Cambridge IGCSE

Chuyên luyện thi IELTS/SAT → AP / IB / A-levels

8020 ENGLISH

Cambridge IGCSE Biology

Giáo trình luyện thi chuyên sâu

Song ngữ Anh–Việt

8020 ENGLISH

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Lời mở đầu · Foreword

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Thành tích 8020 English

9.0 IELTS cao nhất	**1570** SAT cao nhất
5/5 AP — điểm tuyệt đối	**90/100** IB Diploma
100% GV $\geq$ 8.0 IELTS / 1500 SAT	**CMU** Tiến sĩ ĐH #1 Hoa Kỳ về CS

Đội ngũ tiêu biểu: Thầy Châu Cát Tường (Academic Head, ThS Western Sydney, top 1% IELTS 8.5) · TS Nguyễn Anh Huy (Carnegie Mellon, cựu kỹ sư Amazon) · TS Nguyễn Phước Trường (Toán, ĐH Klagenfurt) · cùng đội ngũ giảng viên SAT 1500–1600, IELTS 8.0–8.5.

Kết quả học viên — điểm thi thật: IELTS 8.0–9.0 · SAT 1550 / 1570 / 1590 · AP 5/5 (Calculus BC, Microeconomics) · IB 90/100 (Economics) · Duolingo 110 · PTE 90 · TOEFL 120. **Bảng vàng SAT:** Khánh Đăng 1510 · Thảo Nguyên 1520 · Tâm Anh 1530.

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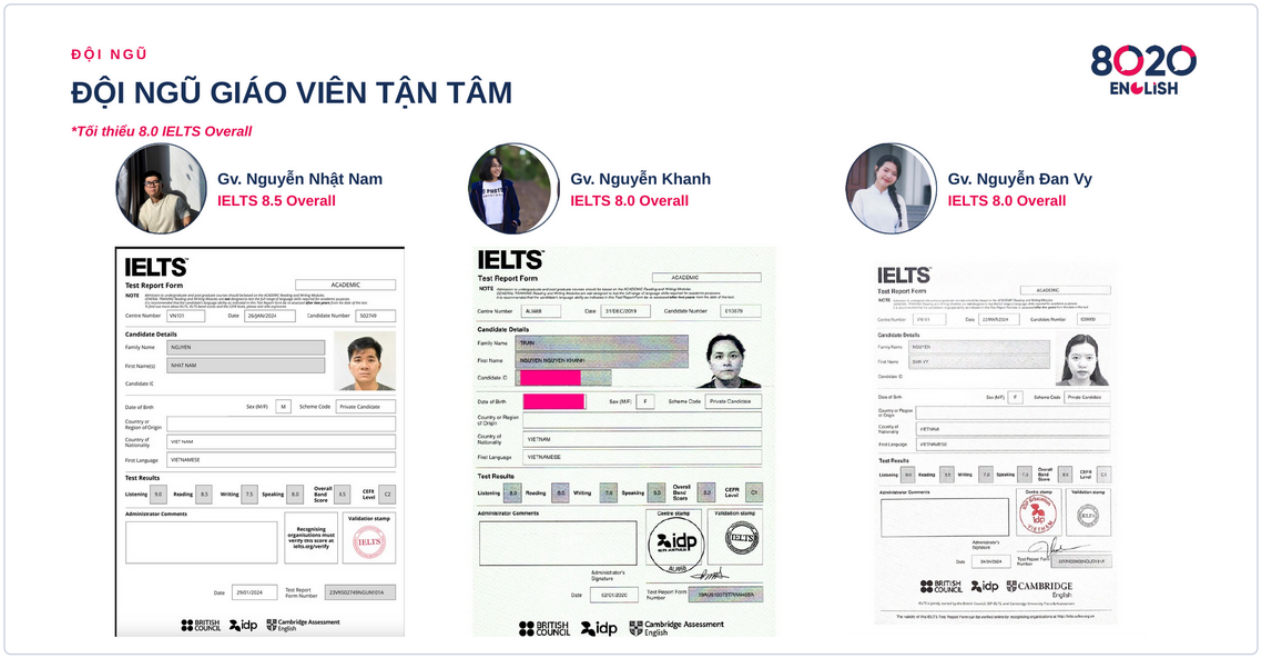

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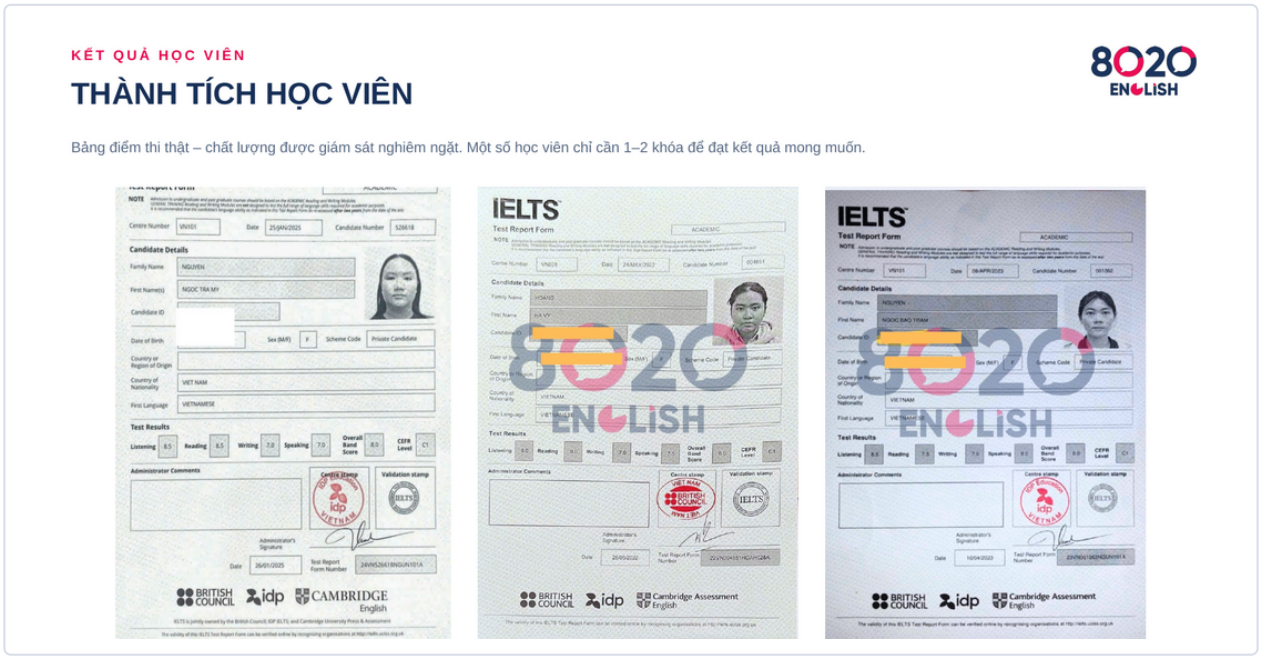

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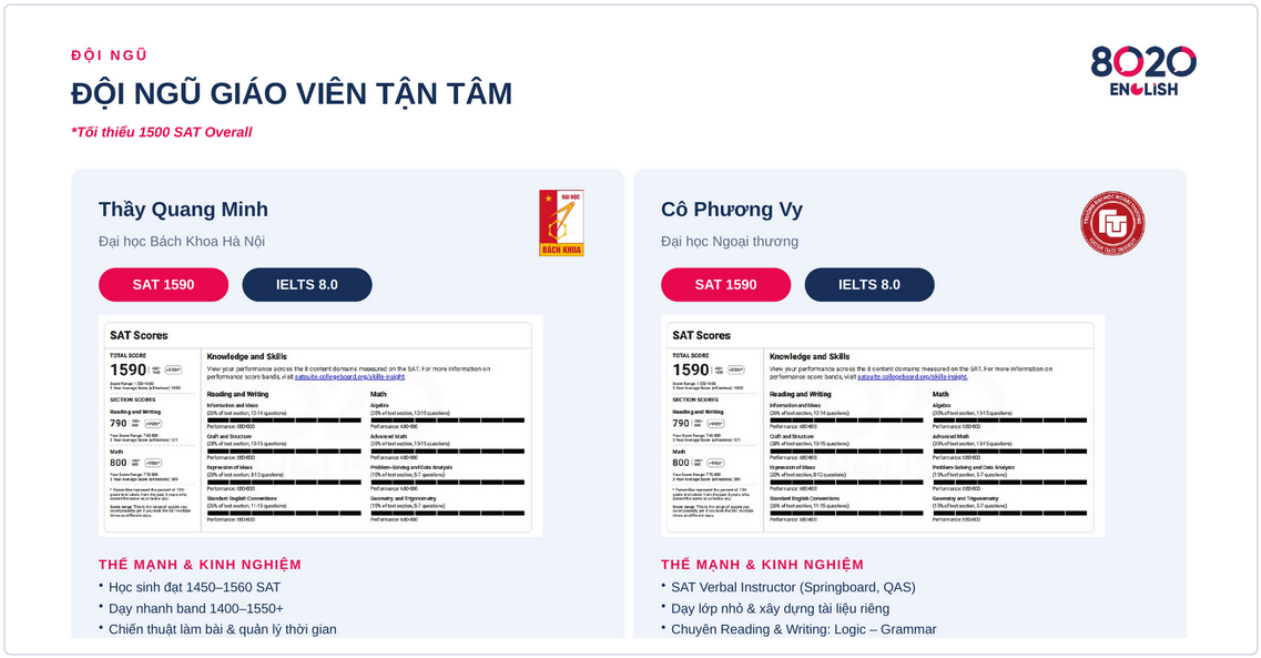

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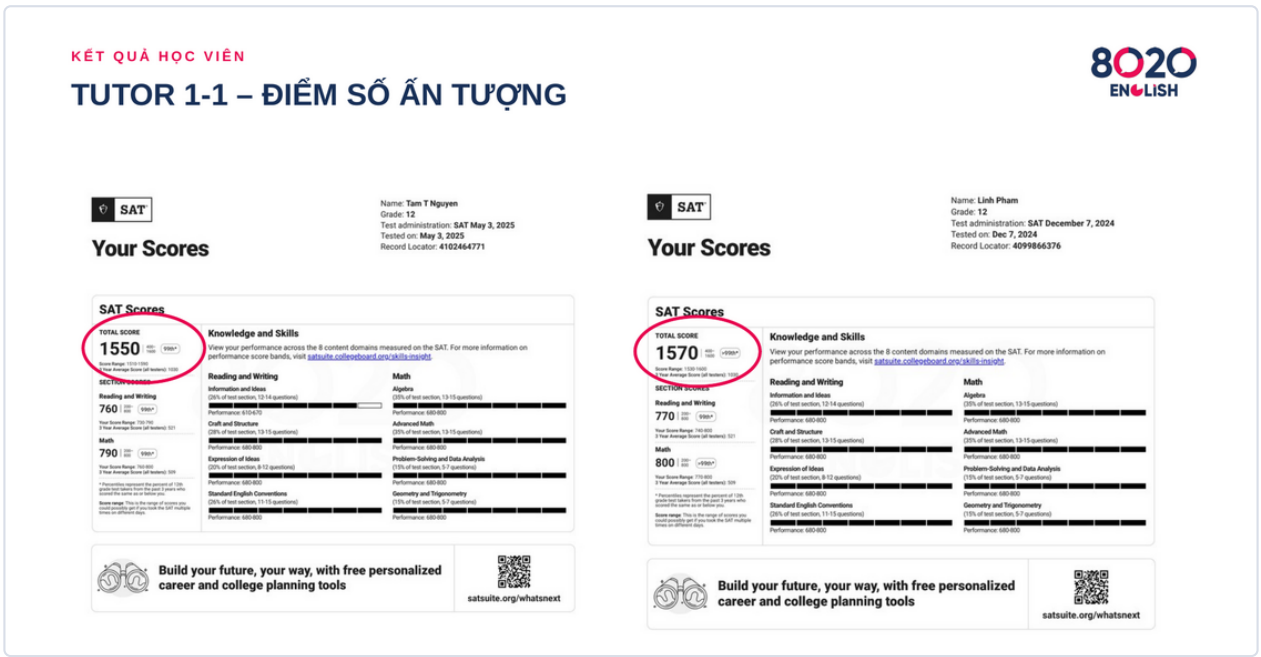
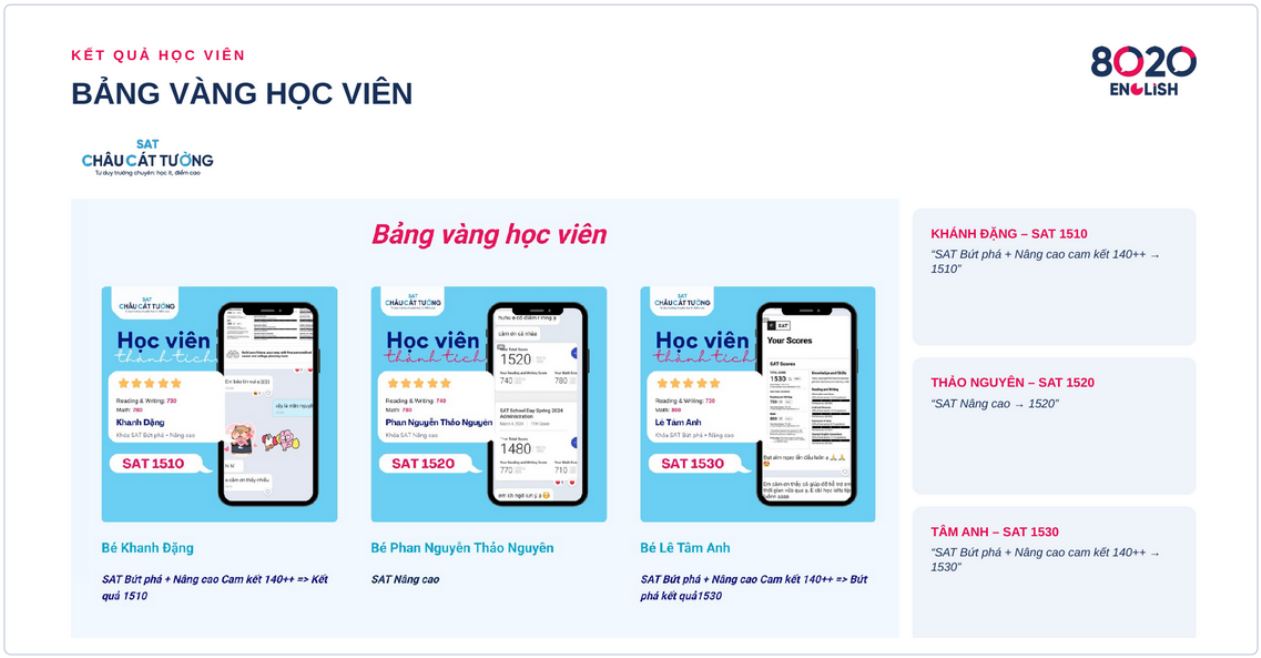
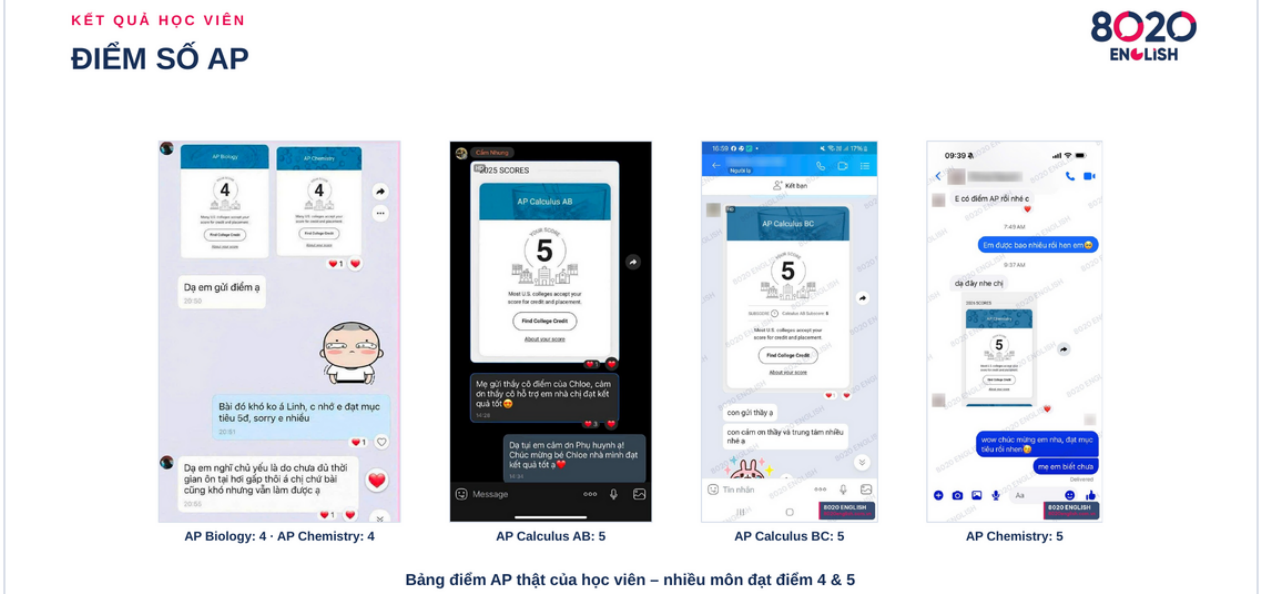


Học viên 8020 — SAT 1550 & 1570 (College Board)



Bảng vàng SAT — Học viên đạt 1510 · 1520 · 1530



Điểm AP thật — Calculus AB/BC 5/5 · Biology & Chemistry 4–5 (College Board)

Mục lục · Contents

Characteristics and Classification of Living Organisms

Mục tiêu Unit: Nêu và giải thích được tám đặc điểm của sự sống (MRS GREN cộng Homeostasis); hiểu khái niệm loài và quy tắc đặt tên khoa học nhị danh; phân biệt được năm giới sinh vật (Động vật, Thực vật, Nấm, Nguyên sinh, Sinh vật nhân sơ) và vị trí đặc biệt của virus; nắm được các bậc phân loại chính; (Supplement) phân biệt các nhóm động vật chân khớp và các lớp động vật có xương sống; (Supplement) xây dựng và sử dụng khoá lưỡng phân để định danh sinh vật.

1.1 Characteristics of Living Organisms

1.1.1 The eight characteristics of life

Every living organism, from a bacterium to a blue whale, shares a common set of life processes. Biologists summarise these using the mnemonic **MRS GREN**, to which a further process, **homeostasis**, is added to give eight characteristics in total.

[MRS GREN + Homeostasis]

- **M**ovement — an action by an organism or part of an organism causing a change of position or place.
- **R**espiration — the chemical reactions in cells that break down nutrient molecules and release energy for metabolism.
- **S**ensitivity — the ability to detect or sense changes in the environment (stimuli) and to make responses.
- **G**rowth — a permanent increase in size and dry mass by an increase in cell number, cell size, or both.
- **R**eproduction — the processes that make more of the same kind of organism.
- **E**xcretion — removal from organisms of the waste products of metabolism (chemical reactions in cells), of toxic materials, and of substances in excess of requirements.
- **N**utrition — taking in of nutrients, which are organic substances and mineral ions, containing raw materials or energy for growth and tissue repair, absorbing and assimilating them.
- **Homeostasis** — the maintenance of a constant internal environment within restricted limits (for example, control of body temperature and blood glucose concentration).

VN **GIẢI THÍCH TIẾNG VIỆT**

Tám đặc điểm của sự sống, ghi nhớ bằng **MRS GREN**: **M**ovement (vận động), **R**espiration (hô hấp tế bào — giải phóng năng lượng, KHÔNG phải là hít thở không khí), **S**ensitivity (cảm ứng), **G**rowth (sinh trưởng — tăng khối lượng khô lâu dài), **R**eproduction (sinh sản), **E**xcretion (bài tiết chất thải trao đổi chất), **N**utrition (dinh dưỡng), và thêm **Homeostasis** (cân bằng nội môi

— giữ môi trường bên trong cơ thể ổn định, ví dụ giữ thân nhiệt và nồng độ đường huyết ổn định). Học sinh Việt Nam thường nhầm *respiration* (hô hấp tế bào, giải phóng năng lượng từ chất dinh dưỡng) với *breathing* (thở — chỉ là sự trao đổi khí ở phổi/mang); trong đề thi IGCSE hai khái niệm này luôn được phân biệt rõ ràng.

(!) Lỗi thường gặp: Đừng nhầm **Excretion** (bài tiết) với **Egestion** (thải phân). Excretion là loại bỏ chất thải *sinh ra từ các phản ứng chuyển hoá bên trong tế bào* (ví dụ CO2 từ hô hấp, urea từ phân giải protein dư). Egestion là việc tống chất không tiêu hoá được (phân) ra khỏi ống tiêu hoá — chất này *chưa từng* đi vào tế bào và không phải là sản phẩm chuyển hoá, nên KHÔNG được tính là bài tiết.

Nhận diện đặc điểm sự sống

A student observes a potted plant over three weeks: it turns its leaves to face a nearby window, its stem becomes measurably taller and heavier, and small green shoots ("suckers") emerge from the base which can be cut off and grown as new independent plants. Identify the characteristic of life demonstrated by each observation.

Turning leaves toward the window: this is a response to a light stimulus, so it is **Sensitivity** (specifically phototropism, a directional growth response, but at IGCSE level it is classified under sensitivity/response to stimuli).
Increase in height and dry mass: a permanent increase in size and dry mass is **Growth**.
New independent plants growing from suckers: producing new individuals of the same species is **Reproduction** (here, asexual reproduction).

1.1.2 Homeostasis: a closer look

Of the eight characteristics of life, homeostasis is the one most easily confused with sensitivity, so it is worth examining separately. **Homeostasis** is the maintenance of a stable internal environment despite changes in external conditions. Two everyday examples make this concrete: (1) after a meal, blood glucose concentration rises; the body responds (via the hormone insulin) by causing cells to take up and store glucose, returning blood glucose concentration back towards its normal range; (2) when the external air temperature falls, the human body responds with mechanisms such as shivering (muscle contractions release heat) to keep the internal body temperature close to 37°C. In both cases, a change is detected, and a corrective response brings the internal condition back towards a set, stable value — this corrective loop is the essence of homeostasis.

VN **GIẢI THÍCH TIẾNG VIỆT**

Homeostasis (cân bằng nội môi) khác với **Sensitivity (cảm ứng)**: cảm ứng chỉ là việc *phát hiện* kích thích và tạo ra phản ứng (ví dụ rụt tay khi chạm vật nóng), còn cân bằng nội môi là việc *duy trì ổn định* một điều kiện bên trong cơ thể (như nhiệt độ, nồng độ đường huyết) trong một giới hạn hẹp, thông qua một vòng phản hồi liên tục: phát hiện sự thay đổi → tạo phản ứng điều chỉnh → đưa giá trị trở lại mức bình thường. Ví dụ run rẩy khi trời lạnh (co cơ sinh nhiệt) hoặc tiết insulin khi đường huyết tăng sau bữa ăn đều là ví dụ về cân bằng nội môi.

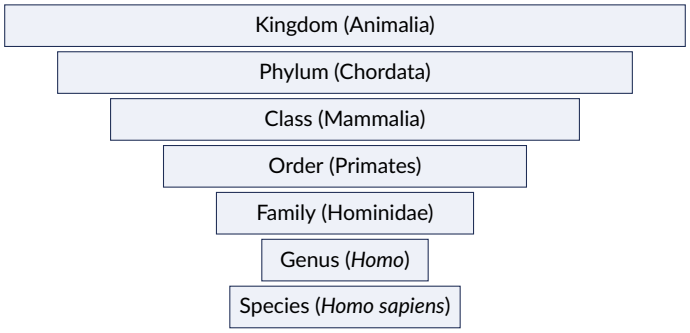
1.1.3 Classification hierarchy

Before naming individual species, biologists first group organisms into a nested hierarchy of taxonomic ranks, from the broadest group down to the most specific.

[Taxonomic hierarchy] Kingdom → Phylum → Class → Order → Family → Genus → Species. Mnemonic: *"**K**ing **P**hilip **C**ame **O**ver **F**or **G**ood **S**oup."* Each rank down the list contains fewer organisms that are more closely related to one another; species is the smallest, most specific group.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bậc phân loại đi từ rộng đến hẹp: **Giới (Kingdom)** → **Ngành (Phylum)** → **Lớp (Class)** → **Bộ (Order)** → **Họ (Family)** → **Chi/Giống (Genus)** → **Loài (Species)**. Càng xuống bậc thấp, số lượng sinh vật trong nhóm càng ít nhưng mức độ quan hệ họ hàng càng gần. Câu thần chú tiếng Anh giúp ghi nhớ thứ tự: "King Philip Came Over For Good Soup" — mỗi chữ cái đầu tương ứng với K-P-C-O-F-G-S.



The taxonomic hierarchy narrows from Kingdom down to Species, illustrated here for modern humans: Kingdom Animalia → Phylum Chordata → Class Mammalia → Order Primates → Family Hominidae → Genus *Homo* → Species *Homo sapiens*.

Ví dụ mẫu · Applying the classification hierarchy

A student is told an organism belongs to Kingdom Animalia, Phylum Chordata, Class Mammalia, Order Carnivora, Family Felidae, Genus *Panthera*, Species *leo*. State the full binomial name of the organism, and explain which two ranks in this list share the most features in common.

Binomial name: combining the genus and species gives ***Panthera leo*** (the lion).
Most similar ranks: **Genus** (*Panthera*) and **Species** (*leo*) are the two most specific, narrowest ranks in the hierarchy, so organisms sharing these two ranks (i.e., belonging to the same species) share the greatest number of features in common and are the most closely related — for example, other species within the same genus *Panthera* include the tiger (*Panthera tigris*) and the leopard (*Panthera pardus*), which resemble the lion less closely than another lion would.

1.1.4 Species and binomial nomenclature

A **species** is defined as a group of organisms that share many features in common and that can interbreed to produce fertile offspring. This is the key biological test of whether two organisms belong to the same species: if their offspring are themselves capable of reproducing, the parents are the same species.

The mule: a classic exception

A horse (*Equus caballus*) and a donkey (*Equus asinus*) can mate to produce a mule. However, a mule is almost always **infertile** (sterile) because horses and donkeys have a different number of chromosomes, so the mule's chromosomes cannot pair up correctly during meiosis. Since

the offspring cannot itself reproduce, this confirms that horses and donkeys are two separate species, even though they can interbreed.

Every species is given a unique two-part scientific name using the **binomial system**, introduced by Carl Linnaeus. The first word is the **genus** name and the second is the **species** name.

[Rules for writing binomial names]

- The genus name is written first and always begins with a **capital letter**.
- The species name is written second and is always **entirely lower-case**, even if it is derived from a person's or place's name.
- Both words together are **italicised** when printed (or underlined when handwritten).
- Example: modern humans are *Homo sapiens*; the domestic dog is *Canis familiaris*; the African lion is *Panthera leo*.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khái niệm **loài** được xác định bằng khả năng **giao phối sinh ra con hữu thụ** (fertile offspring) — nghĩa là bản thân con lai cũng phải có khả năng sinh sản tiếp. Ví dụ con la (mule, lai giữa ngựa và lừa) tuy được sinh ra nhưng **không thể sinh sản** do số lượng nhiễm sắc thể của ngựa và lừa khác nhau, nhiễm sắc thể không thể bắt cặp đúng khi giảm phân — vì vậy ngựa và lừa vẫn được xem là hai loài khác nhau. Về tên khoa học nhị danh: từ đầu (chi/giống — genus) viết hoa chữ cái đầu, từ sau (loài — species) viết thường toàn bộ, và cả cụm từ được **in nghiêng**. Lỗi phổ biến của học sinh: viết hoa cả hai từ, hoặc quên in nghiêng.

Kiểm tra tên khoa học viết đúng quy tắc

Which of the following binomial names is written correctly according to the rules of nomenclature: (a) *felis Catus*, (b) *Felis catus*, (c) Felis Catus, (d) *FELIS CATUS*?

Applying the rules: the genus must start with a capital letter and the species must be entirely lower-case, and the whole name must be italicised. Option (a) fails because the genus is not capitalised. Option (c) fails because the species is capitalised and the text is not italicised. Option (d) fails because both words are capitalised. Only **(b) *Felis catus*** follows every rule correctly.

1.2 The Five Kingdoms

Historically, all living organisms have been grouped into five kingdoms based on features such as cell structure, mode of nutrition, and the presence and composition of a cell wall.

Kingdom	Defining features	Nutrition	Examples
Animalia	Multicellular; no cell wall; no chloroplasts; cells often specialised into tissues/organs; usually able to move actively	Heterotrophic (ingestion of complex organic food)	*Homo sapiens* (human), *Panthera leo* (lion)
Plantae	Multicellular; cell wall made of **cellulose**; chloroplasts containing chlorophyll; large permanent vacuole	Autotrophic (photosynthesis)	*Zea mays* (maize), *Quercus robur* (oak tree)
Fungi	Body often made of thread-like **hyphae** forming a mycelium; cell wall made of **chitin**; no chloroplasts; may be single-celled (yeast) or multicellular (mould, mushroom)	Saprotrophic (extracellular digestion: secrete enzymes onto food, then absorb the digested products)	*Saccharomyces cerevisiae* (yeast), *Agaricus bisporus* (mushroom)
Protoctista	Mostly single-celled (unicellular); eukaryotic; some plant-like (with chloroplasts), some animal-like	Varies: photosynthetic *or* heterotrophic depending on species	*Amoeba proteus*, *Chlamydomonas reinhardtii*
Prokaryotes (bacteria)	Single-celled; **no nucleus** (DNA is a free circular loop in the cytoplasm); cell wall present but **not** made of cellulose; ribosomes smaller than eukaryotic ones	Varies: some photosynthetic, most heterotrophic (saprotrophic or parasitic)	*Escherichia coli*, *Lactobacillus acidophilus*

VN **GIẢI THÍCH TIẾNG VIỆT**

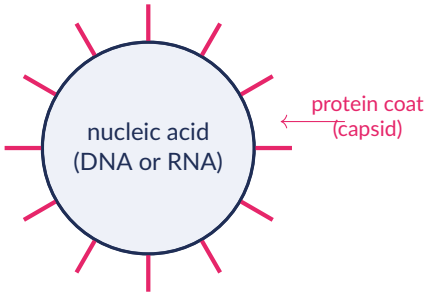
Điểm mấu chốt để phân biệt năm giới: **Động vật** không có thành tế bào, không có lục lạp, dinh dưỡng dị dưỡng (ăn/nuốt thức ăn có sẵn); **Thực vật** có thành tế bào bằng **cellulose**, có lục lạp, tự dưỡng nhờ quang hợp; **Nấm** có thành tế bào bằng **chitin** (KHÔNG phải cellulose), không có lục lạp, dinh dưỡng hoại sinh (tiết enzyme tiêu hoá ra ngoài rồi hấp thụ ngược — khác với động vật là nuốt thức ăn vào trong cơ thể rồi mới tiêu hoá); **Nguyên sinh vật** phần lớn đơn bào, có nhân thật (eukaryote), một số giống thực vật (có lục lạp), một số giống động vật (dị dưỡng); **Sinh vật nhân sơ** (vi khuẩn) đơn bào, không có nhân (không có màng nhân bao quanh vật chất di truyền), thành tế bào không phải cellulose. Học sinh hay nhầm nấm là "thực vật không có lá" — thực chất nấm khác thực vật hoàn toàn về thành phần thành tế bào và cách dinh dưỡng.

1.2.1 Viruses: not part of any kingdom

Why viruses are excluded from the five kingdoms

A **virus** is a microscopic particle consisting only of a strand of nucleic acid (DNA or RNA) surrounded by a **protein coat** (capsid). Viruses have **no cytoplasm, no cell membrane, no ribosomes**, and carry out none of the metabolic reactions of life independently. Because they are not made of cells at all, viruses cannot be classified into any of the five kingdoms (all of which are defined in terms of cell structure). Viruses can only reproduce by **infecting a living host cell** and hijacking that cell's ribosomes and enzymes to manufacture copies of the viral nucleic acid and protein coat; the host cell is often destroyed in the process, releasing new

virus particles.



A generic virus particle: nucleic acid core enclosed within a protein coat (capsid). Example: the influenza virus, which carries RNA inside a protein capsid studded with surface proteins that attach to and infect human respiratory cells; a bacteriophage is a virus with a similar nucleic-acid-plus-capsid structure that instead infects bacteria.

VN **GIẢI THÍCH TIẾNG VIỆT**

Virus **không được xếp** vào bất kỳ giới nào trong năm giới vì virus **không phải là tế bào**: không có tế bào chất, không có màng tế bào, không có ribosome, và không tự thực hiện được các phản ứng chuyển hoá của sự sống. Virus chỉ gồm một đoạn vật chất di truyền (DNA hoặc RNA) được bọc trong lớp **vỏ protein** (capsid). Để nhân lên, virus phải xâm nhập vào một tế bào chủ sống và "chiếm quyền điều khiển" bộ máy ribosome cùng enzyme của tế bào chủ để tổng hợp bản sao vật chất di truyền và vỏ protein của chính nó — quá trình này thường phá huỷ tế bào chủ. Ví dụ: virus cúm (influenza) mang RNA trong vỏ capsid; thể thực khuẩn (bacteriophage) có cấu trúc tương tự nhưng chuyên tấn công vi khuẩn.

1.3 (Supplement) Further Classification of Animals

1.3.1 Arthropod groups

Arthropods (phylum Arthropoda) are animals with a hard external skeleton (exoskeleton), a segmented body, and jointed limbs. The phylum is divided into several major groups distinguished by the number of body parts, legs, and other features.

Group	Body parts	Legs	Antennae / wings	Example
Insects	Head, thorax, abdomen (3 parts)	6 (3 pairs)	1 pair of antennae; wings usually present (0, 2, or 4)	Housefly, honeybee
Arachnids	Cephalothorax, abdomen (2 parts)	8 (4 pairs)	No antennae; no wings	Spider, scorpion
Crustaceans	Head, thorax (often fused as cephalothorax), abdomen	10 or more, varies by species	2 pairs of antennae; no wings	Crab, woodlouse
Myriapods	Head, long segmented trunk	Many pairs, one or two pairs per segment	1 pair of antennae; no wings	Centipede, millipede

VN GIẢI THÍCH TIẾNG VIỆT

Bốn nhóm chân khớp (Supplement) phân biệt chủ yếu qua **số phần cơ thể** và **số chân**: **Côn trùng (Insects)** có 3 phần cơ thể (đầu, ngực, bụng), 6 chân (3 đôi), 1 đôi râu, thường có cánh. **Nhện (Arachnids)** có 2 phần cơ thể, 8 chân (4 đôi), KHÔNG râu, KHÔNG cánh. **Giáp xác (Crustaceans)** thường có 2 đôi râu và số chân nhiều hơn (10 chân trở lên). **Nhiều chân (Myriapods)** có thân dài nhiều đốt, mỗi đốt mang 1–2 đôi chân, 1 đôi râu. Mẹo nhớ nhanh: đếm chân chia 2 ra số đôi — 3 đôi là côn trùng, 4 đôi là nhện.

1.3.2 Vertebrate classes

Vertebrates are animals with a backbone (vertebral column) and, more generally, an internal bony or cartilaginous skeleton. The vertebrates are divided into five classes.

Class	Skin covering	Reproduction	Gas exchange	Thermoregulation	Example
Fish	Scales, covered in mucus	External fertilisation; lay soft eggs in water	Gills	Ectothermic (body temperature varies with surroundings)	*Salmo salar* (salmon)
Amphibians	Moist, permeable skin, no scales	External fertilisation; lay soft eggs in water (or moist places)	Gills (larvae), lungs and skin (adults)	Ectothermic	*Rana temporaria* (frog)
Reptiles	Dry skin covered in scales	Internal fertilisation; lay soft-shelled or leathery eggs on land	Lungs	Ectothermic	*Crocodylus niloticus* (crocodile)
Birds	Feathers	Internal fertilisation; lay hard-shelled eggs, usually incubated	Lungs (with air sacs)	Endothermic (maintains constant body temperature internally)	*Columba livia* (pigeon)
Mammals	Hair/fur, sweat glands	Internal fertilisation; mostly give birth to live young; suckle young with milk from mammary glands	Lungs	Endothermic	*Homo sapiens* (human)

VN GIẢI THÍCH TIẾNG VIỆT

Năm lớp động vật có xương sống (Supplement) phân biệt qua lớp da, cách sinh sản, cơ quan hô hấp, và khả năng điều hoà thân nhiệt. Điểm quan trọng nhất: **Cá** và **Lưỡng cư** thụ tinh ngoài, đẻ trứng mềm trong nước; **Bò sát** và **Chim** thụ tinh trong nhưng bò sát đẻ trứng vỏ mềm/dai còn chim đẻ trứng vỏ cứng; **Thú (Mammals)** hầu hết đẻ con và nuôi con bằng sữa. Về điều hoà thân nhiệt: Cá, Lưỡng cư, Bò sát là **biến nhiệt (ectothermic)** — thân nhiệt thay đổi theo môi trường; Chim và Thú là **đẳng nhiệt (endothermic)** — tự duy trì thân nhiệt ổn định nhờ chuyển hoá nội sinh, đây là lý do chim và thú có thể sống ở vùng cực lạnh.

1.3.3 (Supplement) Dichotomous keys

A **dichotomous key** is a tool used to identify an unknown organism by working through a series of paired statements, each offering two mutually exclusive descriptions of an observable feature. At each stage, the user chooses the statement that matches the organism, which either identifies it or directs them to the next pair of statements.

Ví dụ mẫu · Constructing and using a dichotomous key

Four organisms P, Q, R, S have the following features:

- P: has wings, has 6 legs
- Q: has no wings, has 6 legs
- R: has no wings, has 8 legs
- S: has wings, has 8 legs (unusual example organism for this exercise)

Construct a paired-statement dichotomous key to identify P, Q, R, and S, then use it to identify an organism found to have no wings and 8 legs.

Key:

1a. Organism has 6 legs ..... go to 2

1b. Organism has 8 legs ..... go to 3

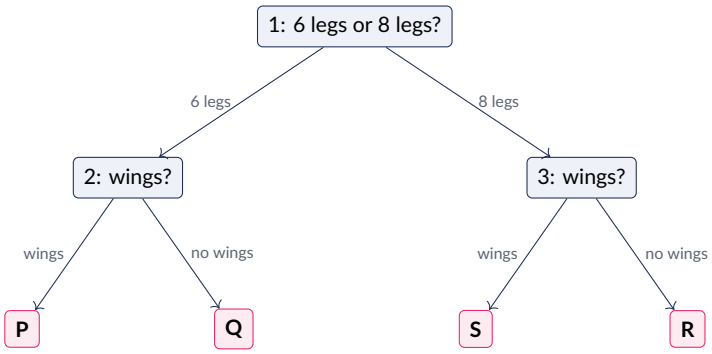
2a. Organism has wings ..... **P**

2b. Organism has no wings ..... **Q**

3a. Organism has wings ..... **S**

3b. Organism has no wings ..... **R**

Using the key: the unknown organism has 8 legs, so at statement 1 we go to statement 3; it has no wings, so statement 3b applies, identifying it as **R**.



Tree diagram representing the dichotomous key above: each branch point is a paired statement, and each leaf is a final identification.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khoá lưỡng phân (Supplement) là công cụ định danh sinh vật bằng một chuỗi các cặp câu hỏi/mệnh đề đối lập nhau về một đặc điểm quan sát được (ví dụ "có cánh" / "không có cánh"). Tại mỗi bước, người dùng chọn mệnh đề đúng với sinh vật đang xét, dẫn tới bước tiếp theo hoặc tới kết quả định danh cuối cùng. Nguyên tắc quan trọng khi **tự xây dựng** khoá: mỗi cặp mệnh đề phải **loại trừ lẫn nhau** (chỉ có thể đúng một trong hai) và phải dựa trên đặc điểm **quan sát được trực tiếp** (hình dạng, số lượng, màu sắc), không dựa vào các đặc điểm mơ hồ như "hành vi phức tạp".

1.4 Practice Bank

Bài tập luyện tập

Which characteristic of life is best defined as "the chemical reactions that break down nutrient molecules in cells to release energy"?

(A) Nutrition
(B) Respiration
(C) Excretion
(D) Growth

Lời giải chi tiết

Answer: (B) Respiration. Respiration is explicitly the release of energy from nutrient molecules through chemical reactions inside cells (mainly the breakdown of glucose). It must not be confused with *breathing* (ventilation of the lungs), which is a physical movement of air, not a chemical process. Nutrition (A) is the intake of nutrients, not their breakdown for energy; excretion (C) is the removal of waste; growth (D) is a permanent increase in size.

Bài tập luyện tập

Write the following in the correct binomial nomenclature format: *panthera tigris* (the tiger), written by a student as "Panthera Tigris" (not italicised).

Lời giải chi tiết

The correct form is ***Panthera tigris***. The genus name *Panthera* must start with a capital letter but the species name *tigris* must be entirely lower-case (the student incorrectly capitalised it), and the whole binomial name must be italicised (or underlined if handwritten), which the student's version was not.

Bài tập luyện tập

A newly discovered single-celled organism is found to have no nucleus, a cell wall that is not made of cellulose, and ribosomes smaller than those typically found in animal or plant cells. To which kingdom does it most likely belong?

(A) Protoctista
(B) Fungi
(C) Prokaryotes
(D) Plantae

Lời giải chi tiết

Answer: (C) Prokaryotes. The absence of a nucleus is the defining feature of a prokaryotic cell, and this rules out Protoctista, Fungi, and Plantae, all of which are eukaryotic kingdoms (their cells possess a true, membrane-bound nucleus). The non-cellulose cell wall and smaller ribosomes are additional confirming features consistent with bacteria.

Bài tập luyện tập

Explain, using the mule as an example, why two organisms that can mate and produce offspring are not necessarily classified as the same species.

Lời giải chi tiết

The biological definition of a species requires that organisms can interbreed to produce **fertile** offspring — offspring that can themselves reproduce. A horse and a donkey can mate and produce a mule, but the mule is (almost always) infertile because the horse and donkey have different numbers of chromosomes, so the chromosomes cannot pair correctly during meiosis in the mule. Since the mule cannot pass on genes to a further generation, horses and donkeys fail the interbreeding test and are classified as two separate species, *Equus caballus* and *Equus asinus*.

Bài tập luyện tập

An organism has a segmented body divided into a cephalothorax and an abdomen, eight jointed legs, no antennae, and no wings. To which arthropod group does it belong? (Supplement)

(A) Insecta
(B) Arachnida
(C) Crustacea
(D) Myriapoda

Lời giải chi tiết

Answer: (B) Arachnida. Two body parts (cephalothorax and abdomen), eight legs, and the absence of both antennae and wings are the defining combination for arachnids (e.g. spiders, scorpions). Insects have three body parts and six legs with antennae; crustaceans have two pairs of antennae; myriapods have many segments each bearing legs, not a two-part body.

Bài tập luyện tập

A student claims: "Fungi are just plants that lack chlorophyll." Explain two reasons why this statement is biologically inaccurate.

Lời giải chi tiết

First, the cell wall composition differs: plant cell walls are made of **cellulose**, whereas fungal cell walls are made of **chitin** — a completely different structural material, not merely "a plant wall without chlorophyll." Second, the mode of nutrition differs fundamentally: plants are autotrophic, manufacturing their own organic food by photosynthesis, whereas fungi are **saprotrophic**, secreting digestive enzymes onto their food and then absorbing the digested (soluble) products — this is a heterotrophic mode of nutrition entirely unlike a plant lacking chlorophyll, which would simply be unable to feed at all.

Bài tập luyện tập

Which statement correctly explains why viruses are not placed into any of the five kingdoms?

(A) Viruses are too small to be observed under a light microscope
(B) Viruses are not made of cells and cannot carry out life processes independently
(C) Viruses do not contain any genetic material
(D) Viruses can only infect bacteria, not plants or animals

Lời giải chi tiết

Answer: (B). All five kingdoms are defined in terms of cell structure, and viruses are acellular (not made of cells) — they lack cytoplasm, a cell membrane, and ribosomes, and cannot independently carry out metabolism, so they cannot be fitted into any kingdom classification scheme. Option (A) is false (size is not the reason for exclusion, and some large viruses are visible with electron microscopes). Option (C) is false — viruses do contain nucleic acid (DNA or RNA). Option (D) is false — viruses infect a very wide range of hosts including bacteria (bacteriophages), plants, and animals.

Bài tập luyện tập

Bird eggs have hard shells while amphibian eggs have soft, jelly-like coverings and must be laid in or near water. Explain the biological reason for this difference. (Supplement)

Lời giải chi tiết

Amphibians undergo external fertilisation and their soft eggs would dry out (desiccate) if laid away from water, and the embryo also requires a moist environment for gas exchange; this restricts amphibians to breeding in or near water. Birds, in contrast, have evolved internal fertilisation and a hard, calcified shell that prevents water loss while still allowing gas exchange through microscopic pores, enabling birds to lay their eggs on dry land, away from water, without the embryo drying out.

Bài tập luyện tập

Place the following into the correct order of the taxonomic hierarchy, from broadest to most specific: Family, Species, Kingdom, Order, Genus, Phylum, Class.

Lời giải chi tiết

The correct order, broadest to most specific, is: **Kingdom** → **Phylum** → **Class** → **Order** → **Family** → **Genus** → **Species**, following the standard hierarchy (mnemonic: "King Philip Came Over For Good Soup"). Each successive rank groups together fewer, more closely related organisms, until species is reached, the smallest and most specific group.

Bài tập luyện tập

An unknown vertebrate has dry, scaly skin, breathes with lungs, lays leathery-shelled eggs on land, and cannot regulate its own body temperature internally. Which vertebrate class is this? (Supplement)

(A) Amphibian
(B) Reptile
(C) Bird
(D) Mammal

Lời giải chi tiết

Answer: (B) Reptile. Dry scaly skin (not moist, ruling out amphibians), lungs (ruling out fish and larval amphibians), leathery-shelled eggs laid on land (distinguishing from amphibians, which lay soft eggs in water, and from birds, which lay hard-shelled eggs), and being ectothermic (unable to regulate body temperature internally, ruling out birds and mammals, which are endothermic) together identify this animal as a reptile.

Bài tập luyện tập

A scientist observes a single-celled organism under the microscope. It has chloroplasts, moves using a flagellum, and has no cell wall made of chitin. It is eukaryotic but is neither clearly "plant-like" nor "animal-like" in every feature. Which kingdom is the best classification, and why?

Lời giải chi tiết

Protoctista. This kingdom contains eukaryotic organisms, mostly single-celled, that do not fit cleanly into the Plantae, Animalia, or Fungi kingdoms — some protoctists (like *Chlamydomonas*) are plant-like (containing chloroplasts and photosynthesising) while others are animal-like (heterotrophic, motile, e.g. *Amoeba*). A single-celled organism with chloroplasts and a flagellum, not clearly fitting the strict multicellular criteria of Plantae, is classified as a protoctist.

Bài tập luyện tập

Explain why binomial nomenclature (using a two-part Latin name) is more useful internationally than using local common names for organisms.

Lời giải chi tiết

Common names vary between languages and even between regions speaking the same language (for example, a single species of plant may have several different common names in different parts of a country), which can cause confusion or misidentification. Binomial nomenclature assigns each species one single, universally recognised, standardised Latin name (genus + species) used by scientists worldwide, regardless of their native language, eliminating ambiguity and allowing precise international communication about a single species.

Bài tập luyện tập

A crustacean and a myriapod are both found on a damp forest floor. State **two** observable features that would allow a student to distinguish between them without a microscope. (Supplement)

Lời giải chi tiết

(1) **Number of antennae:** crustaceans typically have two pairs of antennae, while myriapods have only one pair. (2) **Body shape and leg arrangement:** crustaceans (e.g. woodlice) have a short, compact body with a head/thorax region and a limited number of leg pairs, whereas myriapods (e.g. centipedes, millipedes) have a long, narrow, many-segmented trunk with a leg pair (or two) attached to almost every segment, giving a much higher total leg count.

Bài tập luyện tập

Fill in the missing kingdom in this description: "Multicellular organism; cell wall made of chitin; no chloroplasts; obtains food by secreting enzymes onto organic matter and absorbing the digested products."

(A) Plantae
(B) Fungi
(C) Animalia
(D) Protoctista

Lời giải chi tiết

Answer: (B) Fungi. A chitin cell wall combined with saprotrophic nutrition (secreting enzymes externally then absorbing the products) is unique to the Fungi kingdom. Plantae has a cellulose wall and photosynthesises; Animalia has no cell wall and ingests food; Protoctista is mostly unicellular.

Bài tập luyện tập

A student says: "A virus reproduces by dividing in two, just like a bacterium." Explain what is wrong with this statement.

Lời giải chi tiết

This statement is incorrect. Bacteria are living cells that can independently carry out metabolism and divide by binary fission using their own cellular machinery. Viruses, however, are not cells and have no metabolic machinery of their own (no ribosomes, no enzymes for making proteins); a virus can only replicate by **infecting a living host cell** and hijacking that cell's ribosomes and enzymes to build new copies of the viral nucleic acid and protein coat. Without a host cell, a virus cannot reproduce at all.

