how the variety that produces is counted, classified and – increasingly – defended. It is the unit of microscopes, calculations and definitions done precisely.

WBI12 Cells, Development, Biodiversity and Conservation is the second IAS unit: 1 hour 30 minutes, 80 marks, all compulsory. It assesses Topic 3 (Cell Structure, Reproduction and Development) and Topic 4 (Plant Structure and Function, Biodiversity and Conservation). Expect labelling diagrams, microscope and magnification calculations, the index of diversity and Hardy–Weinberg questions, and long answers on conservation evaluation.

Cell ultrastructure and the microscope

A **eukaryotic** cell is a set of specialised compartments:

Structure	Function
Nucleus and nucleolus	DNA stored behind a double membrane; nucleolus builds ribosomes
Ribosomes (80S)	site of protein synthesis
Rough endoplasmic reticulum	folds and transports proteins made on its ribosomes
Golgi apparatus	modifies, packages and ships proteins in vesicles
Mitochondrion	site of aerobic respiration, ATP production
Chloroplast (plants)	site of photosynthesis
Lysosome	digestive enzymes for worn organelles
Cell-surface membrane	controls transport, recognition

Cells organise into **tissues** (similar cells), **organs** (cooperating tissues) and **organ systems**. A **prokaryotic** cell has none of the membrane-bound organelles: a cell wall, a slime **capsule**, one circular DNA molecule plus **plasmids**, 70S ribosomes, and sometimes a **flagellum**.

Magnification is how much bigger the image is; **resolution** is the smallest separation still seen as two. Light microscopes resolve about 200 nm; electron

beams, far shorter in wavelength, resolve to a few nanometres – but need thin stained sections (TEM) or gold-coated surfaces (SEM). $M = \text{image size/actual size}$, keeping units consistent.

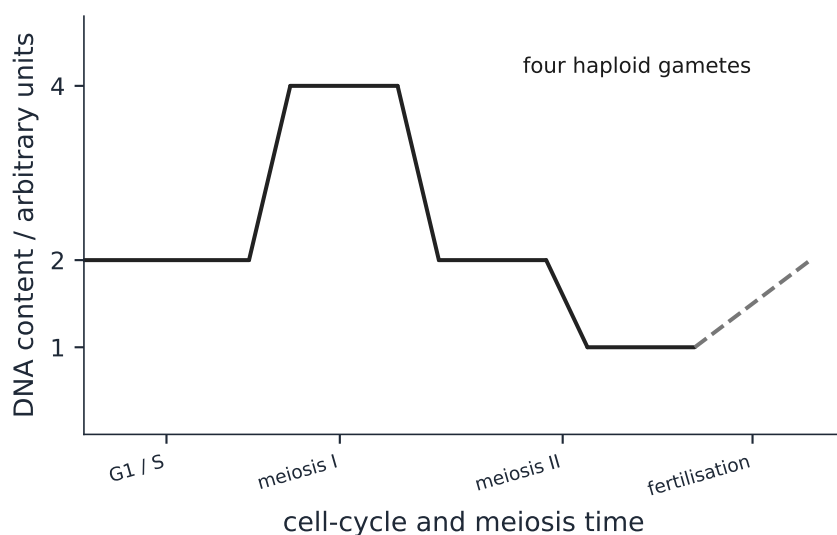
Worked check. A mitochondrion measures 14 mm on a photograph labelled $\times 20\,000$. Actual length = $14\,000\ \mu\text{m}/20\,000 = 0.7\ \mu\text{m}$. A nucleus that must be seen with its double membrane needs an electron microscope: the two membranes lie closer than a light microscope's resolution.

Meiosis: halving and shuffling

Meiosis is two successive divisions after one DNA replication, producing four genetically different **haploid** cells from one **diploid** cell. Two processes create the variation:

- **Independent assortment** – each homologous pair lines up and separates at random in meiosis I; each gamete gets one of each pair, from either parent at random (2^n combinations).
- **Crossing over** – in prophase I, homologous chromatids swap sections, mixing alleles within chromosome pairs.

Mammalian gametes are specialised for delivery and provisioning: the **sperm** carries an **acrosome** (digestive enzymes), a midpiece of mitochondria and a flagellum; the **egg** contributes nearly all cytoplasm and a **zona pellucida** that locks out extra sperm after the **cortical reaction**. In flowering plants the pollen tube delivers two male nuclei: one fertilises the egg, the other the polar nuclei – **double fertilisation**.



Mitosis and the cell cycle

Mitosis gives daughter nuclei the same chromosome number as the parent nucleus. After cytokinesis, a diploid parent normally produces two diploid daughter cells for growth, repair or asexual reproduction. Interphase (G_1 , **S** – DNA replication, G_2) fills most of the cycle; mitosis itself is prophase (chromosomes condense, spindle forms), metaphase (chromosomes line at the equator), anaphase (spindle fibres pull chromatids to poles), telophase (nuclear membranes reform), then **cytokinesis**

The **mitotic index** = cells in mitosis ÷ total cells counted. A high value means a large fraction of the counted cells are dividing. Healthy growing tissues can also have high values, so this alone does not diagnose cancer.