Bài tập luyện tập

Using the dichotomous key constructed earlier in this chapter (organisms P, Q, R, S), identify an organism that has 6 legs and no wings. (Supplement)

Lời giải chi tiết

Following the key: statement 1 asks about the number of legs — the organism has 6 legs, so we go to statement 2. Statement 2 asks about wings — the organism has no wings, so statement 2b applies, identifying the organism as **Q**.

Bài tập luyện tập

A bird and a mammal are both endothermic. Explain what "endothermic" means and give one advantage this provides compared with an ectothermic reptile living in a temperate climate. (Supplement)

Lời giải chi tiết

Endothermic means the organism generates heat internally (through its own metabolism) and can maintain a constant body temperature regardless of the surrounding environmental temperature. The advantage compared with an ectothermic reptile is that a bird or mammal can remain active (able to move quickly, hunt, or forage) at low environmental temperatures, such as at night or in winter, when an ectothermic reptile's body temperature (and therefore its muscle and enzyme activity) would fall too low for it to move efficiently, forcing it to become sluggish or enter a dormant state.

Bài tập luyện tập

Explain why a mushroom is not classified as a plant, even though both mushrooms and plants are often found growing from soil and do not move from place to place.

Lời giải chi tiết

Classification is based on cell structure and mode of nutrition, not on outward appearance or habitat. A mushroom (Fungi) has a cell wall made of **chitin** and has no chloroplasts, so it cannot photosynthesise; it feeds **saprotrophically**, secreting digestive enzymes onto organic matter in the soil and absorbing the digested nutrients. A plant has a cell wall made of **cellulose**, contains chloroplasts, and is autotrophic, manufacturing its own food by photosynthesis. Despite both growing in soil and lacking locomotion, these fundamental cellular and nutritional differences place them in separate kingdoms.

Bài tập luyện tập

State the genus and species name separately for the scientific name *Escherichia coli*, and explain what type of organism this binomial name refers to.

Lời giải chi tiết

The genus is ***Escherichia*** and the species is ***coli***. *Escherichia coli* is a species of rod-shaped bacterium (a prokaryote) commonly found in the intestines of humans and other animals; most strains are harmless and some are even beneficial, though certain strains can cause food poisoning.

Bài tập luyện tập

Which feature would allow you to correctly distinguish a fish from an amphibian, given only an adult specimen of each?

(A) Both live in water, so no feature distinguishes them

(B) Fish have scales and gills throughout life; amphibian adults typically have moist skin and gas exchange partly through lungs and skin

(C) Amphibians lay hard-shelled eggs while fish lay soft eggs

(D) Fish are endothermic while amphibians are ectothermic

Lời giải chi tiết

Answer: (B). Adult fish retain scales and gills as their permanent gas-exchange organ, while adult amphibians (having undergone metamorphosis from an aquatic larval stage) typically breathe using lungs and their moist permeable skin, and have no scales. Option (C) is incorrect (fish and amphibians both lay soft eggs in water); option (D) is incorrect (both fish and amphibians are ectothermic, not endothermic).

Bài tập luyện tập

A researcher wants to identify an unknown insect species collected in the field. Suggest, giving a reason, whether a dichotomous key or a five-kingdom classification chart would be more useful for this task. (Supplement)

Lời giải chi tiết

A **dichotomous key** would be more useful. The five-kingdom classification chart only allows the researcher to confirm that the specimen is an animal (Animalia) — it operates at a very broad level and cannot distinguish between different species of insect. A dichotomous key, by

contrast, uses a series of specific, paired observable features (such as wing venation pattern, number of body segments, or antenna shape) to narrow down step by step to the precise species (or at least genus), which is exactly the level of detail needed to identify an unknown insect.

Bài tập luyện tập

Explain briefly why the statement ”all bacteria are harmful and cause disease” is scientifically inaccurate, referring to the mode of nutrition and ecological roles of Kingdom Prokaryotes.

Lời giải chi tiết

While some prokaryotes are indeed pathogenic (disease-causing) parasites, the vast majority of bacteria are not harmful. Many bacteria are saprotrophic decomposers that break down dead organic matter and recycle nutrients in ecosystems; others live in beneficial partnerships with other organisms (for example, bacteria in the human gut assist digestion, and nitrogen-fixing bacteria in the root nodules of legume plants convert atmospheric nitrogen into a usable form for the plant). Some prokaryotes are even photosynthetic (e.g. cyanobacteria). The kingdom Prokaryotes therefore includes a very wide range of nutritional modes and ecological roles, not just disease-causing organisms.

Bài tập luyện tập

A student measures an unfamiliar leaf-shaped organism and finds it has no nucleus visible under a light microscope but does contain chlorophyll and photosynthesises. Suggest which kingdom this organism most likely belongs to and justify your answer.

Lời giải chi tiết

This organism most likely belongs to **Prokaryotes**, specifically a photosynthetic bacterium such as a cyanobacterium (blue-green alga). The absence of a nucleus is the single defining feature of a prokaryotic cell and immediately rules out Plantae and Protoctista (both eukaryotic groups), even though cyanobacteria do contain chlorophyll and can photosynthesise, superficially resembling a plant-like organism.

Bài tập luyện tập

Two centipede-like organisms are compared: Organism X has one pair of legs per body segment, Organism Y has two pairs of legs per body segment. Using this information alone, can you determine whether X and Y are the same species? Explain. (Supplement)

Lời giải chi tiết

No, this information alone is insufficient. Leg arrangement is only one physical feature and can help distinguish or group organisms taxonomically (for instance, this specific difference actually corresponds to two different myriapod groups: centipedes typically have one pair of legs per segment while millipedes have two pairs per segment), but the definitive test of ”same species” is whether the two organisms can **interbreed to produce fertile offspring**. Structural similarity or difference is used to classify organisms into groups but does not, by itself, confirm or rule out that two organisms belong to the same species.

Bài tập luyện tập

A textbook diagram shows an organism with a two-part body, four pairs of legs, and no antennae, living in a spider's habitat. A second organism, described nearby, has 2 pairs of antennae and 5 pairs of legs and lives in the sea. Classify each organism into its correct arthropod group. (Supplement)

Lời giải chi tiết

The first organism (two body parts, four pairs of legs = 8 legs, no antennae) matches the defining features of **Arachnida** (e.g. a spider). The second organism (2 pairs of antennae, 5 pairs of legs = 10 legs, marine habitat) matches the defining features of **Crustacea** (e.g. a crab).

Bài tập luyện tập

Explain why classifying organisms into a hierarchy (rather than one single large list of all species) is useful to biologists.

Lời giải chi tiết

A hierarchical classification groups organisms according to shared features and evolutionary relatedness at multiple levels, which allows biologists to make useful generalisations and predictions. For example, knowing that an unfamiliar organism belongs to a particular genus lets a biologist reasonably predict many of its features (diet, structure, reproduction) based on known close relatives in the same genus, without needing to study every single species individually. It also makes locating information about a species, and communicating about relationships between species, far more efficient than an unordered list of all known organisms.

Bài tập luyện tập

State whether the following organism is more likely to be ectothermic or endothermic, and justify your answer: "An animal found basking motionless in direct sunlight on a rock during a cool morning, becoming active only once the rock has warmed considerably." (Supplement)

Lời giải chi tiết

This animal is most likely **ectothermic** (e.g. a reptile such as a lizard). Ectothermic animals cannot generate sufficient heat internally to regulate their own body temperature, so they rely on external heat sources such as direct sunlight to raise their body temperature to a level at which their muscles and enzymes can function efficiently; basking motionless in the sun before becoming active is a classic thermoregulatory behaviour of ectotherms, in contrast to endothermic animals (birds, mammals), which can be active regardless of ambient temperature because they generate their own metabolic heat.

Bài tập luyện tập

Give the correct sequence of events describing how an influenza (flu) virus reproduces inside a human respiratory cell.

Lời giải chi tiết

(1) The virus attaches to the surface of a host respiratory cell using proteins on its outer coat. (2) The virus's genetic material (RNA, in the case of influenza) enters the host cell. (3) The viral genetic material takes over the host cell's ribosomes and enzymes, redirecting them to manufacture new copies of viral nucleic acid and new protein coat components, instead of the cell's own proteins. (4) These components self-assemble into new virus particles inside the host cell. (5) The new virus particles are released from the host cell (often destroying or damaging it in the process) and go on to infect further host cells, repeating the cycle.

CAMBRIDGE IGCSE • Unit 2

Cells and Organisation

Mục tiêu Unit: Phát biểu được học thuyết tế bào; mô tả cấu trúc và chức năng của các bào quan trong tế bào động vật và thực vật; phân biệt tế bào nhân sơ và nhân thực; trình bày các cấp độ tổ chức sống từ tế bào đến cơ thể; giải thích sự chuyên hoá tế bào qua các ví dụ cụ thể; thực hiện thành thạo các phép tính độ phóng đại và kích thước thực; (Supplement) trình bày khái niệm tế bào gốc.

2.1 Cell Theory

Cell theory

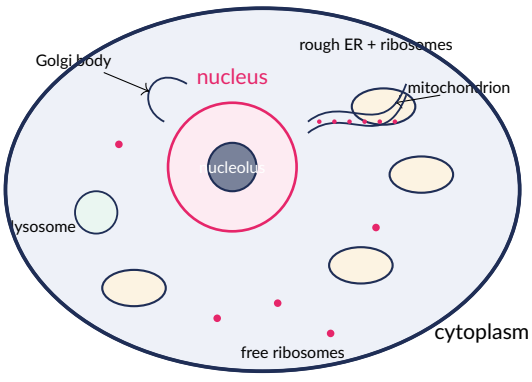
- All living organisms are composed of one or more **cells**.
- The cell is the smallest unit of life — the basic structural and functional unit of all organisms.
- All cells arise from pre-existing cells, by cell division.

VN **GIẢI THÍCH TIẾNG VIỆT**

Học thuyết tế bào khẳng định ba điều: (1) mọi sinh vật sống đều được cấu tạo từ một hoặc nhiều tế bào; (2) tế bào là đơn vị cấu trúc và chức năng nhỏ nhất của sự sống — mọi hoạt động sống (trao đổi chất, sinh sản, cảm ứng...) đều diễn ra ở cấp độ tế bào; (3) mọi tế bào mới đều được sinh ra từ tế bào đã có trước đó thông qua quá trình phân chia tế bào, không có tế bào nào tự nhiên sinh ra từ vật chất không sống.

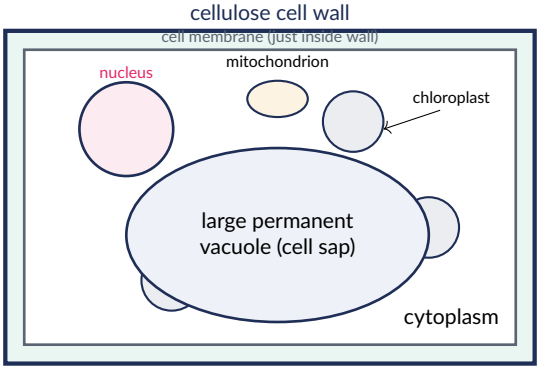
2.2 Animal and Plant Cell Structure

2.2.1 The generalised animal cell



A generalised animal cell in section, showing the nucleus (with nucleolus), cytoplasm, cell membrane, mitochondria, rough endoplasmic reticulum studded with ribosomes, free ribosomes, the Golgi body, and a lysosome.

2.2.2 The generalised plant cell



A generalised plant cell, showing the cellulose cell wall (outer, rigid), cell membrane, nucleus, chloroplasts, mitochondria, cytoplasm, and a large permanent vacuole filled with cell sap.

Organelle	Structure	Function
Nucleus	Largest organelle; bound by a nuclear membrane (envelope); contains chromosomes (DNA) and usually a nucleolus	Controls the cell's activities by controlling which proteins are made; contains the genetic information (DNA), passed on during cell division
Cytoplasm	Jelly-like substance filling the cell, containing dissolved substances and organelles	Site of many metabolic reactions (e.g. glycolysis, part of respiration)
Cell membrane	Thin membrane surrounding the cytoplasm, made mainly of lipids and proteins	Partially permeable — controls the movement of substances into and out of the cell
Mitochondria	Rod- or bean-shaped organelle with a folded inner membrane	Site of (aerobic) respiration — releases energy from glucose
Ribosomes	Very small granules, either free in cytoplasm or attached to rough ER	Site of protein synthesis
Rough endoplasmic reticulum (RER)	Network of membranes studded with ribosomes	Transports proteins made by the attached ribosomes through the cell
Smooth endoplasmic reticulum (SER)	Network of membranes with no ribosomes attached	Synthesises and transports lipids
Golgi body	Stack of curved, flattened membrane sacs	Modifies, packages, and sorts proteins and lipids for secretion or use elsewhere in the cell
Cell wall (plant only)	Rigid layer surrounding the cell membrane, made of **cellulose**	Provides structural support and shape; prevents the cell from bursting when it takes up water
Chloroplast (plant only)	Contains chlorophyll (green pigment) and internal membranes	Site of photosynthesis — traps light energy to make glucose
Permanent vacuole (plant only)	Large, fluid-filled sac bound by a membrane, filled with **cell sap**	Stores cell sap (water, sugars, salts); maintains cell turgor (pressure against the cell wall), keeping the cell rigid

GIẢI THÍCH TIẾNG VIỆT VN

Mỗi bào quan có một vai trò riêng biệt: **Nhân** lưu trữ và điều khiển thông tin di truyền (DNA); **Ti thể** là nơi hô hấp tế bào giải phóng năng lượng; **Ribosome** tổng hợp protein; **Lưới nội chất hạt (RER)** có đính ribosome, vận chuyển protein vừa tổng hợp; **Lưới nội chất trơn (SER)** không

có ribosome, tổng hợp lipid; **Bộ máy Golgi** đóng gói và biến đổi protein/lipid trước khi đưa ra khỏi tế bào. Ở thực vật có thêm ba bào quan đặc trưng KHÔNG có ở tế bào động vật: **thành tế bào** (cellulose, tạo hình dạng cố định), **lục lạp** (quang hợp), và **không bào lớn** (chứa dịch tế bào, tạo áp suất trương giúp tế bào cứng cáp).

2.2.3 Ribosomes, endoplasmic reticulum, and the Golgi body: the secretory pathway

Many proteins made inside a cell are destined to be secreted (released) from the cell, or sent to a specific organelle. These proteins follow a coordinated pathway: ribosomes on the rough ER synthesise the protein and feed it directly into the internal space of the ER; the RER then pinches off small membrane-bound vesicles containing the protein, which travel to the Golgi body; the Golgi body modifies the protein (for example, by adding sugar groups) and repackages it into a new vesicle addressed for its final destination — either the cell membrane (for secretion out of the cell) or another organelle.

VN **GIẢI THÍCH TIẾNG VIỆT**

Con đường bài tiết protein trong tế bào diễn ra theo trình tự: ribosome trên lưới nội chất hạt tổng hợp protein → protein được đưa vào bên trong lưới nội chất hạt → túi màng (vesicle) chứa protein tách ra và di chuyển đến bộ máy Golgi → Golgi chỉnh sửa, đóng gói protein vào túi mới → túi này di chuyển đến đích cuối cùng (màng tế bào để tiết ra ngoài, hoặc một bào quan khác). Đây là một dây chuyền "sản xuất — đóng gói — vận chuyển" rất giống một nhà máy.

2.2.4 Differences between plant and animal cells

[Three key differences]

- **Cell wall:** present (cellulose) in plant cells, absent in animal cells → gives plant cells a fixed shape and structural support, and allows them to withstand internal water pressure without bursting.
- **Permanent vacuole:** large and prominent in mature plant cells, small or absent in animal cells → stores cell sap and, combined with the cell wall, keeps plant cells turgid (firm), supporting non-woody plant structures.
- **Chloroplasts:** present in green plant cells (e.g. leaf mesophyll), absent in animal cells → only plant cells can photosynthesise and manufacture their own organic food.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ba khác biệt cốt lõi giữa tế bào thực vật và động vật: **thành tế bào** (chỉ thực vật có, giúp giữ hình dạng cố định và chống vỡ khi hút nước); **không bào lớn** (chỉ thực vật có không bào lớn thường trực, giúp tạo áp suất trương làm cây đứng vững); **lục lạp** (chỉ có ở tế bào thực vật có màu xanh, cho phép quang hợp). Học sinh cần nhớ: không phải mọi tế bào thực vật đều có lục lạp (ví dụ tế bào rễ không có lục lạp vì không tiếp xúc ánh sáng), nhưng tất cả tế bào thực vật đều có thành tế bào và (thường) có không bào.

2.2.5 Prokaryotic vs eukaryotic cells

[Prokaryotic vs eukaryotic]

- **Nucleus:** eukaryotic cells (animal, plant, fungal, protoctist) have a true nucleus bound by a nuclear membrane; prokaryotic cells (bacteria) have no nucleus — their DNA lies free in the cytoplasm.
- **DNA form:** eukaryotic DNA is linear and organised into chromosomes within the nucleus; prokaryotic DNA is a single circular loop, plus often one or more small circular **plasmids** (extra, separate loops of DNA).
- **Ribosomes:** eukaryotic ribosomes are larger (80S); prokaryotic ribosomes are smaller (70S).
- **Membrane-bound organelles:** eukaryotic cells contain membrane-bound organelles (mitochondria, ER, Golgi body, etc.); prokaryotic cells have no membrane-bound organelles.
- **Size:** prokaryotic cells are typically much smaller (roughly 0.5–5 μm) than eukaryotic cells (roughly 10–100 μm).

VN **GIẢI THÍCH TIẾNG VIỆT**

Khác biệt quan trọng nhất giữa tế bào nhân sơ và nhân thực là **sự hiện diện của nhân thật**: tế bào nhân thực có màng nhân bao quanh DNA; tế bào nhân sơ (vi khuẩn) hoàn toàn không có màng nhân, DNA là một vòng tròn tự do nằm trong tế bào chất, thường kèm thêm các **plasmid** nhỏ (đoạn DNA vòng phụ, có thể trao đổi giữa các vi khuẩn — cơ chế lan truyền gene kháng kháng sinh). Ribosome của vi khuẩn cũng nhỏ hơn (70S so với 80S), và vi khuẩn hoàn toàn không có bào quan có màng bao bọc như ti thể hay lưới nội chất.

2.3 Levels of Organisation

From cell to organism

Cell → Tissue → Organ → Organ system → Organism.

- A **tissue** is a group of cells with similar structure, working together to perform a shared function (e.g. **muscle tissue**, made of many muscle cells that contract together; **xylem tissue** in a plant, made of hollow, dead cells joined end to end for water transport).
- An **organ** is a structure made of several different tissues, working together to perform a specific function (e.g. the **stomach** is an organ made of muscular tissue, glandular tissue that secretes enzymes, and epithelial tissue lining the inner surface).
- An **organ system** is a group of organs with related functions, working together to perform an overall life process (e.g. the **digestive system**, comprising the stomach, small intestine, large intestine, liver, and pancreas, working together to break down and absorb food).

Ví dụ mẫu · Tracing the stomach through the levels of organisation

Explain how the stomach illustrates the levels of organisation from tissue to organ system.

The stomach is built from several types of **tissue**: muscular tissue (in layers, contracting to churn food), glandular (epithelial) tissue (secreting gastric juice containing acid and enzymes such as pepsin), and connective tissue. These different tissues are combined into the **organ** we call the stomach, each contributing a different job to the single, unified function of the organ (mechanical and chemical digestion of food). The stomach does not work alone — it is one

organ within the **digestive system** (organ system), alongside the oesophagus, small intestine, large intestine, liver, and pancreas, all cooperating to digest food and absorb nutrients for the whole **organism**.

VN **GIẢI THÍCH TIẾNG VIỆT**

Các cấp độ tổ chức của sự sống đi từ nhỏ đến lớn: **Tế bào** → **Mô** (nhiều tế bào giống nhau cùng thực hiện một chức năng, ví dụ mô cơ, mô xylem) → **Cơ quan** (nhiều loại mô khác nhau phối hợp, ví dụ dạ dày gồm mô cơ + mô tuyến + mô liên kết) → **Hệ cơ quan** (nhiều cơ quan có chức năng liên quan phối hợp, ví dụ hệ tiêu hoá gồm dạ dày, ruột, gan, tuỵ) → **Cơ thể**. Lỗi thường gặp: nhầm lẫn mô và cơ quan — mô chỉ gồm MỘT loại tế bào (dù có thể có khoảng gian bào), còn cơ quan luôn gồm NHIỀU loại mô khác nhau.

2.4 Cell Specialisation and Differentiation

Not all cells in a multicellular organism look alike or do the same job. During development, cells become **specialised** (or **differentiated**) — they develop a distinctive structure that suits them to carry out a particular function efficiently.

Specialised cell	Key structural features	Link to function
Red blood cell (erythrocyte)	Biconcave disc shape; no nucleus; packed with haemoglobin	Biconcave shape increases surface area for gas exchange; no nucleus leaves more room for haemoglobin, which binds oxygen for transport around the body
Root hair cell	Long, thin extension (root hair) projecting from the cell surface; many mitochondria	Root hair greatly increases surface area for water and mineral ion uptake from soil; mitochondria supply energy for active transport of ions
Palisade mesophyll cell	Tall, column-shaped; packed with many chloroplasts, positioned near the upper leaf surface	Chloroplasts trap light energy for photosynthesis; column shape and position maximise light capture near the leaf's upper (illuminated) surface
Sperm cell	Small, streamlined head containing the nucleus; long tail (flagellum); many mitochondria in the mid-piece	Streamlined shape and flagellum enable swimming to reach the egg cell; mitochondria provide energy for the tail's movement
Neurone (nerve cell)	Long, thin fibre (axon), often with an insulating myelin sheath; many branching dendrites	Long axon allows electrical impulses to be carried rapidly over long distances; dendrites receive signals from many other neurones
Ciliated epithelial cell	Column-shaped cell with hair-like cilia projecting from its surface	Cilia beat in a coordinated, rhythmic motion to sweep mucus (and trapped particles/-pathogens) along a surface, e.g. lining the trachea
Egg cell (ovum)	Large cell with a store of cytoplasm and nutrients; surrounded by a protective membrane	Large food/nutrient reserve supports the early development of the embryo after fertilisation

VN **GIẢI THÍCH TIẾNG VIỆT**

Sự chuyên hoá tế bào (cell specialisation/differentiation) nghĩa là mỗi loại tế bào phát triển cấu trúc riêng biệt để phù hợp tối ưu với chức năng của nó. Ví dụ: **hồng cầu** không có nhân để chứa được nhiều hemoglobin hơn, hình đĩa lõm hai mặt tăng diện tích bề mặt trao đổi khí; **tế bào lông hút rễ** có phần kéo dài tăng diện tích hấp thụ nước; **tế bào mô giậu (palisade)** chứa nhiều lục lạp, xếp gần bề mặt trên của lá để hấp thụ tối đa ánh sáng; **tinh trùng** có đuôi để bơi và nhiều ti thể để cung cấp năng lượng; **neuron** có sợi trục dài để truyền tín hiệu điện nhanh trên quãng đường xa; **tế bào biểu mô có lông** quét chất nhầy dọc theo bề mặt (ví dụ khí quản). Nguyên tắc chung: LUÔN liên hệ đặc điểm cấu trúc với chức năng cụ thể khi trả lời câu hỏi dạng này.

2.4.1 (Supplement) Stem cells

A **stem cell** is an undifferentiated cell that can both divide repeatedly (by mitosis) and differentiate into one or more types of specialised cell. **Embryonic stem cells**, found in early embryos, are able to differentiate into almost any cell type in the body. **Adult stem cells**, found in specific tissues of an adult body (e.g. bone marrow), are more limited — typically able to differentiate only into a restricted range of related cell types (e.g. bone marrow stem cells differentiate into the various types of blood cell). Stem cells have therapeutic potential in medicine — for example, bone marrow stem cell transplants are already used to treat some blood disorders, and research continues into using stem cells to repair damaged tissues or organs. This potential is accompanied by ethical considerations, particularly regarding the use of embryonic stem cells, since obtaining them typically involves the destruction of an early embryo.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tế bào gốc (Supplement) là tế bào chưa biệt hoá, có khả năng vừa **phân chia liên tục** vừa **biệt hoá** thành một hoặc nhiều loại tế bào chuyên hoá. **Tế bào gốc phôi (embryonic)** lấy từ phôi giai đoạn sớm có khả năng biệt hoá thành hầu hết mọi loại tế bào trong cơ thể (toàn năng/đa năng cao); **tế bào gốc trưởng thành (adult)**, ví dụ trong tuỷ xương, chỉ biệt hoá được thành một số loại tế bào giới hạn có liên quan (như các loại tế bào máu). Tiềm năng y học rất lớn (ghép tuỷ xương đã được áp dụng thực tế, nghiên cứu sửa chữa mô/cơ quan hỏng), nhưng việc sử dụng tế bào gốc phôi đi kèm các vấn đề đạo đức vì thường phải phá huỷ phôi sớm để lấy tế bào.

2.5 Magnification and Size Calculations

[The magnification formula]

$$\text{Magnification} = \frac{\text{size of image}}{\text{size of actual (real) object}}$$

Rearranged forms: $\text{actual size} = \dfrac{\text{image size}}{\text{magnification}}$, and $\text{image size} = \text{actual size} \times \text{magnification}$. Always convert to consistent units before calculating (commonly: 1 mm $= 1000$ μm; 1 μm $= 1000$ nm).

VN **GIẢI THÍCH TIẾNG VIỆT**

Công thức độ phóng đại: $\text{Độ phóng đại} = \dfrac{\text{kích thước ảnh}}{\text{kích thước thật}}$. Từ đó suy ra hai công thức biến đổi: kích thước thật = kích thước ảnh ÷ độ phóng đại; kích thước ảnh = kích thước thật × độ phóng đại. Lưu ý bắt buộc: phải đổi tất cả về CÙNG một đơn vị trước khi tính (1 mm = 1000 μm = 1 000 000 nm) — đây là lỗi học sinh mắc phải nhiều nhất trong dạng bài này.

Ví dụ mẫu · Calculating magnification

A drawing of a cell measures 40 mm across. The actual cell measures 0.8 mm across. Calculate the magnification of the drawing.

$$\text{Magnification} = \frac{\text{image size}}{\text{actual size}} = \frac{40 \text{ mm}}{0.8 \text{ mm}} = 50$$

The drawing is magnified $\times 50$ (written as $\times 50$ or "50 times").

Ví dụ mẫu · Finding actual size from magnification

A photomicrograph shows a mitochondrion with an image length of 6.0 cm. The magnification of the photomicrograph is $\times 15\,000$. Calculate the actual length of the mitochondrion, giving your answer in micrometres.

Convert image size to consistent unit: 6.0 cm $= 60$ mm $= 60\,000$ μm.
Apply the formula:

$$\text{Actual size} = \frac{\text{image size}}{\text{magnification}} = \frac{60\,000 \ \mu\text{m}}{15\,000} = 4.0 \ \mu\text{m}$$

The actual length of the mitochondrion is 4.0 μm, a realistic value for a mitochondrion (typically 1–10 μm).

Ví dụ mẫu · Finding image size from actual size and magnification

A plant cell has an actual width of 25 μm. If it is drawn at a magnification of $\times 800$, calculate the width of the drawing in millimetres.

$$\text{Image size} = \text{actual size} \times \text{magnification} = 25 \ \mu\text{m} \times 800 = 20\,000 \ \mu\text{m}$$

Converting to millimetres: $20\,000$ μm $\div 1000 = 20$ mm. The drawing should be 20 mm wide.

(!) Lỗi thường gặp: Lỗi phổ biến nhất trong bài toán độ phóng đại là **quên đổi đơn vị** trước khi tính, hoặc đổi sai chiều (nhân thay vì chia, hoặc ngược lại). Luôn kiểm tra: (1) hai kích thước dùng để tính *Độ phóng đại* phải **cùng đơn vị**; (2) độ phóng đại luôn là một **số không có đơn vị** (vì đơn vị đã triệt tiêu ở tử và mẫu); (3) khi tính *kích thước thật*, kết quả phải nhỏ hơn kích thước ảnh (vì ảnh luôn được phóng to lên so với vật thật).

Ví dụ mẫu · Using a scale bar

An electron micrograph of a nucleus includes a scale bar labelled "1 μm," and the printed scale bar measures 25 mm on the page. On the same micrograph, the diameter of the nucleus measures 60 mm. Calculate the actual diameter of the nucleus.

Establish the scale: 25 mm on the page represents 1 μm in reality, so 1 mm on the page represents $\frac{1}{25}$ μm $= 0.04$ μm.
Apply to the nucleus: 60 mm $\times\ 0.04$ μm per mm $= 2.4$ μm.
The actual diameter of the nucleus is 2.4 μm. (Equivalently: magnification $= 25$ mm $\div 1$ μm $= 25\,000$ μm/μm after converting units consistently; actual size $= 60$ mm $\div 25\,000 \times 1000$ μm/mm, giving the same result.)

2.6 Practice Bank

Bài tập luyện tập

State the three parts of the cell theory.

Lời giải chi tiết

(1) All living organisms are made up of one or more cells. (2) The cell is the basic structural and functional unit of life. (3) All cells arise from pre-existing cells by cell division.

Bài tập luyện tập

A cell drawing has a scale of $\times 400$ and measures 32 mm in length on the page. Calculate the actual length of the cell in micrometres.

Lời giải chi tiết

Actual size $= \dfrac{\text{image size}}{\text{magnification}} = \dfrac{32 \text{ mm}}{400} = 0.08$ mm. Converting to micrometres: $0.08 \text{ mm} \times 1000 = 8$ μm, a plausible size for an animal cell.

Bài tập luyện tập

Which of the following is **not** a feature of a prokaryotic cell?

(A) Circular DNA free in the cytoplasm

(B) Presence of a nuclear membrane

(C) Plasmids

(D) Ribosomes smaller than those of eukaryotic cells

Lời giải chi tiết

Answer: (B). A nuclear membrane surrounding the DNA is the defining feature of a eukaryotic cell — prokaryotic cells have no nucleus at all, and their circular DNA lies free in the cytoplasm (A is a true prokaryotic feature). Plasmids (C) are small additional circular DNA loops found in many bacteria, and prokaryotic ribosomes (D) are indeed smaller (70S) than eukaryotic ribosomes (80S).

Bài tập luyện tập

Arrange the following into the correct order of levels of organisation, from smallest to largest: Organ, Cell, Organism, Tissue, Organ system.

Lời giải chi tiết

The correct order, smallest to largest, is: **Cell** → **Tissue** → **Organ** → **Organ system** → **Organism**. Cells of similar structure group into tissues; different tissues combine to form organs; organs with related functions form organ systems; all organ systems together make up the whole organism.

Bài tập luyện tập

Explain why a mature red blood cell has no nucleus, and suggest one advantage this provides.

Lời giải chi tiết

A mature red blood cell loses its nucleus during development in order to maximise the internal space available for **haemoglobin**, the protein that binds and transports oxygen. The advantage is that, with more haemoglobin packed into each cell, the red blood cell can carry more oxygen, making oxygen transport around the body more efficient; the biconcave disc shape further increases the cell's surface area to volume ratio, speeding up the diffusion of oxygen into and out of the cell.

Bài tập luyện tập

State **two** structural features of a palisade mesophyll cell and explain how each feature suits the cell to its function.

Lời giải chi tiết

(1) The cell contains **many chloroplasts**, which contain chlorophyll to absorb light energy for photosynthesis — more chloroplasts means more photosynthesis can occur per cell. (2) The cell has a **tall, column (elongated) shape** and is positioned near the upper surface of the leaf, which maximises the amount of light captured close to the illuminated surface of the leaf and allows several palisade cells to be packed closely together to increase the total rate of photosynthesis in the leaf.

Bài tập luyện tập

An image of a chloroplast in a photomicrograph is 45 mm long. If the actual length of the chloroplast is $5\ \mu$m, calculate the magnification of the photomicrograph.

Lời giải chi tiết

Convert to the same unit: 45 mm $= 45\,000\ \mu$m. Magnification $= \dfrac{\text{image size}}{\text{actual size}} = \dfrac{45\,000\ \mu\text{m}}{5\ \mu\text{m}} = 9000$. The photomicrograph is magnified $\times 9000$.

Bài tập luyện tập

Which structure is found in a plant cell but never in an animal cell?

(A) Mitochondria
(B) Ribosomes
(C) Cellulose cell wall
(D) Cell membrane

Lời giải chi tiết

Answer: (C) Cellulose cell wall. Mitochondria (A), ribosomes (B), and the cell membrane (D) are all found in both plant and animal cells, since both are eukaryotic and require respiration, protein synthesis, and a boundary membrane. Only a cellulose cell wall (and, more broadly, chloroplasts and a large permanent vacuole) is unique to plant cells among these options.

Bài tập luyện tập

Explain why the stomach is classified as an "organ" rather than a "tissue."

Lời giải chi tiết

A tissue is made up of only one type of cell working together for a single function, whereas the stomach is made up of **several different tissues** — muscular tissue, glandular (secretory) tissue, and epithelial lining tissue — all working together to perform the combined function of mechanical and chemical digestion. Because it is composed of multiple tissue types rather than one, the stomach meets the definition of an organ, not a tissue.

Bài tập luyện tập

A student converts 0.045 mm into micrometres. Show the correct working and result.

Lời giải chi tiết

Since 1 mm $= 1000$ μm, multiply by 1000: 0.045 mm $\times\ 1000 = 45$ μm.

Bài tập luyện tập

State **two** functions of the Golgi body.

Lời giải chi tiết

(1) It modifies proteins and lipids received from the endoplasmic reticulum (for example, by adding sugar chains to proteins). (2) It packages these modified molecules into vesicles and sorts them for transport to their correct destination, whether that is secretion out of the cell (e.g. digestive enzymes, hormones) or delivery to another organelle within the cell.

Bài tập luyện tập

An animal cell and a bacterial cell are both examined under an electron microscope. Which single observation would most reliably distinguish the bacterial cell from the animal cell?

(A) The bacterial cell is smaller

(B) The bacterial cell has no membrane-bound nucleus

(C) The bacterial cell has a cell membrane

(D) The bacterial cell contains ribosomes

Lời giải chi tiết

Answer: (B). While size (A) is often a useful clue, it is not fully reliable as some eukaryotic cells can be small. The presence of a cell membrane (C) and ribosomes (D) does not distinguish them, since both prokaryotic and eukaryotic cells possess these. The absence of a membrane-bound nucleus is the single most definitive, universally reliable distinguishing feature of a prokaryotic cell.

Bài tập luyện tập

(Supplement) Explain the difference between an embryonic stem cell and an adult stem cell in terms of their potential to differentiate.

Lời giải chi tiết

An embryonic stem cell, obtained from an early embryo, retains the ability to differentiate into almost **any** type of specialised cell in the body. An adult stem cell, found in specific tissues of an adult (such as bone marrow), has a more restricted potential and can typically only differentiate into a limited range of related cell types (for example, bone marrow stem cells can become various types of blood cell, but not, say, nerve cells or muscle cells).

Bài tập luyện tập

A student measures the length of a real onion cell as 0.12 mm under a light microscope and then draws it 60 mm long in their notebook. Calculate the magnification of the drawing.

Lời giải chi tiết

Magnification $= \dfrac{\text{image size}}{\text{actual size}} = \dfrac{60\ \text{mm}}{0.12\ \text{mm}} = 500$. The drawing is magnified $\times 500$.

Bài tập luyện tập

Explain why a root hair cell has a long thin extension, and name the process by which mineral ions are absorbed against their concentration gradient.

Lời giải chi tiết

The long, thin extension (root hair) dramatically increases the cell's surface area in contact with the surrounding soil, allowing more water and mineral ions to be absorbed by diffusion and other transport processes. Mineral ions, which are often at a lower concentration in the soil than inside the root hair cell, must be absorbed by **active transport**, a process that moves substances against their concentration gradient using energy released from respiration.

Bài tập luyện tập

Which of the following correctly lists a tissue, an organ, and an organ system (in that order)?

(A) Stomach, digestive system, xylem tissue
(B) Xylem tissue, stomach, digestive system
(C) Digestive system, xylem tissue, stomach
(D) Stomach, xylem tissue, digestive system

Lời giải chi tiết

Answer: (B). Xylem tissue is a tissue (one type of cell working together for water transport); the stomach is an organ (several tissue types combined); the digestive system is an organ system (several organs with a related overall function). Only option (B) places these in the correct tissue → organ → organ system order.

Bài tập luyện tập

Explain, in terms of cell structure, why muscle tissue is described as a "tissue" and not simply a collection of unrelated cells.

Lời giải chi tiết

Muscle tissue consists of many muscle cells that are structurally similar to one another (containing the same specialised contractile proteins) and that work together, contracting in a coordinated way to perform one shared function — generating a force or movement. This coordinated, shared structure and function, using cells of essentially the same type, is exactly what defines a tissue, distinguishing it from a random, unrelated collection of different cell types.

Bài tập luyện tập

A sample of tissue is $50\ \mu$m thick in reality. It is photographed and the resulting image is 10 cm thick. Calculate the magnification used, expressing your answer as a whole number.

Lời giải chi tiết

Convert to the same unit: 10 cm $= 100$ mm $= 100\,000\ \mu$m. Magnification $= \dfrac{100\,000\ \mu\text{m}}{50\ \mu\text{m}} = 2000$. The magnification used was $\times 2000$.

Bài tập luyện tập

Explain why sperm cells contain a large number of mitochondria clustered around the base of the tail (flagellum).

Lời giải chi tiết

The tail (flagellum) of a sperm cell must beat continuously to propel the cell forward on its journey to reach and fertilise an egg cell — this movement requires a large, continuous supply of energy. Mitochondria are the site of aerobic respiration, which releases this energy from glucose; clustering many mitochondria at the base of the tail places the energy source as close as possible to where it is needed, supporting sustained, efficient swimming.

Bài tập luyện tập

State one similarity and one difference between a mitochondrion and a chloroplast.

Lời giải chi tiết

Similarity: both are membrane-bound organelles with an internal folded/layered membrane structure that increases their internal surface area for the reactions they carry out. **Difference:** a mitochondrion is the site of (aerobic) respiration, releasing energy from glucose, and is found in both plant and animal cells; a chloroplast is the site of photosynthesis, trapping light energy to build glucose, and is found only in (green parts of) plant cells, since it contains chlorophyll, which mitochondria do not.

Bài tập luyện tập

A student writes: "Bacteria do not have ribosomes because they are not eukaryotic." Explain why this statement is incorrect.

Lời giải chi tiết

This statement is incorrect. All living cells, whether prokaryotic or eukaryotic, need to synthesise proteins and therefore all possess ribosomes — ribosomes are not exclusive to eukaryotic cells. The actual difference is one of **size and type**: prokaryotic ribosomes are smaller (classified as 70S) than the larger eukaryotic ribosomes (80S), but bacteria certainly do have ribosomes, and in fact rely on them just as much as eukaryotic cells do.

Bài tập luyện tập

An electron micrograph shows a nucleus with a scale bar representing 2 μm measuring 20 mm on the printed page. The nucleus itself measures 50 mm across on the same page. Calculate the actual diameter of the nucleus.

Lời giải chi tiết

The scale shows that 20 mm on the page represents 2 μm in reality, so 1 mm on the page represents $2 \div 20 = 0.1$ μm. The nucleus measures 50 mm on the page, so its actual diameter is 50×0.1 μm $= 5$ μm, a realistic size for a nucleus.

Bài tập luyện tập

Explain why ciliated epithelial cells lining the trachea are important in protecting the lungs, referring to their structure.

Lời giải chi tiết

Ciliated epithelial cells have many hair-like cilia projecting from their exposed surface. These cilia beat in a coordinated, wave-like rhythm that sweeps a layer of mucus (produced by neighbouring goblet cells), along with any trapped dust particles, bacteria, or other pathogens, up and away from the lungs towards the throat, where it can be swallowed or expelled. This protects the delicate gas-exchange surfaces of the lungs from becoming clogged or infected.

Bài tập luyện tập

Give two reasons, other than the presence of chloroplasts, why a leaf palisade cell would not be mistaken for an animal cell under a light microscope.

Lời giải chi tiết

(1) The palisade cell has a rigid **cellulose cell wall** visible as a distinct outer boundary, which animal cells never possess (animal cells have only a cell membrane, with no rigid outer boundary). (2) The palisade cell contains a **large, central permanent vacuole**, clearly visible as a large, often colourless internal space, whereas an animal cell has no such large permanent vacuole (any vacuoles present are small and temporary).

Bài tập luyện tập

A neurone has an axon 1 metre long in an adult human leg. Explain, in terms of structure and function, why such an extreme cell length is necessary and how this relates to cell specialisation.

Lời giải chi tiết

A neurone's function is to carry electrical nerve impulses rapidly between two points in the body — in this case, between the spinal cord and a muscle or receptor in the foot, a considerable physical distance. Rather than relying on a chain of many separate short cells (which would slow signal transmission at each cell junction), the neurone has become a single, highly specialised, extremely elongated cell (its axon) that can carry one continuous electrical impulse the entire distance without interruption, illustrating how cell specialisation can produce extreme, function-specific structural adaptations far removed from a "generalised" cell shape.

Bài tập luyện tập

Explain why plant cells that are not green (for example, root cells) still have a cell wall and a large vacuole, even though they cannot photosynthesise.

Lời giải chi tiết

The cell wall and vacuole are not related to photosynthesis and serve different, general functions common to essentially all plant cells. The **cellulose cell wall** provides structural support and a fixed shape regardless of whether the cell photosynthesises, which is essential everywhere in the plant body, including underground roots. The **permanent vacuole** stores cell sap and helps generate turgor pressure, contributing to the overall rigidity and water balance of the whole plant. Chloroplasts, in contrast, are only needed (and only present) in cells exposed to light that actually carry out photosynthesis, such as leaf mesophyll cells — root cells lack chloroplasts because they are underground and receive no light.

Movement Into and Out of Cells

Mục tiêu Unit: Định nghĩa và phân biệt được khuếch tán, thẩm thấu, và vận chuyển chủ động; giải thích các yếu tố ảnh hưởng đến tốc độ khuếch tán; mô tả và tính toán sự thay đổi khối lượng tế bào thực vật/động vật do thẩm thấu; giải thích hiện tượng trương nước, co nguyên sinh, tan huyết bằng cấu trúc tế bào; tính toán và giải thích tỉ lệ diện tích bề mặt trên thể tích và liên hệ với các bề mặt trao đổi chất.

3.1 Diffusion

Diffusion

Diffusion is the net movement of particles (molecules or ions) from a region of their higher concentration to a region of their lower concentration, down a concentration gradient, as a result of the random motion of particles. Diffusion requires no input of metabolic energy from the cell — it is a passive process, driven purely by the random kinetic movement of particles.

[Factors affecting the rate of diffusion]

- **Concentration gradient:** the steeper the difference in concentration between two regions, the faster the net rate of diffusion.
- **Temperature:** higher temperature gives particles more kinetic energy, so they move faster and diffuse more quickly.
- **Surface area:** a larger surface area (across which diffusion occurs) allows more particles to cross per unit time, increasing the overall rate.
- **Distance (thickness of the exchange surface):** a shorter diffusion distance (thinner membrane/tissue) means particles reach the other side faster, increasing the rate.

VN GIẢI THÍCH TIẾNG VIỆT

Khuếch tán (diffusion) là sự di chuyển của các phân tử từ nơi có nồng độ CAO đến nơi có nồng độ THẤP, theo chiều gradient nồng độ, do chuyển động ngẫu nhiên của các phân tử — quá trình này KHÔNG cần năng lượng từ tế bào. Bốn yếu tố ảnh hưởng đến tốc độ khuếch tán: (1) độ chênh lệch nồng độ càng lớn, khuếch tán càng nhanh; (2) nhiệt độ càng cao, phân tử chuyển động càng nhanh, khuếch tán càng nhanh; (3) diện tích bề mặt càng lớn, càng nhiều phân tử khuếch tán qua cùng lúc; (4) khoảng cách khuếch tán càng ngắn (màng/mô càng mỏng), phân tử càng nhanh đến đích.

Ví dụ mẫu · Diffusion in gas exchange and digestion

Explain how diffusion is involved in (a) gas exchange in the alveoli of the lungs, and (b) the absorption of digested food in the small intestine.

(a) Alveoli: the concentration of oxygen is higher in the air inside the alveoli than in the blood

in the surrounding capillaries (which has just released oxygen to respiring tissues), so oxygen diffuses from the alveolar air into the blood. Simultaneously, the concentration of carbon dioxide is higher in the blood (produced by respiration in body tissues) than in the alveolar air, so carbon dioxide diffuses from the blood into the alveolar air to be exhaled. The huge surface area of the many alveoli, their thin (one-cell-thick) walls, and the short diffusion distance to the surrounding capillaries all maximise the rate of this gas exchange.
(b) Small intestine: digested food molecules (such as glucose and amino acids) are present at a higher concentration inside the lumen of the small intestine than inside the epithelial cells lining it (or in the blood within the villi), so they diffuse from the lumen into these cells and then into the bloodstream. The villi and microvilli lining the small intestine greatly increase the surface area available for this diffusion, speeding up absorption.

VN **GIẢI THÍCH TIẾNG VIỆT**
Khuếch tán đóng vai trò cốt lõi trong hai quá trình trên: ở phế nang, oxy khuếch tán từ khí (nồng độ cao) vào máu (nồng độ thấp) trong khi CO2 khuếch tán ngược lại; diện tích bề mặt phế nang cực lớn và thành mỏng giúp khuếch tán diễn ra nhanh. Ở ruột non, chất dinh dưỡng đã tiêu hoá khuếch tán từ lòng ruột (nồng độ cao) vào tế bào biểu mô và máu (nồng độ thấp); các nhung mao (villi) và vi nhung mao (microvilli) tăng diện tích bề mặt hấp thụ. Đây là ví dụ điển hình về việc cấu trúc sinh học được "thiết kế" để tối ưu hoá khuếch tán.

3.2 Osmosis

Osmosis

Osmosis is the net movement of water molecules from a region of higher water potential (a more dilute solution) to a region of lower water potential (a more concentrated solution), through a **partially permeable membrane**. A **partially permeable membrane** allows small molecules (such as water) to pass through freely, but prevents larger solute molecules (such as sucrose) from passing through.

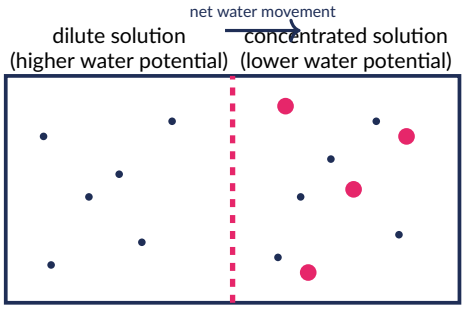
VN **GIẢI THÍCH TIẾNG VIỆT**
Thẩm thấu (osmosis) là một dạng đặc biệt của khuếch tán, chỉ áp dụng cho **phân tử nước**: nước di chuyển từ nơi có **thế nước cao** (dung dịch loãng, ít chất tan) đến nơi có **thế nước thấp** (dung dịch đặc, nhiều chất tan), qua một **màng bán thấm** (chỉ cho phân tử nhỏ như nước đi qua, không cho chất tan lớn như đường đi qua). Học sinh nên hiểu "thế nước cao" đơn giản là "nước loãng hơn / có nhiều phân tử nước tự do hơn."

3.2.1 Water potential explained

It can help to think of **water potential** as a measure of how "free" or concentrated the water molecules are in a solution. Pure water has the highest possible water potential. Dissolving a solute (such as sugar or salt) in water lowers the water potential, because some water molecules become loosely associated with the solute particles and are less free to move. Water always moves, by osmosis, from the solution with the higher (less negative) water potential towards the solution with the lower (more negative) water potential — that is, from dilute towards concentrated — until the water potentials on both sides of the membrane become equal, at which point net movement stops (dynamic equilibrium; individual molecules still move both ways, but with no net flow).

VN **GIẢI THÍCH TIẾNG VIỆT**

Có thể hiểu đơn giản **thế nước** là "mức độ tự do" của phân tử nước trong dung dịch. Nước tinh khiết có thế nước cao nhất. Khi hoà tan chất tan (đường, muối) vào nước, một số phân tử nước bị "giữ lại" quanh các hạt chất tan, làm giảm thế nước của dung dịch đó. Nước luôn di chuyển từ nơi thế nước CAO sang nơi thế nước THẤP (tức từ dung dịch loãng sang dung dịch đặc) cho đến khi thế nước hai bên bằng nhau — lúc này đạt trạng thái cân bằng động (các phân tử vẫn di chuyển hai chiều nhưng không có sự di chuyển ròng).



Osmosis across a partially permeable membrane: small water molecules (dots) can cross freely in both directions, but larger solute molecules (circles) cannot cross the membrane. Because the right side is more concentrated in solute, it has a lower water potential, so there is a net movement of water from left to right until equilibrium is reached.

3.2.2 Osmosis in plant cells

[Plant cells in different solutions]

- **Turgid:** in a dilute solution (or pure water), water enters the cell by osmosis; the cell swells, but the rigid **cellulose cell wall** prevents the cell from bursting, so the cell becomes firm and pressurised (turgid). This turgor pressure is important for supporting non-woody plant tissue.
- **Incipient plasmolysis:** the point at which the cell membrane just begins to pull away from the cell wall, as the cell has lost enough water that it is no longer turgid but the protoplast has not yet visibly separated from the wall.
- **Plasmolysis:** in a strongly concentrated solution, water leaves the cell by osmosis; the cytoplasm shrinks and the cell membrane pulls away from the cell wall, leaving a visible gap. The cell wall itself, being rigid, does not shrink, so it retains its shape even as the cytoplasm inside contracts.

3.2.3 Osmosis in animal cells

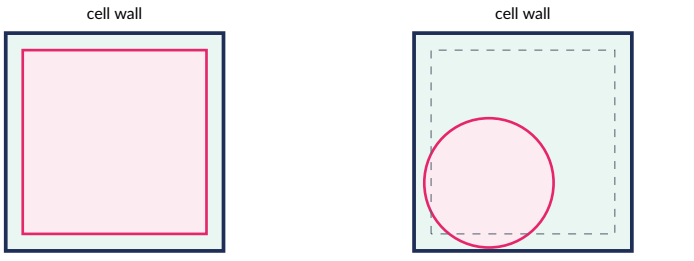
[Animal cells in different solutions]

- In a dilute solution, water enters an animal cell by osmosis; because an animal cell has **no cell wall** to resist the resulting pressure, the cell continues to swell until it bursts — this is called **haemolysis** (specifically for red blood cells) or lysis more generally.
- In a concentrated solution, water leaves an animal cell by osmosis; the cell shrinks and shrivels, a process called **crenation**.

VN **GIẢI THÍCH TIẾNG VIỆT**

Sự khác biệt then chốt giữa tế bào thực vật và động vật trong dung dịch: tế bào thực vật có

thành tế bào nên khi hút nước sẽ trở nên **trương nước (turgid)** nhưng KHÔNG bị vỡ (thành tế bào chống lại áp suất từ bên trong); khi mất nước, tế bào chất co lại tách khỏi thành tế bào — gọi là **co nguyên sinh (plasmolysis)**, còn thành tế bào vẫn giữ nguyên hình dạng. Ngược lại, tế bào động vật KHÔNG có thành tế bào nên khi hút nhiều nước sẽ **vỡ ra (tan bào/tan huyết — lysis/haemolysis)**; khi mất nước sẽ **co quắp lại (crenation)**. Nguyên nhân gốc rễ của mọi khác biệt này chính là sự có/không có thành tế bào cứng.



Turgid (dilute solution) **Plasmolysed** (concentrated solution)

Left: a turgid plant cell in a dilute solution — the cytoplasm presses firmly against the rigid cell wall. Right: a plasmolysed plant cell in a concentrated solution — the cytoplasm has shrunk and pulled away from the cell wall (dashed outline shows where the wall remains), leaving a visible gap.

3.2.4 Practical: osmosis in potato tissue

A classic practical measures the percentage change in mass of potato tissue cylinders placed in a range of sucrose solution concentrations.

[Percentage change in mass formula]

$$\%\text{ change in mass} = \frac{\text{final mass} - \text{initial mass}}{\text{initial mass}} \times 100$$

A **positive** value indicates a mass gain (net water uptake); a **negative** value indicates a mass loss (net water loss).

Ví dụ mẫu · Calculating percentage change in mass — potato osmosis

Potato cylinders of equal size are weighed, placed into sucrose solutions of different concentrations for one hour, blotted dry, and reweighed.

Concentration (mol/dm^3)	Initial mass (g)	Final mass (g)	% change in mass
0.0 (distilled water)	5.20	5.85	$+12.5$
0.4	5.10	5.20	$+2.0$
1.0	5.30	4.77	-10.0

Using the 1.0 mol/dm^3 row, show the calculation used to obtain -10.0%, and explain the biological meaning of this result.

$$\%\text{ change} = \frac{4.77 - 5.30}{5.30} \times 100 = \frac{-0.53}{5.30} \times 100 = -10.0\%$$

The negative result means the potato tissue **lost** mass. This is because the 1.0 mol/dm^3 sucrose solution has a lower water potential than the cell sap inside the potato cells, so water left the potato cells by osmosis into the surrounding solution, causing the cells to become plasmolysed and the tissue to lose mass.

Ví dụ mẫu · Finding the isotonic point

Using the data above, estimate the concentration of sucrose solution at which there would be no net change in mass of the potato tissue (the "isotonic point").

Between 0.4 mol/dm^3 (a gain of $+2.0\%$) and 1.0 mol/dm^3 (a loss of -10.0%), the percentage change crosses from positive to negative, so the isotonic point — where % change $= 0$ — lies somewhere between these two concentrations. A rough linear estimate (interpolation) places it close to $0.4 + 0.6 \times \dfrac{2.0}{2.0 + 10.0} \approx 0.5$ mol/dm^3. At this concentration, the sucrose solution's water potential is approximately equal to the water potential of the cell sap inside the potato cells, so there is no net movement of water in either direction.

VN **GIẢI THÍCH TIẾNG VIỆT**

Điểm mà tại đó phần trăm thay đổi khối lượng bằng 0 gọi là **điểm đẳng trương (isotonic point)** — đây là nồng độ dung dịch có thế nước xấp xỉ bằng thế nước của dịch tế bào bên trong mô đang xét, nên nước không di chuyển ròng theo hướng nào. Đây là cách gián tiếp để ước lượng nồng độ dịch tế bào của một mô thực vật bằng thực nghiệm, không cần đo trực tiếp.

Ví dụ mẫu · Calculating raw percentage change from new data

A visking tubing (partially permeable membrane) bag containing concentrated sugar solution is tied and weighed at 18.4 g, then submerged in distilled water for 30 minutes. It is removed, dried, and reweighed at 21.2 g. Calculate the percentage change in mass and explain the direction of water movement.

$$\%\ \text{change} = \frac{21.2 - 18.4}{18.4} \times 100 = \frac{2.8}{18.4} \times 100 \approx +15.2\%$$

The bag gained 15.2% of its original mass. This is because the sugar solution inside the bag has a lower water potential than the pure water outside, so water moved by osmosis from the distilled water (higher water potential), through the partially permeable visking tubing, into the bag (lower water potential), increasing its mass.

(!) Lỗi thường gặp: Học sinh thường tính sai công thức % thay đổi khối lượng bằng cách chia cho khối lượng **cuối** thay vì khối lượng **ban đầu**. Công thức đúng luôn là $\dfrac{\text{khối lượng cuối} - \text{khối lượng đầu}}{\text{khối lượng ĐẦU}} \times 100$ — mẫu số luôn là khối lượng ban đầu (initial mass), vì đây là giá trị "gốc" để so sánh phần trăm thay đổi.

3.3 Active Transport

Active transport

Active transport is the movement of particles through a cell membrane, from a region of **lower** concentration to a region of **higher** concentration (i.e., against/up the concentration gradient), using energy released from respiration, via specific **carrier proteins** embedded in the cell membrane. Unlike diffusion and osmosis, active transport requires the cell to expend metabolic energy (ATP) because it moves substances the "wrong way" relative to their natural concentration gradient.

[Examples of active transport]

- **Root hair cells** absorb mineral ions (such as nitrate and magnesium ions) from the soil, even when the concentration of these ions is already higher inside the root hair cell than in the surrounding soil water.
- **Glucose reabsorption** in the kidney tubule (or the gut) can continue even after the concentration of glucose inside the transporting cells has risen above the concentration remaining in the fluid outside, ensuring that virtually all filtered glucose is reclaimed rather than lost.

VN GIẢI THÍCH TIẾNG VIỆT

Vận chuyển chủ động (active transport) khác căn bản với khuếch tán và thẩm thấu ở hai điểm: (1) di chuyển **ngược** chiều gradient nồng độ (từ nơi ít đến nơi nhiều); (2) cần **năng lượng** từ hô hấp tế bào (ATP) và **protein vận chuyển** (carrier protein) đặc hiệu trên màng tế bào. Ví dụ điển hình: tế bào lông hút rễ hấp thụ ion khoáng (như nitrate) từ đất dù nồng độ ion trong tế bào đã cao hơn trong đất; ống thận tái hấp thu glucose ngược gradient để đảm bảo gần như không mất glucose qua nước tiểu.

Ví dụ mẫu · Distinguishing active transport from diffusion

A plant is treated with a metabolic poison that stops cellular respiration. Predict and explain the effect this would have on the uptake of (a) water and (b) mineral ions by the root hair cells.

(a) Water uptake: water enters root hair cells by **osmosis**, a passive process that does not require energy from respiration. Uptake of water would therefore **continue largely unaffected** (at least initially), since osmosis depends only on the water potential gradient, not on metabolic energy.
(b) Mineral ion uptake: mineral ions are absorbed against their concentration gradient by **active transport**, which directly requires energy released from respiration. Stopping respiration would remove this energy supply, so active uptake of mineral ions would **stop** (though a small amount might still diffuse in passively if there happened to be a favourable concentration gradient, which is not the normal case for most mineral ions).

3.4 Surface Area to Volume Ratio

Why surface area to volume ratio matters

As an object increases in linear size, its **surface area** increases in proportion to (length)^2, while its **volume** increases in proportion to (length)^3. This means that as an organism (or cell) gets larger, its surface area to volume (SA:V) ratio gets progressively **smaller**. Since the rate at which a cell can exchange substances (oxygen, carbon dioxide, nutrients, waste, heat) with its environment depends on its surface area, but its metabolic demand for these substances depends on its volume, a larger organism struggles more and more to exchange enough material through its outer surface alone. This is why larger or more metabolically active organisms have evolved specialised, folded, flattened, or subdivided exchange surfaces (villi in the gut, alveoli in the lungs, gills in fish, root hairs in plants) to boost the effective surface area available for exchange.

VN GIẢI THÍCH TIẾNG VIỆT

Khi kích thước vật thể tăng lên, **diện tích bề mặt** tăng theo bình phương chiều dài ($\propto L^2$) trong khi **thể tích** tăng theo lập phương chiều dài ($\propto L^3$) — do đó **tỉ lệ diện tích bề mặt/thể tích**

(SA:V) giảm dần khi vật thể lớn lên. Vì tốc độ trao đổi chất (oxy, CO2, chất dinh dưỡng) qua bề mặt tỉ lệ với diện tích bề mặt, còn nhu cầu trao đổi chất tỉ lệ với thể tích (khối lượng tế bào/mô), sinh vật càng lớn thì càng khó trao đổi đủ chất chỉ qua bề mặt ngoài trơn — đây là lý do tiến hoá ra các bề mặt trao đổi **gấp nếp, dẹt, hoặc phân nhánh** như nhung mao ruột, phế nang phổi, mang cá, lông hút rễ — tất cả đều nhằm mục đích TĂNG diện tích bề mặt trao đổi mà không cần tăng thể tích tương ứng.

Ví dụ mẫu · Comparing SA:V ratio for cubes of different size

Calculate the surface area, volume, and SA:V ratio for two cube-shaped cells with side lengths $3\ \mu$m and $9\ \mu$m. Comment on the result.

Cube of side $3\ \mu$m: Surface area $= 6 \times 3^2 = 54\ \mu\text{m}^2$. Volume $= 3^3 = 27\ \mu\text{m}^3$. SA:V $= 54/27 = 2.0$.
Cube of side $9\ \mu$m: Surface area $= 6 \times 9^2 = 486\ \mu\text{m}^2$. Volume $= 9^3 = 729\ \mu\text{m}^3$. SA:V $= 486/729 \approx 0.67$.
Although the larger cube (side $9\ \mu$m, a $3\times$ increase in length) has a far greater absolute surface area and volume, its SA:V ratio (0.67) is three times smaller than that of the small cube (2.0). This confirms that as an object's linear size increases, its surface area to volume ratio decreases, making it relatively harder for the larger cell to exchange substances across its surface fast enough to meet the demands of its (proportionally much greater) internal volume.

Ví dụ mẫu · SA:V ratio for a rectangular block

A block-shaped organism measures 2 cm $\times$ 2 cm $\times$ 4 cm. Calculate its surface area, volume, and SA:V ratio.

Surface area: the block has three pairs of identical rectangular faces: two faces of $2\times2 = 4$ cm^2, two faces of $2 \times 4 = 8$ cm^2, and two faces of $2 \times 4 = 8$ cm^2.

$$\text{Surface area} = 2(4) + 2(8) + 2(8) = 8 + 16 + 16 = 40\ \text{cm}^2$$

Volume: $2 \times 2 \times 4 = 16$ cm^3.
SA:V ratio: $40 \div 16 = 2.5$. This organism has a moderate SA:V ratio of $2.5 : 1$, intermediate between a compact cube and a very elongated or flattened shape (which would have a higher SA:V ratio for the same volume).

Ví dụ mẫu · Why elephants have large ears but mice do not need them

Explain, using the concept of surface area to volume ratio, why African elephants have very large ears relative to their body size, while small mammals such as mice do not need such an adaptation.

An elephant has a very large body size, giving it a very **small** SA:V ratio — its heat-generating volume (from metabolism) is very large compared with its skin surface area (where heat is lost), putting it at risk of overheating. The elephant's large, thin, well-vascularised ears add substantial extra surface area for heat loss by radiation and convection, without requiring a proportionally large increase in body volume — effectively acting as a supplementary heat-exchange surface. A mouse, in contrast, already has a very **large** SA:V ratio because of its small body size, so its existing skin surface is already more than sufficient to lose heat relative to its small volume; the mouse does not need any additional heat-exchange structure (indeed, small mammals more often need to conserve heat, e.g. with fur, rather than lose it).

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Tai voi to và mỏng, có nhiều mạch máu, đóng vai trò như một **bề mặt tản nhiệt bổ sung**: vì voi có kích thước cơ thể lớn nên tỉ lệ SA:V rất nhỏ (thể tích sinh nhiệt tăng nhanh hơn nhiều so với diện tích da tản nhiệt), nên voi dễ bị quá nóng nếu chỉ dựa vào da thông thường. Ngược lại, chuột có kích thước nhỏ nên tỉ lệ SA:V tự nhiên đã rất lớn — diện tích da so với thể tích cơ thể đã đủ để tản nhiệt hiệu quả, nên không cần thêm cấu trúc đặc biệt như tai voi (thực tế động vật nhỏ thường phải giữ ấm — chống mất nhiệt — nhiều hơn là phải tản nhiệt).

3.5 Practice Bank

Bài tập luyện tập

A gas exchange surface becomes thicker due to disease. Explain the effect this would have on the rate of diffusion of oxygen across it.

Lời giải chi tiết

Diffusion rate is inversely related to the distance over which particles must travel — a thicker exchange surface increases the diffusion distance oxygen molecules must cross. This would **decrease** the rate of diffusion of oxygen across the surface, since particles take longer to travel the greater distance, reducing the amount of oxygen able to cross per unit time.

Bài tập luyện tập

Which of the following best describes osmosis?

(A) The movement of any dissolved substance from high to low concentration

(B) The net movement of water molecules from a region of higher water potential to a region of lower water potential, through a partially permeable membrane

(C) The movement of large solute particles through a partially permeable membrane

(D) The movement of water molecules against a water potential gradient using energy

Lời giải chi tiết

Answer: (B). This is the precise definition of osmosis. Option (A) describes diffusion in general (not specific to water). Option (C) is false, since a partially permeable membrane specifically blocks large solute particles. Option (D) is false, since osmosis is a passive process that does not use energy and moves water down (not against) its water potential gradient.

Bài tập luyện tập

A cube-shaped cell has a side length of 4 μm. Calculate its surface area, volume, and SA:V ratio.

Lời giải chi tiết

Surface area $= 6 \times 4^2 = 6 \times 16 = 96$ μm^2. Volume $= 4^3 = 64$ μm^3. SA:V ratio $= 96 \div 64 = 1.5$.

Bài tập luyện tập

A piece of visking tubing containing a concentrated salt solution is placed into distilled water. State and explain the direction of net water movement.

Lời giải chi tiết

The distilled water outside the tubing has a much higher water potential than the concentrated salt solution inside the tubing. Water will therefore move by osmosis **from the distilled water outside, through the partially permeable visking tubing, into the salt solution inside**, moving from the region of higher water potential to the region of lower water potential.

Bài tập luyện tập

A red blood cell is placed into distilled water. Explain what happens to the cell and name this process.

Lời giải chi tiết

Distilled water has a much higher water potential than the cytoplasm of the red blood cell, so water enters the cell by osmosis. Because a red blood cell has **no cell wall** to resist the resulting internal pressure, the cell continues to swell until its cell membrane can no longer withstand the pressure and it bursts. This process is called **haemolysis** (or lysis).

Bài tập luyện tập

Potato tissue of initial mass 4.80 g is placed in a concentrated sucrose solution. After one hour it is removed, blotted, and reweighed at 4.32 g. Calculate the percentage change in mass.

Lời giải chi tiết

$$\%\text{ change} = \frac{4.32 - 4.80}{4.80} \times 100 = \frac{-0.48}{4.80} \times 100 = -10.0\%$$

The tissue lost 10.0% of its original mass, because the surrounding solution had a lower water potential than the cell sap, causing net water loss from the potato cells by osmosis.

Bài tập luyện tập

State two ways in which active transport differs from diffusion.

Lời giải chi tiết

(1) Active transport moves substances **against** their concentration gradient (from lower to higher concentration), whereas diffusion moves substances **down** their concentration gradient (from higher to lower concentration). (2) Active transport requires an input of **energy** from respiration and specific **carrier proteins**, whereas diffusion is passive and requires no metabolic energy.

Bài tập luyện tập

A student compares a large sphere-shaped organism (radius 6 cm) with a small sphere-shaped organism (radius 2 cm). Using the fact that surface area of a sphere $= 4\pi r^2$ and volume $= \frac{4}{3}\pi r^3$,

explain (without full calculation) why the small organism has a higher SA:V ratio.

Lời giải chi tiết

Since surface area scales with r^2 and volume scales with r^3, the ratio SA:V scales with $r^2/r^3 = 1/r$ — meaning SA:V is inversely proportional to radius. As radius r increases, $1/r$ decreases, so a larger organism (larger r) always has a smaller SA:V ratio than a smaller organism (smaller r), regardless of the exact numbers; the small organism with $r = 2$ cm therefore has a higher SA:V ratio than the large organism with $r = 6$ cm.

Bài tập luyện tập

Explain, in terms of cell structure, why a plant cell placed in distilled water becomes turgid rather than bursting like an animal cell would.

Lời giải chi tiết

Water enters both the plant cell and an animal cell by osmosis when placed in distilled water, because the cell's contents have a lower water potential than the surrounding pure water. However, the plant cell is surrounded by a rigid **cellulose cell wall**, which resists the increasing internal (turgor) pressure as the cell swells; the wall prevents the cell from expanding indefinitely, so the cell becomes firm and pressurised (turgid) rather than bursting. An animal cell has no such rigid wall, so nothing opposes the swelling, and it eventually bursts (haemolysis/lysis).

Bài tập luyện tập

A visking tubing bag of initial mass 15.0 g is placed in a sucrose solution for 40 minutes and reweighed at 13.5 g. Calculate the percentage change in mass, and state whether the solution inside the bag or outside the bag had the lower water potential.

Lời giải chi tiết

$$\%\ \text{change} = \frac{13.5 - 15.0}{15.0} \times 100 = \frac{-1.5}{15.0} \times 100 = -10.0\%$$

The bag lost mass, meaning water moved net **out** of the bag into the surrounding solution. This means the water potential **outside** the bag (in the surrounding sucrose solution) was **lower** than the water potential of the solution inside the bag.

Bài tập luyện tập

Explain why root hair cells contain a particularly large number of mitochondria.

Lời giải chi tiết

Root hair cells absorb mineral ions from the soil by **active transport**, since these ions are often at a lower concentration in the soil than inside the root hair cell, requiring movement against the concentration gradient. Active transport requires a continuous supply of energy released from aerobic respiration, so root hair cells contain a large number of mitochondria to generate the energy needed to power this active uptake of mineral ions.

Bài tập luyện tập

Which factor would **not** increase the rate of diffusion of a gas across a membrane?

(A) Increasing the temperature

(B) Increasing the surface area of the membrane

(C) Increasing the thickness of the membrane

(D) Increasing the concentration gradient across the membrane

Lời giải chi tiết

Answer: (C). Increasing the thickness (distance) of the membrane **increases** the diffusion distance, which **decreases**, not increases, the rate of diffusion. All the other options (A, B, D) are factors that genuinely increase the rate of diffusion.

Bài tập luyện tập

A student places identical potato cylinders into pure water and into a 1.0 mol/dm^3 salt solution. After 30 minutes, both cylinders are noticeably softer and more flexible than before the experiment, but for different reasons. Explain the reason in each case.

Lời giải chi tiết

The cylinder in **pure water** becomes soft due to excessive water uptake by osmosis (water potential of pure water is much higher than the cell sap), which can eventually damage cell membranes and cell structure if left too long, though initially cells become turgid. The cylinder in the **concentrated salt solution** becomes soft and flaccid because water has left the cells by osmosis (the salt solution has a much lower water potential than the cell sap), causing the cells to become plasmolysed — the cytoplasm shrinks away from the cell wall, and without full turgor pressure supporting it, the tissue loses its rigidity and becomes limp.

Bài tập luyện tập

Two cells, A and B, are cube-shaped. Cell A has side length $2\ \mu$m and Cell B has side length $6\ \mu$m. Calculate how many times greater the volume of Cell B is compared with Cell A, and how many times greater its surface area is.

Lời giải chi tiết

Cell A: volume $= 2^3 = 8\ \mu$m^3; surface area $= 6 \times 2^2 = 24\ \mu$m^2.
Cell B: volume $= 6^3 = 216\ \mu$m^3; surface area $= 6 \times 6^2 = 216\ \mu$m^2.
Volume ratio: $216 \div 8 = 27$ times greater. Surface area ratio: $216 \div 24 = 9$ times greater. This confirms that tripling the side length ($6 = 3 \times 2$) multiplies volume by $3^3 = 27$ but surface area by only $3^2 = 9$, so Cell B has a much smaller SA:V ratio than Cell A.

Bài tập luyện tập

Explain why crenation occurs when a red blood cell is placed in a concentrated salt solution.

Lời giải chi tiết

The concentrated salt solution has a lower water potential than the cytoplasm inside the red blood cell, so water moves out of the cell by osmosis (from the cell's higher water potential to the solution's lower water potential). Since the red blood cell has no rigid cell wall to maintain its shape, the loss of water and internal volume causes the cell membrane and cytoplasm to shrink and shrivel, producing a wrinkled, crenated appearance.

Bài tập luyện tập

A metabolic poison completely blocks respiration in root hair cells. State and explain the effect on mineral ion uptake and on water uptake.

Lời giải chi tiết

Mineral ion uptake would stop (or be greatly reduced). Mineral ions are absorbed by active transport, which directly requires energy from respiration via carrier proteins; blocking respiration removes this energy supply. **Water uptake would continue relatively normally, at least in the short term.** Water enters by osmosis, a passive process driven only by the water potential gradient, which does not require metabolic energy, so blocking respiration does not directly prevent osmotic water uptake (although indirectly, over a longer period, damage to the cell from lack of energy could eventually disrupt normal function).

Bài tập luyện tập

Give the correct sequence describing what happens to a plant cell placed into a solution more concentrated than its cell sap, from the moment it is placed in solution to full plasmolysis.

Lời giải chi tiết

(1) The surrounding solution has a lower water potential than the cell sap inside the vacuole and cytoplasm. (2) Water moves out of the cell by osmosis, through the partially permeable cell membrane, down the water potential gradient. (3) As water leaves, the volume of the cytoplasm and vacuole decreases, and the cell loses its turgor pressure (reaching "incipient plasmolysis" as the membrane just begins to separate from the wall). (4) With continued water loss, the cell membrane and cytoplasm pull away further from the rigid cellulose cell wall, which does not shrink, leaving a visible fluid-filled gap between the wall and the shrunken protoplast — this is full **plasmolysis**.

Bài tập luyện tập

A student states: "Osmosis is just diffusion, so the two words mean exactly the same thing." Explain why this is not entirely accurate.

Lời giải chi tiết

Osmosis is a special, more specific case of diffusion, not identical to it. Diffusion refers to the net movement of **any** particles (dissolved substances or gases) from high to low concentration, through any medium. Osmosis refers specifically and only to the net movement of **water molecules** across a **partially permeable membrane**, from a region of higher water potential to lower water potential. Every osmosis event is technically a form of diffusion (of water), but not every diffusion event is osmosis (e.g. the diffusion of oxygen gas in air involves no membrane

and no water).

Bài tập luyện tập

Calculate the SA:V ratio of a cylindrical root hair, approximated as a cylinder of radius 0.005 mm and length 1 mm (ignore the circular ends, using curved surface area $= 2\pi rl$ and volume $= \pi r^2 l$), and compare qualitatively with a spherical cell of similar volume.

Lời giải chi tiết

Curved surface area $= 2\pi(0.005)(1) = 0.0314$ mm^2 (to 3 s.f.). Volume $= \pi(0.005)^2(1) = 7.85 \times 10^{-5}$ mm^3. SA:V ratio $= 0.0314 \div 7.85 \times 10^{-5} \approx 400$. This is a very high SA:V ratio compared with a compact spherical cell of similar volume, which would have a much lower SA:V ratio (a sphere minimises surface area for a given volume) — this confirms why the long, thin, projecting shape of a root hair is so effective at maximising surface area for absorbing water and mineral ions.

Bài tập luyện tập

A plant wilts visibly during a hot, dry afternoon but recovers fully after being watered in the evening. Explain this observation in terms of osmosis and turgor pressure.

Lời giải chi tiết

During the hot, dry afternoon, the plant loses water rapidly through transpiration faster than its roots can absorb replacement water from the (possibly drying) soil, so the cells in the stem and leaves lose water and turgor pressure, becoming flaccid (partially plasmolysed) — this loss of turgor causes the visible wilting, as cells are no longer firm enough to hold the plant upright. After watering in the evening, water becomes freely available in the soil at a higher water potential than the cell sap in the root hair cells, so water re-enters the root cells by osmosis and is transported up through the plant, restoring turgor pressure to the stem and leaf cells and allowing the plant to become firm and upright again.

Bài tập luyện tập

Explain why a single-celled organism such as an amoeba does not need specialised gas exchange structures like gills or lungs.

Lời giải chi tiết

A single-celled organism such as an amoeba is extremely small, giving it a very large surface area to volume (SA:V) ratio. This means its entire cell surface is more than sufficient to allow oxygen to diffuse in and carbon dioxide to diffuse out fast enough to meet the (relatively small) metabolic demands of its small volume, simply by diffusion across the general cell membrane. Specialised, surface-area-boosting gas exchange structures (gills, lungs, alveoli) only become necessary in much larger, multicellular organisms whose SA:V ratio is too low for simple diffusion across the outer body surface to meet their much greater metabolic demand.

CAMBRIDGE IGCSE • Unit 4

Biological Molecules and Enzymes

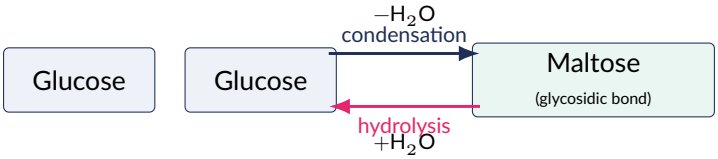
Mục tiêu Unit: Mô tả cấu trúc và vai trò của carbohydrate, lipid, protein; giải thích phản ứng tổng hợp/thuỷ phân tạo và phá vỡ liên kết glycosidic, ester, peptide; thực hiện đúng quy trình và nhận biết kết quả bốn phép thử thức ăn (Benedict, iodine, Biuret, ethanol); định nghĩa enzyme và mô hình ổ khoá – chìa khoá (cùng mô hình khớp cảm ứng — Supplement); giải thích ảnh hưởng của nhiệt độ, pH, nồng độ cơ chất lên tốc độ phản ứng enzyme; tính toán tốc độ phản ứng enzyme từ dữ liệu thời gian.

4.1 Carbohydrates, Lipids, and Proteins

4.1.1 Carbohydrates

Carbohydrates are organic molecules containing carbon, hydrogen, and oxygen, usually in the ratio described by $(CH_2O)_n$. The simplest carbohydrates are **monosaccharides** — single-sugar units such as **glucose** and **fructose**, both small, soluble molecules used directly as an energy source or as building blocks for larger carbohydrates.

Two monosaccharides can join together in a **condensation reaction** (releasing one water molecule) to form a **disaccharide**, linked by a **glycosidic bond**. For example, **maltose** (two glucose units) is formed during starch digestion, and **sucrose** (glucose + fructose) is common table sugar. Many monosaccharide units joined together in long chains form a **polysaccharide**, such as **starch** and **glycogen** (both storage carbohydrates, built from many glucose units) or **cellulose** (a structural carbohydrate forming plant cell walls, also built from glucose but joined by a different type of glycosidic bond that makes it far more rigid and resistant to digestion by most animals).



Condensation reaction joining two glucose monomers into maltose by forming a glycosidic bond and releasing one water molecule; the reverse reaction, hydrolysis, adds one water molecule to break the bond and separate the two glucose units again.

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Carbohydrate gồm 3 nhóm theo kích thước: **Đường đơn (monosaccharide)** như glucose, fructose — nhỏ, tan tốt, dùng làm năng lượng trực tiếp; **Đường đôi (disaccharide)** như maltose (2 glucose), sucrose (glucose + fructose) — hình thành từ phản ứng **ngưng tụ (condensation)** nối 2 đường đơn bằng **liên kết glycosidic**, giải phóng 1 phân tử nước; **Đa đường (polysaccharide)** như tinh bột, glycogen (dự trữ năng lượng), cellulose (cấu trúc thành tế bào thực vật) — gồm rất nhiều đơn vị glucose nối với nhau. Phản ứng ngược lại (**thuỷ phân — hydrolysis**) thêm 1 phân tử nước để bẻ gãy liên kết glycosidic, tách đường đôi/đa đường trở lại thành các đơn vị đường đơn — đây chính là cách enzyme tiêu hoá carbohydrate trong ống tiêu hoá.

4.1.2 Lipids

A **lipid** (fat or oil) is formed from one molecule of **glycerol** joined to three **fatty acid** molecules, each connected by an **ester bond** formed through condensation (releasing three water molecules in total; the reverse, hydrolysis, breaks the ester bonds, adding three water molecules back and regenerating glycerol and three fatty acids). Lipids are important as a concentrated, long-term energy store (yielding more energy per gram than carbohydrates), as thermal insulation (fat stored under the skin), and as a major structural component of cell membranes (phospholipids).

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Lipid được tạo thành từ 1 phân tử **glycerol** liên kết với 3 phân tử **acid béo (fatty acid)** qua 3 **liên kết ester**, hình thành bằng phản ứng ngưng tụ (giải phóng 3 phân tử nước). Vai trò chính: dự trữ năng lượng dài hạn (nhiều năng lượng hơn carbohydrate cùng khối lượng), cách nhiệt (lớp mỡ dưới da), và cấu tạo màng tế bào (phospholipid).

4.1.3 Proteins

A **protein** is built from many **amino acid** monomers joined end to end by **peptide bonds**, again formed by condensation reactions (releasing one water molecule per bond). The specific sequence of amino acids in a chain is called the **primary structure** of the protein, and this sequence determines how the chain folds up into its final three-dimensional shape, which in turn determines the protein's function. Proteins serve many roles: as **enzymes** (biological catalysts), as **structural** molecules (e.g. keratin in hair and nails, collagen in skin and tendons), as **transport** molecules (e.g. haemoglobin, which binds and carries oxygen in red blood cells), as **antibodies** (recognising and binding to specific pathogens as part of the immune response), and as **hormones** (e.g. insulin).

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Protein được tạo thành từ nhiều **amino acid** nối với nhau bằng **liên kết peptide** (cũng qua phản ứng ngưng tụ, giải phóng nước). Trình tự sắp xếp amino acid gọi là **cấu trúc bậc một (primary structure)** — chính trình tự này quyết định cách chuỗi protein cuộn gập thành hình dạng 3 chiều cuối cùng, và hình dạng đó quyết định chức năng của protein. Protein có nhiều vai trò: **enzyme** (xúc tác sinh học), **cấu trúc** (keratin ở tóc/móng, collagen ở da/gân), **vận chuyển** (hemoglobin vận chuyển oxy), **kháng thể** (nhận diện tác nhân gây bệnh), **hormone** (như insulin).

Macromolecule	Built from	Roles / examples
Carbohydrates	Monosaccharides (e.g. glucose) joined by glycosidic bonds	Immediate energy source (glucose); storage (starch in plants, glycogen in animals); structural support (cellulose in plant cell walls)
Lipids	1 glycerol + 3 fatty acids joined by ester bonds	Long-term energy storage; thermal insulation; component of cell membranes (phospholipids)
Proteins	Amino acids joined by peptide bonds	Enzymes (catalysis); structural molecules (keratin, collagen); transport (haemoglobin); antibodies; hormones (insulin)

4.1.4 Water as a biological molecule

Although not itself an organic macromolecule, **water** is essential to every living cell: it acts as a **solvent** in which most biological reactions occur (many substances must be dissolved in water to react or to be transported); it serves as the **transport medium** for dissolved substances around the body (e.g. blood plasma transporting glucose, dissolved gases, and hormones); and it is itself a reactant or product in condensation and hydrolysis reactions.

VN **GIẢI THÍCH TIẾNG VIỆT**

Dù không phải là đại phân tử hữu cơ, **nước** vẫn cực kỳ quan trọng đối với sự sống: là **dung môi** hoà tan hầu hết các chất để phản ứng sinh học có thể xảy ra, là **môi trường vận chuyển** các chất hoà tan trong cơ thể (ví dụ huyết tương vận chuyển glucose, khí hoà tan, hormone), và bản thân nước cũng tham gia trực tiếp vào phản ứng ngưng tụ (giải phóng nước) và thuỷ phân (tiêu thụ nước).

4.2 Food Tests

[The four standard food tests]

- **Benedict's test (reducing sugars):** add Benedict's solution (blue) to the food sample and heat in a water bath. A colour change from blue → green → yellow → **brick-red precipitate** indicates the presence of a reducing sugar (e.g. glucose); the intensity/amount of red precipitate broadly indicates the amount of sugar present.
- **Iodine test (starch):** add iodine solution (orange-brown) directly to the food sample at room temperature, no heating needed. A colour change to **blue-black** indicates the presence of starch.
- **Biuret test (protein):** add sodium hydroxide solution, then add a few drops of dilute copper sulfate solution, and mix (no heating needed). A colour change from blue to **purple/lilac** indicates the presence of protein (specifically, of peptide bonds).
- **Ethanol emulsion test (lipids):** shake the food sample with ethanol, then pour the ethanol layer into water. A **cloudy white emulsion** forming in the water indicates the presence of lipid (fat/oil).

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốn phép thử thức ăn và kết quả dương tính cần nhớ chính xác: **Benedict** (đường khử) — đun nóng, chuyển từ xanh dương → lục → vàng → **tủa đỏ gạch**; **Iodine** (tinh bột) — KHÔNG cần đun, chuyển từ nâu cam sang **xanh đen**; **Biuret** (protein) — thêm NaOH rồi vài giọt CuSO4 loãng, KHÔNG đun, chuyển sang **tím/hoa cà**; **Ethanol** (lipid/chất béo) — lắc với ethanol rồi đổ vào nước, tạo **nhũ tương trắng đục**. Lỗi thường gặp: nhầm màu tủa Benedict (đỏ gạch) với màu Biuret (tím) hoặc nhầm việc Benedict cần đun còn Biuret và Iodine không cần đun.

Ví dụ mẫu · Interpreting an unknown food sample

A student tests an unknown food sample and records the following results: Benedict's test — remains blue (no colour change) after heating; iodine test — turns blue-black; Biuret test — remains blue (no colour change); ethanol emulsion test — no cloudy white layer forms. Identify which of the four biological molecules (reducing sugar, starch, protein, lipid) are present or absent in the sample, and justify each conclusion.

Reducing sugar: absent. Benedict's solution remained blue, which is a negative result — a positive result would show a colour change through green/yellow to a brick-red precipitate.
Starch: present. The iodine solution changed to blue-black, the defining positive result for starch.
Protein: absent. The Biuret reagent remained blue rather than turning purple/lilac, so no protein (no peptide bonds) is present.
Lipid: absent. No cloudy white emulsion formed when the ethanol layer was added to water, so no lipid is present.

Conclusion: the sample contains starch only, among the four substances tested (for example, this pattern of results would be consistent with a sample of plain boiled rice or potato).

4.3 Enzymes

What is an enzyme?

An **enzyme** is a biological catalyst — a protein that speeds up the rate of a specific biochemical reaction without itself being used up or permanently changed by the reaction, by **lowering the activation energy** needed for the reaction to proceed. Because enzymes are not consumed, a single enzyme molecule can catalyse many reactions repeatedly.

4.3.1 The active site and the lock-and-key model

Every enzyme has a specifically shaped region called the **active site**, into which only a substrate molecule of a complementary shape can fit. The **lock-and-key model** describes this: the enzyme (the "lock") has an active site shaped to fit only one specific substrate (the "key"); the substrate binds to form an enzyme–substrate complex, the reaction occurs, and the products (now a different shape) are released, freeing the active site to bind another substrate molecule. This explains **enzyme specificity** — why a given enzyme will only catalyse one particular reaction (or a very narrow range of reactions), since only a substrate of the correct complementary shape can bind to a given active site.

VN **GIẢI THÍCH TIẾNG VIỆT**

Enzyme là chất xúc tác sinh học — một loại protein giúp tăng tốc độ phản ứng hoá học đặc hiệu mà bản thân enzyme không bị biến đổi hay tiêu hao, bằng cách **giảm năng lượng hoạt hoá** cần thiết. **Mô hình ổ khoá – chìa khoá (lock-and-key)**: enzyme (ổ khoá) có **trung tâm hoạt động (active site)** với hình dạng khớp CHÍNH XÁC với một loại cơ chất (substrate, chiếc chìa khoá) duy nhất; cơ chất gắn vào tạo phức hợp enzyme-cơ chất, phản ứng xảy ra, sản phẩm (hình dạng khác) được giải phóng, trung tâm hoạt động trống trở lại để tiếp tục xúc tác. Đây là lý do enzyme có tính **đặc hiệu** rất cao — chỉ xúc tác cho một (hoặc rất ít) loại phản ứng.

4.3.2 (Supplement) The induced-fit model

The **induced-fit model** refines the lock-and-key idea: rather than the active site being a perfectly rigid, pre-formed shape, the active site is somewhat flexible and **changes shape slightly** as the substrate binds, moulding itself more closely around the substrate to form a tighter, more precise fit. This induced change in shape can also help to strain particular bonds in the substrate, making the reaction proceed more readily. The induced-fit model still explains specificity (only a substrate of a broadly appropriate initial shape can trigger and benefit from this induced fit), while better accounting for the slight flexibility observed in real enzyme active sites.

VN **GIẢI THÍCH TIẾNG VIỆT**

Mô hình khớp cảm ứng (induced fit — Supplement) bổ sung cho mô hình ổ khoá-chìa khoá: thay vì trung tâm hoạt động có hình dạng cố định hoàn toàn, nó có tính **linh hoạt nhẹ** và **thay đổi hình dạng một chút** khi cơ chất gắn vào, giúp ôm khít cơ chất hơn và có thể làm căng một số liên kết trong cơ chất, hỗ trợ phản ứng xảy ra dễ dàng hơn. Mô hình này vẫn giải thích được tính đặc hiệu của enzyme, nhưng phản ánh chính xác hơn thực tế là trung tâm hoạt động không hoàn toàn cứng nhắc.

4.3.3 Factors affecting enzyme activity

[Temperature] As temperature rises (from a low starting point), enzyme and substrate molecules gain more **kinetic energy** and move and collide more often and more energetically, so the rate of reaction **increases** up to an **optimum temperature** (around 37°C for most human enzymes). Beyond the optimum, the rate falls **sharply**: excess thermal energy breaks the weak bonds (such as hydrogen bonds) that hold the enzyme's three-dimensional tertiary structure in place, causing the active site to change shape (**denaturation**). Once denatured, the substrate can no longer bind to the altered active site, and the enzyme permanently and irreversibly loses its function.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ảnh hưởng của **nhiệt độ**: khi nhiệt độ tăng, các phân tử có nhiều động năng hơn, va chạm nhiều và mạnh hơn, nên tốc độ phản ứng **tăng** đến **nhiệt độ tối ưu** (thường khoảng 37°C ở người). Vượt quá nhiệt độ này, tốc độ **giảm mạnh** vì nhiệt năng dư thừa phá vỡ các liên kết yếu (như liên kết hydro) giữ cấu trúc bậc ba của enzyme, làm trung tâm hoạt động biến dạng — gọi là **biến tính (denaturation)**. Enzyme biến tính sẽ mất chức năng **vĩnh viễn** vì cơ chất không còn khớp được với trung tâm hoạt động đã đổi hình dạng.

(!) Lỗi thường gặp: Nhiều học sinh nghĩ nhiệt độ THẤP cũng làm enzyme "biến tính" — điều này SAI. Nhiệt độ thấp chỉ làm **giảm động năng** của phân tử, khiến enzyme và cơ chất va chạm ít hơn nên phản ứng **chậm lại**, nhưng cấu trúc enzyme vẫn nguyên vẹn. Nếu tăng nhiệt độ trở lại mức phù hợp, enzyme sẽ hoạt động bình thường trở lại. Ngược lại, biến tính do nhiệt độ CAO (hoặc pH cực đoan) là **không thể đảo ngược (irreversible)**.

[pH] Each enzyme has an **optimum pH** at which its rate of reaction is fastest (e.g. pepsin in the stomach has an optimum pH around 2, strongly acidic; most enzymes in the small intestine, such as amylase, have an optimum pH close to neutral or slightly alkaline). Moving away from the optimum pH in either direction (more acidic or more alkaline) slows the reaction; at extremes of pH, the enzyme becomes **denatured** — excess H^+ or OH^- ions disrupt the ionic and hydrogen bonds maintaining the enzyme's tertiary structure, permanently changing the shape of the active site.

VN **GIẢI THÍCH TIẾNG VIỆT**

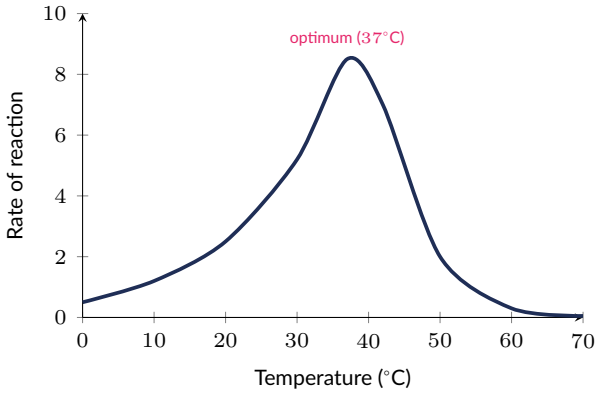
Mỗi enzyme có một **pH tối ưu** riêng (ví dụ pepsin trong dạ dày hoạt động tốt nhất ở pH ≈ 2 — rất acid; amylase ở ruột non hoạt động tốt ở pH gần trung tính). Lệch khỏi pH tối ưu (dù theo chiều acid hơn hay base hơn) đều làm chậm phản ứng; ở pH cực đoan, enzyme bị **biến tính** do ion H^+ hoặc OH^- dư thừa phá vỡ liên kết ion và liên kết hydro giữ cấu trúc bậc ba, làm biến dạng vĩnh viễn trung tâm hoạt động — tương tự cơ chế biến tính do nhiệt độ cao.

[Substrate concentration] At a fixed enzyme concentration, increasing substrate concentration (starting from a low level) **increases** the rate of reaction, because more substrate molecules are available to collide with and bind to the (currently under-used) active sites. However, once substrate concentration is high enough, essentially **all** the enzyme's active sites are continuously occupied (saturated); adding still more substrate can no longer increase the rate further, since the enzyme concentration itself (the number of active sites available) becomes the limiting factor. The rate therefore rises and then **plateaus** (levels off) at a maximum rate.

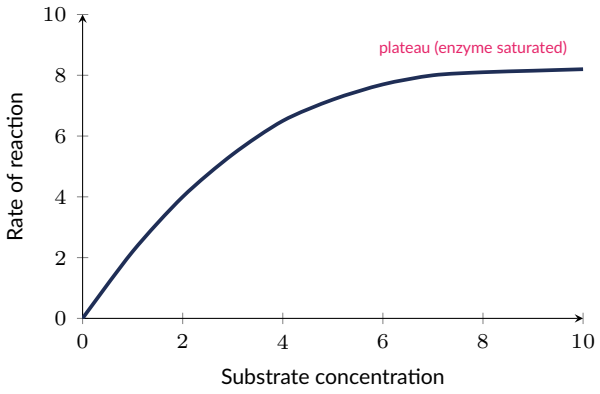
GIẢI THÍCH TIẾNG VIỆT

VN

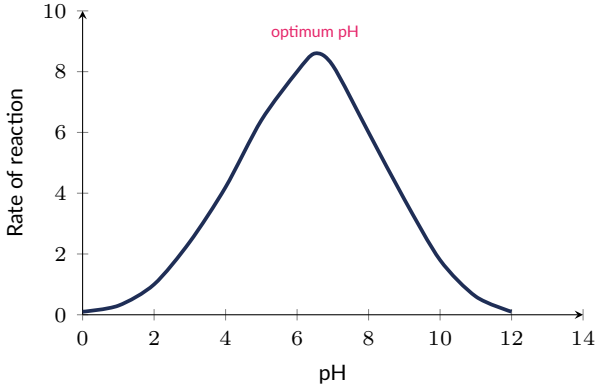
Ảnh hưởng của **nồng độ cơ chất** (khi giữ nguyên nồng độ enzyme): tăng nồng độ cơ chất ban đầu làm tốc độ phản ứng **tăng** vì có nhiều cơ chất va chạm và gắn vào các trung tâm hoạt động còn trống. Tuy nhiên khi nồng độ cơ chất đủ cao, TẤT CẢ trung tâm hoạt động của enzyme đã bị chiếm dụng liên tục (bão hoà) — lúc này thêm cơ chất không làm tăng tốc độ được nữa vì **số lượng enzyme** (số trung tâm hoạt động) mới là yếu tố giới hạn. Do đó đồ thị tốc độ phản ứng theo nồng độ cơ chất có dạng tăng rồi **đi ngang (plateau)**.



Rate of enzyme reaction against temperature: rate rises to an optimum around 37°C, then falls sharply as denaturation occurs above the optimum.



Rate of enzyme reaction against substrate concentration (enzyme concentration fixed): rate rises steeply at first, then levels off to a plateau once all active sites are continuously occupied.



Rate of enzyme reaction against pH: a bell-shaped curve peaking at the enzyme's optimum pH, falling away (denaturation) at more acidic or more alkaline pH values.

Ví dụ mẫu · Calculating rate from time — the amylase–iodine reaction

A student mixes starch solution with amylase at three different temperatures and uses a drop of iodine solution, tested every 30 seconds, to check when starch is fully broken down (the iodine test turns from blue-black to orange-brown/no colour change, indicating all starch has been digested). The times taken are: $20°$C — 240 s; $37°$C — 60 s; $50°$C — 600 s (enzyme has begun to denature). Calculate the rate of reaction at each temperature (rate $= 1/$time) and describe the overall trend.

Rate at $20°$C $= \dfrac{1}{240} = 0.0042\ \text{s}^{-1}$ Rate at $37°$C $= \dfrac{1}{60} = 0.0167\ \text{s}^{-1}$ Rate at $50°$C $= \dfrac{1}{600} = 0.0017\ \text{s}^{-1}$

Trend: the rate increases substantially from $20°$C to $37°$C (roughly a $4\times$ increase), consistent with rising kinetic energy speeding up enzyme–substrate collisions as temperature approaches the optimum. Between $37°$C and $50°$C, the rate falls sharply, to below even the $20°$C value, because amylase begins to denature above its optimum temperature — the enzyme's active site loses its shape, so far fewer functional enzyme molecules remain to catalyse the reaction, despite the higher temperature.

Ví dụ mẫu · Comparing rates across a full temperature range

Using the following data for the same amylase-iodine experiment, calculate the rate of reaction at each temperature and identify the approximate optimum temperature.

Temperature (°C)	Time for starch to disappear (s)	Rate ($1/$time, s^{-1})
10	480	?
25	150	?
40	45	?
55	300	?

Calculating each rate:

$10°$C : $\dfrac{1}{480} = 0.0021$ $25°$C : $\dfrac{1}{150} = 0.0067$ $40°$C : $\dfrac{1}{45} = 0.0222$ $55°$C : $\dfrac{1}{300} = 0.0033\ (\text{s}^{-1})$

The rate rises steadily from $10°$C to $40°$C (the highest rate recorded, 0.0222 s^{-1}), then falls sharply at $55°$C. The approximate optimum temperature therefore lies close to $40°$C, consistent with the expected optimum around human body temperature ($37°$C); above this, the sharp drop in rate at $55°$C indicates that denaturation has begun.

4.4 Practice Bank

Bài tập luyện tập

Explain why increasing the temperature beyond an enzyme's optimum causes a sharp decrease in the rate of reaction, rather than the rate simply staying constant.

Lời giải chi tiết

Beyond the optimum temperature, the excess thermal energy is enough to break the weak bonds (such as hydrogen bonds) that hold the enzyme's tertiary structure — and therefore the precise shape of its active site — in place. This causes the enzyme to become **denatured**: its

active site changes shape irreversibly, so the substrate can no longer bind to it. Since more and more enzyme molecules become denatured as temperature rises further above the optimum, the number of functional enzyme molecules able to catalyse the reaction falls rapidly, causing a sharp decrease (rather than a plateau) in the overall rate of reaction.