Worked check. A root-tip squash shows 36 of 450 cells in mitosis: index = $36/450 = 0.08 = 8\%$. If the cycle takes 20 hours, mitosis occupies $0.08 \times 20 = 1.6$ hours.

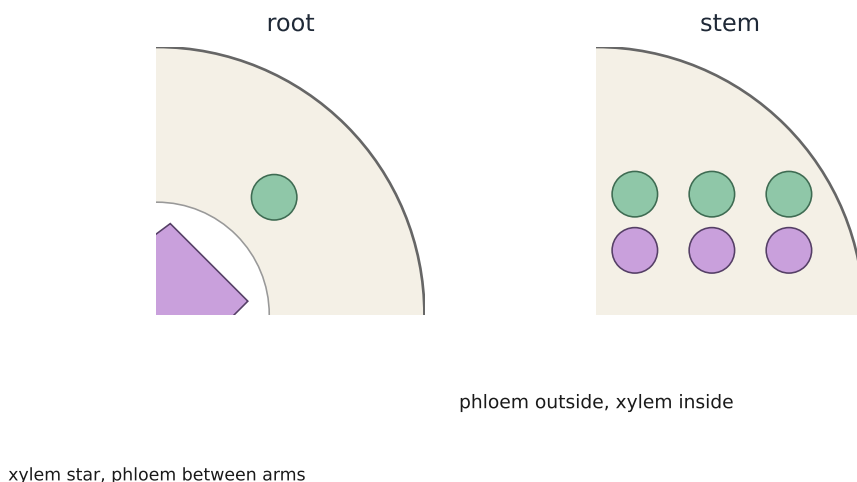
Stem cells and switching genes on

A **totipotent** stem cell can form a whole organism (the first divisions of the zygote); a **pluripotent** cell (inner **blastocyst**) can form any tissue but not the whole organism. Differentiation happens by **differential gene expression**: most specialised body cells retain the same genome, but each type expresses a different subset of genes. One gene can yield several proteins by **post-transcriptional modification** – RNA splicing choices of the pre-mRNA. The final phenotype also reflects the environment (height needs both genes and nutrition) and, for many traits, multiple genes acting together (**polygenic** inheritance giving continuous variation).

Plant transport tissues

Plant cells add a cellulose **cell wall** joined to neighbours by **plasmodesmata**. Cellulose chains bundle into **microfibrils** whose criss-cross laying gives tensile strength; secondary thickening with lignin strengthens and waterproofs.

Tissue	Built from	Function
Xylem	dead hollow cells, lignified walls	water and mineral transport; support
Phloem	living sieve-tube elements + companion cells	translocation of sugars



Water and ions matter beyond drinking: **nitrate** builds amino acids, **calcium** cross-links pectin in walls and signals inside cells, **magnesium** sits at the heart of chlorophyll – a shortage yellows the leaves.

Measuring life: classification and biodiversity

Classification arranges life by shared characteristics; the **three-domain system** (Bacteria, Archaea, Eukarya) rests on molecular evidence – ribosomal RNA sequences – that revealed Archaea are closer to us than to bacteria. Within a habitat, diversity has two measures:

- **Species richness** – how many species.
- **Index of diversity** – $D = \frac{N(N-1)}{\sum n(n-1)}$, where N is all individuals and n each species' count. Higher D , more diverse.

Worked check. Habitat A: 3 species with counts 40, 35, 25 ($N = 100$). $D = 100 \times 99 / (40 \times 39 + 35 \times 34 + 25 \times 24) = 9900 / (1560 + 1190 + 600) = 9900 / 3350 = 2.96$. Habitat B: 3 species, counts 90, 6, 4: $D = 9900 / (8010 + 30 + 12) = 1.23$. Same richness, very different balance – D sees what richness cannot.

Within one species, the **heterozygosity index** $H = (\text{number of heterozygotes}) \div (\text{number of individuals})$ measures genetic variety. A species found nowhere else is **endemic** – and its island home makes it both precious and fragile.

Niches, Hardy–Weinberg and conservation

A **niche** is a species' way of life: its role, its requirements, its tolerances. Adaptations come in three registers – anatomical (thick fur), physiological (enzyme variants), behavioural (migration timing).