Bài tập luyện tập

A food sample gives a purple/lilac colour with Biuret reagent and a blue-black colour with iodine solution. What does this sample contain?

(A) Starch only
(B) Protein only
(C) Both starch and protein
(D) Neither starch nor protein

Lời giải chi tiết

Answer: (C) Both starch and protein. A purple/lilac colour with Biuret reagent is the positive result for protein, and a blue-black colour with iodine solution is the positive result for starch. Since both positive results are reported, the sample must contain both substances.

Bài tập luyện tập

Explain why increasing substrate concentration eventually stops increasing the rate of an enzyme-catalysed reaction, even though enzyme concentration remains constant.

Lời giải chi tiết

At low substrate concentrations, many of the enzyme's active sites are unoccupied at any given moment, so adding more substrate gives more opportunities for substrate to collide with and bind to a free active site, increasing the rate. However, once substrate concentration is high enough, all of the (fixed number of) active sites are continuously occupied — the enzyme is **saturated**. Beyond this point, the rate is limited by how quickly each occupied active site can process its substrate and release the product, not by the amount of substrate available, so adding more substrate has no further effect and the rate reaches a plateau.

Bài tập luyện tập

Match each food test with its correct positive-result colour change: (i) Benedict's test, (ii) iodine test, (iii) Biuret test, (iv) ethanol emulsion test. Colour options: blue-black; brick-red precipitate; purple/lilac; cloudy white emulsion.

Lời giải chi tiết

(i) Benedict's test → **brick-red precipitate** (positive for reducing sugar, after heating). (ii) Iodine test → **blue-black** (positive for starch, no heating needed). (iii) Biuret test → **purple/lilac** (positive for protein, using NaOH then dilute copper sulfate, no heating). (iv) Ethanol emulsion test → **cloudy white emulsion** (positive for lipid).

Bài tập luyện tập

Describe, step by step, the correct procedure for carrying out the Biuret test on a liquid food sample.

Lời giải chi tiết

(1) Place a sample of the liquid food into a test tube. (2) Add an equal volume of sodium hydroxide solution and mix. (3) Add a few drops of dilute copper sulfate solution and mix gently (do NOT add excess, and do NOT heat the mixture). (4) Observe the colour: if the mixture turns **purple/lilac**, protein is present; if it remains blue, protein is absent.

Bài tập luyện tập

A student places starch solution and amylase in a water bath at 5°C for 20 minutes, and observes almost no digestion of starch has occurred. Explain why this does not mean the amylase has been permanently damaged.

Lời giải chi tiết

At 5°C, molecules (both enzyme and substrate) have very little kinetic energy, so they move slowly and collide only rarely, resulting in a very slow rate of reaction — this explains the lack of digestion observed. However, low temperature does not break the bonds that maintain the enzyme's tertiary structure (unlike high temperature), so the amylase's active site remains correctly shaped and undamaged. If the temperature were raised towards the enzyme's optimum, the amylase would resume normal, faster activity — confirming that the low temperature only slowed the reaction rather than permanently denaturing the enzyme.

Bài tập luyện tập

Explain, using the lock-and-key model, why an enzyme that digests starch (amylase) cannot also digest protein.

Lời giải chi tiết

According to the lock-and-key model, an enzyme's active site has a specific three-dimensional shape that is complementary only to the shape of its particular substrate. Amylase's active site is shaped to fit specifically the glycosidic bonds and structure of starch molecules. A protein molecule has a completely different molecular shape (built from amino acids joined by peptide bonds, not glucose units joined by glycosidic bonds), so it cannot fit into or bind with amylase's active site — this lack of a complementary shape is what makes amylase (and enzymes generally) specific to one substrate or reaction type.

Bài tập luyện tập

Starch digestion by amylase is timed at three pH values: pH 4 takes 300 s, pH 7 takes 60 s, pH 10 takes 480 s. Calculate the rate of reaction at each pH and identify the likely optimum pH region.

Lời giải chi tiết

Rate $= 1/\text{time}$: at pH 4, rate $= 1/300 = 0.0033$ s^{-1}; at pH 7, rate $= 1/60 = 0.0167$ s^{-1}; at pH 10, rate $= 1/480 = 0.0021$ s^{-1}. The fastest rate (shortest time) occurs at pH 7, with much slower rates at both pH 4 and pH 10, so the optimum pH for this amylase lies close to pH 7 (neutral) — consistent with amylase's known optimum pH range around neutral to slightly alkaline conditions.

Bài tập luyện tập

Which statement about enzymes is correct?

(A) Enzymes are used up during the reactions they catalyse

(B) Enzymes increase the activation energy required for a reaction

(C) Enzymes are proteins that act as biological catalysts and are not permanently changed by the reaction

(D) Enzymes can catalyse any reaction regardless of substrate shape

Lời giải chi tiết

Answer: (C). Enzymes are proteins that speed up reactions without being consumed or permanently altered, allowing repeated use. Option (A) is false — enzymes are not used up. Option (B) is false — enzymes **lower**, not increase, the activation energy required. Option (D) is false — enzymes are highly specific, only catalysing reactions involving a substrate that fits their active site shape.

Bài tập luyện tập

Explain, using the concept of condensation and hydrolysis, how a disaccharide such as maltose is both formed and broken down in the body.

Lời giải chi tiết

Maltose is **formed** by a **condensation reaction** between two glucose molecules: a glycosidic bond forms between them, and one water molecule is released in the process (this occurs, for example, inside a starch molecule as it is built up from many glucose units). Maltose is **broken down** (digested) by the reverse process, **hydrolysis**: the enzyme maltase adds one water molecule across the glycosidic bond, breaking it and releasing the two individual glucose molecules, which can then be absorbed and used by the body.

Bài tập luyện tập

(Supplement) Explain how the induced-fit model differs from the simple lock-and-key model of enzyme action.

Lời giải chi tiết

The lock-and-key model treats the enzyme's active site as a rigid, fixed shape that only a substrate of an exactly complementary shape can fit into, like a key fitting a lock. The induced-fit model refines this: the active site is somewhat flexible, and as the correct substrate begins to bind, the active site **changes shape slightly**, moulding around the substrate to form a closer, tighter fit. This induced change can also help strain specific bonds within the substrate, assisting the reaction to proceed. Both models explain enzyme specificity, but induced fit better reflects the flexibility observed in real enzyme active sites.

Bài tập luyện tập

A student tests four unlabelled food samples (W, X, Y, Z) and obtains the following results. Identify which biological molecule(s) each sample contains.
W: Benedict's — brick-red precipitate; iodine — stays orange-brown; Biuret — stays blue.

X: Benedict's — stays blue; iodine — stays orange-brown; Biuret — turns purple; ethanol — no emulsion.
Y: All four tests negative except the ethanol emulsion test, which shows a cloudy white emulsion.
Z: Iodine turns blue-black; all other tests negative.

Lời giải chi tiết

Sample W contains a **reducing sugar** (Benedict's positive) but no starch or protein (iodine and Biuret both negative). **Sample X** contains **protein** (Biuret positive, turning purple) but no reducing sugar, starch, or lipid. **Sample Y** contains **lipid** only (positive ethanol emulsion test, cloudy white emulsion, with all other tests negative). **Sample Z** contains **starch** only (iodine positive, blue-black, with all other tests negative).

Bài tập luyện tập

Explain why boiling a solution of an enzyme before adding it to its substrate results in no reaction occurring at all.

Lời giải chi tiết

Boiling raises the temperature far above the enzyme's optimum temperature, providing enough thermal energy to break the bonds maintaining the enzyme's precise tertiary structure. This causes the enzyme to become permanently **denatured**: the shape of its active site is irreversibly changed, so the substrate can no longer bind to it at all. Since the enzyme cannot be "un-denatured" by cooling it back down, and no functional enzyme molecules remain, no reaction occurs even if the boiled enzyme is subsequently added to fresh substrate at a suitable temperature.

Bài tập luyện tập

State the type of bond formed when three fatty acids join to a glycerol molecule to form a lipid, and state whether this reaction releases or consumes water.

Lời giải chi tiết

The bond formed is an **ester bond** (one ester bond forms between glycerol and each of the three fatty acids, so three ester bonds form in total). This is a **condensation reaction**, which **releases** water (one water molecule per ester bond formed, so three molecules of water in total for a complete lipid molecule).

Bài tập luyện tập

A rate-of-reaction graph for an enzyme plotted against pH shows a single symmetrical peak. Explain why the rate falls on **both** sides of the peak, rather than only at high pH.

Lời giải chi tiết

The peak represents the enzyme's optimum pH, at which the ionic and hydrogen bonds maintaining its tertiary structure (and hence its active site shape) are in their ideal, stable configuration for substrate binding. Moving to either a more acidic pH (excess H^+ ions) or a more

alkaline pH (excess OH^- ions) disrupts these same bonds, though in different ways at each extreme, distorting the tertiary structure and the shape of the active site in both directions away from the optimum. Since either direction of pH change disrupts the necessary bonds and reduces substrate binding, the rate of reaction falls on both sides of the optimum, producing a roughly symmetrical, bell-shaped curve.

Bài tập luyện tập

Which of the following would you expect to happen if enzyme concentration is doubled while substrate concentration is kept very high (in excess)?

(A) The rate of reaction would double

(B) The rate of reaction would stay the same, since substrate is already in excess

(C) The rate of reaction would fall to zero

(D) The rate of reaction would double only at low temperatures

Lời giải chi tiết

Answer: (A). If substrate is in excess (not limiting), then the rate of reaction is directly limited by the number of active sites available, i.e. the enzyme concentration. Doubling the enzyme concentration doubles the number of active sites available to bind substrate simultaneously, so (as long as substrate remains in excess and does not itself become limiting) the rate of reaction would also approximately double.

Bài tập luyện tập

Explain why testing an unknown solution with iodine gives useful information even though it does not require heating, whereas Benedict's test requires heating in a water bath.

Lời giải chi tiết

The iodine test relies on a direct chemical/physical interaction between iodine and the coiled structure of starch molecules, which produces the blue-black colour immediately at room temperature — no chemical reaction requiring activation energy is needed. Benedict's test, in contrast, relies on a genuine chemical (redox) reaction between the reducing sugar and the copper(II) ions in Benedict's solution, reducing them to insoluble copper(I) oxide (the brick-red precipitate); this reaction requires heating to provide enough energy to proceed at a reasonable rate, which is why a water bath is used.

Bài tập luyện tập

A student is given an amylase enzyme and asked to determine its optimum temperature experimentally. Outline a suitable method, including how the time for starch to disappear would be measured.

Lời giải chi tiết

Prepare starch solution and amylase solution, and place separate portions in water baths at a range of temperatures (e.g. 10°C, 20°C, 30°C, 40°C, 50°C, 60°C), allowing time for both solutions to reach each temperature. At each temperature, mix a fixed volume of starch solution with a fixed volume of amylase solution and start a timer. At regular intervals (e.g. every 30 seconds), remove a small drop of the mixture and combine it with a drop of iodine solution on a spotting

tile; while starch is still present, the iodine will turn blue-black. Record the time at which the iodine solution **no longer** turns blue-black (indicating all starch has been digested) for each temperature. Calculate the rate of reaction at each temperature (rate $= 1/\text{time}$) and plot rate against temperature; the temperature giving the highest calculated rate is the estimated optimum temperature.

Bài tập luyện tập

Explain why cellulose (in plant cell walls) cannot be digested by human digestive enzymes, even though both cellulose and starch are polysaccharides made of glucose units.

Lời giải chi tiết

Although cellulose and starch are both polysaccharides built from glucose monomers, the glucose units in cellulose are joined by a different type of glycosidic bond arrangement than in starch, giving cellulose a different overall molecular shape (long, straight, tightly cross-linked chains) compared with starch. Human digestive enzymes (such as amylase) have active sites shaped specifically to fit the glycosidic bonds found in starch, and this shape is not complementary to the differently-arranged bonds in cellulose. Since no active site fits, human enzymes cannot bind to or break down cellulose, which is why cellulose passes through the human digestive system largely undigested (as dietary fibre).

Bài tập luyện tập

A reaction mixture of enzyme and substrate is tested at 0°C, 37°C, and 80°C, giving times to complete a colour-change reaction of 900 s, 30 s, and no reaction (even after 30 minutes) respectively. Calculate the rates at 0°C and 37°C, and explain the result at 80°C.

Lời giải chi tiết

Rate at 0°C $= 1/900 = 0.0011$ s^{-1}. Rate at 37°C $= 1/30 = 0.033$ s^{-1} — about 30 times faster than at 0°C, reflecting greatly increased kinetic energy and collision frequency near the enzyme's optimum temperature. At 80°C, no reaction occurs at all (an effective rate of zero) because this temperature is far above the enzyme's optimum; the enzyme has become completely and irreversibly **denatured** — the bonds maintaining its tertiary structure have broken, permanently altering the active site's shape so that no substrate can bind, however long the reaction mixture is left.

Bài tập luyện tập

Give one similarity and one difference between the formation of a peptide bond (in proteins) and a glycosidic bond (in carbohydrates).

Lời giải chi tiết

Similarity: both bonds are formed by a **condensation reaction**, in which two monomers join together and one molecule of water is released. **Difference:** a peptide bond forms specifically between the amino group of one **amino acid** and the carboxyl group of another amino acid (joining amino acid monomers into a protein chain), whereas a glycosidic bond forms specifically between two **monosaccharide** (sugar) monomers (joining them into a disaccharide or polysaccharide) — the two bonds link entirely different classes of monomer and are broken

by different specific enzymes during hydrolysis (proteases for peptide bonds; carbohydrases such as amylase or maltase for glycosidic bonds).

Plant Nutrition: Photosynthesis

Mục tiêu Unit: Viết và cân bằng phương trình quang hợp (dạng chữ và dạng ký hiệu); xác định nơi xảy ra quang hợp trong lục lạp; nêu nguồn gốc của từng nguyên liệu (CO_2, nước, ánh sáng); giải thích số phận của glucose (hô hấp, tinh bột, protein, cellulose, chất béo); phân tích các yếu tố giới hạn tốc độ quang hợp (ánh sáng, CO_2, nhiệt độ) qua đồ thị; mô tả phương pháp đếm bọt khí ở rong đuôi chó để khảo sát tốc độ quang hợp và các hạn chế của phương pháp; giải thích cấu tạo lá phù hợp với chức năng quang hợp và trao đổi khí; và nêu vai trò của magnesium, nitrate đối với dinh dưỡng thực vật.

5.1 The Photosynthesis Equation

Photosynthesis is the process by which green plants (and some other organisms) manufacture carbohydrates from raw materials using light energy, converting that light energy into chemical energy stored in the bonds of the product. In words:

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \text{glucose} + \text{oxygen}$$

and in balanced symbols:

$$6\,CO_2 + 6\,H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6\,O_2$$

Where photosynthesis happens

Photosynthesis occurs inside **chloroplasts**, organelles found mainly in the mesophyll cells of leaves. Chloroplasts contain the green pigment **chlorophyll**, which absorbs light energy (mainly red and blue light; green light is reflected, which is why leaves look green) and converts it into chemical energy. (Supplement) Two linked sets of reactions take place: a **light-dependent stage** in the internal membranes of the chloroplast, in which light energy splits water and generates energy carriers, and a **light-independent stage** in the fluid surrounding those membranes (the stroma), in which CO_2 is combined with the energy carriers from the light-dependent stage to build glucose. IGCSE does not require the biochemical detail of either stage — only that both occur inside the chloroplast and that light is required for the first stage to proceed.

VN **GIẢI THÍCH TIẾNG VIỆT**

Phương trình quang hợp cần nhớ chính xác cả dạng chữ lẫn dạng ký hiệu đã cân bằng: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$, xảy ra nhờ ánh sáng và chất diệp lục (chlorophyll) — ánh sáng và chlorophyll được viết phía trên/dưới mũi tên vì đó là **điều kiện phản ứng**, không phải chất tham gia hay sản phẩm. Lỗi rất hay gặp: học sinh liệt kê chlorophyll như một chất phản ứng (reactant) trong phương trình — **sai**, chlorophyll chỉ là chất xúc tác hấp thụ ánh sáng, không bị tiêu hao. Quang hợp diễn ra trong **lục lạp** (chloroplast), chủ yếu ở tế bào mô giậu và mô xốp của lá.

Checking that the symbol equation balances

Verify that $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ is correctly balanced by counting atoms of each element on both sides.

Left-hand side: $6CO_2$ gives 6 C and 12 O; $6H_2O$ gives 12 H and 6 O. Totals: C $= 6$, H $= 12$, O $= 12 + 6 = 18$.
Right-hand side: $C_6H_{12}O_6$ gives 6 C, 12 H, 6 O; $6O_2$ gives 12 O. Totals: C $= 6$, H $= 12$, O $= 6 + 12 = 18$.
Both sides have C $= 6$, H $= 12$, O $= 18$ — the equation is balanced. This atom-counting check is a fast way to confirm you have copied a photosynthesis equation correctly in an examination.

5.1.1 Photosynthesis versus respiration: a useful comparison

Photosynthesis and (aerobic) respiration are often compared because their overall word equations are, in effect, the reverse of one another — but they are not simply "the same reaction backwards": they occur in different organelles, under different conditions, and (in green plants) both happen simultaneously.

Feature	Photosynthesis	Aerobic respiration
Overall equation	$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
Energy change	Light energy is **absorbed** and converted into chemical energy stored in glucose	Chemical energy stored in glucose is **released** (as ATP, then usable energy)
Site in the cell	Chloroplasts only	Mitochondria (and cytoplasm), in *every* living cell
When it occurs	Only in light, in cells containing chlorophyll	Continuously, day and night, in all living cells
Occurs in which organisms	Green plants, algae, some bacteria	All living organisms

VN **GIẢI THÍCH TIẾNG VIỆT**

Quang hợp và hô hấp hiếu khí có phương trình gần như ngược nhau, nhưng **không phải là một phản ứng đảo chiều đơn giản**: quang hợp chỉ xảy ra ở tế bào có lục lạp và cần ánh sáng, trong khi hô hấp xảy ra ở **mọi** tế bào sống, **liên tục** cả ngày lẫn đêm, tại ti thể (mitochondria). Lỗi hay gặp: cho rằng ban đêm cây "chỉ hô hấp, không quang hợp" — điều này đúng, nhưng cần nói rõ thêm rằng **ban ngày cây thực hiện đồng thời cả hai quá trình**, và tốc độ quang hợp ban ngày thường lớn hơn nhiều so với tốc độ hô hấp, nên cây vẫn hấp thụ ròng CO_2 vào ban ngày dù đồng thời tạo ra CO_2 từ hô hấp.

5.2 Raw Materials for Photosynthesis

Each raw material used in photosynthesis has a distinct route into the leaf cell.

- **Carbon dioxide** diffuses from the atmosphere into the leaf through tiny pores called **stomata** (singular: stoma) on the leaf surface, then diffuses between spongy mesophyll cells (through the air spaces) and into palisade cells, where it dissolves and is used in the chloroplast. Diffusion occurs because respiration inside the cell keeps using up CO_2 for photosynthesis, maintaining a concentration gradient from the atmosphere (high CO_2) to inside the leaf (lower CO_2).

- **Water** is absorbed by root hair cells from the soil and transported upward through the **xylem** vessels of the root, stem and leaf veins, eventually reaching mesophyll cells by osmosis.
- **Light** is absorbed by chlorophyll molecules packed into the internal membranes of chloroplasts. Without light, the light-dependent stage cannot proceed and glucose synthesis stops (though the plant continues to respire).

VN **GIẢI THÍCH TIẾNG VIỆT**

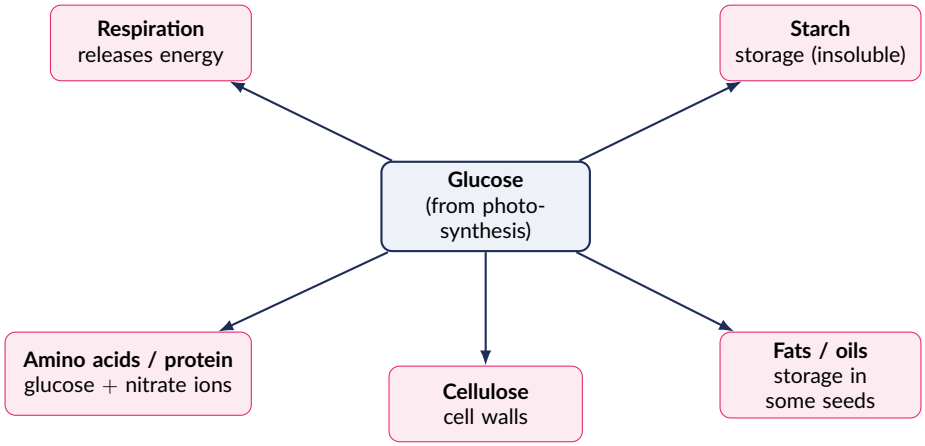
Ba nguyên liệu của quang hợp đến từ ba nguồn khác nhau, cần phân biệt rõ khi trả lời câu hỏi: CO_2 khuếch tán từ không khí qua **khí khổng** (stomata); nước được hấp thụ ở rễ và vận chuyển lên lá qua **mạch gỗ** (xylem); ánh sáng được hấp thụ bởi **chất diệp lục** trong lục lạp. Một câu hỏi thường gặp là "nêu con đường của CO_2 từ không khí đến lục lạp" — câu trả lời đầy đủ phải nêu: khuếch tán qua khí khổng → qua khoảng gian bào ở mô xốp → vào tế bào mô giậu → hoà tan và đi vào lục lạp.

5.3 The Fate of Glucose

Glucose produced by photosynthesis is rarely stored as glucose itself. Instead it is converted into other compounds or used immediately, following several possible pathways.

What happens to the glucose made in photosynthesis

- **Respiration:** much of the glucose is immediately broken down in respiration to release energy (ATP) for the plant's own life processes (active transport, cell division, protein synthesis).
- **Converted to starch for storage:** glucose molecules are joined together into long, insoluble starch chains, stored in organelles such as amyloplasts in roots, stems and seeds. Starch is used as the storage carbohydrate rather than glucose because starch is **insoluble** in water, so it does not dissolve out of storage cells and, critically, does not lower the water potential of the cell (an accumulation of soluble glucose would draw water in by osmosis and could cause the cell to swell or burst); starch is also more compact than an equivalent mass of dissolved glucose.
- **Converted to amino acids, then protein:** glucose is combined with **nitrate ions** (absorbed from the soil by root hair cells via **active transport**, against the concentration gradient, using energy from respiration) to build amino acids, which are then joined into proteins for growth and repair.
- **Converted to cellulose:** glucose molecules are linked to form cellulose, used to build new **cell walls** as the plant grows.
- **Converted to fats/oils:** in some plants, especially oil-storing seeds (e.g. sunflower, groundnut, rapeseed), glucose is converted into fats and oils as a compact, energy-dense storage form.



The five main fates of glucose produced by photosynthesis.

VN **GIẢI THÍCH TIẾNG VIỆT**

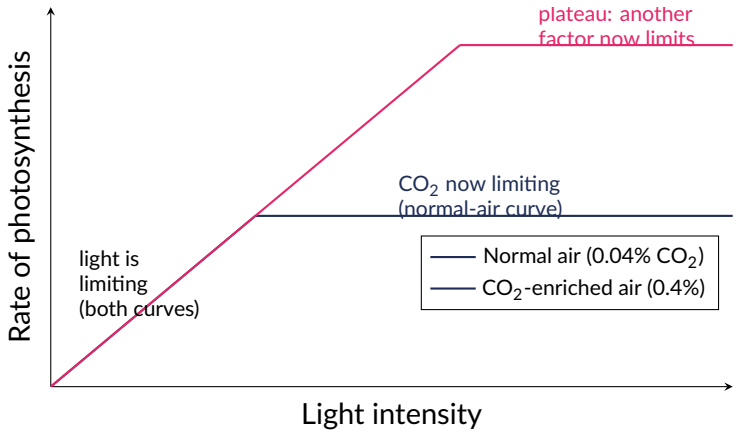
Cần phân biệt rõ vai trò của từng con đường: **hô hấp** tiêu thụ glucose để giải phóng năng lượng; **tinh bột** là dạng dự trữ (không hoà tan, không ảnh hưởng áp suất thẩm thấu); **protein** cần thêm **nitrate** (hấp thụ chủ động ở rễ) chứ không chỉ từ glucose; **cellulose** dùng làm vách tế bào (không phải màng tế bào); **chất béo/dầu** là dạng dự trữ năng lượng cô đặc ở một số hạt. Lỗi thường gặp: nói tinh bột được "hấp thụ chủ động" giống nitrate — sai, tinh bột là sản phẩm được **tổng hợp** trong tế bào lá/rễ, không phải chất được hấp thụ từ đất.

(!) Lỗi thường gặp: Đừng nhầm giữa **nguyên liệu** của quang hợp (CO_2, nước, ánh sáng) với **sản phẩm** (glucose, oxygen) và với **số phận sau đó** của sản phẩm (tinh bột, protein, cellulose, chất béo). Ba nhóm này thường bị trộn lẫn trong bài làm của học sinh khi trả lời câu hỏi "quang hợp cần gì" hay "glucose đi về đâu".

5.4 Limiting Factors of Photosynthesis

The rate of photosynthesis is controlled by three environmental factors: **light intensity**, **carbon dioxide concentration**, and **temperature**. At any given moment, one of these is in shortest supply relative to what the plant could otherwise use, and it is this factor — the **limiting factor** — that sets the rate. Increasing a limiting factor increases the rate of photosynthesis; increasing any other (non-limiting) factor has no effect until it, in turn, becomes the limiting factor.

Limiting factor principle: the rate of a process that depends on several factors is limited by whichever factor is nearest its minimum, not by the factors that are in ample supply. On a rate-versus-light-intensity graph, a rising straight-line section means light intensity is limiting; a flat (plateau) section means light intensity is *not* limiting there — something else (CO_2 concentration or temperature) has become the limiting factor.

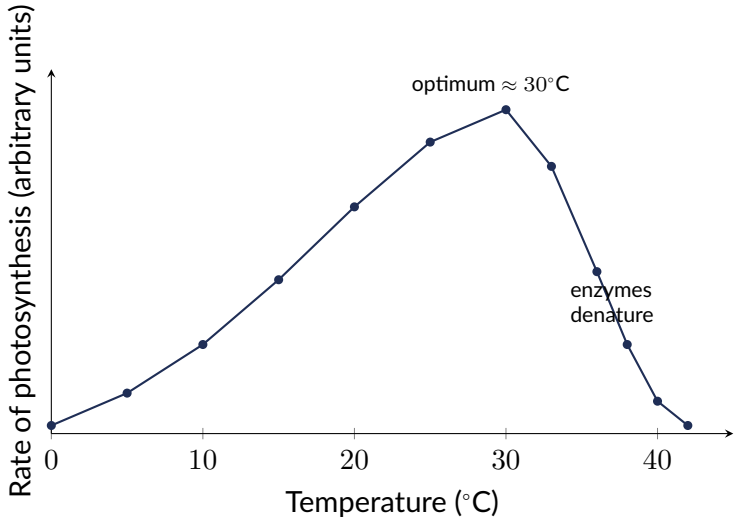


Rate of photosynthesis versus light intensity at two CO_2 concentrations. The two curves overlap while light intensity is limiting; the normal-air curve plateaus earlier because CO_2 becomes limiting there, while the enriched-CO_2 curve continues rising until it plateaus at a higher light intensity.

Greenhouse CO_2 enrichment

A grower keeps tomato plants in a greenhouse under increasing light intensity and measures the rate of photosynthesis, first in normal air (0.04% CO_2) and then after injecting extra CO_2 (0.4%), keeping temperature constant throughout. The graph above shows the results: in normal air the rate plateaus at a lower light intensity than in CO_2-enriched air. Explain why enriching the air with CO_2 raises the plateau.

At low light intensity, both curves rise together and overlap: light intensity is the limiting factor in both cases, because there is more than enough CO_2 available for the (still slow) rate of photosynthesis at low light. As light intensity increases and the rate of photosynthesis increases, the plant's demand for CO_2 increases. In normal air, the limited supply of CO_2 (0.04%) cannot keep up with this demand beyond a certain point, so CO_2 becomes the new limiting factor and the rate plateaus even though light keeps increasing. Providing extra CO_2 removes this restriction, so the rate can keep rising with light intensity for longer, plateauing at a higher rate before some other factor (e.g. temperature, or the plant's own enzyme/chlorophyll capacity) eventually limits it instead. This is exactly why commercial greenhouses inject CO_2 to increase crop yield.



Rate of photosynthesis versus temperature at constant light intensity and CO_2 concentration. The rate rises with

temperature (enzyme activity in the light-independent stage speeds up) up to an optimum, then falls sharply as enzymes begin to denature.

Temperature as a limiting factor

Explain the shape of the rate-versus-temperature graph above, in particular why the rate rises up to about 30°C but then falls sharply above that, rather than levelling off as it does for light intensity or CO_2.

Below the optimum, higher temperature gives molecules more kinetic energy, so enzyme-catalysed reactions in the light-independent stage of photosynthesis proceed faster — more successful enzyme-substrate collisions per second — so the rate of photosynthesis increases with temperature, as it would for any enzyme-controlled process. Unlike light intensity or CO_2 concentration, however, temperature does not simply plateau when it stops being limiting: above roughly 30–35°C (depending on species) the enzymes controlling the light-independent stage begin to **denature** — their tertiary structure, including the shape of the active site, is disrupted by excess heat energy, so substrate can no longer bind efficiently. The rate therefore falls sharply rather than staying flat, because the enzymes themselves are being permanently damaged, not merely running at their maximum unassisted rate.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ba yếu tố giới hạn quang hợp có **cách đọc đồ thị** khác nhau: đồ thị theo **cường độ ánh sáng** hoặc theo **nồng độ** CO_2 có dạng đường thẳng đi lên rồi **nằm ngang** (plateau) — đoạn nằm ngang nghĩa là yếu tố đang xét không còn là yếu tố giới hạn nữa, một yếu tố khác đã trở thành giới hạn. Ngược lại, đồ thị theo **nhiệt độ** có dạng hình chuông: tăng lên đến nhiệt độ tối ưu rồi **giảm mạnh** (không nằm ngang) vì enzyme bị biến tính (denature) ở nhiệt độ cao — đây là khác biệt quan trọng học sinh hay quên khi mô tả đồ thị nhiệt độ giống hệt đồ thị ánh sáng/CO_2.

(!) Lỗi thường gặp: Không được nói "nhiệt độ giới hạn quang hợp giống hệt ánh sáng và CO_2" — ánh sáng/CO_2 tăng thì tốc độ tăng dần rồi **đi ngang** (không giảm); còn nhiệt độ tăng quá cao thì tốc độ **giảm hẳn** do enzyme biến tính, chứ không chỉ đi ngang.

5.5 Investigating the Rate of Photosynthesis

A common practical method estimates the rate of photosynthesis in an aquatic plant such as *Cabomba* or *Elodea* (pondweed) by counting the **oxygen bubbles** released from a freshly cut stem underwater over a fixed time, or by collecting the gas in a capillary tube/syringe and measuring its volume. Light intensity can be varied by changing the distance between the pondweed and a lamp; CO_2 concentration can be varied by adding sodium hydrogencarbonate solution (a source of dissolved CO_2) to the water; temperature can be controlled with a water bath.

Limitations of the bubble-counting method

- Bubbles vary in **size**, so counting the number of bubbles per minute is not a reliable measure of the *volume* of gas released unless bubble size is also controlled for (e.g. by collecting gas in a syringe and reading off a volume instead of counting bubbles).
- The gas collected is not pure oxygen — it also contains dissolved gases (including some CO_2 and nitrogen) that diffuse out of the water, so bubble volume overestimates true oxygen output.
- Bubbles can stick to the cut stem or to the sides of the apparatus rather than being released steadily, causing uneven or missed counts.

- Moving the lamp closer changes light intensity according to the **inverse square law** (intensity $\propto 1/\text{distance}^2$), not in direct proportion to distance, so equal changes in distance do not give equal changes in light intensity — and the lamp itself may warm the water, introducing temperature as an uncontrolled variable.

Despite these limitations, the method remains useful because it is simple, requires only basic apparatus, and gives a repeatable relative measure of how rate changes with one variable at a time, provided all other variables are kept constant.

Calculating the rate of oxygen release from bubble counts

A student counts bubbles released from a cut stem of pondweed and, using a microscope eyepiece graticule, estimates each bubble to be a sphere of diameter 2 mm (radius 1 mm $= 0.1$ cm). In 3 minutes, 54 bubbles are released. Calculate (a) the volume of one bubble, (b) the total volume of gas released, and (c) the rate of gas release in cm^3 per minute.

(a) Volume of a sphere $= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(0.1)^3 = \frac{4}{3}\pi(0.001) = 0.00419$ cm^3 (3 s.f.).

(b) Total volume $= 54 \times 0.00419 = 0.226$ cm^3 (3 s.f.).

(c) Rate $= \frac{0.226}{3} = 0.0754$ cm^3 min^{-1} (3 s.f.).

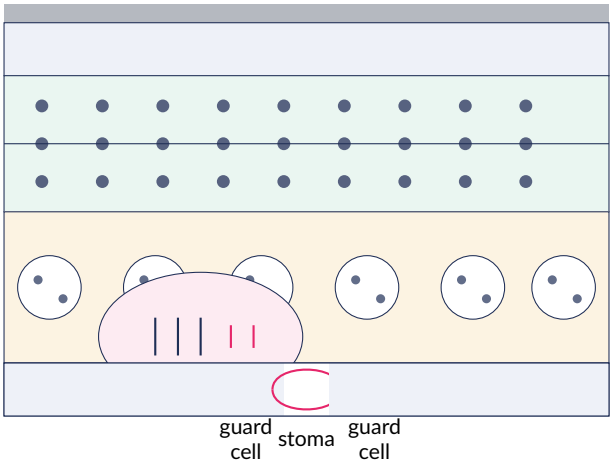
This calculation shows precisely why raw bubble counts are unreliable on their own: the answer depends entirely on the assumed bubble diameter, which in a real experiment varies from bubble to bubble — a strong argument for measuring collected gas volume directly with a syringe or capillary tube rather than counting bubbles.

VN **GIẢI THÍCH TIẾNG VIỆT**

Phương pháp đếm bọt khí từ rong đuôi chó (*Elodea*/*Cabomba*) là cách gián tiếp để ước lượng tốc độ quang hợp thông qua tốc độ giải phóng oxygen. Cần nhớ **ba biến số** có thể thay đổi: cường độ ánh sáng (di chuyển đèn), nồng độ CO_2 (thêm dung dịch sodium hydrogencarbonate), nhiệt độ (dùng bể ổn nhiệt) — và mỗi lần chỉ nên thay đổi **một biến**, giữ nguyên các biến còn lại (biến kiểm soát). Hạn chế cần nêu khi được hỏi: kích thước bọt khí không đều, khí thu được không phải oxygen tinh khiết, khoảng cách đèn không tỉ lệ thuận với cường độ sáng (theo định luật nghịch đảo bình phương).

5.6 Leaf Structure and Adaptations for Photosynthesis

The internal structure of a typical dicotyledonous leaf is closely adapted to maximise light absorption, gas exchange, and water/mineral supply while minimising water loss.



Cuticle — waxy, waterproof, reduces water loss; transparent

Upper epidermis — single layer, transparent, no chloroplasts

Palisade mesophyll — tall, closely packed cells; most chloroplasts here, near the top, to absorb maximum light

Spongy mesophyll — loosely packed, irregular cells with large air spaces

Vascular bundle (CO_2, O_2) — xylem brings water/minerals in; phloem carries sugars away; gives support

Lower epidermis — contains most of the stomata

Transverse section through a dicotyledonous leaf, showing tissues adapted for photosynthesis and gas exchange.

Why each leaf feature helps photosynthesis:

- Leaves are broad and thin, giving a **large surface area** for light absorption and a **short diffusion distance** for gases.
- The **cuticle** and **upper epidermis** are transparent, letting light pass through to the mesophyll with minimal absorption/reflection loss, while the cuticle reduces water loss by evaporation.
- **Palisade mesophyll** cells are elongated and packed near the upper surface, with most of the leaf's chloroplasts, so they intercept the most light.
- **Spongy mesophyll** has large, interconnected air spaces, giving a large internal surface area for gas exchange and allowing CO_2 and O_2 to diffuse rapidly between the atmosphere (via stomata) and mesophyll cells.
- **Guard cells and stomata** regulate gas exchange (CO_2 in, O_2 out) and control water loss; most stomata are on the **lower** epidermis (shaded, cooler, less direct sun) to minimise water loss by evaporation while still allowing gas exchange.
- **Vascular bundles** (xylem and phloem) deliver water and mineral ions to the mesophyll and remove the sugars produced, while also giving the leaf mechanical support.

How guard cells open and close a stoma

Guard cells are kidney-shaped and have an uneven cell wall — thicker on the side next to the pore, thinner on the outer side. When water enters the guard cells by osmosis, they become **turgid**; because the inner wall stretches less than the outer wall, the guard cells bow outward and the stoma **opens**, typically during daylight when photosynthesis needs CO_2. When the guard cells lose water and become **flaccid**, they straighten and the stoma **closes**, reducing water loss (e.g. at night, or under water stress).

GIẢI THÍCH TIẾNG VIỆT

VN

Cấu tạo lá là dạng câu hỏi "giải thích vì sao" rất hay gặp — luôn trả lời theo cặp **đặc điểm** → **lợi ích**: mô giậu có nhiều lục lạp và nằm gần mặt trên → hấp thụ nhiều ánh sáng nhất; mô xốp có khoảng gian bào lớn → tăng diện tích khuếch tán khí; khí khổng tập trung ở biểu bì dưới → giảm mất nước do bay hơi (mặt dưới ít ánh nắng trực tiếp hơn); tế bào bảo vệ (guard cells) trương nước (turgid) → khí khổng mở; mất nước (flaccid) → khí khổng đóng, do vách trong dày hơn vách ngoài nên khi trương nước tế bào cong ra ngoài.

5.7 Mineral Nutrition

Besides carbon dioxide, water and light, plants need certain mineral ions absorbed from the soil solution by root hair cells, by **active transport** (movement against a concentration gradient, requiring energy from respiration — see the cell transport unit for the underlying mechanism). Two mineral ions are specified for photosynthesis and growth:

Mineral ion	Role in the plant	Deficiency symptom
Magnesium (Mg^{2+})	Component needed to build the chlorophyll molecule	**Chlorosis** — yellowing of leaves, especially between the veins, because less chlorophyll can be made; photosynthesis and growth both slow down
Nitrate (NO_3^-)	Combined with glucose to make amino acids, then proteins, for growth	**Stunted growth** (poor protein synthesis, few new cells); older leaves may yellow as nitrogen compounds are moved to newer growth

Diagnosing a mineral deficiency

A gardener notices that the older leaves of a tomato plant are pale yellow between the veins, while the veins themselves remain green, and the plant's growth rate has not changed much. A second, unrelated plant shows generally poor, stunted growth with smaller leaves overall, but no obvious yellowing pattern between veins. Suggest, with reasons, which mineral ion is likely deficient in each case.

Plant 1 (yellowing specifically between the veins, veins green): this is the classic pattern of **chlorosis** caused by **magnesium deficiency**. Magnesium is a structural component of chlorophyll; without enough magnesium, less chlorophyll can be synthesised, so the tissue between veins (where chlorophyll would normally be concentrated) loses its green colour, while the veins — supplied more directly by the vascular tissue — often stay greener for longer.

Plant 2 (general stunted growth, no distinctive yellowing pattern): this matches **nitrate deficiency**. Without enough nitrate, the plant cannot make sufficient amino acids and protein for new cell growth, so overall growth is slow and leaves are smaller, but there is no specific chlorophyll-related colour pattern (magnesium supply is adequate, so chlorophyll production itself is not directly impaired).

VN **GIẢI THÍCH TIẾNG VIỆT**

Hai loại thiếu hụt khoáng chất hay bị nhầm lẫn: thiếu **magnesium** → **vàng lá giữa các gân** (chlorosis) vì thiếu nguyên liệu tạo diệp lục; thiếu **nitrate** → **còi cọc, chậm lớn** vì thiếu nguyên liệu tạo protein, không nhất thiết vàng lá theo kiểu giữa gân. Ghi nhớ: "thiếu Mg → vàng lá; thiếu nitrate → còi cọc." Cả hai ion đều được hấp thụ ở lông hút rễ bằng **vận chuyển chủ động** (active transport), tiêu tốn năng lượng từ hô hấp của tế bào rễ.

(!) Lỗi thường gặp: Đừng viết rằng thiếu nitrate gây vàng lá giữa gân giống hệt thiếu magnesium — hai triệu chứng khác nhau: magnesium liên quan trực tiếp đến **chlorophyll** (màu xanh lá), còn nitrate liên quan đến **protein** (tăng trưởng), nên biểu hiện chính của thiếu nitrate là **còi cọc / chậm lớn** chứ không phải một kiểu vàng lá đặc trưng.

Allocating glucose output

A sunflower plant produces 20 g of glucose in one day. Suppose 35% is used in respiration, 30% is converted to starch for storage, 20% is converted to amino acids/protein, and the remaining 15% is converted to cellulose. Calculate the mass (in grams) allocated to each pathway.

Respiration: $0.35 \times 20 = 7.0$ g.
Starch: $0.30 \times 20 = 6.0$ g.
Protein: $0.20 \times 20 = 4.0$ g.
Cellulose: $0.15 \times 20 = 3.0$ g.
Check: $7.0+6.0+4.0+3.0 = 20.0$ g, which accounts for the entire glucose output — confirming the percentages were applied correctly and consistently.

5.8 Testing a Leaf for Starch

The standard practical test for photosynthetic activity uses **iodine solution**, which turns from browny-orange to **blue-black** in the presence of starch. Before testing, a leaf must be **destarched** (kept in the dark for at least 24 hours so existing starch is used up by respiration/translocated away) and then decolourised by boiling in ethanol (to remove chlorophyll, which would otherwise mask the iodine colour change) before iodine is added.

Predicting the outcome of a starch test

A destarched plant has one leaf partly covered with black foil (so only part of the leaf receives light) and is then left in bright light for several hours. The leaf is removed, decolourised in boiling ethanol, rinsed, and flooded with iodine solution. Predict and explain the result.

The **uncovered** part of the leaf receives light, so it can photosynthesise and build up starch; iodine solution applied there will turn **blue-black**. The **covered** part is shielded from light, so no photosynthesis (and therefore no starch synthesis) occurs there even though the leaf tissue is otherwise identical; iodine solution applied there will remain its original browny-orange colour. The sharp boundary between the blue-black and orange regions, matching the shape of the foil, is used as evidence that **light is necessary for photosynthesis** (and hence for starch production).

VN **GIẢI THÍCH TIẾNG VIỆT**

Thí nghiệm thử tinh bột bằng dung dịch iodine là thí nghiệm kinh điển chứng minh ánh sáng cần thiết cho quang hợp. Các bước bắt buộc: (1) khử tinh bột sẵn có (để cây trong tối ≥ 24 giờ); (2) khử màu diệp lục (đun lá trong ethanol sôi — dùng nồi cách thủy vì ethanol dễ cháy); (3) rửa lá bằng nước nóng cho mềm; (4) nhỏ dung dịch iodine — vùng có tinh bột chuyển **xanh đen**, vùng không có tinh bột vẫn giữ màu **nâu cam**. Lỗi hay gặp: quên bước khử tinh bột ban đầu, khiến kết quả không phản ánh đúng thí nghiệm đang làm.

5.9 Practice Bank

Bài tập luyện tập

Which row correctly shows the raw materials and their sources for photosynthesis?

(A) CO_2 from stomata; water from xylem; light absorbed by chlorophyll

(B) CO_2 from xylem; water from stomata; light absorbed by nitrate

(C) O_2 from stomata; water from phloem; light absorbed by chlorophyll

(D) CO_2 from phloem; water from stomata; light absorbed by chlorophyll

Lời giải chi tiết

(A). Carbon dioxide diffuses in through stomata; water arrives via the xylem from the roots; light is absorbed by chlorophyll in chloroplasts. The other options swap sources incorrectly (xylem carries water, not CO_2; phloem carries sugars, not water in; oxygen is a product, not a raw material).

Bài tập luyện tập

Write the balanced symbol equation for photosynthesis, and state which two conditions must be written on the arrow rather than as reactants.

Lời giải chi tiết

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$. Light energy and chlorophyll are written above/below the arrow because they are conditions/catalytic requirements for the reaction, not reactants that are consumed and appear as separate terms on the left-hand side.

Bài tập luyện tập

A greenhouse grower doubles the light intensity on a crop but sees no increase in the rate of photosynthesis. Suggest two possible reasons and describe an experiment to distinguish between them.

Lời giải chi tiết

Two possible reasons: (1) CO_2 concentration is limiting, so extra light cannot be used because there is not enough CO_2 to combine with; (2) temperature is limiting (too low, so enzyme activity in the light-independent stage is slow; or too high, causing enzyme denaturation). To distinguish: repeat the light-intensity experiment while enriching the air with extra CO_2 (e.g. via sodium hydrogencarbonate solution in a pondweed experiment, or CO_2 injection in a greenhouse) but keeping temperature constant. If the rate now increases with light intensity, CO_2 was the limiting factor. If it still does not increase, repeat again while raising (or lowering) temperature instead, keeping CO_2 and light constant, to test temperature as the limiting factor.

Bài tập luyện tập

Explain why a plant kept at 2°C shows almost no photosynthesis even in bright light and with plenty of CO_2 available.

Lời giải chi tiết

At very low temperature, molecules have little kinetic energy, so enzyme-substrate collisions in the light-independent stage are rare and slow; enzyme activity (and hence the rate of glucose synthesis) is very low regardless of how much light or CO_2 is supplied. Temperature is the limiting factor here, even though light and CO_2 are both abundant.

Bài tập luyện tập

A student destarches a plant, then exposes one whole leaf to light for four hours in a CO_2-free atmosphere (created using soda lime, which absorbs CO_2), while a second, similar leaf on the same plant is exposed to light in normal air. Predict and explain the outcome of testing both leaves with iodine solution.

Lời giải chi tiết

The leaf in normal air will test positive for starch (**blue-black** with iodine), because it has CO_2, water and light available and can photosynthesise normally. The leaf in the CO_2-free atmosphere will test negative (**remains browny-orange**) because, even with light and water present, the absence of CO_2 prevents photosynthesis — CO_2 is an essential raw material, so no glucose (and hence no starch) can be made. This experiment demonstrates that CO_2 is necessary for photosynthesis.

Bài tập luyện tập

Which leaf tissue contains the greatest density of chloroplasts, and why is this an advantage?

(A) Spongy mesophyll, because its air spaces let in more light

(B) Palisade mesophyll, because it is positioned near the upper surface to intercept the most light

(C) Upper epidermis, because it is the first layer light reaches

(D) Lower epidermis, because it contains the stomata

Lời giải chi tiết

(B). Palisade mesophyll cells are elongated, tightly packed, and positioned just below the upper epidermis, containing the highest density of chloroplasts of any leaf tissue — maximising the capture of incoming light. The upper epidermis is transparent but has no chloroplasts (option C wrong); spongy mesophyll has fewer chloroplasts and its air spaces are for gas diffusion, not light capture (option A wrong); the lower epidermis mainly houses stomata and guard cells, not photosynthetic tissue (option D wrong).

Bài tập luyện tập

Explain, in terms of turgor, how a guard cell opens a stoma.

Lời giải chi tiết

Water moves into the guard cells by osmosis, making them **turgid**. Because the guard cell wall is thicker on the side facing the pore and thinner on the outer side, the outer wall stretches more than the inner wall as the cell swells, causing the pair of guard cells to bow apart and the stoma to **open**. When water is lost and the guard cells become flaccid, they return to a straighter shape and the stoma closes.

Bài tập luyện tập

Most stomata on a typical dicotyledonous leaf are found in the lower epidermis rather than the upper epidermis. Suggest why.

Lời giải chi tiết

The lower surface of the leaf is shaded and receives less direct sunlight than the upper surface, so it is cooler; placing most stomata there reduces water loss by evaporation (transpiration) while still allowing enough gas exchange for photosynthesis, since CO_2 can still diffuse through the internal air spaces of the spongy mesophyll to reach all cells. Concentrating stomata on the upper surface would expose them to more heat and direct light, increasing water loss

unnecessarily.

Bài tập luyện tập

A plant's leaves turn pale yellow between the veins, while the veins remain green; overall growth rate is roughly normal. Identify the likely mineral deficiency and explain the mechanism.

Lời giải chi tiết

This is **magnesium deficiency**. Magnesium is required to build the chlorophyll molecule; without enough magnesium, chlorophyll synthesis is reduced, so the tissue between the veins (where chlorophyll is normally concentrated) loses its green colour — a condition called **chlorosis**. The veins, supplied more directly, often remain greener for longer. Because this specifically affects chlorophyll rather than protein synthesis, overall growth rate can remain close to normal even while the leaf colour changes.

Bài tập luyện tập

A different plant shows generally stunted growth and small, pale leaves, but no distinctive between-vein yellowing pattern. Identify the likely mineral deficiency and explain the mechanism.

Lời giải chi tiết

This is **nitrate deficiency**. Nitrate ions are combined with glucose to build amino acids and then proteins, which are essential for making new cells (growth). Without enough nitrate, protein synthesis is limited, so growth is stunted and leaves are smaller; because chlorophyll synthesis (which mainly needs magnesium) is not directly affected, there is no specific between-vein chlorosis pattern, though leaves may appear generally paler as nitrogen compounds are redistributed from older to newer tissue.

Bài tập luyện tập

Explain why starch, rather than glucose, is used as the main storage carbohydrate in plants.

Lời giải chi tiết

Starch is insoluble in water, so it does not dissolve out of storage cells and does not affect the cell's water potential — a build-up of soluble glucose, by contrast, would lower the water potential inside the cell and draw water in by osmosis, risking swelling or bursting. Starch is also more compact than an equivalent mass of dissolved glucose, making it efficient for long-term storage in organs such as roots, stems and seeds.

Bài tập luyện tập

A student proposes measuring the rate of photosynthesis in pondweed simply by counting the number of bubbles released per minute. Give two limitations of this method and suggest one improvement.

Lời giải chi tiết

Limitations: (1) bubbles vary in size, so the number of bubbles does not directly correspond to a fixed volume of gas; (2) the gas released is not pure oxygen (it includes other dissolved gases), so bubble count/volume overestimates true oxygen production. **Improvement:** collect the gas in a graduated syringe or capillary tube over a fixed time and read off the actual volume produced, rather than counting bubbles, giving a quantitative and more reliable measure of gas output regardless of bubble size.

Bài tập luyện tập

In a bubble-counting experiment, a student assumes each bubble is a sphere of radius 0.15 cm. If 40 bubbles are collected in 2 minutes, calculate the rate of gas release in $\text{cm}^3\ \text{min}^{-1}$.

Lời giải chi tiết

Volume of one bubble $= \dfrac{4}{3}\pi r^3 = \dfrac{4}{3}\pi(0.15)^3 = \dfrac{4}{3}\pi(0.003375) = 0.01414\ \text{cm}^3$.
Total volume $= 40 \times 0.01414 = 0.5655\ \text{cm}^3$.
Rate $= \dfrac{0.5655}{2} = 0.283\ \text{cm}^3\ \text{min}^{-1}$ (3 s.f.).

Bài tập luyện tập

State the equation for aerobic respiration and explain how it relates to the glucose produced in photosynthesis.

Lời giải chi tiết

Aerobic respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (releasing energy). This is essentially the reverse of photosynthesis in terms of reactants and products: glucose made in photosynthesis is broken down in respiration to release the energy the plant needs for active transport, growth and other life processes, producing CO_2 and water as by-products (some of which can be reused in further photosynthesis).

Bài tập luyện tập

A hydroponics company wants to maximise tomato yield in winter, when natural light and outdoor temperature are both low. Suggest, with reasons, three interventions based on the limiting factor principle.

Lời giải chi tiết

(1) **Add artificial lighting** to raise light intensity, since low natural light in winter is likely limiting; (2) **Heat the greenhouse** to bring temperature closer to the optimum for enzyme activity in the light-independent stage (without exceeding it, which would cause denaturation and reduce the rate); (3) **Inject extra** CO_2 into the greenhouse air, since raising light and temperature alone will increase the plant's demand for CO_2, which could then become the new limiting factor. Addressing only one factor without the others would cause the rate to plateau as soon as a different factor becomes limiting.

Bài tập luyện tập

Explain why a plant grown in soil with plenty of nitrate but no light at all still cannot make protein, even though nitrate is available.

Lời giải chi tiết

Protein synthesis in plants requires amino acids, which are made by combining nitrate ions with **glucose** produced in photosynthesis. Without light, photosynthesis cannot occur, so no new glucose is made; existing glucose/starch reserves will eventually be used up by respiration. Even with abundant nitrate available, there is no glucose to combine it with, so amino acid (and hence protein) synthesis cannot continue.

Bài tập luyện tập

Which of the following is *not* a fate of glucose produced by photosynthesis?

(A) Conversion to starch for storage

(B) Breakdown in respiration to release energy

(C) Direct absorption by root hair cells from the soil

(D) Conversion to cellulose for cell walls

Lời giải chi tiết

(C). Root hair cells absorb water and mineral ions (such as nitrate) from the soil — they do not absorb glucose from the soil. Glucose is made inside the plant by photosynthesis and is then used in respiration, converted to starch, cellulose, protein (with nitrate), or fats/oils, as appropriate.

Bài tập luyện tập

A leaf section is examined under a microscope. Layer X, just below the upper epidermis, contains tall, closely packed cells full of chloroplasts. Layer Y, below layer X, contains loosely arranged cells with large air spaces between them. Identify X and Y and state one function of each.

Lời giải chi tiết

X is the **palisade mesophyll**: its tall, closely packed cells contain most of the leaf's chloroplasts, maximising light absorption for photosynthesis. Y is the **spongy mesophyll**: its large air spaces provide a large surface area for gas exchange, allowing CO_2 to diffuse quickly from the stomata to the photosynthesising cells, and O_2 to diffuse out.

Bài tập luyện tập

Explain why CO_2 continues to diffuse into a photosynthesising leaf even though CO_2 is also produced by the leaf's own respiration.

Lời giải chi tiết

During the day, the rate of photosynthesis in a green leaf is normally much higher than the rate of respiration, so photosynthesis uses up CO_2 faster than respiration produces it. This keeps the CO_2 concentration inside the leaf lower than in the surrounding atmosphere, maintaining

a concentration gradient that causes net diffusion of CO_2 into the leaf through the stomata, even though some CO_2 is simultaneously being generated internally by respiration.

Bài tập luyện tập

A plant seed (e.g. sunflower) stores much of its food reserve as oil rather than starch. Suggest one advantage of this for a seed that must be dispersed and survive before germination.

Lời giải chi tiết

Fats/oils release more energy per gram than an equal mass of carbohydrate when respired, and are more compact for a given amount of stored energy. This allows the seed to carry a large energy reserve for germination and early seedling growth without adding excessive mass or bulk, which is an advantage for a small seed that must be dispersed (e.g. by wind or animals) and survive a dormant period before germinating.

Bài tập luyện tập

Two identical pondweed samples are placed in test tubes of water, one with sodium hydrogencarbonate solution added (extra dissolved CO_2) and one in plain pond water, both under identical bright light and temperature. Predict and explain which sample releases oxygen bubbles faster.

Lời giải chi tiết

The sample with sodium hydrogencarbonate solution will release bubbles faster, provided CO_2 (not light or temperature) is the limiting factor under these bright, warm conditions. Extra dissolved CO_2 removes this restriction, allowing a higher rate of photosynthesis and therefore faster oxygen release, until some other factor (e.g. light intensity or temperature) becomes limiting instead.

Bài tập luyện tập

A leaf is completely destarched, then half of it is covered with aluminium foil, and the whole leaf is left in bright light for six hours. After testing with iodine solution, describe the expected appearance of the leaf and explain the significance of the result.

Lời giải chi tiết

The uncovered half will stain **blue-black** (starch present, because photosynthesis occurred where light reached the leaf), while the foil-covered half will remain **browny-orange** (no starch, because no light reached that part, so no photosynthesis occurred there). The clear boundary between the two colours, matching the edge of the foil, provides evidence that **light is required for photosynthesis** (and therefore for starch production), since every other condition (temperature, CO_2, water supply) was the same for both halves of the same leaf.

Bài tập luyện tập

Explain why boiling a leaf in ethanol before applying iodine solution is a necessary step in the starch test, and why this step is carried out using a water bath rather than a direct flame.

Lời giải chi tiết

Boiling the leaf in ethanol removes (dissolves out) the green chlorophyll pigment, which would otherwise mask the blue-black colour change produced by iodine reacting with starch, making the result difficult to see clearly. Ethanol is highly flammable, so it is heated using a water bath (indirect heating) rather than a direct flame, to avoid igniting the ethanol vapour.

Bài tập luyện tập

A student states: "Increasing light intensity always increases the rate of photosynthesis." Explain why this statement is not always true, using the limiting factor principle.

Lời giải chi tiết

This is only true while light intensity is the limiting factor. Once light intensity is high enough that the rate of photosynthesis is instead limited by CO_2 concentration or by temperature (enzyme activity), further increases in light intensity will not increase the rate — the graph of rate against light intensity plateaus at this point. Only increasing whichever factor is currently limiting will raise the rate further.

Bài tập luyện tập

Outline, step by step, how you would test whether chlorophyll is necessary for starch production, using a variegated leaf (one with green and white patches).

Lời giải chi tiết

(1) Destarch the plant by keeping it in the dark for at least 24 hours. (2) Expose the variegated leaf to bright light for several hours so any chlorophyll-containing regions can photosynthesise. (3) Draw or photograph the leaf first, noting which areas are green and which are white, before further treatment. (4) Remove the leaf, decolourise it by boiling in ethanol (using a water bath), then rinse in warm water to soften it. (5) Flood the leaf with iodine solution and observe the colour pattern. (6) Compare the iodine-staining pattern to the original green/white pattern: green (chlorophyll-containing) areas should stain blue-black (starch present), while white (chlorophyll-lacking) areas should remain browny-orange (no starch), showing that chlorophyll is necessary for starch (and hence glucose) production via photosynthesis.

Bài tập luyện tập

A plant is placed in an atmosphere with normal CO_2 but kept in total darkness for two days, then iodine-tested. State and explain the expected result, and explain how this result is used as a control in starch-test experiments.

Lời giải chi tiết

The leaf will test **negative** for starch (remains browny-orange), because without light no photosynthesis can occur, so existing starch reserves are used up by respiration over the two days and no new starch is made. This "destarched" state is exactly why plants are kept in the dark before a starch-test experiment: it ensures that any starch detected afterwards must have been made *during* the experimental treatment (e.g. exposure to light), rather than being left over from before the experiment began.

Bài tập luyện tập

A plant absorbs nitrate ions from the soil by active transport. State what is meant by active transport and explain why it requires energy from respiration, unlike diffusion.

Lời giải chi tiết

Active transport is the movement of substances (here, nitrate ions) across a cell membrane from a region of lower concentration to a region of higher concentration — against the concentration gradient — using energy released by respiration (as ATP) and carrier proteins in the membrane. This differs from diffusion, which moves substances down a concentration gradient (high to low) and needs no additional cellular energy, since it relies only on the random movement of particles. Because nitrate ions in the soil are often at lower concentration than inside root hair cells, the plant must expend energy to accumulate them, which is why active transport (not diffusion) is required.

Bài tập luyện tập

A plant produces 15 g of glucose in a day. If 40% is respired, 25% becomes starch, 25% becomes protein (with nitrate), and the rest becomes cellulose, calculate the mass converted to cellulose.

Lời giải chi tiết

Percentage for cellulose $= 100\% - 40\% - 25\% - 25\% = 10\%$.
Mass $= 0.10 \times 15 = 1.5$ g converted to cellulose.

Bài tập luyện tập

Summarise, in one or two sentences each, the roles of magnesium and nitrate in plant nutrition, and state the deficiency symptom associated with each.

Lời giải chi tiết

Magnesium is needed to build chlorophyll; deficiency causes **chlorosis** (yellowing between the veins), because less chlorophyll can be made. **Nitrate** is combined with glucose to make amino acids and protein for growth; deficiency causes **stunted growth**, because insufficient protein can be synthesised for new cells.

Bài tập luyện tập

Explain why cutting off the water supply to a potted plant on a hot, sunny day rapidly reduces its rate of photosynthesis, even though light and CO_2 are both still available.

Lời giải chi tiết

Without a water supply, the plant loses more water by transpiration than it can replace, so guard cells lose turgor and stomata tend to close to conserve water. Closed stomata block the diffusion pathway that CO_2 normally uses to enter the leaf, so even though CO_2 is abundant in the atmosphere outside, it can no longer reach the mesophyll cells in sufficient quantity. CO_2 availability inside the leaf therefore becomes the limiting factor, and the rate of photosynthesis falls sharply, independent of light intensity.

Bài tập luyện tập

State two features of the spongy mesophyll that adapt it for efficient gas exchange, and explain how each feature helps.

Lời giải chi tiết

(1) **Large, interconnected air spaces** between cells: these give gases a continuous, low-resistance pathway to move by diffusion between the stomata and every mesophyll cell, rather than having to pass through many cell layers. (2) **Large surface area of cell walls bordering the air spaces**: this maximises the area across which CO_2 can diffuse into cells and O_2 can diffuse out, increasing the rate of gas exchange for a given concentration gradient.

Human Nutrition

Mục tiêu Unit: Nêu thành phần của chế độ ăn cân bằng (carbohydrate, chất béo, protein, vitamin, khoáng chất, chất xơ, nước) và giải thích cơ chế gây ra bệnh khi thiếu hụt từng chất; giải thích vì sao nhu cầu năng lượng thay đổi theo tuổi, giới tính, mức độ vận động và thai kỳ; mô tả cấu tạo và chức năng của từng cơ quan trong ống tiêu hoá; phân biệt tiêu hoá cơ học và tiêu hoá hoá học; lập bảng enzyme tiêu hoá (nơi sản xuất, nơi tác động, cơ chất, sản phẩm); giải thích sự hấp thụ ở ruột non qua cấu tạo lông nhung (villi); và tính toán hàm lượng năng lượng của thực phẩm từ thành phần dinh dưỡng.

6.1 Components of a Balanced Diet

A **balanced diet** contains the right types and amounts of nutrients needed to keep the body healthy: carbohydrates, fats, proteins, vitamins, mineral ions, fibre (roughage) and water, in appropriate proportions for an individual's age, sex, and activity level.

The seven components of diet, and why each is needed

- **Carbohydrates** (e.g. starch, sugars): the body's main energy source, broken down and respired to release energy.
- **Fats** (lipids): a concentrated energy store, used for insulation, and needed to build cell membranes.
- **Proteins**: built from amino acids; needed for growth, tissue repair, and to make enzymes and antibodies.
- **Vitamins**: organic compounds needed in small amounts for specific metabolic roles (see below); most cannot be made by the body and must come from food.
- **Mineral ions**: inorganic ions needed for specific structural and physiological roles (see below).
- **Fibre / roughage**: largely indigestible plant material (mostly cellulose) that adds bulk to food, stimulating the muscular wall of the intestine (peristalsis) and helping prevent constipation.
- **Water**: needed as a solvent for reactions and transport within the body, and to prevent dehydration; makes up a large proportion of blood plasma, cytoplasm and other body fluids.

Nutrient	Function / why needed	Deficiency disease	Mechanism of deficiency
Vitamin C	Needed to make **collagen**, a protein in connective tissue, skin, blood vessel walls and gums	Scurvy	Without enough vitamin C, collagen cannot be properly synthesised, so blood vessels, gums and skin weaken — causing bleeding gums, slow wound healing and joint pain
Vitamin D	Needed for the small intestine to **absorb calcium** from food	Rickets	Without enough vitamin D, too little calcium is absorbed, so bones do not harden (mineralise) properly, becoming soft and bending under body weight, especially in children
Calcium	Structural component of bones and teeth; needed for muscle contraction and blood clotting	Weak bones/-teeth	Without enough calcium, bones and teeth cannot be properly mineralised, becoming weak and prone to fracture
Iron	Needed to make **haemoglobin**, the oxygen-carrying pigment in red blood cells	Anaemia	Without enough iron, insufficient haemoglobin is made, reducing the blood's oxygen-carrying capacity, causing tiredness and breathlessness

VN **GIẢI THÍCH TIẾNG VIỆT**

Mỗi chất dinh dưỡng cần được học theo cặp **vai trò** → **bệnh thiếu hụt** → **cơ chế**, không chỉ nhớ tên bệnh: thiếu **vitamin C** → bệnh **scurvy** (chảy máu chân răng, vết thương lâu lành) vì thiếu nguyên liệu tạo **collagen**; thiếu **vitamin D** → bệnh **còi xương (rickets)** vì cơ thể không hấp thụ đủ **calcium** dù ăn đủ calcium; thiếu **iron** → **thiếu máu (anaemia)** vì không đủ nguyên liệu tạo **haemoglobin**, giảm khả năng vận chuyển oxygen. Lỗi thường gặp: nói thiếu calcium và thiếu vitamin D là "giống nhau" — thực ra thiếu vitamin D làm giảm **hấp thụ** calcium dù chế độ ăn có đủ calcium, còn thiếu calcium trực tiếp là do khẩu phần ăn không cung cấp đủ calcium.

(!) Lỗi thường gặp: Đừng viết "vitamin D giúp tạo xương" một cách chung chung — câu trả lời chính xác hơn theo IGCSE là vitamin D cần thiết để **ruột non hấp thụ calcium**; chính calcium

mới trực tiếp làm cứng (mineralise) xương và răng.

6.1.1 Energy requirements vary with age, sex, activity and pregnancy

Different people need different daily energy intakes because their rate of **respiration** (which uses food energy) differs.

Why energy needs differ between people

- **Age:** growing children and teenagers need extra energy for building new tissue (growth), while older adults, having stopped growing and often being less physically active, typically need less.
- **Sex:** adult males generally have a higher proportion of muscle mass than adult females of similar body size, and muscle tissue respires more actively even at rest, so average energy requirements are usually higher for men.
- **Activity level:** muscle contraction during physical activity requires large amounts of ATP from respiration, so manual labourers and athletes need substantially more energy than people with sedentary lifestyles.
- **Pregnancy and breastfeeding:** a pregnant woman needs extra energy and nutrients to support the growth of the fetus and her own increased metabolism; a breastfeeding woman needs extra energy to produce milk.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nguyên tắc chung: nhu cầu năng lượng cao hơn khi cơ thể **hô hấp nhiều hơn** — do đang lớn (trẻ em, thanh thiếu niên cần năng lượng cho tăng trưởng), do khối cơ nhiều hơn (nam giới trung bình), do vận động nhiều (lao động chân tay, vận động viên), hoặc do đang nuôi dưỡng thai nhi/tiết sữa (phụ nữ mang thai, cho con bú). Khi trả lời câu hỏi dạng này, luôn nối với **hô hấp** làm gốc lý giải, không chỉ liệt kê "cần nhiều năng lượng hơn" mà không giải thích tại sao.

6.2 Energy Content of Food

Different food groups release different amounts of energy per gram when respired. The approximate energy values used at IGCSE level are:

Approximate energy values: carbohydrate $\approx 17\,\text{kJ/g}$; protein $\approx 17\,\text{kJ/g}$; fat $\approx 37\,\text{kJ/g}$. Fat releases roughly twice as much energy per gram as carbohydrate or protein, because fat molecules contain proportionally more carbon-hydrogen bonds, which release more energy when oxidised in respiration.

Calculating the energy content of a meal

A meal contains 60 g of carbohydrate, 20 g of protein, and 15 g of fat. Calculate its total energy content in kJ.

Carbohydrate: $60 \times 17 = 1020$ kJ.
Protein: $20 \times 17 = 340$ kJ.
Fat: $15 \times 37 = 555$ kJ.
Total $= 1020 + 340 + 555 = 1915$ kJ.

Comparing two meals

Meal A contains 70 g carbohydrate, 10 g protein and 5 g fat. Meal B contains 40 g carbohydrate, 15 g protein and 20 g fat. Calculate the energy content of each and state which meal provides more energy.

Meal A: $(70 \times 17) + (10 \times 17) + (5 \times 37) = 1190 + 170 + 185 = 1545$ kJ.
Meal B: $(40 \times 17) + (15 \times 17) + (20 \times 37) = 680 + 255 + 740 = 1675$ kJ.
Meal B provides more energy (1675 kJ vs 1545 kJ), even though it contains less carbohydrate overall, because it contains substantially more fat, which releases over twice the energy per gram of carbohydrate or protein.

Working backwards from total energy

A 200 g food item contains 60% carbohydrate and 10% fat by mass, with the remainder being protein and indigestible material of negligible energy value. Calculate the total energy content, assuming the remaining 30% is entirely protein.

Mass of carbohydrate $= 0.60 \times 200 = 120$ g; energy $= 120 \times 17 = 2040$ kJ.
Mass of fat $= 0.10 \times 200 = 20$ g; energy $= 20 \times 37 = 740$ kJ.
Mass of protein $= 0.30 \times 200 = 60$ g; energy $= 60 \times 17 = 1020$ kJ.
Total energy $= 2040 + 740 + 1020 = 3800$ kJ.

VN **GIẢI THÍCH TIẾNG VIỆT**

Dạng bài tính năng lượng thực phẩm luôn theo ba bước: (1) xác định khối lượng (g) của từng nhóm chất; (2) nhân với hệ số năng lượng tương ứng (17 kJ/g cho carbohydrate và protein, 37 kJ/g cho chất béo); (3) cộng tổng. Lỗi hay gặp: dùng nhầm hệ số của chất béo cho carbohydrate hoặc ngược lại, hoặc quên đổi phần trăm ($\%$) sang khối lượng thực tế (gam) trước khi nhân.

6.3 Mechanical versus Chemical Digestion

Digestion is the breakdown of large, insoluble food molecules into small, soluble molecules that can be absorbed into the blood. It involves two distinct kinds of process, which normally act together.

Two kinds of digestion

Mechanical digestion is the physical breakdown of food into smaller pieces without changing its chemical structure — e.g. chewing (mastication) by the teeth, and churning by the muscular wall of the stomach. This increases the **surface area** of food, allowing digestive enzymes to act faster in the next stage.

Chemical digestion is the breakdown of large molecules into smaller, soluble molecules by **enzymes**, through hydrolysis reactions — e.g. amylase breaking down starch into maltose, protease breaking down protein into amino acids, lipase breaking down fat into fatty acids and glycerol.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tiêu hoá **cơ học** (mechanical) chỉ làm nhỏ thức ăn về mặt vật lý (nhai, co bóp dạ dày) — **không** làm thay đổi cấu trúc hoá học của phân tử thức ăn, mục đích chính là tăng **diện tích bề mặt** để enzyme hoạt động hiệu quả hơn ở bước sau. Tiêu hoá **hoá học** (chemical) dùng **enzyme** để bẻ gãy liên kết hoá học, biến phân tử lớn không tan thành phân tử nhỏ hoà tan được. Lỗi hay gặp: cho rằng nhai thức ăn là tiêu hoá hoá học — sai, nhai chỉ là tiêu hoá **cơ học**.

6.3.1 Teeth and mechanical digestion in the mouth

Mechanical digestion in the mouth is carried out mainly by the teeth, which have different shapes adapted to different mechanical roles.

Tooth type	Shape	Mechanical function
Incisors	Flat, chisel-shaped, sharp edge	Biting off pieces of food
Canines	Pointed, cone-shaped	Gripping and tearing food
Premolars	Broad, ridged surface, two cusps	Crushing and beginning to grind food
Molars	Broad, ridged surface, several cusps	Grinding and crushing food into small fragments

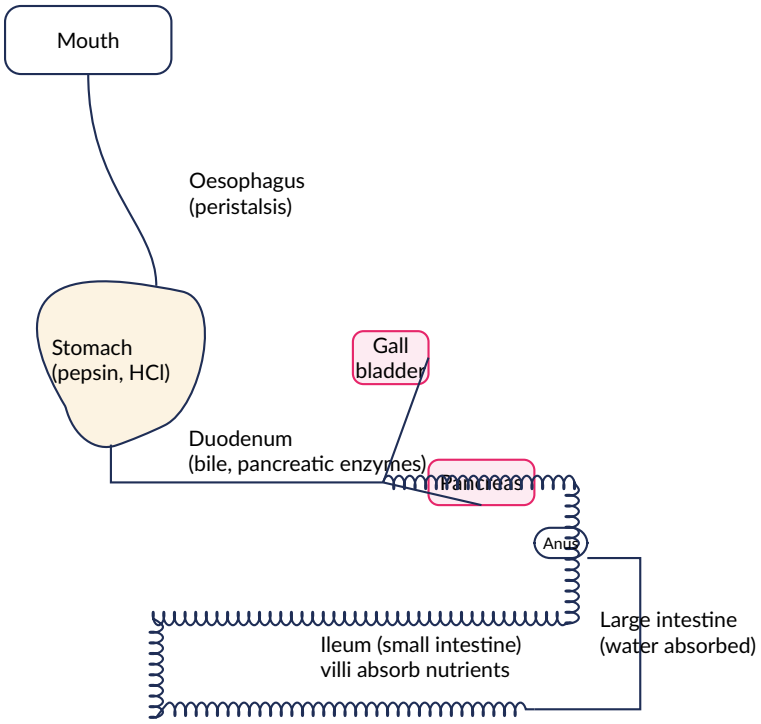
Chewing (mastication) breaks food into smaller pieces, mixing it with saliva to form a soft, moist mass (a **bolus**) that can be swallowed easily and that presents a much larger surface area to salivary amylase and, later, to other digestive enzymes.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốn loại răng có hình dạng khác nhau tương ứng với chức năng cơ học khác nhau: răng cửa (incisors) — cạnh sắc để cắn; răng nanh (canines) — nhọn để xé; răng tiền hàm và răng hàm (premolars/molars) — mặt rộng có gờ để nghiền nát thức ăn. Mục đích chung của nhai là tăng **diện tích bề mặt** thức ăn, giúp enzyme tiêu hoá hoá học ở bước sau hoạt động hiệu quả hơn, đồng thời trộn thức ăn với nước bọt tạo thành khối mềm (bolus) dễ nuốt.

6.4 The Alimentary Canal: Structure and Function

Food passes along the **alimentary canal** (gut), a long muscular tube from mouth to anus, with accessory organs (salivary glands, liver, pancreas) adding secretions along the way.



Schematic of the human alimentary canal and accessory organs (liver not shown separately from the gall bladder/bile pathway).

Organ	Structure / secretion	Role in digestion
Mouth	Teeth (mechanical breakdown); salivary glands secrete saliva containing **salivary amylase**	Mechanical digestion (chewing) increases surface area; amylase begins chemical digestion of starch into maltose
Oesophagus	Muscular tube connecting mouth to stomach; no digestion occurs here	Transports the food bolus to the stomach by **peristalsis** (Supplement: coordinated waves of muscle contraction)
Stomach	Muscular wall (churns food); glands secrete **pepsin** and **hydrochloric acid (HCl)**	HCl gives a strongly acidic environment (pH ≈ 2), the optimum pH for pepsin, and kills many ingested bacteria; pepsin begins protein digestion (protein $\rightarrow$ peptides)
Duodenum (small intestine)	Receives **bile** from the liver (stored in the gall bladder) and **pancreatic juice** from the pancreas (amylase, protease, lipase)	Bile emulsifies fats (physical process, not enzymic) and neutralises stomach acid, raising pH to the optimum for pancreatic enzymes; pancreatic enzymes continue digestion of starch, protein and fat
Ileum (small intestine)	Long tube lined with finger-like **villi** (and microvilli on villus cells)	Main site of **absorption** of digested food molecules (glucose, amino acids, fatty acids, glycerol) into the blood and lymph
Large intestine (colon)	Wider tube, no villi	Absorbs **water** (and some mineral ions) from the remaining undigested material, compacting it into **faeces** for egestion

Bile is not an enzyme. Bile, made in the liver and stored in the gall bladder, **emulsifies** fat — breaking large fat droplets into many smaller droplets — which increases the surface area of fat exposed to **lipase**, speeding up (chemical) fat digestion by the enzyme. Bile also neutralises the acidic, partly digested food (chyme) arriving from the stomach, raising the pH to the optimum for pancreatic and intestinal enzymes, which do not work well in acidic conditions.

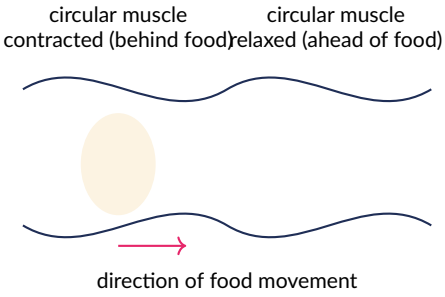
VN **GIẢI THÍCH TIẾNG VIỆT**

Cần phân biệt rõ: **mật (bile)** không phải enzyme — nó chỉ **nhũ tương hoá** (emulsify) chất béo, tức là làm nhỏ giọt mỡ về mặt vật lý (tăng diện tích bề mặt), không bẻ gãy liên kết hoá học. Việc bẻ gãy chất béo thành acid béo và glycerol là do enzyme **lipase** đảm nhiệm. Ngoài ra, mật còn **trung hoà acid** từ dạ dày, đưa pH về mức tối ưu cho enzyme ở ruột non. Lỗi rất hay gặp trong bài thi: gọi mật là "enzyme tiêu hoá chất béo" — sai.

(!) Lỗi thường gặp: Đừng nhầm vai trò của **HCl trong dạ dày**: HCl **không** phải là enzyme tiêu hoá protein — pepsin mới là enzyme. HCl có hai vai trò: (1) tạo pH tối ưu (≈ 2) cho pepsin hoạt động; (2) tiêu diệt phần lớn vi khuẩn có trong thức ăn.

6.4.1 (Supplement) Peristalsis

Food is moved along the alimentary canal by **peristalsis**: waves of alternating contraction and relaxation of two muscle layers in the gut wall — **circular muscle** (which encircles the tube) and **longitudinal muscle** (which runs along its length).



Peristalsis: circular muscle contracts behind the food bolus (narrowing the tube) while it relaxes ahead of the bolus (widening the tube), pushing food steadily onward; longitudinal muscle shortens the section ahead of the bolus to help move it forward.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nhu động ruột (peristalsis) hoạt động nhờ **hai lớp cơ đối lập**: cơ vòng (circular muscle) co lại **phía sau** khối thức ăn để đẩy thức ăn tới trước, trong khi cơ vòng phía **trước** khối thức ăn giãn ra để tạo khoảng trống; cơ dọc (longitudinal muscle) co ngắn đoạn ống phía trước giúp thức ăn di chuyển thuận lợi hơn. Đây là chuyển động **không tự chủ** (involuntary), không cần điều khiển ý thức.

6.5 Enzymes of Digestion

Digestive enzymes are produced at specific sites and act at specific sites, which may be the same organ or a different one further along the gut.

Enzyme	Site(s) of production	Site(s) of action	Substrate	Product(s)
Amylase	Salivary glands; pancreas	Mouth; duodenum/small intestine	Starch	Maltose
Protease (e.g. pepsin, trypsin)	Stomach wall (pepsin); pancreas (trypsin)	Stomach (pepsin); duodenum/small intestine (trypsin)	Protein	Peptides / amino acids
Lipase	Pancreas	Duodenum/small intestine (after bile emulsification)	Fats (lipids)	Fatty acids + glycerol

Distinguishing site of production from site of action

State the site of production and the site of action of pancreatic amylase, and explain why these are different organs.

Pancreatic amylase is **produced** in the pancreas but is secreted, via the pancreatic duct, into the **duodenum** (the first part of the small intestine), where it **acts** on starch. The pancreas is

a gland dedicated to producing digestive secretions (enzymes) and does not itself come into direct contact with large amounts of food; the enzyme must therefore be delivered through a duct to the part of the gut (the duodenum) where digestion of that particular food type actually needs to happen.

Identifying an enzyme from substrate and product

A food-science student is given an unlabelled digestive enzyme and told only that it converts protein into peptides and amino acids, and that it works best at a strongly acidic pH. Identify the enzyme and its most likely site of production and action.

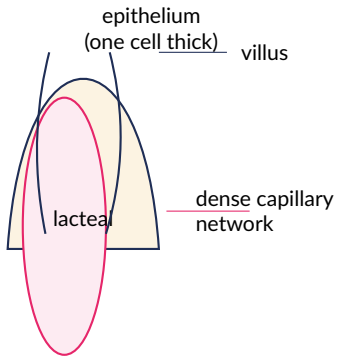
An enzyme that breaks down protein is a **protease**. Because it works best in strongly acidic conditions (rather than the near-neutral pH of the mouth or the slightly alkaline pH of the small intestine after bile has neutralised the chyme), this points specifically to **pepsin**, which is produced by glands in the stomach wall and acts in the stomach, where hydrochloric acid maintains the low pH (around pH 2) that is pepsin's optimum. A protease with a neutral or slightly alkaline optimum, by contrast, would more likely be a pancreatic protease (e.g. trypsin) acting in the duodenum.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bảng enzyme tiêu hoá cần nhớ rõ **"nơi sản xuất"** khác với **"nơi tác động"**: ví dụ amylase tụy được **sản xuất ở tụy** nhưng **tác động ở tá tràng/ruột non**; pepsin được sản xuất và tác động cùng ở **dạ dày**. Câu hỏi thi hay hỏi riêng biệt hai thông tin này, học sinh dễ nhầm lẫn nếu học thuộc lòng mà không hiểu enzyme phải được "vận chuyển" tới nơi cần tác động qua ống dẫn (duct).

6.6 Absorption in the Small Intestine

The ileum is highly adapted to absorb digested food molecules (glucose, amino acids, fatty acids, glycerol, vitamins, minerals) efficiently into the blood and lymphatic system.



A single villus in the wall of the ileum. Millions of villi (each covered in microvilli) give the small intestine a very large internal surface area for absorption.

Adaptations of villi for absorption

- **Very large surface area:** millions of finger-like villi, each covered in microscopic microvilli on individual cells, greatly increase the surface area available for absorption.
- **Wall one cell thick:** the epithelium of a villus is only one cell thick, minimising the diffusion

distance between the gut lumen and the blood/lymph.

- **Dense capillary network:** each villus contains a network of blood capillaries that continuously carry away absorbed glucose and amino acids, maintaining a steep concentration gradient that keeps diffusion (and active transport) proceeding rapidly.
- **Lacteal:** each villus contains a lymph vessel (lacteal) that absorbs digested fats (as fatty acids and glycerol, reassembled into fat droplets) into the lymphatic system rather than directly into the blood.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốn đặc điểm thích nghi của lông nhung (villi) cần nhớ đầy đủ để trả lời trọn vẹn: **diện tích bề mặt lớn** (nhiều lông nhung + vi lông nhung), **thành mỏng một lớp tế bào** (giảm quãng đường khuếch tán), **mạng lưới mao mạch dày đặc** (liên tục vận chuyển chất đã hấp thụ đi, duy trì chênh lệch nồng độ), và **mạch bạch huyết trung tâm (lacteal)** chuyên hấp thụ chất béo đã tiêu hoá. Lỗi hay gặp: chỉ nêu "diện tích bề mặt lớn" mà quên ba đặc điểm còn lại, khiến câu trả lời không trọn điểm.

6.7 The Large Intestine and Egestion

After nutrients have been absorbed in the small intestine, the remaining material — mostly water, indigestible fibre, and gut bacteria — passes into the **large intestine (colon)**. Its main function is to absorb **water** (and some mineral ions) back into the blood, compacting the waste into semi-solid **faeces**, which are stored in the rectum before being removed from the body through the anus — a process called **egestion** (the removal of undigested material that was never absorbed, distinct from **excretion**, the removal of waste products of metabolism such as urea).

(!) Lỗi thường gặp: Đừng nhầm **egestion** (thải phân — chất chưa từng được tiêu hoá/hấp thụ) với **excretion** (bài tiết — loại bỏ chất thải trao đổi chất như urea ra khỏi cơ thể, ví dụ qua thận). Đây là hai khái niệm khác nhau thường bị dùng lẫn lộn.

Effect of gall bladder removal

Some patients have their gall bladder surgically removed due to gallstones. Bile is still produced by the liver and can still reach the duodenum directly, but is no longer stored and concentrated between meals. Explain the likely effect on fat digestion after a large, fatty meal.

Normally, the gall bladder stores and concentrates bile between meals, then releases a large, concentrated volume into the duodenum in response to a fatty meal, providing a strong emulsifying effect exactly when it is most needed. Without a gall bladder, bile trickles into the duodenum continuously at a lower, more dilute rate rather than being released in a concentrated burst. After a particularly large or fatty meal, the available bile may be insufficient to emulsify all the fat efficiently, so fat digestion (and absorption) can be less complete and slower, sometimes leading to digestive discomfort or fatty, poorly-digested stools until the small intestine adapts.

VN **GIẢI THÍCH TIẾNG VIỆT**

Túi mật (gall bladder) chỉ có vai trò **dự trữ và cô đặc** mật do gan sản xuất — bản thân nó **không tạo ra** mật. Sau khi cắt túi mật, gan vẫn tiết mật bình thường, nhưng mật chảy liên tục với nồng độ loãng hơn thay vì được "bơm" một lượng lớn, cô đặc đúng lúc có bữa ăn nhiều chất béo — do đó bệnh nhân thường được khuyên ăn giảm chất béo mỗi bữa sau phẫu thuật.

6.7.1 Sphincters and the passage of chyme

Between successive organs of the alimentary canal are ring-shaped muscles called **sphincters**, which stay contracted (closed) most of the time and relax briefly to let food pass in one direction. The **cardiac sphincter** at the top of the stomach normally prevents acidic stomach contents from moving back up into the oesophagus, and the **pyloric sphincter** at the base of the stomach controls the slow, regulated release of partly digested, acidic food (called **chyme**) into the duodenum, allowing time for bile and pancreatic secretions to neutralise the acid and begin digestion before more chyme arrives.

VN **GIẢI THÍCH TIẾNG VIỆT**

Cơ vòng (sphincter) hoạt động như một "cái van một chiều": cơ vòng tâm vị (cardiac sphincter) ở đầu trên dạ dày ngăn thức ăn/acid trào ngược lên thực quản; cơ vòng môn vị (pyloric sphincter) ở đầu dưới dạ dày kiểm soát tốc độ đẩy **chyme** (hỗn hợp thức ăn đã tiêu hoá một phần, có tính acid) xuống tá tràng từng đợt nhỏ, giúp mật và dịch tụy có đủ thời gian trung hoà acid trước khi lượng chyme tiếp theo đến.

6.8 Practice Bank

Bài tập luyện tập

Match each organ to its main digestive role: mouth, stomach, duodenum, ileum, large intestine.

(A) Mouth — water absorption

(B) Stomach — pepsin and HCl begin protein digestion

(C) Duodenum — absorption of amino acids only

(D) Ileum — HCl kills bacteria

Lời giải chi tiết

(B). The stomach secretes pepsin (a protease) and hydrochloric acid, beginning chemical digestion of protein and providing the acidic optimum pH for pepsin. (A) is wrong — water absorption is mainly in the large intestine; (C) is wrong — the duodenum is mainly a site of continued digestion (bile, pancreatic enzymes), with absorption occurring mainly further along in the ileum; (D) is wrong — HCl is secreted in the stomach, not the ileum.

Bài tập luyện tập

A meal contains 10 g protein, 5 g fat and 70 g carbohydrate. Calculate its total energy content in kJ.

Lời giải chi tiết

Protein: $10 \times 17 = 170$ kJ. Fat: $5 \times 37 = 185$ kJ. Carbohydrate: $70 \times 17 = 1190$ kJ.
Total $= 170 + 185 + 1190 = 1545$ kJ.

Bài tập luyện tập

Explain why a child with rickets may still have a diet containing plenty of calcium-rich foods, yet still develop the disease.

Lời giải chi tiết

Rickets is caused by a deficiency of **vitamin D**, which is required for the small intestine to absorb calcium from digested food. Even if the diet contains plenty of calcium, without enough

vitamin D that calcium cannot be efficiently absorbed into the blood, so too little calcium reaches the bones for proper mineralisation. The bones remain soft and can bend under the body's weight, producing the characteristic bowed legs of rickets, even though dietary calcium intake itself was adequate.

Bài tập luyện tập

Amylase in saliva begins digesting starch in the mouth, but its action appears to stop once food reaches the stomach. Explain why, in terms of enzyme properties.

Lời giải chi tiết

Salivary amylase has an optimum pH close to neutral (around pH 7), typical of the mouth. The stomach secretes hydrochloric acid, making its contents strongly acidic (around pH 2). This acidic environment is far from amylase's optimum pH, and denatures the enzyme (altering the shape of its active site), so it can no longer bind starch effectively — amylase activity is effectively halted once food is thoroughly mixed with stomach acid.

Bài tập luyện tập

State the site of production and site of action of pepsin, and explain why, unlike pancreatic amylase, these are the same organ.

Lời giải chi tiết

Pepsin is both **produced** and **acts** in the **stomach**. Glands in the stomach wall secrete pepsin directly into the stomach lumen, where protein digestion begins immediately, so no duct or transport to a separate organ is needed — unlike the pancreas, which produces enzymes for use further along the gut (the duodenum) and must deliver them via the pancreatic duct.

Bài tập luyện tập

Which of the following best describes the role of bile in digestion?

(A) It is an enzyme that breaks down fat into fatty acids and glycerol

(B) It emulsifies fat, increasing surface area for lipase, and neutralises stomach acid

(C) It digests protein in the stomach

(D) It is absorbed directly into the lacteal in the small intestine

Lời giải chi tiết

(B). Bile is not an enzyme; it emulsifies fat (a physical process that increases surface area for lipase to act on) and neutralises acidic chyme arriving from the stomach, raising the pH to the optimum for pancreatic and intestinal enzymes. Options A and C wrongly describe bile as an enzyme; option D confuses bile with the digested fat that is absorbed via the lacteal.

Bài tập luyện tập

Explain, using the structure of a villus, why the small intestine is efficient at absorbing digested nutrients into the blood.

Lời giải chi tiết

Villi greatly increase the internal **surface area** of the small intestine; their epithelial wall is only **one cell thick**, minimising diffusion distance; each villus has a **dense capillary network** that continuously removes absorbed glucose and amino acids, maintaining a steep concentration gradient for diffusion; and each villus contains a **lacteal** that absorbs digested fats into the lymphatic system. Together, these features maximise the rate of absorption of all major nutrient types.

Bài tập luyện tập

A patient is diagnosed with anaemia. State the likely dietary deficiency and explain the mechanism linking this deficiency to the symptoms of anaemia (tiredness, breathlessness).

Lời giải chi tiết

The likely deficiency is **iron**. Iron is required to make **haemoglobin**, the oxygen-carrying pigment in red blood cells. Without enough iron, less haemoglobin can be produced, reducing the blood's capacity to carry oxygen to respiring tissues. Because tissues (especially muscles and the brain) receive less oxygen for aerobic respiration, the patient experiences tiredness and breathlessness, particularly during exertion.

Bài tập luyện tập

Distinguish between mechanical and chemical digestion, giving one example of each occurring in the mouth.

Lời giải chi tiết

Mechanical digestion is the physical breakdown of food into smaller pieces without altering its chemical structure — e.g. chewing by the teeth in the mouth, which increases surface area. **Chemical digestion** is the breakdown of large molecules into smaller, soluble molecules using enzymes — e.g. salivary amylase in the mouth, which begins breaking down starch into maltose.

Bài tập luyện tập

Explain why fibre (roughage), although not digested or absorbed, is still considered an important part of a balanced diet.

Lời giải chi tiết

Fibre (mainly cellulose from plant cell walls) cannot be digested by human enzymes, so it is not broken down or absorbed. However, it adds bulk to the contents of the gut, which stretches the intestinal wall and stimulates **peristalsis** (muscular contractions that move food along). Without enough fibre, the movement of waste material through the gut slows down, which can lead to constipation; adequate fibre intake helps maintain regular, efficient movement of gut contents.

Bài tập luyện tập

A 150 g food sample contains 50% carbohydrate, 20% protein and 10% fat by mass (the rest is water and indigestible material). Calculate its total energy content.

Lời giải chi tiết

Carbohydrate: $0.50 \times 150 = 75$ g $\rightarrow 75 \times 17 = 1275$ kJ.
Protein: $0.20 \times 150 = 30$ g $\rightarrow 30 \times 17 = 510$ kJ.
Fat: $0.10 \times 150 = 15$ g $\rightarrow 15 \times 37 = 555$ kJ.
Total $= 1275 + 510 + 555 = 2340$ kJ.

Bài tập luyện tập

Explain why a labourer doing heavy manual work each day needs a higher daily energy intake than an office worker of the same age and sex.

Lời giải chi tiết

Muscle contraction during physical activity requires ATP, generated by respiration, which uses up food energy. A labourer's muscles contract far more, and for longer, during a working day than an office worker's, so the labourer's rate of respiration (and hence energy demand) is substantially higher. To balance this increased energy expenditure and avoid a net loss of body mass, the labourer needs a higher daily energy intake from food.

Bài tập luyện tập

State two functions of hydrochloric acid in the stomach.

Lời giải chi tiết

(1) It provides the strongly acidic environment (pH ≈ 2) that is the **optimum pH for pepsin** to function effectively. (2) It **kills many of the bacteria** present in swallowed food, reducing the risk of infection from ingested pathogens.

Bài tập luyện tập

A person switches from a diet high in animal fat to one much lower in fat but similar in total mass of food eaten each day. Predict and explain the effect on their total daily energy intake, assuming carbohydrate and protein intake stay the same.

Lời giải chi tiết

Total daily energy intake will **decrease**, because fat releases roughly 37 kJ/g, more than double the energy released by an equal mass of carbohydrate or protein (17 kJ/g each). Replacing fat mass with an equal mass of lower-energy food (or simply removing fat without replacing it) reduces total energy intake even if the total mass of food eaten stays similar.

Bài tập luyện tập

Explain why pancreatic juice contains three different types of digestive enzyme (amylase, protease, lipase) rather than just one.

Lời giải chi tiết

A typical meal contains a mixture of carbohydrate, protein and fat, each of which requires a different enzyme to hydrolyse it, because each enzyme is specific to one type of substrate (a consequence of the specific shape of each enzyme's active site). Amylase acts on starch,

protease acts on protein, and lipase acts on fat; secreting all three together in pancreatic juice allows the duodenum to digest all major food components simultaneously and efficiently.

Bài tập luyện tập

Describe the pathway and role of peristalsis in moving a food bolus from the mouth to the stomach.

Lời giải chi tiết

After swallowing, the food bolus enters the oesophagus, where **peristalsis** moves it toward the stomach: circular muscle in the gut wall contracts immediately behind the bolus, narrowing the tube and pushing it forward, while circular muscle ahead of the bolus relaxes, widening the tube to receive it; longitudinal muscle shortens the section ahead to assist movement. This wave of alternating contraction and relaxation travels along the oesophagus, moving the bolus independently of gravity (so swallowing works even upside down), until it reaches the stomach.

Bài tập luyện tập

A vegetarian diet is sometimes at risk of insufficient iron intake. Explain the physiological consequence if this deficiency is not corrected, in terms of oxygen transport.

Lời giải chi tiết

Iron is an essential component of haemoglobin, the oxygen-carrying pigment inside red blood cells. Insufficient dietary iron reduces the amount of haemoglobin that can be synthesised, lowering the oxygen-carrying capacity of the blood. This results in **anaemia**: tissues receive less oxygen for aerobic respiration, causing symptoms such as fatigue, pale skin, and breathlessness on exertion, since cells cannot generate ATP as efficiently without sufficient oxygen delivery.

Bài tập luyện tập

Explain why the large intestine, unlike the small intestine, is not lined with villi, yet still performs an essential digestive function.

Lời giải chi tiết

By the time food residue reaches the large intestine, essentially all digestible nutrients (sugars, amino acids, fatty acids, glycerol) have already been absorbed in the small intestine, so there is no longer a need for the very large absorptive surface area that villi provide for nutrient uptake. The large intestine's essential function is instead to absorb **water** (and some mineral ions) from the remaining waste material, which does not require the same specialised villus structure — a large, folded internal surface without villi is sufficient for water reabsorption, compacting the residue into faeces.

Bài tập luyện tập

A student claims that "digestion" and "absorption" mean the same thing. Explain why this is incorrect, using an example.

Lời giải chi tiết

Digestion is the chemical (and mechanical) breakdown of large, insoluble food molecules into small, soluble molecules — e.g. starch broken down by amylase into maltose. **Absorption** is the separate process of those small, soluble molecules moving across the gut wall into the blood or lymph — e.g. maltose (broken down further into glucose) passing into the capillaries of a villus. Digestion must occur before absorption is possible, but the two are distinct processes occurring in different ways (enzyme action versus diffusion/active transport across a membrane).

Bài tập luyện tập

Calculate the total energy content of a snack containing 8 g protein, 12 g fat and 25 g carbohydrate.

Lời giải chi tiết

Protein: $8 \times 17 = 136$ kJ. Fat: $12 \times 37 = 444$ kJ. Carbohydrate: $25 \times 17 = 425$ kJ.
Total $= 136 + 444 + 425 = 1005$ kJ.

Bài tập luyện tập

Explain why a person who has had part of their small intestine surgically removed (due to disease) may struggle to maintain a healthy body mass, even while eating a normal amount of food.

Lời giải chi tiết

The small intestine, particularly the ileum, is the main site of absorption of digested nutrients into the blood, thanks to its villi providing a very large surface area. With less small intestine available, there is less absorptive surface area and a shorter length of gut over which nutrients can be absorbed, so a smaller proportion of the food eaten is actually absorbed into the body before the remaining, unabsorbed material passes into the large intestine and is egested. Even eating a normal quantity of food, the person absorbs fewer nutrients overall, which can make it difficult to obtain enough energy and nutrients to maintain a healthy body mass.

Bài tập luyện tập

Outline the roles of the mouth, stomach and duodenum in the digestion of a meal containing starch, protein and fat, describing what happens to each nutrient at each stage.

Lời giải chi tiết

Mouth: teeth mechanically break food into smaller pieces (increasing surface area); salivary amylase begins chemical digestion of starch into maltose; protein and fat are not chemically digested here.
Stomach: the muscular wall churns food (further mechanical digestion); pepsin begins chemical digestion of protein into peptides, in the strongly acidic environment (HCl) that is pepsin's optimum pH and also kills ingested bacteria; starch digestion by salivary amylase stops once the acidic environment denatures it; fat is not yet chemically digested.
Duodenum: bile (from the liver, stored in the gall bladder) emulsifies fat and neutralises stomach acid; pancreatic amylase continues starch digestion to maltose; pancreatic protease con-

tinues protein digestion to peptides/amino acids; pancreatic lipase digests emulsified fat into fatty acids and glycerol.