The **Hardy–Weinberg equation** – tracks allele frequencies in a

large, randomly breeding population with no selection, migration or mutation:

$$p^2 + 2pq + q^2 = 1$$

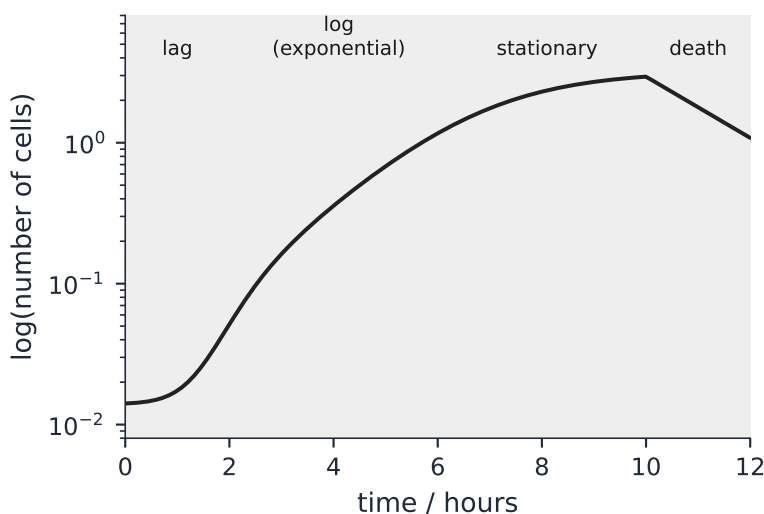
q^2 = frequency of the homozygous recessive genotype. If 4 % of a population shows the recessive phenotype, $q^2 = 0.04$, so $q = 0.2$, $p = 0.8$, carriers $2pq = 0.32$.

Worked check. Of 500 foxes, 45 are homozygous recessive: $q^2 = 0.09$, $q = 0.3$, $p = 0.7$. Expected carriers = $2pq \times 500 = 0.42 \times 500 = 210$.

Conservation questions want balance. Zoos and **seed banks** keep species against extinction and run captive breeding, but cost space, lose natural behaviour and serve few individuals; habitat protection and **corridors** preserve ecology at scale but need land, money and political will. Credit the specific argument, not the sentiment.

Culturing and growing microbes

For the microbiology here (and Unit 4's): grow bacteria on nutrient agar or in broth, using **aseptic technique** – use approved teaching cultures, sterilised equipment and the school's supervised handling, incubation and disposal procedures. Secure lids as specified by that procedure. Lower incubation temperatures reduce some risks; they do not guarantee that pathogens cannot grow. Count colonies on spread or pour plates (each colony from one cell or a clump: **colony-forming units**), or count cells with a haemocytometer, or follow **turbidity** in broth.



Worked check. In the exponential phase, the growth-rate constant $k = (\log_{10} N_t - \log_{10} N_0) / (0.301 \times t)$. From 1×10^4 to 4×10^7 cells in 4 hours: log difference = 3.602, so $k = 3.602 / (0.301 \times 4) \approx 3.0$ divisions per hour – about a 20-minute generation time.

Check yourself

1. Calculate the actual width of a nucleus that appears 24 mm wide at $\times 4\,000$. Give your answer in μm .
2. Name the two processes in meiosis that create genetic variation, and state when each happens.
3. A cell has 2 a.u. of DNA in G1. Sketch how DNA content changes through S phase, meiosis I and meiosis II.
4. Explain why all cells of a blastocyst can become any tissue, but a mature muscle cell cannot.
5. Explain two ways xylem is adapted to its function, one structural and one chemical.
6. Two habitats each contain 5 plant species. Explain why the index of diversity can still differ between them.
7. In a population of 1 000, 16 people show a recessive condition. Calculate q , p and the expected number of carriers.
8. A species of snail is endemic to one island. Explain why endemic species face higher extinction risk.
9. State three conditions a population must meet for the Hardy–Weinberg equation to hold.
10. Give one benefit and one limitation of seed banks compared with protecting habitat.

Answers: 1 $24\,000/4\,000 = 6\ \mu\text{m}$; 2 crossing over in prophase I, independent assortment in metaphase/anaphase I (and II); 3 rises to 4 in S, halves to 2 after meiosis I, halves to 1 after meiosis II, restored to 2 at fertilisation; 4 blastocyst cells are pluripotent – all genes still switchable; a muscle cell has switched off other pathways permanently in ordinary conditions; 5 hollow, lignified dead cells form continuous water columns with no cytoplasm to resist flow; lignin waterproofs and strengthens walls against collapse; 6 D weighs the evenness of abundance, not just the species count; 7 $q^2 = 0.016$, $q \approx 0.126$, $p \approx 0.874$, carriers $2pq \approx 0.22$, about 220 people; 8 a single local event (storm, disease, introduced predator, habitat loss) removes the whole species at once; 9 large population, random mating, no selection/mutation/migration; 10 seed banks store genetic diversity cheaply and safely against habitat loss (benefit) but species exist out of their ecology – no interactions, no evolution in place, and recolonisation is uncertain (limitation).