Bài tập luyện tập

Explain the role of the pyloric sphincter, and predict what might happen to digestion in the duodenum if it opened too quickly and released a large volume of acidic chyme all at once.

Lời giải chi tiết

The pyloric sphincter normally releases chyme from the stomach into the duodenum gradually, in small amounts, allowing time for bile and pancreatic secretions to neutralise the acid and for enzymes to begin acting before the next portion arrives. If it opened too quickly and released a large volume of acidic chyme at once, the available bile and pancreatic juice might not be sufficient to neutralise all the acid immediately, so the duodenum would be exposed to an abnormally low pH for longer. Since pancreatic and intestinal enzymes work best near neutral pH, this could temporarily reduce the efficiency of starch, protein and fat digestion in the duodenum.

Bài tập luyện tập

A processed food label states that a 50 g serving contains 30 g carbohydrate, 2 g protein and 10 g fat (the rest is water/fibre with negligible energy value). Calculate the energy content per serving, and per 100 g of food.

Lời giải chi tiết

Per serving (50 g): carbohydrate $30 \times 17 = 510$ kJ; protein $2 \times 17 = 34$ kJ; fat $10 \times 37 = 370$ kJ.
Total $= 510 + 34 + 370 = 914$ kJ per 50 g serving.
Per 100 g: since 100 g is twice the serving size, energy content $= 914 \times 2 = 1828$ kJ per 100 g.

Bài tập luyện tập

Explain why babies are often breastfed rather than given only water in the first months of life, in terms of nutrient and energy requirements.

Lời giải chi tiết

Water alone contains no carbohydrate, fat, protein, vitamins or minerals, so it cannot supply the energy or the raw materials a rapidly growing baby needs. Breast milk, by contrast, is a balanced source of carbohydrate (lactose), fat, protein, vitamins, minerals and water together, meeting the very high relative energy and nutrient demands of early growth and development (extensive new tissue formation requires large amounts of protein and energy, proportionally more than an adult needs relative to body mass).

Bài tập luyện tập

State the mechanical function of molars and explain how their shape relates to that function.

Lời giải chi tiết

Molars grind and crush food into small fragments. Their broad, ridged chewing surface with several cusps provides a large, uneven area that can apply crushing force across a wide area of food and mesh food between the ridges as the jaws close, breaking it into many small pieces — unlike the sharp, narrow edge of an incisor, which is shaped for biting off pieces rather than grinding them.

Bài tập luyện tập

A patient who has lost most of their molars due to poor dental health finds that undigested lumps of vegetable matter sometimes appear in their faeces. Suggest an explanation linking mechanical digestion to chemical digestion.

Lời giải chi tiết

Without functional molars, food cannot be ground down effectively in the mouth, so large fragments of plant material (with a low surface-area-to-volume ratio) enter the rest of the gut only partly broken down mechanically. Digestive enzymes act at the surface of food particles, so large, poorly chewed fragments present much less surface area for amylase, protease and lipase to act on per unit time. As a result, chemical digestion of these fragments may be incomplete by the time they reach the large intestine, so some plant material passes through largely undigested and appears in the faeces.

Bài tập luyện tập

Calculate the energy density (kJ per gram) of a food that is 80% fat and 20% carbohydrate by mass, and compare it with a food that is 80% carbohydrate and 20% fat by mass.

Lời giải chi tiết

Take a 100 g sample of each for convenience.
Food 1 (80% fat, 20% carbohydrate): fat 80 g $\times\, 37 = 2960$ kJ; carbohydrate 20 g $\times\, 17 = 340$ kJ.
Total $= 3300$ kJ per 100 g, i.e. energy density $= 33.0$ kJ/g.
Food 2 (80% carbohydrate, 20% fat): carbohydrate 80 g $\times\, 17 = 1360$ kJ; fat 20 g $\times\, 37 = 740$ kJ.
Total $= 2100$ kJ per 100 g, i.e. energy density $= 21.0$ kJ/g.
Food 1 has a substantially higher energy density (33.0 vs 21.0 kJ/g) because it is predominantly fat, which releases more than double the energy per gram of carbohydrate.

CAMBRIDGE IGCSE • Unit 7

Transport in Plants and Animals

Mục tiêu Unit: Mô tả cấu tạo và chức năng của mạch gỗ (xylem) và mạch rây (phloem); định nghĩa thoát hơi nước (transpiration), mô tả đường đi của nước từ lông hút rễ đến khí khổng, và giải thích các yếu tố ảnh hưởng đến tốc độ thoát hơi nước; tính toán tốc độ hút nước bằng máy đo thế nước (potometer); giải thích tuần hoàn kép ở người và cấu tạo/chức năng của tim, van tim, mạch máu; so sánh cấu tạo động mạch, tĩnh mạch, mao mạch; nêu thành phần máu và chức năng từng loại; mô tả cơ chế đông máu cơ bản; và giải thích bệnh mạch vành.

7.1 Xylem and Phloem: The Two Transport Tissues of Plants

Plants have two specialised vascular tissues, each transporting different substances in different directions.

Xylem: composed of dead cells joined end to end into long, hollow tubes, with walls thickened and strengthened by **lignin**. Xylem transports **water and dissolved mineral ions** in one direction only — upward, from root to leaf — and, because lignified walls are rigid, also provides mechanical support to the plant.

Phloem: composed of living cells — **sieve tube elements** (which lack a nucleus but remain alive, with perforated end walls called sieve plates) supported by adjacent **companion cells** (which retain a nucleus and carry out the metabolic activity needed to load/unload the sieve tubes). Phloem transports dissolved **sucrose and amino acids**, a process called **translocation**, from a **source** (where these substances are made or stored, e.g. a photosynthesising leaf) to a **sink** (where they are used or stored, e.g. a growing root, fruit or seed) — and can therefore transport in *either* direction, depending on which organs are acting as sources and sinks at a given time.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bảng so sánh cần thuộc lòng: mạch gỗ (xylem) gồm **tế bào chết**, thành có **lignin** hoá gỗ, vận chuyển **nước và ion khoáng** theo **một chiều** (từ rễ lên lá), đồng thời có vai trò **nâng đỡ cơ học**. Mạch rây (phloem) gồm **tế bào sống** (ống rây + tế bào kèm), vận chuyển **đường sucrose và amino acid** theo cơ chế gọi là **translocation**, có thể đi **hai chiều** tuỳ vị trí "nguồn" (source, ví dụ lá đang quang hợp) và "đích" (sink, ví dụ rễ/quả/hạt đang phát triển). Lỗi hay gặp: nói mạch rây chỉ vận chuyển một chiều từ lá xuống rễ — sai, chiều vận chuyển phụ thuộc vào đâu là nguồn, đâu là đích tại thời điểm đó (ví dụ khi hạt nảy mầm, chất dinh dưỡng có thể đi từ hạt — nguồn — lên chồi non — đích).

Tracing a labelled sugar through phloem

A radioactively labelled sugar is fed to a mature, photosynthesising leaf near the top of a plant. A short time later, the label is detected in the roots but not in a young, actively growing leaf near the top of the same plant. Explain this result in terms of source and sink.

The mature, photosynthesising leaf is acting as a **source** — it produces more sugar than it needs

and exports the surplus via phloem. The roots, which cannot photosynthesise and need sugar for respiration and growth, are acting as a **sink** at this time, so labelled sugar is translocated there. The young, growing leaf near the top, by contrast, is likely still importing sugar from elsewhere rather than exporting it (young leaves often are not yet net photosynthetic exporters), so it is not the destination for sugar leaving the mature leaf; alternatively, translocation in phloem follows source-to-sink pathways rather than simply moving toward the nearest tissue, so proximity to the source leaf does not guarantee that labelled sugar arrives there.

7.1.1 How water first enters the plant: root hair cells

Water enters the plant at the roots through **root hair cells**, single-celled extensions of the root epidermis with a large surface area (an advantage shared with many other absorptive surfaces in biology, such as villi in the small intestine). Soil water usually has a higher water potential (more dilute, less negative) than the cytoplasm of the root hair cell, so water moves into the cell by **osmosis**, down this water potential gradient, across the partially permeable cell membrane. Water then passes across the root cortex, cell to cell (by osmosis, since each cell in the pathway has a slightly more negative water potential than the one before it) or between cells, until it reaches the xylem at the centre of the root.

VN **GIẢI THÍCH TIẾNG VIỆT**

Lông hút rễ (root hair cell) hấp thụ nước theo cơ chế **thẩm thấu** (osmosis): nước trong đất thường có thế nước cao hơn (loãng hơn) so với bên trong tế bào lông hút, nên nước di chuyển vào tế bào theo gradien thế nước, qua màng bán thấm. Đây là lý do lông hút có diện tích bề mặt lớn — tương tự nguyên tắc thích nghi tăng diện tích hấp thụ đã gặp ở lông nhung ruột non (villi).

7.2 Transpiration

Transpiration is the loss of water vapour from the surface of a plant, mainly through the stomata of the leaves, following evaporation from the walls of mesophyll cells into the air spaces of the leaf.

The transpiration pathway

Water moves through the plant along a continuous pathway: soil water → absorbed by **root hair cells** (by osmosis) → across the root **cortex** cells → into the **xylem** of the root → up the xylem of the stem → into the xylem of a leaf vein → out into **leaf mesophyll cells** → evaporates into the leaf's internal air spaces → diffuses out through open **stomata** into the atmosphere.

What pulls water up the xylem: the transpiration pull

As water evaporates from mesophyll cell walls and diffuses out through the stomata, it is continuously replaced by water drawn out of the leaf xylem, which in turn pulls up more water from the xylem below it, and so on, all the way down to the roots. This continuous pulling force is called **transpiration pull**. It works because water molecules are strongly attracted to each other by hydrogen bonding, a property called **cohesion**, which allows them to be pulled up as a continuous, unbroken column inside the narrow xylem vessels, rather like pulling a chain from one end (Supplement: this combination of evaporation-driven tension and water cohesion is sometimes called the **cohesion-tension** mechanism). Because this process needs no direct energy input from the plant's own metabolism (it is driven by evaporation, a physical process), transpiration is sometimes described as an inevitable "necessary evil" — a consequence of having stomata open for gas exchange during photosynthesis.

VN **GIẢI THÍCH TIẾNG VIỆT**

Con đường thoát hơi nước cần trình bày đầy đủ theo đúng thứ tự: lông hút rễ → vỏ rễ (cortex) → mạch gỗ rễ → mạch gỗ thân → mạch gỗ gân lá → tế bào thịt lá (mesophyll) → khoảng gian bào → khí khổng → khí quyển. "Lực kéo thoát hơi nước" (transpiration pull) hình thành do nước bay hơi liên tục ở đầu trên (lá), kéo theo cả cột nước phía dưới đi lên nhờ lực **liên kết** (cohesion) giữa các phân tử nước (liên kết hydrogen). Học sinh không cần nhớ thuật ngữ "cohesion-tension" để làm bài IGCSE, chỉ cần hiểu ý tưởng: nước bay hơi ở lá tạo ra lực kéo, và các phân tử nước dính chặt với nhau nên bị kéo lên thành cột liên tục.

7.2.1 Factors affecting the rate of transpiration

Four environmental factors

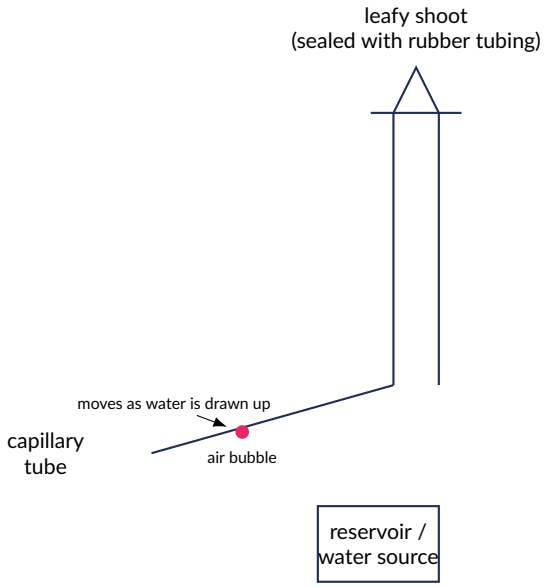
- **Temperature:** higher temperature gives water molecules more kinetic energy, increasing the rate of evaporation from mesophyll cell walls and increasing the rate of diffusion of water vapour out through the stomata — so transpiration rate increases with temperature.
- **Humidity:** transpiration relies on a concentration gradient of water vapour between the moist air inside the leaf and the drier air outside. In humid air, this gradient is smaller (the outside air is already close to saturated with water vapour), so diffusion of water vapour out of the stomata is slower — transpiration rate decreases as humidity increases.
- **Wind / air movement:** moving air continuously sweeps away the layer of humid air that builds up close to the leaf surface, maintaining a steep concentration gradient between the leaf's internal air spaces and the surrounding atmosphere — so transpiration rate increases in windy conditions.
- **Light intensity:** light does not directly affect the physical process of evaporation, but it causes stomata to open (since photosynthesis requires CO_2 to enter through open stomata in the light) — more open stomata means a larger area through which water vapour can diffuse out, so transpiration rate increases with light intensity (indirectly, via stomatal opening).

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốn yếu tố ảnh hưởng đến tốc độ thoát hơi nước cần giải thích theo **cơ chế**, không chỉ liệt kê: nhiệt độ tăng → bay hơi nhanh hơn; độ ẩm tăng → chênh lệch nồng độ hơi nước giảm → thoát hơi chậm lại; gió/luồng không khí → thổi bay lớp không khí ẩm quanh lá, duy trì chênh lệch nồng độ lớn → thoát hơi nhanh hơn; ánh sáng mạnh → khí khổng **mở** nhiều hơn (để lấy CO_2 quang hợp) → diện tích thoát hơi lớn hơn. Lỗi hay gặp: nói "ánh sáng làm nước bay hơi nhanh hơn trực tiếp" — không chính xác, ánh sáng tác động **gián tiếp** thông qua việc mở khí khổng.

7.3 The Potometer: Measuring the Rate of Water Uptake

A **potometer** is used to estimate the rate of transpiration indirectly, by measuring the rate at which a leafy shoot takes up water — a reasonable estimate because roughly 99% of water taken up by a plant is lost via transpiration, with only a small fraction used in photosynthesis or retained in cells. An air bubble is introduced into the capillary tube of the potometer, and the distance it moves in a given time is used, together with the tube's radius, to calculate the volume of water taken up (since the tube is a cylinder, $V = \pi r^2 h$, where h is the distance moved by the bubble).



Simplified potometer: a leafy shoot draws water up a graduated capillary tube; the air bubble's movement over time is used to estimate the rate of water uptake.

Basic potometer calculation

In a potometer experiment, an air bubble moves 8 cm along a capillary tube of radius 0.05 cm in 4 minutes. Calculate the rate of water uptake in cm^3 min^{-1}.

Volume $= \pi r^2 h = \pi(0.05)^2(8) = \pi(0.0025)(8) = \pi(0.02) = 0.0628$ cm^3 (3 s.f.).

Rate $= \dfrac{0.0628}{4} = 0.0157$ cm^3 min^{-1} (3 s.f.).

Potometer calculation with a wider tube

A second potometer, with a wider capillary tube of radius 0.1 cm, shows the bubble moving 12 cm in 6 minutes. Calculate the rate of water uptake, and compare it with the rate found in the previous example.

Volume $= \pi r^2 h = \pi(0.1)^2(12) = \pi(0.01)(12) = \pi(0.12) = 0.377$ cm^3 (3 s.f.).

Rate $= \dfrac{0.377}{6} = 0.0628$ cm^3 min^{-1} (3 s.f.).

This rate (0.0628 cm^3 min^{-1}) is about four times the rate in the previous example (0.0157 cm^3 min^{-1}), illustrating that the tube radius has a large effect on the calculated volume ($V \propto r^2$), so bubble distance alone cannot be compared meaningfully between potometers with different tube radii — the radius must always be taken into account.

Comparing potometer results under two conditions

The same shoot is tested twice: first in still air, where the bubble moves 6 cm in 5 minutes in a tube of radius 0.05 cm; then with a fan blowing air across the leaves, where the bubble moves 15 cm in 5 minutes in the same tube. Calculate the rate of water uptake in each case and comment on the result.

Still air: $V = \pi(0.05)^2(6) = \pi(0.0025)(6) = 0.0471$ cm^3; rate $= \dfrac{0.0471}{5} = 0.00942$ cm^3 min^{-1}.

With fan: $V = \pi(0.05)^2(15) = \pi(0.0025)(15) = 0.1178$ cm^3; rate $= \dfrac{0.1178}{5} =$

0.0236 cm^3 min^{-1}.
The rate with the fan is about 2.5 times higher than in still air, consistent with moving air sweeping away the humid layer of air next to the leaf surface, maintaining a steeper water vapour concentration gradient and increasing the rate of transpiration (and hence water uptake).

Potometer results across a temperature series

A student measures water uptake at three temperatures, using the same potometer (tube radius 0.05 cm) each time: at 15°C, the bubble moves 4 cm in 5 minutes; at 25°C, it moves 9 cm in 5 minutes; at 35°C, it moves 15 cm in 5 minutes. Calculate the rate at each temperature and describe the trend.

At 15°C: $V = \pi(0.05)^2(4) = 0.0314$ cm^3; rate $= \dfrac{0.0314}{5} = 0.00628$ cm^3 min^{-1}.

At 25°C: $V = \pi(0.05)^2(9) = 0.0707$ cm^3; rate $= \dfrac{0.0707}{5} = 0.0141$ cm^3 min^{-1}.

At 35°C: $V = \pi(0.05)^2(15) = 0.1178$ cm^3; rate $= \dfrac{0.1178}{5} = 0.0236$ cm^3 min^{-1}.

The rate of water uptake increases steadily with temperature (roughly tripling from 15°C to 35°C), consistent with warmer conditions increasing the kinetic energy of water molecules, speeding up evaporation from mesophyll cell walls and hence the transpiration pull driving water uptake.

VN **GIẢI THÍCH TIẾNG VIỆT**

Công thức cốt lõi của potometer là **thể tích hình trụ**: $V = \pi r^2 h$, trong đó h là quãng đường bọt khí di chuyển. Ba bước tính toán: (1) tính V từ bán kính ống và quãng đường di chuyển; (2) chia cho thời gian để ra tốc độ; (3) so sánh tốc độ giữa các điều kiện thí nghiệm khác nhau (chỉ so sánh được khi cùng bán kính ống, hoặc phải tính lại thể tích thực nếu bán kính khác nhau). Lỗi rất hay gặp: so sánh trực tiếp quãng đường bọt khí di chuyển (h) giữa hai ống có bán kính khác nhau mà quên rằng $V \propto r^2$, khiến kết luận sai.

(!) Lỗi thường gặp: Máy đo potometer đo tốc độ **hút nước** của cành cây, không đo trực tiếp tốc độ thoát hơi nước — đây chỉ là một **ước lượng** vì phần lớn (khoảng 99%) nước hút vào bị mất qua thoát hơi nước, một phần nhỏ được giữ lại trong tế bào hoặc dùng cho quang hợp. Khi được hỏi "potometer đo cái gì", câu trả lời chính xác là "tốc độ hút nước ($\approx$ tốc độ thoát hơi nước)", không phải "tốc độ thoát hơi nước" một cách tuyệt đối.

Why a cut flower wilts if an air bubble enters the stem

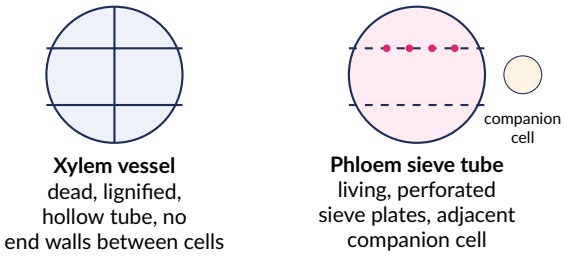
A cut flower is placed in a vase, but the stem was cut in air rather than underwater, allowing an air bubble to become trapped inside the xylem. Explain why the flower wilts even though the vase contains plenty of water.

The transpiration pull relies on a continuous, unbroken column of water inside each xylem vessel, held together by cohesion (hydrogen bonding) between water molecules, so that the pulling force generated by evaporation at the leaf can be transmitted all the way down to the water source at the cut end of the stem. An air bubble breaks this continuity: gas molecules do not cohere to water in the same way, so the pulling force cannot be transmitted past the bubble. Water above the bubble can no longer be replaced from the vase below, so the leaves above the blockage continue to lose water by transpiration faster than it can be resupplied,

and they wilt — even though the vase itself still holds plenty of water. This is exactly why cut flowers and plant cuttings are conventionally re-cut **underwater** before being placed in a vase, to avoid air entering the xylem in the first place.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nếu có bọt khí lọt vào mạch gỗ (air lock/embolism), cột nước liên tục trong mạch gỗ bị **ngắt quãng** tại vị trí bọt khí, vì lực kéo thoát hơi nước cần một cột nước **liên tục** nhờ lực liên kết (cohesion) giữa các phân tử nước để truyền lực từ lá xuống rễ. Bọt khí (chất khí, không có lực liên kết như nước) làm gián đoạn cột nước này, khiến nước phía trên bọt khí không thể được kéo lên tiếp dù dưới bọt khí vẫn còn nhiều nước — do đó cành hoa bị héo dù cắm trong bình đầy nước. Đây là lý do khi cắm hoa, người ta thường cắt cành hoa **dưới nước** để tránh không khí lọt vào mạch gỗ.



Simplified comparison of a xylem vessel (dead, lignified, hollow, no perforated end walls) and a phloem sieve tube element with its adjacent companion cell (living, sieve plates with pores).

7.4 The Human Circulatory System: Double Circulation

Humans (and other mammals) have a **double circulatory system**: blood passes through the heart *twice* for each complete circuit of the body, via two separate circuits.

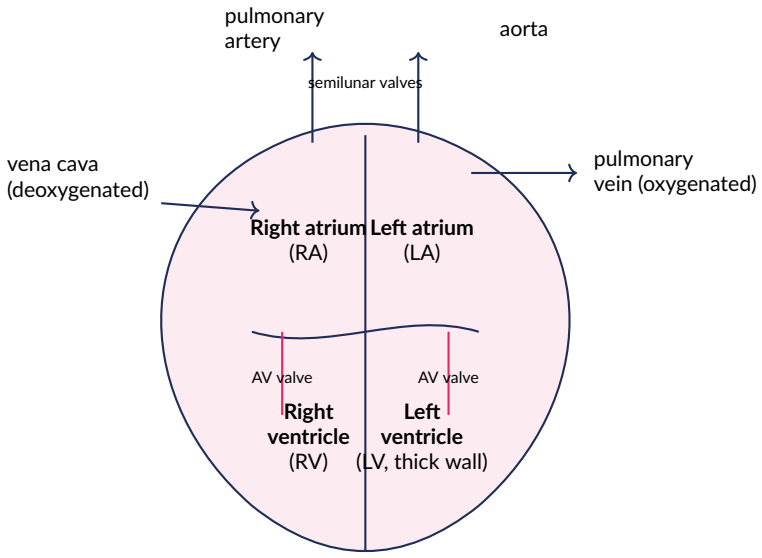
Pulmonary and systemic circulation

The **pulmonary circulation** carries deoxygenated blood from the heart to the lungs (to pick up oxygen and release CO_2) and oxygenated blood back to the heart. The **systemic circulation** carries oxygenated blood from the heart to all other body tissues (to deliver oxygen and nutrients) and deoxygenated blood back to the heart. Because blood returns to the heart *between* the two circuits, it can be re-pressurised before being sent around the body — this allows the systemic circuit, which must reach every organ of the body (often much further than the lungs), to be driven at much higher pressure than the pulmonary circuit, without over-pressurising the delicate capillaries of the lungs. Double circulation also keeps oxygenated and deoxygenated blood almost entirely separate, so that blood reaching body tissues is as fully oxygenated as possible.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tuần hoàn kép (double circulation) nghĩa là máu đi qua tim **hai lần** trong một vòng tuần hoàn đầy đủ: vòng **phổi** (pulmonary) — tim → phổi → tim; vòng **hệ thống** (systemic) — tim → toàn cơ thể → tim. Lý do tiến hoá ra tuần hoàn kép: (1) giữ máu giàu oxygen và máu nghèo oxygen **tách biệt**, không bị pha trộn; (2) máu được **tăng áp lại** sau khi qua tim, nên vòng hệ thống (đi xa, khắp cơ thể) có thể duy trì áp suất cao hơn nhiều so với vòng phổi (đi gần, mao mạch phổi mỏng manh, cần áp suất thấp để tránh tổn thương).

7.5 Heart Structure and Function



Simplified diagram of the human heart (anterior view; left/right as seen from the observer facing the heart, so the heart's left side appears on the diagram's right).

Chambers, valves and major vessels

The heart has four chambers: two thin-walled **atria** (upper chambers, receiving blood) and two thicker-walled **ventricles** (lower chambers, pumping blood out). **Atrioventricular (AV) valves** (tricuspid on the right, bicuspid/mitral on the left) prevent backflow of blood from ventricles into atria when the ventricles contract; **semilunar valves** in the pulmonary artery and aorta prevent backflow of blood into the ventricles once it has been ejected. Major vessels: the **vena cava** brings deoxygenated blood from the body into the right atrium; the **pulmonary artery** carries deoxygenated blood from the right ventricle to the lungs; the **pulmonary vein** returns oxygenated blood from the lungs to the left atrium; the **aorta** carries oxygenated blood from the left ventricle to the body. Fine branches of the **coronary arteries**, arising from the base of the aorta, supply the heart muscle itself with oxygenated blood.

Why the left ventricle wall is much thicker than the right: the left ventricle must generate enough pressure to pump blood all the way around the **systemic circuit** (to every organ in the body, often much further and against higher resistance), whereas the right ventricle only needs to pump blood the short distance to the **lungs** at lower pressure (protecting the delicate lung capillaries from damage). More muscle in the wall means a more forceful contraction and higher pressure generated, so the left ventricle's thicker wall reflects the higher pressure needed for the longer, more resistant systemic circuit.

VN **GIẢI THÍCH TIẾNG VIỆT**

Thành tâm thất trái (left ventricle) dày hơn hẳn tâm thất phải vì phải bơm máu đi **khắp cơ thể** (vòng hệ thống) — xa hơn và cần áp suất cao hơn nhiều so với việc bơm máu chỉ đến **phổi** (vòng phổi, gần, cần áp suất thấp để tránh làm vỡ mao mạch phổi mỏng manh). Van tim (van nhĩ-thất và van bán nguyệt) đều có chung một nguyên tắc: ngăn máu chảy **ngược chiều**, đảm bảo máu chỉ di chuyển một chiều qua tim.

(!) Lỗi thường gặp: Trên sơ đồ tim nhìn từ phía trước (như hình vẽ trong sách), bên **trái** của tim (tâm nhĩ trái, tâm thất trái) lại nằm ở phía **bên phải** của hình vẽ — vì hình vẽ theo góc nhìn của người quan sát đối diện với bệnh nhân. Đây là lỗi định hướng rất hay gặp khi học sinh làm bài dán nhãn sơ đồ tim.

7.5.1 (Supplement) Coronary heart disease

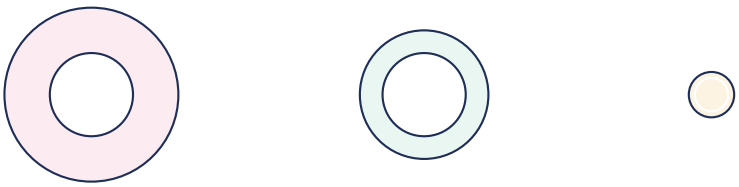
The heart muscle itself is supplied with oxygenated blood by the **coronary arteries**. In **coronary heart disease**, fatty deposits (largely cholesterol) build up inside the walls of the coronary arteries, narrowing the lumen and restricting blood flow to the heart muscle; if a coronary artery becomes completely blocked, the section of heart muscle it supplies is starved of oxygen and can die (a heart attack). Risk factors include a diet high in saturated fat (which raises blood cholesterol, contributing to fatty deposits), smoking (damages artery walls and raises blood pressure), and lack of exercise (associated with higher blood pressure and poorer cardiovascular fitness).

VN **GIẢI THÍCH TIẾNG VIỆT**

Bệnh mạch vành (coronary heart disease) xảy ra khi **chất béo tích tụ** trong thành động mạch vành, làm hẹp lòng mạch, giảm lượng máu giàu oxygen đến nuôi chính cơ tim; nếu tắc hoàn toàn, phần cơ tim tương ứng bị thiếu oxygen và có thể chết (nhồi máu cơ tim). Ba yếu tố nguy cơ chính cần nhớ: chế độ ăn nhiều chất béo bão hoà, hút thuốc lá, và ít vận động.

7.6 Blood Vessels

Vessel	Wall structure	Reasoning	Lumen / valves
Artery	Thick wall with much muscle and elastic tissue	Withstands and maintains high pressure pumped from the heart; elastic tissue stretches and recoils to smooth out pulses of pressure	Narrow lumen; no valves (pressure keeps blood flowing forward)
Vein	Thinner wall, less muscle/elastic tissue	Blood pressure is much lower by the time blood returns to the heart, so a thick wall is not needed	Wide lumen; contains **valves** to prevent backflow, since pressure alone cannot keep blood moving against gravity
Capillary	Wall only one cell thick	Minimises diffusion distance for exchange of gases, nutrients and waste between blood and tissue cells	Very narrow lumen (often single file of red blood cells); no valves



Relative wall thickness and lumen size of an artery, vein and capillary (schematic cross-sections, not to a single common scale).

Why veins need valves but arteries do not

Explain why veins contain valves along their length, while arteries do not.

Blood in arteries is still under relatively high pressure directly from the pumping heart, which is generally sufficient to keep it flowing in the correct direction without the need for valves. By the time blood has passed through the narrow capillary network and entered veins, most of that pressure has been lost through resistance in the capillaries; in many parts of the body (especially the legs), venous blood must also flow *against* gravity to return to the heart. Without valves, this low-pressure blood could easily flow backward under gravity between heartbeats or during muscle relaxation; valves close after blood passes, preventing this backflow and ensuring blood moves in only one direction, back toward the heart.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bảng so sánh động mạch/tĩnh mạch/mao mạch cần trả lời theo kiểu **cấu tạo** → **lý do**: động mạch thành dày, nhiều cơ và mô đàn hồi vì phải chịu áp lực cao trực tiếp từ tim; tĩnh mạch thành mỏng hơn nhưng có **van** vì áp lực máu đã giảm nhiều, cần van để tránh máu chảy ngược (đặc biệt ở chân, phải thắng trọng lực); mao mạch thành chỉ dày **một lớp tế bào** để rút ngắn quãng đường khuếch tán, phù hợp với vai trò trao đổi chất ở cấp độ mô.

7.7 Blood Components

Plasma, cells and platelets

Plasma is the pale yellow liquid part of blood (mostly water) that transports dissolved substances: glucose and amino acids (absorbed from digestion), CO_2 and urea (waste products for excretion), hormones (chemical messengers), and heat (helping distribute body heat evenly and regulate temperature).

Red blood cells (erythrocytes) contain **haemoglobin**, which combines reversibly with oxygen to transport it from the lungs to respiring tissues; they are **biconcave** in shape (increasing surface area to volume ratio for gas exchange) and have **no nucleus** (leaving more internal space for haemoglobin).

White blood cells (leucocytes) defend the body against pathogens: **phagocytes** engulf and digest pathogens directly, while **lymphocytes** produce antibodies as part of the specific immune response (detailed in the diseases and immunity unit).

Platelets are small cell fragments involved in **blood clotting** at a wound site, helping to seal damaged blood vessels and prevent both blood loss and pathogen entry.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốn thành phần của máu cần nhớ đúng chức năng: **huyết tương (plasma)** — vận chuyển chất hoà tan (glucose, amino acid, CO_2, urea, hormone, nhiệt); **hồng cầu** — vận chuyển oxygen nhờ haemoglobin, hình đĩa lõm hai mặt và không nhân để tối ưu vận chuyển; **bạch cầu** — có hai loại chính, thực bào (phagocyte) nuốt trực tiếp mầm bệnh và bạch huyết bào (lymphocyte) tạo kháng thể; **tiểu cầu (platelet)** — tham gia đông máu tại vết thương.

7.7.1 (Supplement) Blood clotting

When a blood vessel is damaged, **platelets** accumulate at the site and, together with substances released from the damaged tissue, trigger a chain of reactions that converts the soluble plasma protein **fibrinogen** into insoluble **fibrin**. Fibrin strands form a mesh across the wound, trapping red blood cells and forming a **clot**, which seals the wound, prevents further blood loss, and blocks the entry of pathogens through the broken skin.

Effect of a low platelet count

A patient has an abnormally low platelet count. Predict and explain the effect on the patient's ability to respond to a small cut.

With too few platelets, the chain of reactions that converts fibrinogen into fibrin is triggered less effectively (or too slowly) at the wound site, so a stable fibrin mesh (clot) forms more slowly or incompletely. As a result, the patient is likely to bleed for longer than normal from even a small cut, and the wound is left open to infection by pathogens for a longer period, since the physical barrier normally provided by a clot is delayed or reduced.

VN **GIẢI THÍCH TIẾNG VIỆT**

Đông máu là một cơ chế bảo vệ không đặc hiệu quan trọng: tiểu cầu (platelet) tập trung tại vết thương, kích hoạt biến đổi **fibrinogen** (protein hoà tan trong huyết tương) thành **fibrin** (dạng sợi không hoà tan), tạo thành lưới giữ hồng cầu lại, hình thành cục máu đông — bịt kín vết thương và ngăn mầm bệnh xâm nhập. Số lượng tiểu cầu thấp → đông máu chậm/kém → chảy máu kéo dài và tăng nguy cơ nhiễm trùng.

7.8 Practice Bank

Bài tập luyện tập

Which row correctly describes xylem and phloem?

(A) Xylem: living cells, transports sucrose; Phloem: dead cells, transports water

(B) Xylem: dead cells, transports water/minerals upward; Phloem: living cells, translocates sucrose/amino acids

(C) Xylem: living cells, transports water; Phloem: dead cells, translocates sucrose

(D) Xylem: dead cells, transports sucrose; Phloem: living cells, transports water

Lời giải chi tiết

(B). Xylem consists of dead, lignified cells that transport water and mineral ions upward (and provide support); phloem consists of living cells (sieve tube elements and companion cells) that translocate sucrose and amino acids between sources and sinks.

Bài tập luyện tập

Explain why the left ventricle wall is much thicker than the right ventricle wall.

Lời giải chi tiết

The left ventricle pumps blood into the systemic circuit, which supplies the whole body and requires much higher pressure to overcome the greater distance and resistance involved. The right ventricle only pumps blood to the nearby lungs at lower pressure, protecting the delicate lung capillaries. More muscle in the left ventricle wall allows it to contract more forcefully, generating the higher pressure the systemic circuit requires.

Bài tập luyện tập

Explain why veins, unlike arteries, contain valves.

Lời giải chi tiết

Blood pressure in veins is much lower than in arteries, having already dropped substantially while passing through the capillary network. In many parts of the body, venous blood must flow against gravity to reach the heart; valves prevent this low-pressure blood from flowing backward, ensuring one-way flow toward the heart. Arterial blood is under high enough pressure directly from the heart that backflow is not a significant risk, so arteries do not need valves.

Bài tập luyện tập

An air bubble moves 12 cm along a potometer capillary tube of radius 0.1 cm in 6 minutes. Calculate the rate of water uptake.

Lời giải chi tiết

$V = \pi r^2 h = \pi(0.1)^2(12) = \pi(0.01)(12) = 0.377$ cm^3 (3 s.f.).
Rate $= \dfrac{0.377}{6} = 0.0628$ cm^3 min^{-1} (3 s.f.).

Bài tập luyện tập

A cut flower is left standing in a vase of water, but the stem was cut in air (not underwater), and an air bubble becomes trapped in the xylem. Explain why the flower still wilts.

Lời giải chi tiết

The transpiration pull relies on a continuous, unbroken column of water inside the xylem, held together by cohesion between water molecules, to transmit the pulling force from the evaporating surface of the leaf all the way down to the water source. An air bubble breaks this continuity: air molecules do not cohere to water the same way, so the pulling force cannot be transmitted past the bubble. Water above the bubble can no longer be replaced from below, so the leaves above the blockage lose water through transpiration faster than it can be replaced, and the flower wilts even though water is freely available in the vase.

Bài tập luyện tập

A radioactively labelled sugar is applied to a mature leaf. It is later detected in the roots and in a developing fruit, but not in a neighbouring mature leaf of similar age. Explain this pattern using the concepts of source and sink.

Lời giải chi tiết

The labelled leaf is acting as a **source**, exporting surplus sugar it has produced by photosynthesis. The roots and the developing fruit are both acting as **sinks** at this time — the roots need sugar for respiration and growth, and the fruit needs sugar for its own growth and storage — so labelled sugar is translocated to both. A neighbouring mature leaf of similar age is likely also photosynthesising and acting as a source itself (or, at most, self-sufficient), rather than importing sugar, so it does not receive the labelled sugar from the first leaf.

Bài tập luyện tập

State two functions of blood plasma, giving one substance transported in each case.

Lời giải chi tiết

(1) Transport of the waste products of metabolism for excretion — e.g. carrying **urea** from the liver to the kidneys, and **carbon dioxide** from respiring tissues to the lungs. (2) Transport of digested food substances — e.g. carrying **glucose** and amino acids from the small intestine to body cells. (Other valid answers: transport of hormones, or distribution of heat around the body.)

Bài tập luyện tập

A patient has an abnormally low platelet count. Explain the likely effect on their response to a minor skin cut.

Lời giải chi tiết

Platelets trigger the conversion of fibrinogen into fibrin at a wound site, forming the fibrin mesh that traps red blood cells and forms a clot. With too few platelets, this clotting process is slower and less effective, so the patient is likely to bleed for longer than normal from even a minor cut, and the wound remains open to infection by pathogens for longer, since the clot's protective barrier forms more slowly.

Bài tập luyện tập

Explain why increasing air movement (wind) around a leafy shoot increases its rate of transpiration.

Lời giải chi tiết

A layer of relatively humid air tends to build up next to the leaf surface as water vapour diffuses out of the stomata; this reduces the concentration gradient between the inside of the leaf and the surrounding air, slowing further diffusion. Moving air continuously sweeps this humid layer away, replacing it with drier air, which maintains a steeper concentration gradient of water vapour between the leaf's internal air spaces and the atmosphere, so water vapour diffuses out faster and the transpiration rate increases.

Bài tập luyện tập

A potometer bubble moves 5 cm in 2 minutes through a tube of radius 0.08 cm. Calculate the rate of water uptake in $\text{cm}^3\ \text{min}^{-1}$.

Lời giải chi tiết

$V = \pi r^2 h = \pi(0.08)^2(5) = \pi(0.0064)(5) = 0.1005$ cm^3 (4 s.f.).
Rate $= \dfrac{0.1005}{2} = 0.0503$ $\text{cm}^3\ \text{min}^{-1}$ (3 s.f.).

Bài tập luyện tập

Explain why capillary walls are only one cell thick, relating this feature to the function of capillaries.

Lời giải chi tiết

Capillaries are the site of exchange between blood and body tissues — oxygen, glucose and other substances diffuse out to tissue cells, while CO_2 and other wastes diffuse into the blood. A wall only one cell thick minimises the diffusion distance between blood plasma and tissue fluid, allowing this exchange to occur quickly and efficiently across the very large total surface area provided by the capillary network.

Bài tập luyện tập

Describe the double circulation of blood in humans, naming the two circuits and explaining one advantage of this arrangement.

Lời giải chi tiết

The **pulmonary circulation** carries deoxygenated blood from the heart to the lungs and oxygenated blood back to the heart; the **systemic circulation** carries oxygenated blood from the heart to the rest of the body and deoxygenated blood back to the heart. Because blood passes through the heart between the two circuits, it can be re-pressurised, allowing the systemic circuit (which must reach the whole body) to operate at much higher pressure than the pulmonary circuit (which only needs to reach the nearby lungs) — protecting the delicate lung capillaries while still delivering oxygenated blood at high pressure to distant tissues.

Bài tập luyện tập

Name the valve that prevents blood flowing back from the left ventricle into the left atrium, and the valve that prevents blood flowing back from the aorta into the left ventricle.

Lời giải chi tiết

The **bicuspid (mitral) valve**, an atrioventricular valve, prevents backflow from the left ventricle into the left atrium. The **semilunar valve** in the aorta (the aortic valve) prevents backflow from the aorta into the left ventricle once blood has been ejected.

Bài tập luyện tập

Explain why fatty deposits in a coronary artery can lead to a heart attack.

Lời giải chi tiết

Fatty deposits narrow the lumen of the coronary artery, restricting the flow of oxygenated blood to the section of heart muscle it supplies. If the artery becomes completely blocked (e.g. by a blood clot forming on the fatty deposit), that section of heart muscle is deprived of oxygen and cannot respire aerobically; without oxygen, the muscle cells cannot generate enough energy to survive and function, and heart tissue begins to die — this is a heart attack, which can seriously impair the heart's ability to pump blood.

Bài tập luyện tập

State three risk factors for coronary heart disease.

Lời giải chi tiết

(1) A diet high in saturated fat, which raises blood cholesterol and contributes to fatty deposits in artery walls. (2) Smoking, which damages artery walls and raises blood pressure. (3) Lack of exercise, associated with poorer cardiovascular fitness and higher blood pressure. (Other valid answers: obesity, high blood pressure, family history/genetics.)

Bài tập luyện tập

A student says "light directly speeds up the evaporation of water from a leaf, increasing transpiration." Explain why this is a slightly inaccurate description of how light affects transpiration rate.

Lời giải chi tiết

Light does not directly increase the physical rate of evaporation from cell walls (that is influenced by temperature and humidity, not light itself). Instead, light causes stomata to open (since photosynthesis needs CO_2, which enters through open stomata in daylight); this larger open pore area increases the surface through which water vapour can diffuse out of the leaf, indirectly increasing the transpiration rate. The effect of light is therefore mediated through stomatal opening, not through directly speeding up evaporation itself.

Bài tập luyện tập

Explain why red blood cells have no nucleus and are biconcave in shape.

Lời giải chi tiết

Having no nucleus leaves more internal space for **haemoglobin**, the protein that binds oxygen, maximising the amount of oxygen each cell can carry. The **biconcave** shape increases the cell's surface area relative to its volume, allowing oxygen to diffuse into and out of the cell more quickly, and also allows the cell to flex and pass through narrow capillaries.

Bài tập luyện tập

Distinguish between the roles of phagocytes and lymphocytes among white blood cells, in one sentence each.

Lời giải chi tiết

Phagocytes engulf and digest pathogens directly, as part of the body's non-specific defence. **Lymphocytes** recognise specific antigens and produce antibodies against them, as part of the body's specific immune response.

Bài tập luyện tập

A potometer bubble is found to move faster on a hot, dry, windy day than on a cool, humid, still day, all else being equal. Explain this observation in terms of three separate factors.

Lời giải chi tiết

Higher temperature increases the kinetic energy of water molecules, speeding up evaporation from mesophyll cell walls. **Lower humidity** means a larger concentration gradient of water vapour between the inside of the leaf and the outside air, so diffusion out through the stomata is faster. **Greater wind/air movement** continuously removes the humid air layer next to the leaf surface, maintaining a steep concentration gradient. All three factors act together to increase the rate of transpiration (and hence water uptake, as measured by the potometer) on a hot, dry, windy day compared with a cool, humid, still day.

Bài tập luyện tập

Explain why xylem vessels, despite being made of dead cells, are still essential living structures for the plant.

Lời giải chi tiết

Although the cells themselves are dead (having lost their cytoplasm and nucleus during development), the hollow, lignified tubes they form are essential for the plant's survival: they provide the continuous, low-resistance pathway needed to transport water and mineral ions from the roots to the rest of the plant, without which cells throughout the plant would lack water for turgidity, photosynthesis and metabolic reactions. Being dead is in fact an advantage here, since it leaves an unobstructed hollow tube (no cytoplasm or organelles blocking the lumen) for efficient bulk flow of water.

Bài tập luyện tập

A plant physiologist increases the CO_2 concentration around a leafy shoot while keeping light, temperature and humidity constant. Explain whether this is likely to have a significant direct effect on the rate of transpiration.

Lời giải chi tiết

CO_2 concentration is not one of the main environmental factors that directly affects transpiration rate (which is controlled mainly by temperature, humidity, air movement and light-driven stomatal opening). However, CO_2 concentration can have an indirect effect via stomatal behaviour: if CO_2 concentration around the leaf is raised substantially, stomata may partially close (since the plant needs less stomatal opening to obtain sufficient CO_2 for photosynthesis), which could slightly reduce transpiration by reducing the area available for water vapour to diffuse out. Overall, though, the direct effect of CO_2 on transpiration is much smaller than that of temperature, humidity or wind.

Bài tập luyện tập

Calculate the rate of water uptake if a potometer bubble moves 20 cm in 8 minutes through a capillary tube of radius 0.06 cm.

Lời giải chi tiết

$V = \pi r^2 h = \pi(0.06)^2(20) = \pi(0.0036)(20) = 0.2262$ cm^3 (4 s.f.).
Rate $= \dfrac{0.2262}{8} = 0.0283$ cm^3 min^{-1} (3 s.f.).

Bài tập luyện tập

Explain, with reference to companion cells, why phloem sieve tube elements can transport sucrose actively even though the sieve tube elements themselves have very few organelles.

Lời giải chi tiết

Sieve tube elements are living but have lost most of their organelles (including the nucleus) to maximise internal space for the flow of sap, so they cannot independently carry out the metabolic activity (e.g. active loading of sucrose) needed for translocation. Each sieve tube element is closely associated with a **companion cell**, which retains a nucleus and a full set of organelles and carries out this metabolic work on the sieve tube element's behalf, including providing the energy (ATP) needed to actively load sucrose into the sieve tubes at the source.

Bài tập luyện tập

A patient's blood test shows a much lower than normal red blood cell count. Predict and explain the likely symptoms.

Lời giải chi tiết

Fewer red blood cells means less haemoglobin overall, reducing the blood's capacity to carry oxygen from the lungs to respiring tissues. Tissues receive less oxygen for aerobic respiration and therefore generate less ATP, leading to symptoms such as tiredness, weakness, and breathlessness on exertion — this condition is a form of anaemia (whether caused by iron deficiency, blood loss, or another cause affecting red blood cell numbers).

Bài tập luyện tập

Explain why a plant wilts on a hot, dry, windy afternoon even though its soil still contains some water.

Lời giải chi tiết

On a hot, dry, windy afternoon, the rate of transpiration (water loss from the leaves) is at its highest, because high temperature speeds up evaporation, low humidity maintains a steep water-vapour concentration gradient, and wind continuously removes the humid air layer next to leaves. If the rate at which roots can absorb water from the soil (which may itself be limited if the soil is only moderately moist) cannot keep pace with this very high transpiration rate, the plant loses water faster than it is replaced. Cells lose turgor as a result, and the plant wilts, even though the soil is not completely dry — the imbalance between water loss and water uptake, not total absence of soil water, causes the wilting.

Bài tập luyện tập

State the four chambers of the heart and, for each, whether it contains oxygenated or deoxygenated blood.

Lời giải chi tiết

Right atrium: deoxygenated blood (received from the vena cava). **Right ventricle:** deoxygenated blood (pumped to the pulmonary artery). **Left atrium:** oxygenated blood (received from the pulmonary vein). **Left ventricle:** oxygenated blood (pumped to the aorta).

Bài tập luyện tập

Explain why blood entering the right atrium from the vena cava must pass through the lungs before it can be pumped around the systemic circuit.

Lời giải chi tiết

Blood returning via the vena cava is deoxygenated, having already delivered its oxygen to body tissues in the systemic circuit. Before this blood can usefully supply the body again, it must pick up a fresh supply of oxygen (and release CO_2) in the lungs, via the pulmonary circulation. The right side of the heart (right atrium, right ventricle) exists specifically to send this deoxygenated blood to the lungs first; only after returning from the lungs as oxygenated blood (via the pulmonary vein into the left atrium) can it be pumped into the systemic circuit by the left ventricle.

Bài tập luyện tập

Explain, in terms of water potential, how water moves from the soil into a root hair cell and then across the root cortex toward the xylem.

Lời giải chi tiết

Soil water usually has a higher water potential (more dilute solution, less negative) than the cytoplasm inside a root hair cell, so water moves into the root hair cell by **osmosis**, down this water potential gradient, across the partially permeable cell membrane. As water enters, the root hair cell's water potential rises slightly, but the next cell across the cortex (closer to the xylem) typically has a slightly lower (more negative) water potential, so water continues to move cell-to-cell by osmosis along a chain of decreasing water potential, until it reaches the xylem, where it is drawn upward by the transpiration pull.

Bài tập luyện tập

A student compares two plants, one kept in bright light and one kept in the dark, otherwise under identical conditions. Predict which plant will show a higher transpiration rate, and explain why.

Lời giải chi tiết

The plant kept in **bright light** will show a higher transpiration rate. Light causes stomata to open more widely (since photosynthesis requires CO_2 uptake, which needs open stomata), providing a larger surface area through which water vapour can diffuse out of the leaf. The plant in the

dark will have more closed stomata (since there is no need to admit CO_2 for photosynthesis), restricting the pathway for water vapour loss and resulting in a lower transpiration rate.

Bài tập luyện tập

Summarise, in a short table or list, one structural feature and its functional reason for each of: xylem, phloem, artery, vein, capillary.

Lời giải chi tiết

Xylem: lignified, dead, hollow cells — gives a rigid, unobstructed tube for one-way upward water transport and mechanical support. **Phloem:** living sieve tube elements with companion cells — allows active, energy-requiring loading/unloading of sucrose for translocation in either direction. **Artery:** thick, muscular, elastic wall — withstands and smooths high pressure directly from the heart. **Vein:** wide lumen with valves — accommodates low-pressure flow and prevents backflow, especially against gravity. **Capillary:** wall one cell thick — minimises diffusion distance for efficient exchange between blood and tissue cells.

Diseases and Immunity

Mục tiêu Unit: Định nghĩa mầm bệnh (pathogen) và phân loại thành bốn nhóm (vi khuẩn, virus, nấm, nguyên sinh động vật) kèm ví dụ bệnh và đường lây truyền; mô tả các hàng rào bảo vệ không đặc hiệu của cơ thể (da, chất nhầy/lông mao, acid dạ dày, đông máu, thực bào); giải thích đáp ứng miễn dịch đặc hiệu (kháng nguyên, tế bào lympho, kháng thể, tế bào nhớ, đáp ứng lần đầu và lần hai); phân biệt miễn dịch chủ động và thụ động; giải thích cơ chế tiêm vaccine và khái niệm miễn dịch cộng đồng; và nêu khái quát về kháng thể đơn dòng.

8.1 Pathogens and Transmission

A **pathogen** is a disease-causing organism. Pathogens fall into four major groups, each with characteristic diseases and transmission routes.

Pathogen group	Disease	Causative organism	Transmission route
Bacterium	Cholera	*Vibrio cholerae*	Contaminated water or food (faecal-oral route); poor sanitation
Bacterium	Tuberculosis (TB)	*Mycobacterium tuberculosis*	Airborne droplets from coughing/sneezing of an infected person
Virus	Measles	Measles virus	Airborne droplets from coughing/sneezing
Virus	HIV/AIDS	Human immunodeficiency virus	Unprotected sexual contact; contaminated blood/needles; mother to child (pregnancy, birth, breastfeeding)
Fungus	Athlete's foot	*Tinea* fungus	Direct or indirect contact (e.g. shared floors, towels), especially in warm, moist conditions
Protoctist	Malaria	*Plasmodium* (a protoctist)	Vector-borne: transmitted by the bite of an infected *Anopheles* mosquito

Modes of transmission — the underlying categories

- **Direct contact:** pathogen passes directly from an infected person/surface to another person (e.g. athlete's foot fungus via shared surfaces).
- **Droplet infection:** pathogen is expelled in tiny droplets of saliva/mucus during coughing or sneezing and inhaled by another person (e.g. measles, tuberculosis).
- **Contaminated food or water (faecal-oral route):** pathogen from an infected person's faeces contaminates water or food that another person then consumes (e.g. cholera).

- **Vector-borne:** an intermediate organism (a **vector**, often an insect) carries the pathogen from one host to another without necessarily becoming ill itself (e.g. *Anopheles* mosquitoes transmitting malaria).
- **Bodily fluids / blood-borne:** pathogen passes via blood, semen or other bodily fluids, including through shared needles, unprotected sex, or mother-to-child transmission (e.g. HIV).

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Bốn nhóm mầm bệnh cần nhớ cùng ví dụ bệnh và đường lây: **vi khuẩn** (bacterium) — tả (cholera, qua nước/thức ăn ô nhiễm), lao (tuberculosis, qua giọt bắn khi ho); **virus** — sởi (measles, qua giọt bắn), HIV/AIDS (qua quan hệ tình dục không an toàn, máu, mẹ sang con); **nấm** (fungus) — nấm chân (athlete's foot, qua tiếp xúc trực tiếp/gián tiếp); **nguyên sinh động vật** (protoctist) — sốt rét (malaria, qua **vật trung gian truyền bệnh (vector)** là muỗi *Anopheles*). Lỗi hay gặp: gọi muỗi là "mầm bệnh" — **sai**, muỗi chỉ là vector, mầm bệnh thực sự là ký sinh trùng *Plasmodium* sống bên trong muỗi và được truyền vào máu người khi muỗi đốt.

Reasoning about mosquitoes as a vector

Explain why controlling the mosquito population is an effective public health strategy against malaria, even though mosquitoes are not themselves the pathogen.

Malaria is caused by the protoctist *Plasmodium*, but this pathogen can only be transmitted between humans via the bite of an infected *Anopheles* mosquito, which acts as the disease's **vector**. If mosquito numbers are reduced (e.g. by removing standing water where they breed, using insecticide-treated bed nets, or spraying insecticide), the chance of an infected mosquito biting an uninfected person falls sharply, breaking the transmission cycle between people — even though this strategy does not act on *Plasmodium* itself. This illustrates why vector control can be highly effective against vector-borne diseases in general.

8.1.1 (Supplement) Why antibiotics treat bacterial but not viral infections

Bacteria are complete, living cells with their own cell wall, membrane, cytoplasm, ribosomes and metabolic machinery; **antibiotics** work by disrupting processes specific to bacterial cells (e.g. bacterial cell wall synthesis) without harming the much larger, structurally different cells of the human body. Viruses, in contrast, are not cells at all — merely genetic material (DNA or RNA) enclosed in a protein coat — and can only reproduce by hijacking the internal machinery of a living host cell. Because viruses lack the bacterial-specific structures and processes that antibiotics target, **antibiotics have no effect on viral infections**; viral diseases (e.g. measles, HIV) instead rely on prevention (vaccination) or, in some cases, specific antiviral drugs, rather than antibiotics.

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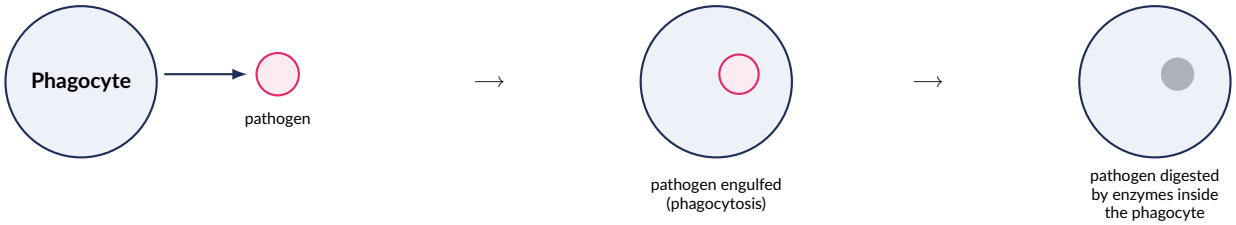
Vi khuẩn là **tế bào sống hoàn chỉnh** (có vách tế bào, màng, tế bào chất, ribosome) nên **kháng sinh (antibiotics)** có thể tấn công các cấu trúc/quá trình đặc trưng của vi khuẩn (ví dụ tổng hợp vách tế bào) mà không hại tế bào người. Virus **không phải là tế bào** — chỉ là vật chất di truyền bọc trong lớp vỏ protein, phải "mượn" bộ máy của tế bào chủ để nhân lên — nên **kháng sinh hoàn toàn không có tác dụng với virus**. Đây là lý do bệnh do virus (sởi, HIV) không thể chữa bằng kháng sinh, mà chủ yếu phòng ngừa bằng vaccine.

8.2 Non-Specific Defences Against Pathogens

The body has several **non-specific** defences (acting the same way against any pathogen, without recognising which particular species it is) that form the first lines of defence before the specific immune response is engaged.

Non-specific defence mechanisms

- **Skin:** an intact physical barrier that most pathogens cannot penetrate; skin also secretes slightly acidic, antimicrobial substances that inhibit bacterial growth on its surface.
- **Mucus and cilia in the trachea/airways:** the lining of the trachea secretes sticky **mucus** that traps inhaled pathogens and dust particles; microscopic hair-like **cilia** on the cells lining the trachea beat continuously, sweeping the mucus (and trapped pathogens) up toward the throat, where it can be swallowed or coughed out, away from the lungs.
- **Stomach acid:** hydrochloric acid secreted by the stomach creates a strongly acidic environment (pH $\approx$ 2) that kills many pathogens ingested with food or drink before they can reach the intestines.
- **Blood clotting:** when the skin is damaged, platelets and damaged tissue trigger the conversion of fibrinogen into fibrin, forming a clot that seals the wound, both preventing blood loss and blocking the entry route pathogens would otherwise use.
- **Phagocytosis:** certain white blood cells (**phagocytes**) engulf and digest pathogens directly (see below), acting against any pathogen they encounter, not just one specific type.



Phagocytosis: a phagocyte engulfs a pathogen, enclosing it in a vesicle, then digests it using enzymes.

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Năm hàng rào bảo vệ không đặc hiệu cần trình bày theo cơ chế cụ thể, không chỉ liệt kê tên: **da** — rào chắn vật lý; **chất nhầy + lông mao ở khí quản** — chất nhầy giữ mầm bệnh lại, lông mao quét chất nhầy lên họng để nuốt/ho ra ngoài; **acid dạ dày** — tiêu diệt mầm bệnh theo đường ăn uống; **đông máu** — bịt kín vết thương, ngăn đường xâm nhập; **thực bào (phagocytosis)** — bạch cầu thực bào nuốt và tiêu hoá mầm bệnh bằng enzyme, không phân biệt loại mầm bệnh cụ thể (đây là điểm khác biệt với đáp ứng miễn dịch **đặc hiệu** ở phần sau).

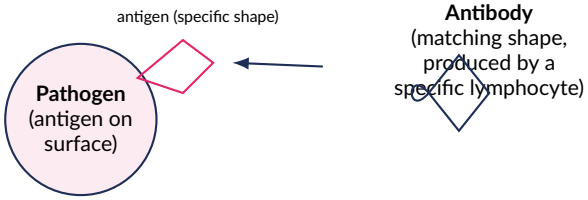
(!) Lỗi thường gặp: Đừng nhầm **thực bào (phagocytosis)** — một cơ chế **không đặc hiệu** — với đáp ứng miễn dịch **đặc hiệu** của tế bào lympho. Thực bào tấn công **bất kỳ** mầm bệnh nào nó gặp phải; tế bào lympho chỉ tạo kháng thể **đặc hiệu** với một loại kháng nguyên nhất định.

8.3 Specific Immune Response

Unlike non-specific defences, the **specific immune response** recognises and responds to one particular pathogen, based on molecules called **antigens** on its surface.

Antigens, lymphocytes, antibodies

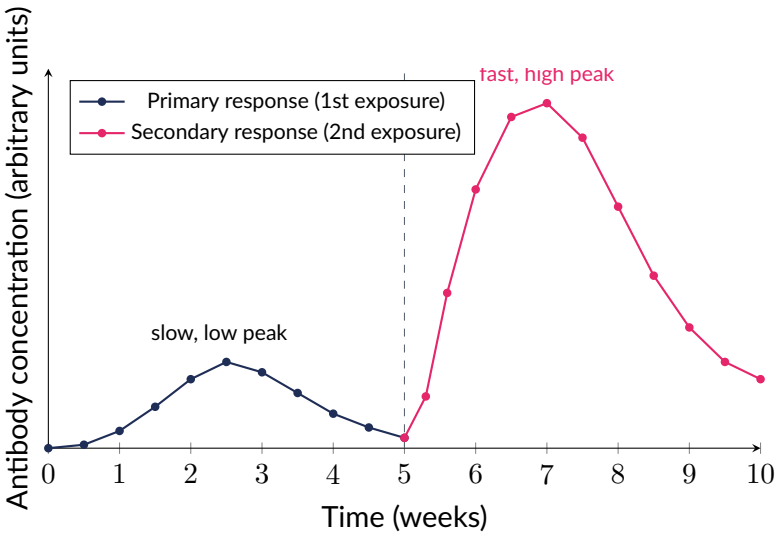
An **antigen** is a molecule (usually a protein) on the surface of a pathogen (or other foreign cell) that the immune system can recognise as "non-self". **Lymphocytes** (a type of white blood cell) can detect specific antigens; when a lymphocyte encounters a pathogen bearing an antigen it recognises, it is stimulated to multiply and produce large numbers of **antibodies** — proteins that bind specifically to that antigen, in a highly specific "lock-and-key"-like interaction (each antibody's shape matches only one, or a very limited range of, antigen shapes). Antibodies bound to a pathogen can cause it to clump together (agglutination), mark it for destruction by phagocytes, or neutralise toxins it produces, helping to clear the infection.



Schematic of antigen–antibody specificity: each antibody's binding site shape matches only its specific antigen, similar to a lock and key.

Memory cells and the secondary response

After an infection is cleared, some of the lymphocytes that responded remain in the body as long-lived **memory cells**, "primed" to recognise the same antigen if it is encountered again. The first time a particular pathogen infects the body, the **primary response** is relatively slow to develop and produces a comparatively low peak concentration of antibodies, because few lymphocytes initially recognise the antigen and must first multiply. If the same pathogen is encountered again, memory cells allow a much faster, stronger **secondary response**: antibody concentration rises sooner and reaches a much higher peak, often clearing the pathogen before symptoms of disease can develop.



Antibody concentration versus time for a first (primary) and second (secondary) exposure to the same pathogen. The secondary response, driven by memory cells from the first exposure, begins sooner, rises faster, and reaches a much higher peak.

Reading the primary/secondary response graph

Using the graph above, explain why a person who has previously had chickenpox rarely develops symptoms again, even after being re-exposed to the virus years later.

During the first infection, the immune system mounts a **primary response**: lymphocytes that recognise the chickenpox virus's antigens are relatively rare at first, so it takes time for them to multiply and produce enough antibodies to clear the infection — during this delay, the virus multiplies enough to cause the symptoms of chickenpox. Crucially, some of these lymphocytes persist afterward as long-lived **memory cells**. On re-exposure years later, these memory cells allow a much faster **secondary response**: antibody production begins almost immediately and reaches a much higher concentration in a shorter time, typically destroying the virus before it can multiply enough to cause noticeable symptoms. This is why chickenpox (and many other viral infections) typically confers long-lasting immunity after a single infection.

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Đáp ứng miễn dịch đặc hiệu dựa trên **kháng nguyên** (antigen, phân tử lạ trên bề mặt mầm bệnh) được tế bào **lympho** nhận diện, kích thích sản xuất **kháng thể** (antibody) đặc hiệu theo kiểu "chìa khoá–ổ khoá". Sau lần nhiễm đầu tiên, một số tế bào lympho tồn tại lâu dài thành **tế bào nhớ** (memory cells), giúp lần nhiễm thứ hai (đáp ứng thứ cấp/secondary response) diễn ra **nhanh hơn** và đạt nồng độ kháng thể **cao hơn nhiều** so với lần đầu (đáp ứng sơ cấp/primary response) — thường đủ nhanh để tiêu diệt mầm bệnh trước khi kịp gây triệu chứng bệnh. Đây chính là cơ sở khoa học của cả miễn dịch tự nhiên sau khi mắc bệnh lẫn tiêm vaccine.

Primary versus secondary response, summarised: the **primary response** (first exposure to an antigen) is slow to start, needs time for the few matching lymphocytes to multiply, and produces a relatively low peak antibody concentration — disease symptoms typically appear during this delay. The **secondary response** (subsequent exposure to the same antigen) starts almost immediately, because memory cells from the first exposure are already numerous, and produces a much higher peak antibody concentration in less time — often clearing the pathogen before symptoms can develop. Both vaccination and natural infection can establish the memory cells that make a fast secondary response possible.

8.4 Active versus Passive Immunity

Active immunity: the body produces its **own** antibodies, either after natural infection or after vaccination, because its own lymphocytes have been directly stimulated by the antigen. Because memory cells are formed, active immunity is typically **long-lasting** (sometimes lifelong).

Passive immunity: the body receives **ready-made** antibodies from another source — e.g. antibodies passed from mother to fetus across the placenta, or in breast milk to a newborn, or injected as an antiserum for emergency treatment. Because the individual's own lymphocytes were never stimulated by the antigen, no memory cells are formed, so passive immunity is typically **short-lived** (the borrowed antibodies are gradually broken down and not replaced).

Type	How it arises	Duration / memory cells
Natural active	Body produces its own antibodies after a real infection	Long-lasting; memory cells formed
Artificial active (vaccination)	Body produces its own antibodies after exposure to a safe form of antigen (vaccine)	Long-lasting; memory cells formed
Natural passive	Antibodies received from mother, via placenta (before birth) or breast milk (after birth)	Short-lived; no memory cells formed
Artificial passive	Ready-made antibodies injected directly (antiserum), e.g. for emergency treatment after exposure to a toxin or pathogen	Short-lived; no memory cells formed

(!) Lỗi thường gặp: Học sinh hay nhầm giữa hai loại miễn dịch: **chủ động (active)** — cơ thể **tự tạo** kháng thể (do nhiễm bệnh tự nhiên hoặc tiêm vaccine), có **tế bào nhớ** nên hiệu quả **lâu dài**; **thụ động (passive)** — cơ thể **nhận** kháng thể có sẵn từ nguồn khác (mẹ truyền qua nhau thai/sữa mẹ, hoặc tiêm huyết thanh kháng thể), **không tạo tế bào nhớ** nên chỉ có tác dụng **tạm thời**. Ghi nhớ: "chủ động = tự làm = lâu dài; thụ động = được cho = ngắn hạn."

Why breastfed babies are temporarily protected

Explain why a breastfed baby is often protected against certain infections that its mother is immune to, even though the baby's own immune system has never encountered those pathogens, and why this protection fades within the baby's first year.

Breast milk (and, before birth, blood crossing the placenta) contains antibodies made by the **mother's** immune system, which are passed directly to the baby. These maternal antibodies can bind to and help destroy pathogens the baby is exposed to, providing protection without the baby's own lymphocytes ever needing to recognise the antigen — this is **passive immunity**. Because the baby's own immune system was never stimulated to produce these antibodies itself, no memory cells are formed in the baby, and the maternal antibodies are gradually broken down over time without being replenished (since the baby is not making new ones of its own). As a result, this passive protection is temporary and fades within the first months to about a year of life, unless the baby's own immune system separately encounters (or is vaccinated against) the same pathogens and develops active immunity.

8.5 Vaccination

Vaccination deliberately triggers active immunity without causing the disease itself, by introducing a safe form of the pathogen's antigens into the body.

How a vaccine works

A vaccine typically contains a dead or weakened (**attenuated**) form of a pathogen, or isolated fragments of its antigens, which are unable to cause the disease itself but which still carry the antigens that the immune system can recognise. When introduced into the body (usually by injection), lymphocytes recognise these antigens and mount a **primary response**, producing antibodies and — crucially — forming **memory cells**, just as they would after a real infection. If

the vaccinated person is later exposed to the actual, live pathogen, their memory cells allow a fast, strong **secondary response**, usually clearing the pathogen before it can multiply enough to cause noticeable symptoms.

VN **GIẢI THÍCH TIẾNG VIỆT**

Vaccine hoạt động bằng cách đưa vào cơ thể một dạng **an toàn** của mầm bệnh (đã chết, làm yếu đi, hoặc chỉ là mảnh kháng nguyên) — đủ để hệ miễn dịch **nhận diện** và tạo đáp ứng sơ cấp (kháng thể + tế bào nhớ), nhưng **không đủ** để gây bệnh thật sự. Khi gặp mầm bệnh thật sau này, cơ thể đã có tế bào nhớ sẵn, tạo đáp ứng thứ cấp nhanh và mạnh, thường tiêu diệt mầm bệnh trước khi kịp gây triệu chứng. Đây là lý do vaccine tạo ra **miễn dịch chủ động**, không phải miễn dịch thụ động.

Why vaccines use weakened or dead pathogens, not fully active ones

Explain why vaccines are made using dead or weakened pathogens (or antigen fragments) rather than fully active, disease-causing pathogens.

The purpose of a vaccine is to trigger the immune system to recognise a pathogen's antigens and build up memory cells, *without* the recipient having to suffer the actual disease first. A dead or weakened pathogen (or an isolated antigen fragment) still displays the antigens needed for lymphocytes to recognise and respond to, but cannot multiply and cause the full disease process (or can only do so very mildly, in the case of some attenuated vaccines). Using a fully active pathogen would risk causing the very disease the vaccine is meant to prevent, defeating its purpose and posing unacceptable risk, especially to vulnerable individuals.

8.5.1 (Supplement) Herd immunity

When a sufficiently high proportion of a population is immune to a particular pathogen (through vaccination or prior infection), the pathogen finds it much harder to spread from one susceptible person to another, because most of the people an infected individual might contact are already immune. This reduced transmission, called **herd immunity**, indirectly protects even those who are not immune themselves (e.g. people who cannot be vaccinated for medical reasons), because the chain of transmission through the population is broken.

VN **GIẢI THÍCH TIẾNG VIỆT**

Miễn dịch cộng đồng (herd immunity) xảy ra khi **tỉ lệ đủ cao** trong quần thể đã miễn dịch (do tiêm vaccine hoặc từng mắc bệnh), khiến mầm bệnh khó lây lan vì phần lớn người mà một người nhiễm bệnh tiếp xúc đều đã miễn dịch. Nhờ đó, ngay cả những người **chưa** miễn dịch (ví dụ không thể tiêm vaccine vì lý do sức khoẻ) cũng được bảo vệ gián tiếp, vì chuỗi lây truyền trong cộng đồng bị cắt đứt.

8.5.2 (Supplement) Monoclonal antibodies

Monoclonal antibodies are identical antibodies, all produced from a single clone of lymphocytes, and are therefore all specific to exactly one antigen. Because of this precise specificity, they have important applications in diagnosis and treatment — for example, in a home pregnancy test, monoclonal antibodies are designed to bind specifically to a hormone (human chorionic gonadotrophin, hCG) present in the urine of pregnant women, producing a visible colour change only when that specific hormone is present.

VN **GIẢI THÍCH TIẾNG VIỆT**

Kháng thể đơn dòng (monoclonal antibodies) là các kháng thể **giống hệt nhau**, được sản xuất từ **một dòng tế bào duy nhất**, nên chỉ đặc hiệu với **một** loại kháng nguyên. Ứng dụng quen thuộc nhất là que thử thai tại nhà: kháng thể đơn dòng được thiết kế để liên kết đặc hiệu với hormone hCG có trong nước tiểu phụ nữ mang thai, tạo ra vạch màu chỉ khi có hormone này.

Why a monoclonal antibody test is specific

A home pregnancy test gives a positive result only in the presence of hCG, not other hormones present in urine. Explain why, in terms of antibody structure.

The monoclonal antibodies used in the test are all identical copies derived from a single original lymphocyte (a single "clone"), so every antibody molecule in the test has exactly the same binding site shape — one that fits only the hCG molecule, in a highly specific lock-and-key-like interaction. Other hormones in urine have different molecular shapes that do not fit this binding site, so they do not trigger the colour-change reaction. This precise specificity, arising from the antibodies all being identical clones targeting one antigen, is what allows the test to distinguish hCG from other substances in urine reliably.

Reasoning about herd immunity thresholds

Public health authorities often state that around 95% of a population needs to be immune to measles to sustain herd immunity, because measles is highly contagious. If a city of $500{,}000$ people has a vaccination coverage of 88%, estimate how many additional people would need to become immune to reach the 95% herd immunity target.

Number currently immune $\approx 0.88 \times 500{,}000 = 440{,}000$.
Target number immune $= 0.95 \times 500{,}000 = 475{,}000$.
Additional people needed $= 475{,}000 - 440{,}000 = 35{,}000$ people.
This shows why even a seemingly high vaccination rate (88%) can fall meaningfully short of the herd immunity threshold for a highly contagious disease like measles, leaving tens of thousands of people at elevated risk of a local outbreak.

8.6 Practice Bank

Bài tập luyện tập

Which row correctly matches pathogen group, disease and transmission route?

(A) Bacterium — malaria — vector (mosquito)
(B) Protoctist — malaria — vector (mosquito)
(C) Virus — cholera — contaminated water
(D) Fungus — HIV/AIDS — airborne droplets

Lời giải chi tiết

(B). Malaria is caused by *Plasmodium*, a protoctist, transmitted via the bite of an infected *Anopheles* mosquito (a vector). Cholera is caused by a bacterium (transmitted via contaminated water, not by a virus); HIV/AIDS is caused by a virus (transmitted via bodily fluids, not airborne droplets); athlete's foot, not HIV, is the fungal example.

Bài tập luyện tập

Explain why a breastfed baby is temporarily protected against certain diseases the mother is immune to, and why this protection does not last.

Lời giải chi tiết

Breast milk contains antibodies made by the mother's own immune system, passed to the baby — this is **passive immunity**. Because the baby's own lymphocytes were never stimulated to recognise the relevant antigens, no memory cells form in the baby, and the maternal antibodies are gradually broken down without being replaced. Protection therefore fades over time (typically within the first year), unless the baby's own immune system separately develops active immunity to the same pathogens.

Bài tập luyện tập

Explain why vaccines typically contain dead or weakened pathogens rather than fully active ones.

Lời giải chi tiết

The aim of a vaccine is to trigger the immune system to recognise the pathogen's antigens and produce memory cells, without causing the actual disease. A dead or weakened (attenuated) pathogen, or isolated antigen fragments, still carries the antigens needed to stimulate this response, but cannot cause full-blown disease. Using a fully active pathogen would risk causing the very illness the vaccine is meant to prevent.

Bài tập luyện tập

Explain why mosquitoes are described as a "vector" for malaria rather than as the pathogen itself.

Lời giải chi tiết

The pathogen that actually causes malaria is the protoctist *Plasmodium*. The mosquito does not itself cause the disease; it merely carries *Plasmodium* from one infected person to another when it feeds on blood, acting as a **vector** (transport agent) for transmission. Distinguishing the vector from the pathogen matters because control strategies can target either the vector (e.g. bed nets, eliminating mosquito breeding sites) or the pathogen itself (e.g. antimalarial drugs), and these require different approaches.

Bài tập luyện tập

A person who had chickenpox as a child rarely catches it again, even after being exposed to the virus decades later. Explain this in terms of memory cells and the secondary immune response.

Lời giải chi tiết

After the first (childhood) infection, some lymphocytes that recognised the chickenpox virus's antigens persisted as long-lived **memory cells**. On re-exposure to the virus later in life, these memory cells allow a fast **secondary response**: antibody production begins almost immediately and reaches a much higher concentration than during the first infection, typically destroying the virus before it can multiply enough to cause noticeable symptoms — unlike the

slower, weaker **primary response** that occurred during the original childhood infection.

Bài tập luyện tập

Two regions are comparing strategies against cholera and measles respectively. Region A improves its water sanitation infrastructure; Region B runs a vaccination campaign. Explain which intervention is more directly suited to each disease.

Lời giải chi tiết

Cholera is transmitted mainly via contaminated water and food (the faecal-oral route), so improving **water sanitation** (clean drinking water, proper sewage treatment) directly targets its main transmission pathway, reducing new infections without necessarily requiring a vaccine. Measles is transmitted via airborne droplets between people, a route that sanitation infrastructure does not address; a **vaccination campaign** instead builds active immunity (and, at sufficient coverage, herd immunity) across the population, which is the more directly effective intervention for an airborne viral disease like measles.

Bài tập luyện tập

Describe the mechanism of phagocytosis and explain why it is classified as a non-specific defence.

Lời giải chi tiết

A phagocyte (a type of white blood cell) engulfs a pathogen, enclosing it within a vesicle inside the cell, and then digests it using enzymes. This process is classified as **non-specific** because a phagocyte will engulf and digest essentially any pathogen it encounters, without first needing to recognise a particular antigen specific to that pathogen — unlike lymphocytes, which respond specifically to one type of antigen at a time.

Bài tập luyện tập

Explain two roles of hydrochloric acid as a non-specific defence, and state why this defence would not protect against a pathogen entering through a cut in the skin.

Lời giải chi tiết

Hydrochloric acid in the stomach kills many pathogens that are swallowed with food or drink, by creating a strongly acidic environment most microorganisms cannot survive; it also helps activate pepsin for protein digestion (a digestive rather than defensive role). It would not protect against a pathogen entering through a skin wound, because stomach acid only acts on material that passes through the digestive tract — a pathogen entering directly through broken skin bypasses the stomach entirely, and is instead met by other defences such as blood clotting and phagocytosis.

Bài tập luyện tập

Which of the following best distinguishes active immunity from passive immunity?

(A) Active immunity is always from vaccination; passive immunity is always from natural infection

(B) Active immunity involves the body's own antibody production and memory cells; passive immunity involves receiving ready-made antibodies with no memory cells formed

(C) Active immunity is short-term; passive immunity is long-lasting

(D) There is no meaningful difference between the two

Lời giải chi tiết

(B). Active immunity arises when the body's own lymphocytes are stimulated (by infection or vaccination) to produce antibodies and memory cells, giving long-lasting protection. Passive immunity involves receiving antibodies made by another organism (e.g. via placenta, breast milk, or injected antiserum), which provides immediate but temporary protection since no memory cells are formed. Option A is wrong because active immunity can come from either natural infection or vaccination; option C reverses the durations; option D is incorrect, as the distinction is biologically and clinically important.

Bài tập luyện tập

Explain why herd immunity can protect unvaccinated individuals in a population, using the concept of transmission chains.

Lời giải chi tiết

If a high enough proportion of a population is immune (through vaccination or prior infection), an infected individual is statistically likely to come into contact mostly with people who are already immune, rather than with susceptible people. This breaks the chain of transmission, since the pathogen cannot easily pass from person to person through the population. As a result, even people who are not immune themselves (e.g. those who cannot be vaccinated for medical reasons) are indirectly protected, because they are much less likely to encounter an infectious case in the first place.

Bài tập luyện tập

Describe how monoclonal antibodies are used in a home pregnancy test.

Lời giải chi tiết

Monoclonal antibodies used in a pregnancy test are all identical and specific to one particular hormone, human chorionic gonadotrophin (hCG), which is present in the urine of pregnant women. When urine is applied to the test strip, if hCG is present, it binds specifically to these monoclonal antibodies, triggering a visible colour change (e.g. a coloured line). Because the antibodies are specific only to hCG, the test does not react to other substances in urine, giving a reliable, specific result.

Bài tập luyện tập

A student says "the primary and secondary immune responses are basically the same, just at different times." Explain why this statement is inaccurate, referring to the antibody-concentration-versus-time graph.

Lời giải chi tiết

The two responses differ in both speed and magnitude, not just timing. The **primary response** (first exposure) is slow to begin and reaches a relatively low peak antibody concentration, because initially very few lymphocytes recognise the pathogen's antigen and must first multiply before large-scale antibody production begins. The **secondary response** (subsequent exposure) begins almost immediately and reaches a much higher peak antibody concentration in less time, because memory cells from the first exposure are already present in large numbers and can respond immediately. The statement is therefore inaccurate: it is not simply the same response occurring twice, but a qualitatively faster and stronger response the second time, due to memory cells.

Bài tập luyện tập

Explain why mucus and cilia in the trachea are considered a non-specific defence rather than part of the specific immune response.

Lời giải chi tiết

Mucus traps any inhaled particles or pathogens indiscriminately, and cilia sweep this mucus (and whatever it has trapped) upward regardless of what species of pathogen is involved — there is no recognition of a specific antigen, and no memory cells are formed as a result. This makes it a **non-specific** defence, unlike the specific immune response, which relies on lymphocytes recognising and responding to a particular antigen unique to one pathogen.

Bài tập luyện tập

A patient with a rare medical condition cannot receive certain vaccines. Explain how they might still benefit from a community vaccination programme even without being vaccinated themselves.

Lời giải chi tiết

If a sufficiently high proportion of the surrounding population is vaccinated (and therefore immune), the pathogen has far fewer susceptible hosts to spread between, reducing its overall circulation in the community. This **herd immunity** effect lowers the unvaccinated patient's own risk of exposure, since they are less likely to encounter an infectious case, even though they have no personal immunity of their own to the disease.

Bài tập luyện tập

Distinguish between an antigen and an antibody.

Lời giải chi tiết

An **antigen** is a molecule (usually a protein) found on the surface of a pathogen (or other foreign cell) that the immune system can recognise as foreign ("non-self"). An **antibody** is a protein produced by lymphocytes in response to a specific antigen, which binds specifically to that antigen (in a highly specific, "lock-and-key"-like manner) to help neutralise or mark the pathogen for destruction.

Bài tập luyện tập

Explain why blood clotting is classified as a defence mechanism, not merely a repair mechanism.

Lời giải chi tiết

While blood clotting does help repair a damaged blood vessel by sealing the wound, it also serves a defensive role: an open wound is a direct route by which pathogens can enter the body, bypassing the intact skin barrier. By sealing the wound quickly with a fibrin clot, blood clotting blocks this entry route, preventing pathogens from gaining easy access to the body's internal tissues — in addition to its role in preventing further blood loss.

Bài tập luyện tập

A student vaccinated against measles as a child is later exposed to the measles virus as an adult but does not develop symptoms. Using the concept of memory cells, explain why.

Lời giải chi tiết

The measles vaccine introduced a safe form of the measles antigens (without causing full disease), stimulating the student's lymphocytes to mount a primary response and, crucially, to form **memory cells** specific to the measles virus's antigens. On later exposure to the actual virus, these memory cells enable a fast, strong **secondary response**: antibodies are produced quickly and in large quantities, typically clearing the virus before it can multiply enough to cause the symptoms of measles.

Bài tập luyện tập

Explain why tuberculosis (an airborne bacterial disease) and athlete's foot (a fungal disease spread by contact) require different public health control strategies.

Lời giải chi tiết

Tuberculosis spreads via airborne droplets released when an infected person coughs or sneezes, so control strategies focus on measures such as ventilation, mask-wearing, prompt diagnosis and treatment, and vaccination, which reduce the spread of infectious droplets through the air. Athlete's foot spreads by direct or indirect contact (e.g. shared floors or towels in warm, moist environments), so control instead focuses on hygiene measures such as not sharing towels, wearing sandals in communal showers, and keeping feet clean and dry — measures aimed at preventing skin-to-surface-to-skin transmission rather than airborne spread.

Bài tập luyện tập

Summarise, using the terms antigen, lymphocyte, antibody and memory cell, what happens in the body the first time it encounters a new pathogen.

Lời giải chi tiết

The pathogen's surface **antigens** are detected by a small number of **lymphocytes** that happen to recognise that particular antigen shape. These lymphocytes are stimulated to multiply and to produce large numbers of **antibodies** specific to that antigen, which help destroy or

neutralise the pathogen — this initial, relatively slow reaction is the primary response. Some of the responding lymphocytes persist afterward as long-lived **memory cells**, which remain in the body ready to mount a much faster secondary response if the same antigen is ever encountered again.

Bài tập luyện tập

Explain why HIV, which is transmitted through bodily fluids, requires different prevention advice from measles, which is transmitted through airborne droplets.

Lời giải chi tiết

Because HIV spreads through contact with infected blood, semen, or from mother to child, prevention focuses on measures such as safe sexual practices (e.g. condom use), not sharing needles, and screening blood products — reducing direct contact with infected bodily fluids. Measles spreads through the air via droplets from coughing or sneezing, so prevention instead relies on vaccination (to build population-level immunity) and isolating infectious individuals, since airborne transmission cannot be prevented simply by avoiding bodily fluid contact.

Bài tập luyện tập

A doctor prescribes antibiotics for a patient with tuberculosis but explains that antibiotics would not help a patient with measles. Explain the biological reasoning behind this difference.

Lời giải chi tiết

Tuberculosis is caused by a **bacterium**, a complete living cell with its own cell wall and metabolic machinery; antibiotics work by disrupting processes specific to bacterial cells (such as cell wall synthesis), killing or stopping the growth of the bacterium without harming human cells. Measles is caused by a **virus**, which is not a cell and has no cell wall or independent metabolism of its own — it hijacks a host cell's machinery to reproduce. Since viruses lack the structures and processes that antibiotics target, antibiotics have no effect on them; measles is instead prevented by vaccination rather than treated with antibiotics.

Bài tập luyện tập

A city has a vaccination coverage of 70% against a disease requiring 90% coverage for herd immunity, in a population of $2{,}000{,}000$ people. Calculate how many more people need to become immune to reach the herd immunity threshold.

Lời giải chi tiết

Currently immune: $0.70 \times 2{,}000{,}000 = 1{,}400{,}000$.
Target immune: $0.90 \times 2{,}000{,}000 = 1{,}800{,}000$.
Additional people needed: $1{,}800{,}000 - 1{,}400{,}000 = 400{,}000$ people.

Bài tập luyện tập

Explain why a monoclonal antibody used in a diagnostic test must come from a single clone of lymphocytes rather than from many different lymphocytes.

Lời giải chi tiết

Different lymphocytes normally produce antibodies with different binding-site shapes, each specific to a different antigen. If a diagnostic test used antibodies from many different lymphocyte clones, the mixture would bind to a range of different antigens, making the test unreliable and non-specific (it might react to substances other than the one being tested for). Using antibodies from a single clone ensures every antibody molecule has an identical, precisely specific binding site for one target antigen, giving a reliable, specific test result.

Bài tập luyện tập

Outline the general steps of the specific immune response the first time a new pathogen enters the body, from initial antigen detection to the eventual formation of memory cells.

Lời giải chi tiết

(1) The pathogen's antigens are detected by the small number of lymphocytes that happen to have a matching binding site shape. (2) These lymphocytes are stimulated to multiply rapidly, producing a large population of identical, antigen-specific cells. (3) Many of these cells produce and release large quantities of antibodies specific to the pathogen's antigen, which help destroy the pathogen or neutralise its toxins (agglutination, marking for phagocytosis, or direct neutralisation). (4) This whole process (the primary response) is relatively slow, which is why symptoms of disease typically develop before the infection is cleared. (5) After the infection is cleared, some of the responding lymphocytes persist in the body long-term as memory cells, ready to trigger a much faster secondary response if the same antigen is encountered again.

Bài tập luyện tập

Classify each of the following as natural active, artificial active, natural passive, or artificial passive immunity: (a) a child recovering from chickenpox; (b) a baby receiving antibodies through breast milk; (c) a traveller receiving a rabies vaccination before visiting a high-risk area; (d) a snake-bite victim receiving an injection of antivenom antibodies.

Lời giải chi tiết

(a) **Natural active** — the child's own immune system produced antibodies (and memory cells) in response to a real infection. (b) **Natural passive** — the baby receives ready-made antibodies from the mother via breast milk, without producing its own. (c) **Artificial active** — the traveller's own immune system produces antibodies (and memory cells) in response to a vaccine, a deliberately administered safe antigen source. (d) **Artificial passive** — the patient receives ready-made antibodies by injection (antivenom), without their own immune system needing to respond first.

Bài tập luyện tập

Explain why artificial passive immunity (e.g. antivenom injection) is used for emergency treatment rather than vaccination, even though vaccination gives longer-lasting protection.

Lời giải chi tiết

Vaccination (artificial active immunity) works by stimulating the body's own immune system to produce antibodies and memory cells, but this process takes days to weeks to build up

sufficient antibody levels — far too slow to help someone facing an immediate, severe threat, such as snake venom already acting in their body. Injecting ready-made antibodies (artificial passive immunity) provides an **immediate** supply of protective antibodies, acting within hours, which is essential in an emergency, even though this protection is short-lived and does not build long-term immunity through memory cells.

Bài tập luyện tập

Sketch and describe the antigen-antibody interaction, explaining why an antibody produced against one pathogen typically does not protect against a different, unrelated pathogen.

Lời giải chi tiết

An antibody has a binding site with a specific three-dimensional shape that fits only the particular antigen shape it was produced against, similar to a key fitting only one lock. A different, unrelated pathogen has antigens with a different molecular shape, which does not fit the binding site of an antibody produced against the first pathogen, so no effective binding (and therefore no protective effect) occurs. This is why immunity gained against one pathogen (e.g. measles) does not protect against a structurally unrelated pathogen (e.g. chickenpox) — a new, specific immune response (and new antibodies) must be generated for each different antigen encountered.

Bài tập luyện tập

A researcher wants to develop a rapid diagnostic test for a new bacterial infection. Explain why monoclonal antibodies would be a suitable tool for this purpose.

Lời giải chi tiết

Monoclonal antibodies can be produced so that every antibody molecule is identical and specific to one particular antigen unique to the target bacterium. This means the test will react (e.g. produce a colour change) only when that specific bacterial antigen is present in a sample, giving a reliable, specific result and avoiding false positives from unrelated substances or other microorganisms that might be present in the sample.

Bài tập luyện tập

A country introduces a new vaccine and, over several years, sees both the number of cases of the disease and the number of deaths from it fall dramatically, even among some unvaccinated infants too young to receive the vaccine. Explain both observations.

Lời giải chi tiết

The fall in cases among vaccinated individuals is explained by **active immunity**: their immune systems produced antibodies and memory cells in response to the vaccine's antigens, allowing a fast secondary response (or preventing infection establishing at all) on exposure to the real pathogen. The protection seen even in unvaccinated infants too young to be vaccinated is explained by **herd immunity**: with a high proportion of the surrounding population immune, the pathogen has far fewer opportunities to spread from person to person, so even those without personal immunity are much less likely to be exposed to an infectious case in the first place.

Bài tập luyện tập

Explain why a person recovering from an infection for the first time typically feels ill for a period of days before starting to recover, in terms of the primary immune response.

Lời giải chi tiết

During a first (primary) infection, only a small number of lymphocytes initially recognise the pathogen's antigen, and these must first multiply into a large enough population before they can produce enough antibodies to bring the infection under control. During this delay — while lymphocyte numbers and antibody concentration are still building up — the pathogen continues to multiply and cause the symptoms of disease. Once antibody concentration rises enough to overwhelm the pathogen (the peak of the primary response), the infection is brought under control and the person begins to recover, though this whole process typically takes several days to weeks, unlike the much faster secondary response after any future exposure to the same pathogen.

Gas Exchange and Respiration

Mục tiêu Unit: Phân biệt hô hấp tế bào (respiration) với thông khí/hô hấp cơ học (breathing/ventilation); phương trình hô hấp hiếu khí và kị khí (ở người và ở nấm men) cùng sự khác biệt sản phẩm; cấu tạo hệ hô hấp (khí quản, phế quản, tiểu phế quản, phế nang) và các đặc điểm thích nghi của phế nang cho trao đổi khí; cơ chế hít vào/thở ra dựa trên thay đổi thể tích–áp suất lồng ngực; thành phần khí hít vào và thở ra; ảnh hưởng của vận động lên nhịp thở và nhịp tim; tính toán tốc độ thông khí (ventilation rate); và (Supplement) tác hại của khói thuốc lá lên hệ hô hấp.

9.1 Respiration versus Breathing

Two words that sound similar in everyday English refer to two very different biological processes, and confusing them is one of the most common errors in IGCSE Biology.

Respiration is a **chemical process** that occurs continuously inside every living cell (in every plant, animal, fungus, and microorganism). It is the controlled release of energy from nutrient molecules (mainly glucose), catalysed by enzymes, and packaged into a usable form for the cell's activities. Respiration never stops – it happens whether or not an organism is breathing at that instant, and even in organisms with no lungs or gills at all (e.g. plants, or single-celled organisms).

Breathing (also called **ventilation**) is a **mechanical, muscular process**: the physical movement of air into and out of the gas exchange system (lungs). Breathing supplies the oxygen needed for aerobic respiration and removes the carbon dioxide it produces, but breathing itself involves no chemical reaction – it is simply moving a gas mixture in and out.

Respiration $\neq$ breathing. Respiration is the chemical release of energy from food, occurring inside cells at all times. Breathing (ventilation) is the mechanical movement of air in and out of the lungs, which merely supplies/removes the gases that respiration uses/produces.

VN **GIẢI THÍCH TIẾNG VIỆT**

Đây là cặp thuật ngữ gây nhầm lẫn nhiều nhất trong chương này: **hô hấp (respiration)** là một quá trình **hoá học**, xảy ra liên tục trong MỌI tế bào sống, giải phóng năng lượng từ glucose. **Thở/thông khí (breathing/ventilation)** chỉ là một quá trình **cơ học**, là sự di chuyển không khí ra vào phổi nhờ hoạt động của cơ. Một sinh vật có thể ngừng thở tạm thời (nín thở) nhưng tế bào của nó vẫn đang hô hấp; ngược lại, thực vật hô hấp suốt ngày đêm dù không hề có phổi hay "thở" theo nghĩa cơ học.

9.2 Aerobic Respiration

Aerobic respiration is the release of energy from glucose using oxygen. It takes place in the mitochondria of cells and releases a relatively large amount of energy per glucose molecule because glucose is broken down completely into carbon dioxide and water.

$$\text{Word equation:} \quad \text{glucose} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} \ (+ \text{energy})$$

$$\text{Symbol equation:} \quad C6H12O6 + 6O2 -> 6CO2 + 6H2O \quad (+ \text{energy})$$

Aerobic respiration releases **much more energy per glucose molecule** than anaerobic respiration, because glucose is fully oxidised all the way to CO2 and H2O. This is why the body strongly prefers aerobic respiration whenever enough oxygen is available.

VN **GIẢI THÍCH TIẾNG VIỆT**

Hô hấp hiếu khí cần oxy và giải phóng **nhiều năng lượng hơn hẳn** so với hô hấp kị khí, vì glucose bị phân giải hoàn toàn thành khí carbon dioxide và nước. Đây là lý do cơ thể luôn ưu tiên hô hấp hiếu khí khi có đủ oxy cung cấp cho tế bào.

9.3 Anaerobic Respiration

When insufficient oxygen is available, cells can still release some energy from glucose by **anaerobic respiration** – respiration without oxygen. Anaerobic respiration releases far less energy per glucose molecule than aerobic respiration because glucose is only partially broken down. Critically, the products of anaerobic respiration are **different** depending on the organism.

9.3.1 Anaerobic respiration in humans (muscle cells)

During vigorous exercise, muscle cells may not receive oxygen fast enough to meet demand. Muscle cells then respire anaerobically:

$$\text{glucose} \longrightarrow \text{lactic acid} \ (+ \text{ energy})$$

No carbon dioxide is produced by this pathway. The lactic acid that accumulates in muscles contributes to muscle fatigue and cramp, and is later broken down (mostly in the liver) once oxygen supply is restored – part of the reason breathing and heart rate stay elevated for a while after exercise stops. This extra oxygen required after exercise to break down accumulated lactic acid is called the **oxygen debt** (Supplement).

9.3.2 Anaerobic respiration in yeast (fermentation)

Yeast (a single-celled fungus) respires anaerobically by **fermentation**, producing different end products:

$$\text{glucose} \longrightarrow \text{ethanol} + \text{carbon dioxide} \ (+ \text{ energy})$$

This is the process exploited in brewing (alcohol production) and in bread-making (the CO2 produced makes dough rise).

(!) Lỗi thường gặp: A very common exam error is to write "glucose → lactic acid + carbon dioxide" for human anaerobic respiration, mixing up the human and yeast pathways. Remember: **human muscle** anaerobic respiration produces **lactic acid only** (no CO2); **yeast** anaerobic respiration (fermentation) produces **ethanol AND carbon dioxide**. The two pathways share only one feature: neither uses oxygen, and both release much less energy than aerobic respiration.

	Human muscle (anaerobic)	**Yeast (anaerobic / fermentation)**
Reactant	Glucose	Glucose
Products	Lactic acid **only**	Ethanol **and** carbon dioxide
Oxygen used?	No	No
CO2 produced?	**No**	**Yes**
Energy released	Much less than aerobic	Much less than aerobic
Everyday relevance	Muscle fatigue/cramp during vigorous exercise; oxygen debt afterwards	Brewing (alcohol); baking (dough rises)

Contrasting the two anaerobic pathways – a frequently tested distinction.

VN **GIẢI THÍCH TIẾNG VIỆT**

Hai con đường hô hấp kị khí KHÔNG giống nhau: ở **người/cơ**, glucose chỉ tạo ra **axit lactic**, hoàn toàn không có CO2. Ở **nấm men** (lên men), glucose tạo ra **cả ethanol lẫn** CO2. Học sinh Việt Nam thường nhầm lẫn viết cả hai phương trình đều có CO2 – đây là lỗi bị trừ điểm rất phổ biến. Mẹo nhớ: chỉ có nấm men mới "sủi bọt khí" (CO2) khi lên men; cơ người khi thiếu oxy chỉ tích luỹ axit lactic gây mỏi cơ, không sinh khí.

Ví dụ mẫu · Identifying the respiration pathway

A runner sprints 200 m at maximum effort. Explain why their leg muscles are likely to be respiring anaerobically during the final seconds of the race, and state the immediate product formed.

During maximal effort, the muscles' demand for energy (and therefore oxygen) rises faster than the heart and lungs can deliver oxygen to the muscle cells via the blood. Once oxygen delivery cannot keep pace with demand, muscle cells switch to (or supplement aerobic respiration with) **anaerobic respiration**, converting glucose directly into **lactic acid** (with no CO2 produced by this pathway) while still releasing some energy, allowing the sprint to continue briefly at maximum intensity.

9.4 The Gas Exchange System: Structure

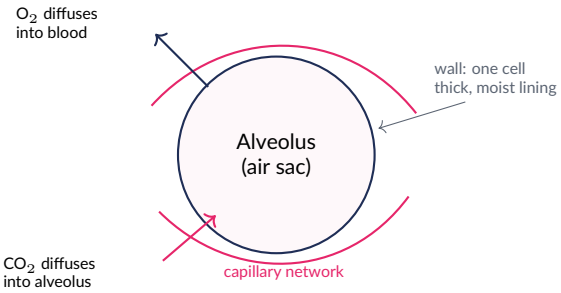
Air travels from the mouth/nose through the following structures on its way to the site of gas exchange:

$$\text{trachea} \longrightarrow \text{bronchi} \longrightarrow \text{bronchioles} \longrightarrow \text{alveoli}$$

The **trachea** (windpipe) is supported by C-shaped rings of **cartilage**, which hold the airway permanently open, preventing it from collapsing as air pressure changes during breathing (the incomplete "C" shape allows the oesophagus, lying directly behind, to bulge slightly during swallowing). The trachea divides into two **bronchi** (singular: bronchus), one entering each lung; bronchi are also supported by cartilage rings. Each bronchus divides repeatedly into progressively narrower **bronchioles**, which lack cartilage but have smooth muscle in their walls (allowing their diameter to be adjusted). Bronchioles end in clusters of tiny air sacs, the **alveoli** (singular: alveolus) – the actual site of gas exchange.

Alveolar adaptations for efficient gas exchange:

- **Enormous total surface area**: several hundred million alveoli per pair of lungs give a combined internal surface area of roughly 50 –75 m^2 (many times the surface area of the skin), maximising the area across which diffusion can occur.
- **Wall only one cell thick**: the alveolus wall (squamous epithelium) and the adjacent capillary wall are each a single, extremely thin layer of cells, minimising the diffusion distance for gases.
- **Moist lining**: a thin film of moisture coats the inner alveolar surface, allowing oxygen and carbon dioxide to dissolve before diffusing across the membranes.
- **Dense capillary network**: alveoli are surrounded by a rich network of blood capillaries; continuous blood flow constantly carries away diffused oxygen and delivers fresh carbon dioxide, maintaining steep concentration (diffusion) gradients in both directions.



A single alveolus and its surrounding capillary network. Oxygen diffuses from the air in the alveolus, across the thin moist alveolar and capillary walls, into the blood; carbon dioxide diffuses in the opposite direction, from the blood into the alveolar air space, to be breathed out.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốn đặc điểm thích nghi của phế nang cần nhớ chính xác: (1) **số lượng cực lớn** ⇒ tổng diện tích bề mặt khổng lồ; (2) **thành mỏng một lớp tế bào** ⇒ quãng đường khuếch tán ngắn; (3) **lớp lót ẩm** ⇒ khí phải hoà tan trước khi khuếch tán; (4) **mạng lưới mao mạch dày đặc** ⇒ máu liên tục lưu thông giữ cho chênh lệch nồng độ khí luôn ở mức cao (duy trì gradient khuếch tán). Đề thi thường yêu cầu liệt kê đủ CẢ BỐN đặc điểm này, không chỉ một hai điểm.

(!) Lỗi thường gặp: Do not describe the cartilage rings of the trachea as complete circles. They are **C-shaped** (incomplete at the back, where the trachea lies against the oesophagus). This gap of soft tissue allows the oesophagus to bulge slightly outward as a lump of food (bolus) passes down it during swallowing, without being obstructed by rigid cartilage – while the front and sides of the trachea remain firmly held open.

Structure	Supporting tissue	Main function
Trachea	C-shaped cartilage rings (incomplete, facing the oesophagus)	Carries air to the bronchi; cartilage keeps the airway permanently open
Bronchi	Cartilage rings (complete or near-complete)	Carry air from trachea into each lung
Bronchioles	Smooth muscle, no cartilage	Carry air to alveoli; diameter can be adjusted by muscle contraction/relaxation
Alveoli	Single layer of squamous epithelium, moist lining	Site of gas exchange between air and blood

Structure-function summary of the airway pathway from trachea to alveoli.

9.5 The Mechanism of Breathing

Breathing works because changing the **volume** of the thorax (chest cavity) changes the **pressure** of the air inside the lungs relative to atmospheric pressure outside the body: increasing thoracic volume lowers the pressure inside the lungs below atmospheric pressure, so air flows *in*; decreasing thoracic volume raises the pressure inside the lungs above atmospheric pressure, so air flows *out*. Air always flows from a region of higher pressure to a region of lower pressure.

9.5.1 Inhalation (breathing in)

- The **external intercostal muscles** (between the ribs) contract, pulling the rib cage **upward and outward**.

- The **diaphragm** (a dome-shaped sheet of muscle beneath the lungs) contracts and **flattens**, moving downward.
- Together, these two changes **increase the volume** of the thoracic cavity.
- This increase in volume causes the air pressure inside the lungs to **fall below** atmospheric pressure.
- Air therefore flows **into** the lungs, down the pressure gradient, until pressure inside the lungs equals atmospheric pressure again.

9.5.2 Exhalation (breathing out)

- The external intercostal muscles **relax**, and the rib cage moves **downward and inward** (under gravity and elastic recoil of the lungs); during forced exhalation, the **internal intercostal muscles** additionally contract to pull the ribs down more forcefully.
- The diaphragm **relaxes**, returning to its resting **dome shape**, moving upward.
- Together, these changes **decrease the volume** of the thoracic cavity.
- This decrease in volume causes the air pressure inside the lungs to **rise above** atmospheric pressure.
- Air therefore flows **out of** the lungs, down the pressure gradient, until pressure inside the lungs equals atmospheric pressure again.

	Inhalation	Exhalation
Intercostal muscles	External intercostals contract	External intercostals relax (internal contract if forced)
Ribcage	Moves up and out	Moves down and in
Diaphragm	Contracts, flattens, moves down	Relaxes, domes upward
Thoracic volume	Increases	Decreases
Pressure in lungs	Falls below atmospheric	Rises above atmospheric
Air movement	Into the lungs	Out of the lungs

The mechanics of breathing: volume change drives pressure change, and pressure difference drives airflow.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nguyên tắc cốt lõi: **tăng thể tích lồng ngực ⇒ giảm áp suất trong phổi ⇒ không khí đi VÀO**; **giảm thể tích lồng ngực ⇒ tăng áp suất trong phổi ⇒ không khí đi RA**. Đây là mối quan hệ thể tích–áp suất cơ bản (không cần nêu tên định luật Boyle trong bài thi IGCSE, chỉ cần hiểu và trình bày đúng mối quan hệ tỉ lệ nghịch này). Cơ liên sườn ngoài và cơ hoành co lại đồng thời để MỞ RỘNG lồng ngực khi hít vào.

9.6 Composition of Inhaled and Exhaled Air

The proportions of gases in air change as it passes through the body, because oxygen is absorbed into the blood and carbon dioxide is released from the blood at the alveoli.

Gas	Inhaled air (%)	Exhaled air (%)	Change
Oxygen	≈ 21	≈ 16	Decreases (absorbed into blood)
Carbon dioxide	≈ 0.04	≈ 4	Increases (released from blood)
Nitrogen	≈ 78	≈ 78	Unchanged
Water vapour	Variable (low)	Higher (near saturation)	Increases (evaporation from moist lining)

Approximate percentage composition of inhaled versus exhaled air.

Why does nitrogen stay constant? Nitrogen gas is chemically inert in the human body under normal conditions – it is not used by respiration, not absorbed into the blood in any significant amount, and not produced by any process in the lungs. It simply passes through the gas exchange system unchanged, so its percentage in inhaled and exhaled air is essentially identical.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nitơ chiếm khoảng 78% ở cả khí hít vào lẫn khí thở ra, KHÔNG đổi, vì cơ thể người không sử dụng nitơ trong hô hấp và cũng không tạo ra nitơ – khí này chỉ "đi qua" phổi mà không tham gia phản ứng trao đổi khí nào. Ngược lại, oxy giảm (do khuếch tán vào máu) và CO2 tăng (do khuếch tán từ máu ra) một cách đáng kể.

9.7 Exercise, Breathing, and Heart Rate

During exercise, muscles respire faster to release more energy, increasing their demand for oxygen and increasing their rate of carbon dioxide production. The body responds with several coordinated changes:

- **Breathing rate** (breaths per minute) increases, and **breathing depth** (tidal volume, the volume of air moved per breath) also increases – together increasing the total **ventilation rate** (see below), supplying oxygen to the alveoli faster and removing carbon dioxide faster.
- **Heart rate** increases, pumping blood (and therefore oxygen) to the muscles faster, and returning carbon dioxide-laden blood to the lungs faster.

These changes are linked: as muscle respiration rate rises, blood carbon dioxide concentration rises, which is detected by receptors that stimulate the brain's breathing control centre and the heart, increasing both breathing rate/depth and heart rate to match the muscles' increased demand for oxygen and increased output of carbon dioxide.

9.8 Ventilation Rate Calculations

The **ventilation rate** (also called minute ventilation) is the total volume of air moved into (or out of) the lungs per minute:

$$\textbf{Ventilation rate} = \textbf{breathing rate} \times \textbf{tidal volume}$$

where breathing rate is measured in breaths per minute, and tidal volume is the volume of air moved in one normal breath (commonly measured in cm^3 or litres).

Ví dụ mẫu · Resting ventilation rate

At rest, a student breathes 14 breaths/min, with a tidal volume of $500\,\text{cm}^3$ per breath. Calculate the ventilation rate.

$$\text{Ventilation rate} = 14 \times 500 = 7000\ \text{cm}^3/\text{min}\ (= 7\ \text{L/min}).$$

Ví dụ mẫu · Ventilation rate during exercise

During moderate exercise, the same student's breathing rate rises to 25 breaths/min and tidal volume rises to 800 cm^3. (a) Calculate the new ventilation rate. (b) By what factor has ventilation increased compared to rest (7000 cm^3/min)?

(a) $25 \times 800 = 20{,}000$ cm^3/min ($= 20$ L/min).

(b) $\dfrac{20{,}000}{7000} \approx 2.9\times$ the resting ventilation rate.

Ví dụ mẫu · Working backward for tidal volume

A sprinter's ventilation rate is measured at $27{,}000$ cm^3/min during a race, with a breathing rate of 30 breaths/min. Calculate the tidal volume.

$$\text{Tidal volume} = \frac{\text{Ventilation rate}}{\text{Breathing rate}} = \frac{27{,}000}{30} = 900 \text{ cm}^3 \text{ per breath.}$$

Ví dụ mẫu · Total air breathed over time

Using the resting values above (14 breaths/min, tidal volume 500 cm^3), calculate the total volume of air breathed in over a 10 minute period of quiet sitting.

Ventilation rate $= 7000$ cm^3/min (from the first example). Over 10 min:

$$\text{Total volume} = 7000 \times 10 = 70{,}000 \text{ cm}^3 \ (= 70 \text{ L}).$$

Ví dụ mẫu · Comparing two individuals

Person A: 16 breaths/min, tidal volume 450 cm^3. Person B: 12 breaths/min, tidal volume 600 cm^3. Which person has the higher resting ventilation rate?

Person A: $16 \times 450 = 7200$ cm^3/min.

Person B: $12 \times 600 = 7200$ cm^3/min.

Both have exactly the **same ventilation rate** (7200 cm^3/min), even though they achieve it with different combinations of breathing rate and depth – illustrating that ventilation rate depends on *both* variables, not on breathing rate alone.

Ví dụ mẫu · Estimating oxygen absorbed per minute

Using the resting ventilation rate of 7000 cm^3/min found earlier, and the approximate composition figures for oxygen ($21\,\%$ inhaled, $16\,\%$ exhaled), estimate the volume of oxygen absorbed into the blood each minute at rest.

Assume the volume of air inhaled per minute is approximately equal to the volume exhaled per minute (7000 cm^3/min). The fall in oxygen percentage from inhaled to exhaled air represents oxygen retained by the body:

$$\%\ O_2 \text{ absorbed} = 21\% - 16\% = 5\%.$$

$$O_2 \text{ absorbed per minute} \approx 7000 \times 0.05 = 350 \text{ cm}^3 \text{ per minute.}$$

This simple estimate assumes inhaled and exhaled air volumes are approximately equal over a minute, which is reasonable at rest.

VN **GIẢI THÍCH TIẾNG VIỆT**
Khi tính tốc độ thông khí (ventilation rate), luôn nhớ công thức: **tốc độ thông khí = nhịp thở × thể tích khí lưu thông (tidal volume)**. Đơn vị hai đại lượng phải khớp nhau (nhịp thở/phút, thể tích mỗi nhịp) để kết quả ra đúng đơn vị thể tích/phút. Một sai lầm phổ biến là chỉ nhìn vào nhịp thở tăng mà quên rằng độ sâu mỗi nhịp thở (tidal volume) cũng thường tăng khi vận động – cả hai yếu tố cùng góp phần làm tăng tốc độ thông khí.

9.9 (Supplement) Smoking and the Gas Exchange System

Tobacco smoke contains many harmful substances that damage the gas exchange system and cardiovascular system over time.

- **Tar**: a sticky brown residue that accumulates in the airways and lungs. Tar paralyses and eventually destroys the **cilia** lining the trachea and bronchi (cilia normally beat to sweep mucus, dust, and trapped microorganisms upward and out of the airways). Without functioning cilia, mucus (and the bacteria/debris it traps) accumulates in the airways, increasing the risk of infection and causing the persistent "**smoker's cough**" as the body tries to clear the airway by coughing instead. Long-term tar exposure is strongly linked to **chronic bronchitis** (chronic inflammation and excess mucus production in the airways) and is a major cause of **lung cancer** (tar contains carcinogens that damage DNA in airway/lung cells, potentially causing uncontrolled cell division).
- **Carbon monoxide (CO)**: a gas in tobacco smoke that binds to **haemoglobin** in red blood cells far more readily (and more permanently) than oxygen does, forming carboxyhaemoglobin. This reduces the oxygen-carrying capacity of the blood, so less oxygen is delivered to body tissues – placing extra strain on the heart, which must work harder to compensate, and is particularly harmful during pregnancy (reduced oxygen delivery to the fetus).
- **Nicotine**: an addictive substance that keeps smokers dependent on cigarettes. Nicotine also increases heart rate and blood pressure, and constricts blood vessels, adding further strain on the cardiovascular system.
- **Emphysema**: long-term smoking can break down the walls between alveoli, merging many small alveoli into fewer, larger air spaces. This drastically reduces the total surface area available for gas exchange, causing breathlessness even at rest.

VN **GIẢI THÍCH TIẾNG VIỆT**
Ba tác nhân chính trong khói thuốc lá cần phân biệt rõ: **nhựa thuốc lá (tar)** phá huỷ lông mao (cilia) ⇒ chất nhầy không được quét đi ⇒ ho, viêm phế quản mãn tính, ung thư phổi; **khí carbon monoxide (CO)** gắn với hemoglobin bền hơn oxy ⇒ giảm khả năng vận chuyển oxy của máu ⇒ tim phải làm việc nhiều hơn; **nicotine** gây nghiện và làm tăng nhịp tim/huyết áp. Về lâu dài, hút thuốc còn phá huỷ vách phế nang, gây **khí phế thũng** (emphysema) – giảm hẳn diện tích bề mặt trao đổi khí.

(!) Lỗi thường gặp: Students sometimes state that carbon monoxide "poisons" the lungs directly. In fact, CO's main harmful action is at the level of the **blood** – it binds haemoglobin (out-competing oxygen), so the fundamental problem is reduced oxygen **transport** to all body tissues, not direct lung tissue damage (which is instead mainly caused by tar and other irritants in smoke).

9.10 Practice Questions

Bài tập luyện tập

Which statement correctly distinguishes respiration from breathing?

(A) Respiration is mechanical; breathing is chemical

(B) Both occur only in animals with lungs

(C) Respiration is a chemical process in living cells; breathing is the mechanical movement of air

(D) Breathing releases energy directly from glucose

Lời giải chi tiết

Respiration is the chemical release of energy from glucose in cells; breathing (ventilation) is only the mechanical movement of air into and out of the lungs. **(C)**.

Bài tập luyện tập

Write the word equation for aerobic respiration.

Lời giải chi tiết

Glucose + oxygen → carbon dioxide + water (+ energy).

Bài tập luyện tập

A sprinter's leg muscles run short of oxygen near the end of a $100\,\text{m}$ race. State the product formed by anaerobic respiration in the muscle cells, and explain why no carbon dioxide is produced by this pathway.

Lời giải chi tiết

The product is **lactic acid**. Human muscle anaerobic respiration only partially breaks down glucose into lactic acid; this pathway does not involve the breakdown steps that release CO2, unlike aerobic respiration (or yeast fermentation), so no carbon dioxide is released.

Bài tập luyện tập

Yeast is used in bread-making. Explain, in terms of anaerobic respiration, why bread dough rises when left in a warm place.

Lời giải chi tiết

Yeast cells in the dough respire anaerobically (fermentation): glucose → ethanol + carbon dioxide (+ energy). The carbon dioxide gas produced becomes trapped as bubbles within the dough, causing it to expand (rise).

Bài tập luyện tập

Explain why the percentage of nitrogen is essentially the same in inhaled and exhaled air.

Lời giải chi tiết

Nitrogen is not used in respiration and is not produced by any process in the gas exchange system; it is not absorbed into or released from the blood in the lungs, so it simply passes through unchanged, leaving its percentage in inhaled and exhaled air essentially identical (both approximately 78%).

Bài tập luyện tập

List the pathway of structures air passes through from the mouth/nose to the alveoli.

Lời giải chi tiết

Trachea $\rightarrow$ bronchi $\rightarrow$ bronchioles $\rightarrow$ alveoli.

Bài tập luyện tập

Explain the function of the cartilage rings in the trachea.

Lời giải chi tiết

The C-shaped cartilage rings hold the trachea permanently open, preventing it from collapsing or being squeezed shut as air pressure inside changes during breathing, ensuring an unobstructed airway at all times.

Bài tập luyện tập

List four features of alveoli that adapt them for efficient gas exchange.

Lời giải chi tiết

(1) Enormous total surface area (huge numbers of alveoli); (2) walls only one cell thick, minimising diffusion distance; (3) a moist inner lining allowing gases to dissolve; (4) a dense network of surrounding capillaries that maintains steep diffusion gradients by constantly removing/-supplying gases.

Bài tập luyện tập

During inhalation, what happens to (a) the external intercostal muscles, (b) the diaphragm, and (c) the volume of the thorax?

(A) (a) relax (b) domes upward (c) decreases

(B) (a) contract (b) flattens, moves down (c) increases

(C) (a) contract (b) domes upward (c) decreases

(D) (a) relax (b) flattens (c) increases

Lời giải chi tiết

During inhalation, external intercostal muscles contract (ribs up and out) and the diaphragm contracts and flattens (moves down), together increasing thoracic volume. **(B)**.

Bài tập luyện tập

Explain, in terms of pressure, why air flows into the lungs during inhalation.

Lời giải chi tiết

Contraction of the intercostal muscles and diaphragm increases the volume of the thoracic cavity. This increase in volume causes the air pressure inside the lungs to fall below atmospheric pressure. Since air flows from high to low pressure, air flows into the lungs until the pressure inside equals atmospheric pressure again.

Bài tập luyện tập

A student breathes at 15 breaths/min with a tidal volume of 600 cm^3. Calculate their ventilation rate.

Lời giải chi tiết

Ventilation rate $= 15 \times 600 = 9000$ cm^3/min (9 L/min).

Bài tập luyện tập

An athlete's ventilation rate during hard exercise is $24{,}000$ cm^3/min, with a breathing rate of 32 breaths/min. Calculate the tidal volume.

Lời giải chi tiết

Tidal volume $= \dfrac{24{,}000}{32} = 750$ cm^3 per breath.

Bài tập luyện tập

At rest, ventilation rate is 6600 cm^3/min at 12 breaths/min. During exercise it rises to $22{,}000$ cm^3/min at 20 breaths/min. Calculate the tidal volume in each case, and state whether breathing depth increased.

Lời giải chi tiết

Rest: tidal volume $= 6600/12 = 550$ cm^3.
Exercise: tidal volume $= 22{,}000/20 = 1100$ cm^3.
Breathing depth (tidal volume) **doubled** from 550 to 1100 cm^3, showing that during exercise ventilation increases through greater breathing depth as well as greater breathing rate.

Bài tập luyện tập

Explain why both breathing rate and heart rate increase during exercise, linking your answer to muscle respiration.

Lời giải chi tiết

Exercising muscles respire faster, using oxygen more quickly and producing carbon dioxide more quickly. Rising CO2 concentration in the blood is detected and stimulates an increase in

breathing rate and depth (to supply oxygen faster and remove CO2 faster) and an increase in heart rate (to transport oxygen to, and carbon dioxide away from, the muscles faster), matching gas exchange to the muscles' increased metabolic demand.

Bài tập luyện tập

Which gas increases in percentage from inhaled to exhaled air by the largest relative amount?

(A) Nitrogen
(B) Oxygen
(C) Carbon dioxide
(D) Water vapour

Lời giải chi tiết

Carbon dioxide rises from about 0.04% to about 4% – roughly a 100-fold relative increase, far larger proportionally than the change in oxygen (falls from 21% to 16%) or water vapour. **(C)**.

Bài tập luyện tập

Explain why smokers commonly develop a persistent cough ("smoker's cough"), referring to cilia and mucus.

Lời giải chi tiết

Tar in cigarette smoke damages and destroys the cilia lining the airways. Cilia normally beat to sweep mucus (which traps dust, bacteria, and debris) up and out of the airways. Without functioning cilia, mucus and trapped particles/bacteria accumulate in the airways, increasing infection risk; the body compensates by coughing to try to clear the airway, producing a persistent cough.

Bài tập luyện tập

Explain how carbon monoxide from cigarette smoke reduces the amount of oxygen delivered to body tissues.

Lời giải chi tiết

Carbon monoxide binds to haemoglobin in red blood cells more readily (and more stably) than oxygen does, forming carboxyhaemoglobin. Haemoglobin bound to CO cannot also carry oxygen, so the blood's oxygen-carrying capacity is reduced, meaning less oxygen reaches respiring body tissues for a given volume of blood.

Bài tập luyện tập

State two long-term lung conditions strongly associated with smoking, other than lung cancer.

Lời giải chi tiết

Chronic bronchitis (persistent airway inflammation and excess mucus caused by tar damage) and emphysema (breakdown of alveolar walls, reducing gas-exchange surface area).

Bài tập luyện tập

A $500\,\text{cm}^3$ sample of exhaled air is analysed. Approximately what volume of this sample is carbon dioxide?

(A) $0.2\,\text{cm}^3$
(C) $80\,\text{cm}^3$
(B) $20\,\text{cm}^3$
(D) $200\,\text{cm}^3$

Lời giải chi tiết

Exhaled air is roughly 4% CO2: $500 \times 0.04 = 20$ cm^3. **(B)**.

Bài tập luyện tập

Distinguish between the bronchi and the bronchioles, in terms of both structure and cartilage content.

Lời giải chi tiết

Bronchi are the two larger airways (one to each lung) branching from the trachea, and like the trachea, they are supported by rings of cartilage to keep them open. Bronchioles are the much narrower airways formed by repeated branching of the bronchi; they lack cartilage but contain smooth muscle in their walls, allowing their diameter to be actively adjusted, and they terminate in clusters of alveoli.

Bài tập luyện tập

A patient's resting ventilation rate is $7200\,\text{cm}^3/\text{min}$. If their breathing rate is measured at $18\,\text{breaths/min}$, what is their tidal volume? Is this within a typical resting range?

Lời giải chi tiết

Tidal volume $= 7200/18 = 400$ cm^3. This is within the typical resting tidal volume range for humans (commonly quoted as roughly 400–600 cm^3 at rest).

Bài tập luyện tập

Explain why lactic acid accumulation during vigorous exercise causes breathing and heart rate to remain elevated for some time even after exercise stops (oxygen debt).

Lời giải chi tiết

During vigorous exercise, muscles respiring anaerobically build up lactic acid. After exercise stops, extra oxygen is still needed to help break down this accumulated lactic acid (largely in the liver). This extra oxygen requirement is the **oxygen debt**; breathing rate and heart rate stay elevated after exercise to supply this additional oxygen until the lactic acid has been cleared and normal resting conditions are restored.

Bài tập luyện tập

A gas exchange surface is said to be efficient if it has a large surface area, a short diffusion distance, and a steep concentration gradient maintained across it. Explain how the alveolus

satisfies all three conditions.

Lời giải chi tiết

Large surface area: hundreds of millions of alveoli together provide a total surface area of roughly $50–75$ m^2. **Short diffusion distance:** both the alveolar wall and the adjacent capillary wall are only one cell thick, so gases cross only two thin cell layers. **Steep concentration gradient:** continuous blood flow through the dense capillary network constantly removes diffused oxygen and delivers fresh carbon dioxide, ensuring the concentration difference driving diffusion never runs down.

Bài tập luyện tập

Which of the following would most directly increase the ventilation rate the most, all else being equal?

(A) Doubling breathing rate only, tidal volume unchanged

(B) Doubling tidal volume only, breathing rate unchanged

(C) Doubling both breathing rate and tidal volume

(D) Halving breathing rate and halving tidal volume

Lời giải chi tiết

Since ventilation rate $=$ breathing rate $\times$ tidal volume, doubling *both* factors quadruples the ventilation rate, giving by far the largest increase among the options. **(C)**.

Bài tập luyện tập

Explain why the water vapour content of exhaled air is higher than that of inhaled air.

Lời giải chi tiết

As air passes over the moist lining of the airways and alveoli, water evaporates from these moist surfaces into the air. By the time air is exhaled, it has picked up this extra water vapour and is close to saturated with moisture (and warmed to body temperature), so exhaled air contains more water vapour than the (typically drier, cooler) inhaled air.

Bài tập luyện tập

A student claims: ”Anaerobic respiration in humans releases more energy per glucose molecule than aerobic respiration, because it happens faster.” Evaluate this claim.

Lời giải chi tiết

The claim is incorrect. Anaerobic respiration releases considerably **less** energy per glucose molecule than aerobic respiration, because glucose is only partially broken down (to lactic acid) rather than fully oxidised to carbon dioxide and water. Anaerobic respiration may occur rapidly when oxygen is limited, but speed of onset is unrelated to the total energy yield per glucose molecule – in fact it is a trade-off: a smaller energy yield obtained without needing oxygen.

Bài tập luyện tập

Explain why chronic bronchitis, caused by long-term smoking, tends to make a person feel breathless and prone to chest infections.

Lời giải chi tiết

Tar damages the cilia that normally sweep mucus out of the airways, so mucus (along with trapped bacteria and debris) builds up and narrows the airways, restricting airflow and making breathing more difficult (breathlessness). The build-up of mucus and bacteria also increases susceptibility to respiratory infections, since pathogens are no longer efficiently cleared from the airways.

Bài tập luyện tập

A student breathes at a resting rate of 13 breaths/min with tidal volume $500\,\text{cm}^3$. During a light jog this rises to 22 breaths/min with tidal volume $700\,\text{cm}^3$. Calculate the ventilation rate in both cases and the percentage increase.

Lời giải chi tiết

Rest: $13 \times 500 = 6500$ cm^3/min.
Jog: $22 \times 700 = 15{,}400$ cm^3/min.
Percentage increase $= \dfrac{15{,}400 - 6500}{6500} \times 100 \approx 137\%$ increase in ventilation rate.

Bài tập luyện tập

Emphysema destroys the walls between adjacent alveoli, merging many small alveoli into fewer, larger air spaces. Explain the effect this has on gas exchange efficiency.

Lời giải chi tiết

Merging many small alveoli into fewer larger spaces greatly reduces the total internal surface area available for gas exchange (a few large spaces have far less combined surface area than the same volume divided into hundreds of millions of tiny alveoli). With less surface area across which oxygen and carbon dioxide can diffuse, gas exchange becomes less efficient, causing breathlessness, especially during exertion.

Bài tập luyện tập

State whether each of the following is best classified as respiration or breathing: (a) glucose being broken down in a muscle cell; (b) the ribcage moving upward and outward; (c) carbon dioxide being released from a plant cell at night.

Lời giải chi tiết

(a) **Respiration** (a chemical reaction releasing energy from glucose inside the cell). (b) **Breathing** (a mechanical movement of the ribcage as part of ventilation). (c) **Respiration** (plant cells respire continuously, including at night when photosynthesis is not occurring, releasing CO2 as a by-product).

Bài tập luyện tập

Explain why the bronchioles, unlike the trachea and bronchi, do not need rings of cartilage.

Lời giải chi tiết

Bronchioles are much narrower than the trachea and bronchi, and by this point the air pressure changes acting on them are far less likely to cause the airway to collapse. Instead of rigid cartilage, bronchiole walls contain smooth muscle, which allows their diameter to be actively narrowed or widened, fine-tuning airflow to different parts of the lung – a function rigid cartilage could not provide.

Bài tập luyện tập

A resting adult has a ventilation rate of $6000\,\text{cm}^3/\text{min}$. After starting to climb stairs, their breathing rate increases from 12 to $20\,\text{breaths}/\text{min}$, and their tidal volume increases from 500 to $750\,\text{cm}^3$. Calculate the new ventilation rate and state two other changes to the circulatory system that would accompany this increase in activity.

Lời giải chi tiết

New ventilation rate $= 20 \times 750 = 15{,}000$ cm^3/min (compared with $12 \times 500 = 6000$ cm^3/min at rest – a $2.5\times$ increase, consistent with the given resting value). Accompanying circulatory changes: **heart rate increases**, pumping oxygenated blood to the leg muscles faster and returning CO2-rich blood to the lungs faster; blood flow may also be redirected preferentially toward the working muscles.

Excretion, Homeostasis and Coordination

Mục tiêu Unit: Định nghĩa bài tiết (excretion) và các chất thải chính của cơ thể; cấu tạo thận/nephron và cơ chế hai giai đoạn siêu lọc (ultrafiltration) cùng tái hấp thu chọn lọc (selective reabsorption); (Supplement) vai trò của ADH trong điều hoà tái hấp thu nước; nguyên tắc cân bằng nội môi và vòng phản hồi âm; điều hoà đường huyết bằng insulin/glucagon và (Supplement) tiểu đường tuýp 1/2; điều nhiệt (thermoregulation) qua giãn/co mạch máu da và đổ mồ hôi/rùng mình; cấu tạo neuron và synapse; cung phản xạ (reflex arc) và các bài toán tính thời gian phản xạ; bảng so sánh hormone và so sánh thần kinh–hormone; và hướng động (tropism) ở thực vật qua cơ chế auxin.

10.1 Excretion

Excretion is the removal from the body of the waste products of metabolism (chemical reactions inside cells), and of substances present in excess of the body's needs. Excretion is distinct from egestion (the removal of undigested food/faeces, which was never part of the body's internal chemistry).

The three main routes of excretion in humans are:

- **Carbon dioxide**, a waste product of aerobic respiration in every cell, is carried by the blood to the lungs and removed by **gas exchange** (breathed out).
- **Urea**, a nitrogen-containing waste product formed in the **liver** by the breakdown (**deamination**) of excess amino acids, is carried by the blood to the **kidneys** and removed in urine.
- **Excess water and excess mineral ions** are also removed by the **kidneys** in urine, in amounts that vary according to the body's current needs.

Deamination: when more protein is eaten than the body needs, excess amino acids cannot be stored, so the liver removes their nitrogen-containing amino group, converting it to **ammonia** and then rapidly to the much less toxic **urea**, which is released into the blood for excretion by the kidneys. The remaining (non-nitrogen) part of the amino acid can be used in respiration or converted to fat/glycogen for storage.

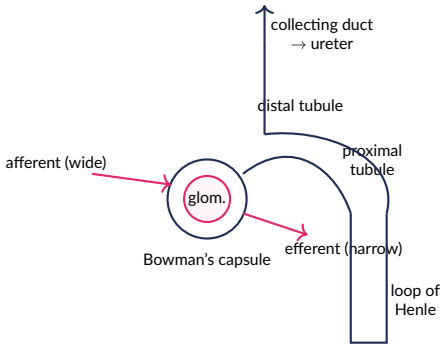
VN **GIẢI THÍCH TIẾNG VIỆT**

Bài tiết (excretion) khác với việc thải phân (egestion): phân chưa từng là một phần của quá trình chuyển hoá bên trong cơ thể (thức ăn không được tiêu hoá), trong khi các chất bài tiết (CO_2, urea, nước/ion dư thừa) là sản phẩm PHỤ của các phản ứng hoá học diễn ra trong tế bào. Ba đường bài tiết chính: CO_2 qua phổi, urea (từ gan, do khử amin axit amin dư thừa) và nước/ion dư qua thận.

10.2 Kidney and Nephron Structure

Each kidney contains roughly a million tiny filtering units called **nephrons**. Each nephron begins with a cup-shaped structure, the **Bowman's capsule**, which surrounds a knot of capillaries called the **glomerulus**. Blood enters the glomerulus through a wide **afferent (renal) arteriole** and leaves through a narrower **efferent arteriole**; this difference in diameter maintains a high hydrostatic (blood)

pressure within the glomerulus. Fluid forced out of the glomerulus enters the **proximal convoluted tubule**, then passes through the **loop of Henle**, the **distal convoluted tubule**, and finally into a **collecting duct**, which carries urine to the renal pelvis, ureter, and bladder.



A single nephron: blood is filtered at the Bowman's capsule/glomerulus; filtrate flows through the proximal tubule, loop of Henle, distal tubule, and collecting duct, with reabsorption occurring along the way.

10.3 Ultrafiltration and Selective Reabsorption

Urine formation happens in two distinct stages.

10.3.1 Stage 1: Ultrafiltration at the Bowman's capsule

The narrower efferent arteriole restricts blood outflow from the glomerulus more than the wide afferent arteriole allows in, so blood pressure inside the glomerular capillaries is unusually high. This high pressure forces small dissolved substances – **water**, **glucose**, **amino acids**, **urea**, and **mineral ions** – out of the capillary walls, through a filtering basement membrane, and into the Bowman's capsule, forming **filtrate**. **Red blood cells, white blood cells, platelets, and large plasma proteins** are too large to pass through the pores of the capillary wall and basement membrane, so they remain in the blood and continue into the efferent arteriole.

> **Ultrafiltration is a pressure- and size-based process, not a selective one:** everything small enough is forced out regardless of whether the body needs it (including useful glucose and amino acids); only particle **size** determines what enters the filtrate at this stage. Selectivity about what the body actually needs happens *afterward*, in stage 2.

10.3.2 Stage 2: Selective reabsorption along the tubule

As filtrate flows along the nephron tubule, useful substances are reabsorbed back into the surrounding blood capillaries:

- **Glucose and amino acids** are normally reabsorbed **completely** (100%) in the proximal convoluted tubule, by **active transport** against their concentration gradient (the cells lining this region are packed with mitochondria to supply the ATP needed) – the body needs all of this glucose and amino acid supply, so none should appear in healthy urine.
- **Water** is reabsorbed at various points along the tubule (proximal tubule, loop of Henle, and especially the collecting duct), mostly by **osmosis**, in an amount that depends on the body's hydration state.
- **Mineral ions** (e.g. sodium) are reabsorbed selectively, partly by active transport, in amounts matched to the body's current needs – more is reabsorbed if the body is low in a particular ion, less if there is a surplus.
- **Urea** is not actively reabsorbed and remains largely in the tubule fluid to be excreted; only water and useful solutes are selectively taken back.

The fluid that remains after selective reabsorption – containing water, urea, and excess mineral ions, but normally no glucose, no amino acids, no proteins, and no blood cells – is **urine**.

VN **GIẢI THÍCH TIẾNG VIỆT**

Quá trình tạo nước tiểu gồm HAI giai đoạn tách biệt: (1) **siêu lọc** (ultrafiltration) tại cầu thận – lọc theo ÁP SUẤT và KÍCH THƯỚC phân tử, không có tính chọn lọc (mọi chất nhỏ đều bị đẩy ra, kể cả glucose/axit amin có ích); (2) **tái hấp thu chọn lọc** (selective reabsorption) dọc theo ống thận – ở đây cơ thể mới thực sự "chọn" giữ lại glucose và axit amin (100%, bằng vận chuyển chủ động) và điều chỉnh lượng nước/ion tái hấp thu tuỳ theo nhu cầu. Nước tiểu bình thường KHÔNG chứa glucose hay protein – nếu có, đó là dấu hiệu bệnh lý (ví dụ tiểu đường không kiểm soát).

Ví dụ mẫu · Interpreting urine test results

A urine sample from patient X tests positive for glucose. A urine sample from patient Y contains urea and excess salt, but no glucose or protein. Comment on each result.

Patient X: healthy nephrons reabsorb glucose completely in the proximal convoluted tubule, so glucose should not normally appear in urine. Glucose in the urine suggests either (a) blood glucose concentration is so high that the filtrate glucose exceeds the tubule's reabsorption capacity (as in uncontrolled diabetes), or (b) the reabsorption mechanism itself is impaired.

Patient Y: this is a **normal** result – urea (a waste product not reabsorbed) and excess mineral ions/water (reabsorbed only as needed, with surplus excreted) are expected components of healthy urine, while the absence of glucose and protein indicates ultrafiltration and selective reabsorption are both functioning correctly.

Ví dụ mẫu · Why blood cells never appear in normal filtrate

Explain why red blood cells do not normally appear in the fluid entering the Bowman's capsule, using ideas about ultrafiltration.

The basement membrane and capillary wall of the glomerulus act as a size-selective filter: only molecules below a certain size (water, glucose, amino acids, urea, ions) can be forced through the pores by the high blood pressure in the glomerulus. Red blood cells are far larger than these pores, so no matter how high the pressure, they physically cannot pass through and remain in the blood, exiting via the efferent arteriole.

10.4 (Supplement) ADH and the Control of Water Reabsorption

The amount of water reabsorbed in the collecting duct is fine-tuned by a hormone, **antidiuretic hormone (ADH)**. Receptors in the **hypothalamus** detect the water potential (concentration) of the blood. If the blood becomes too concentrated (water potential too low – e.g. after sweating heavily or not drinking enough), the hypothalamus signals the **pituitary gland** to release **more ADH** into the blood. ADH makes the walls of the **collecting duct more permeable to water**, so more water is reabsorbed back into the blood, producing a smaller volume of more concentrated urine, and restoring blood water potential toward normal. If the blood is too dilute (water potential too high – e.g. after drinking a large volume of water), **less ADH** is released, the collecting duct becomes less permeable to water, less water is reabsorbed, and a larger volume of more dilute urine is produced.

VN **GIẢI THÍCH TIẾNG VIỆT**

ADH (hormone chống lợi niệu) được vùng dưới đồi (hypothalamus) "ra lệnh" tuyến yên (pituitary) tiết ra khi máu quá đặc (thiếu nước): ADH làm thành ống góp (collecting duct) trở nên

THẤM NƯỚC HƠN ⇒ tái hấp thu nhiều nước hơn ⇒ nước tiểu ít và đặc. Khi máu quá loãng (thừa nước), ADH tiết ít hơn ⇒ ống góp kém thấm nước hơn ⇒ nước tiểu nhiều và loãng. Đây là một ví dụ điển hình khác của vòng phản hồi âm (negative feedback).

10.5 Homeostasis and Negative Feedback

Homeostasis is the maintenance of a constant internal environment within narrow limits, despite changes in the external environment or in the body's own activity (e.g. constant blood glucose concentration, constant body temperature, constant blood water potential). Homeostasis is achieved through **negative feedback**: any change away from a set (normal) level is detected and automatically triggers a response that pushes the level back *toward* the set point, opposing (counteracting) the original change.

General negative feedback loop: receptor detects a deviation from the set point → information is sent to a **coordinator** (often part of the brain or another control centre) → the coordinator triggers an **effector** (muscle or gland) to respond → the effector's action brings the level back toward the set point → the receptor detects the corrected level and the response is switched off (or reduced). This self-correcting loop keeps the internal environment stable.

VN **GIẢI THÍCH TIẾNG VIỆT**

Vòng phản hồi âm (negative feedback) là nguyên tắc chung của MỌI cơ chế cân bằng nội môi: thụ thể (receptor) phát hiện sự lệch khỏi mức bình thường → trung tâm điều phối (coordinator) xử lý thông tin → cơ quan đáp ứng (effector) tạo ra phản ứng → phản ứng đó "kéo" giá trị TRỞ VỀ mức bình thường (ngược chiều với sự thay đổi ban đầu) – do đó gọi là "âm" (negative). Học sinh cần áp dụng đúng khung này cho MỌI ví dụ: đường huyết, nhiệt độ, nước trong máu.

10.6 Blood Glucose Regulation

Blood glucose concentration is maintained within narrow limits by two antagonistic hormones from the **pancreas**, both following the negative feedback pattern above.

Insulin and glucagon: an antagonistic pair

When blood glucose concentration **rises** above normal (e.g. after a meal), the pancreas detects this and releases more **insulin**. Insulin causes liver and muscle cells to take up glucose from the blood and **convert it to glycogen** for storage (and also promotes glucose uptake/use by body cells generally), **lowering** blood glucose concentration back toward normal.
When blood glucose concentration **falls** below normal (e.g. between meals or during exercise), the pancreas releases more **glucagon**. Glucagon causes the liver to **break down stored glycogen back into glucose** and release it into the blood, **raising** blood glucose concentration back toward normal.

VN **GIẢI THÍCH TIẾNG VIỆT**

Insulin và glucagon là một cặp hormone đối kháng (antagonistic) từ tuyến tuỵ, hoạt động theo nguyên tắc phản hồi âm: đường huyết TĂNG → tiết **insulin** → gan/cơ hấp thu glucose và chuyển thành glycogen dự trữ → đường huyết GIẢM về bình thường. Đường huyết GIẢM → tiết **glucagon** → gan phân giải glycogen thành glucose, giải phóng vào máu → đường huyết TĂNG về bình thường. Hai hormone này có tác dụng NGƯỢC CHIỀU nhau nhưng cùng mục đích: giữ đường huyết ổn định.

Ví dụ mẫu · Tracing the negative feedback loop for blood glucose

Shortly after eating a large, sugary meal, a person's blood glucose concentration rises sharply. Describe, step by step, how the body responds to bring it back to normal.

(1) Receptor: cells in the pancreas detect the rise in blood glucose concentration above the normal set point. **(2) Coordinator/effector combined:** the pancreas responds directly by secreting more **insulin** into the blood. **(3) Effect on target cells:** insulin binds receptors on liver and muscle cells, causing them to take up glucose from the blood and convert it to glycogen for storage. **(4) Correction:** blood glucose concentration falls back toward the normal set point. **(5) Switch-off:** as glucose concentration approaches normal, the stimulus for insulin release fades, and insulin secretion decreases – completing the negative feedback loop.

Ví dụ mẫu · Effect of insufficient insulin

Predict what would happen to a person's blood glucose concentration after a meal if their pancreas could not produce sufficient insulin, and explain why.

Without enough insulin, liver and muscle cells cannot take up glucose from the blood and convert it to glycogen efficiently. As a result, blood glucose concentration would **remain abnormally high** (hyperglycaemia) after a meal instead of returning to normal, since the main mechanism for removing excess glucose from the blood is impaired. Over time, persistently high blood glucose can damage blood vessels, nerves, and organs.

10.6.1 (Supplement) Diabetes: Type 1 and Type 2

Type 1 diabetes results from the pancreas producing **insufficient (or no) insulin**, usually because the insulin-producing cells have been destroyed; it typically develops in children or young people and is treated with regular **insulin injections** (or an insulin pump), since the body cannot produce its own.

Type 2 diabetes occurs when body cells become **less sensitive to insulin** (insulin resistance), so a given amount of insulin has less effect on glucose uptake, even though the pancreas may still produce insulin (sometimes even more than normal, to compensate). It is often associated with lifestyle factors such as obesity and typically develops later in life; it is commonly managed through diet, exercise, and medication, with insulin sometimes required in more advanced cases.

	Type 1 diabetes	Type 2 diabetes
Cause	Insufficient/no insulin production	Reduced sensitivity of body cells to insulin
Typical onset	Often in childhood/young adulthood	Often later in life; strongly linked with lifestyle/obesity
Main treatment	Insulin injections/pump	Diet, exercise, medication (occasionally insulin)

Type 1 versus Type 2 diabetes: contrasting causes and management.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tiểu đường tuýp 1: tuỵ KHÔNG sản xuất đủ (hoặc không sản xuất) insulin ⇒ phải tiêm insulin, thường khởi phát khi còn trẻ. Tiểu đường tuýp 2: tuỵ vẫn có thể tiết insulin nhưng tế bào cơ thể GIẢM ĐỘ NHẠY với insulin (kháng insulin), thường liên quan đến lối sống/béo phì, khởi phát muộn hơn, kiểm soát chủ yếu bằng chế độ ăn, vận động, thuốc.

10.7 Thermoregulation

Human body temperature is maintained close to $37\,^{\circ}$C, the temperature at which most enzymes work optimally. The **hypothalamus** (in the brain) acts as the body's thermostat: it contains thermoreceptors that monitor the temperature of blood flowing through it, and also receives information from thermoreceptors in the skin.

10.7.1 Response to overheating

- **Vasodilation**: blood vessels (arterioles) supplying capillaries near the skin surface widen, increasing blood flow close to the surface. More heat is lost from the blood to the surroundings by radiation, cooling the blood (and therefore the body).
- **Sweating**: sweat glands secrete more sweat onto the skin surface. As sweat evaporates, it takes latent heat from the skin, cooling the body.

10.7.2 Response to cooling

- **Vasoconstriction**: arterioles supplying capillaries near the skin surface narrow, reducing blood flow close to the surface (blood is diverted to deeper vessels). Less heat is lost by radiation, conserving body heat.
- **Shivering**: rapid, involuntary contraction of skeletal muscles increases the rate of respiration in those muscles, releasing heat as a by-product and warming the body.
- **Hair erector muscles** contract, causing body hairs to stand up (**piloerection**), trapping a thicker layer of insulating air close to the skin – reducing heat loss (though of limited effect in humans, given relatively sparse body hair, this response is far more significant in furrier mammals).

Overheating → vasodilation & sweating (lose heat); cooling → vasoconstriction, shivering & piloerection (conserve/generate heat). Both sets of responses are triggered and coordinated by the hypothalamus and operate by negative feedback, correcting the deviation from $37\,^{\circ}$C and then switching off once normal temperature is restored.

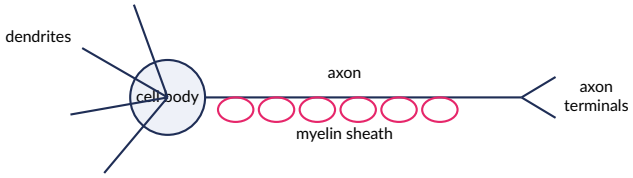
VN **GIẢI THÍCH TIẾNG VIỆT**

Vùng dưới đồi (hypothalamus) đóng vai trò "bộ điều nhiệt" của cơ thể. Khi CƠ THỂ NÓNG: mạch máu da GIÃN (vasodilation, mất nhiệt qua bức xạ nhiều hơn) và đổ MỒ HÔI (bay hơi lấy nhiệt, làm mát da). Khi CƠ THỂ LẠNH: mạch máu da CO LẠI (vasoconstriction, giảm mất nhiệt), cơ RÙNG MÌNH (shivering, tăng hô hấp ở cơ, sinh nhiệt), và cơ dựng lông co lại làm lông dựng đứng (hiệu ứng hạn chế ở người do lông thưa). Tất cả đều là ví dụ của phản hồi âm.

(!) Lỗi thường gặp: A common error is to say vasodilation "releases sweat" or that vasoconstriction "stops sweating." Vasodilation/vasoconstriction concern only the **diameter of blood vessels** (and therefore how much heat is lost by **radiation** from blood near the skin surface); sweating is a completely separate response involving **sweat glands** and heat loss by **evaporation**. Both mechanisms act together during overheating, but they are physically distinct processes.

10.8 Nervous Coordination: Neurones and Synapses

The nervous system coordinates rapid responses using specialised cells called **neurones** (nerve cells), which carry electrical impulses.



Structure of a neurone: dendrites receive impulses and carry them toward the cell body (containing the nucleus); the axon carries the impulse away from the cell body to the axon terminals; the myelin sheath (formed by Schwann cells) insulates the axon and speeds up impulse conduction.

Dendrites receive nerve impulses from other neurones (or from a receptor) and carry them toward the **cell body**, which contains the nucleus and directs the cell's activities. The **axon** carries the nerve impulse away from the cell body, often over long distances, to the **axon terminals**. Many axons are wrapped in a fatty **myelin sheath**, formed by supporting (Schwann) cells; myelin acts as an electrical insulator and greatly **speeds up** the conduction of the nerve impulse along the axon compared with an unmyelinated axon.

A **synapse** is the tiny gap between the axon terminal of one neurone and the dendrite (or cell body) of the next. When an electrical impulse reaches the axon terminal, it triggers the release of a chemical **neurotransmitter**, which **diffuses** across the synaptic gap and binds to receptor molecules on the membrane of the next neurone, triggering a new electrical impulse there. Because neurotransmitter is only ever released from the presynaptic (first) neurone's terminal, and receptors are only present on the postsynaptic (second) neurone's membrane, impulses can only cross a synapse in **one direction**.

VN **GIẢI THÍCH TIẾNG VIỆT**

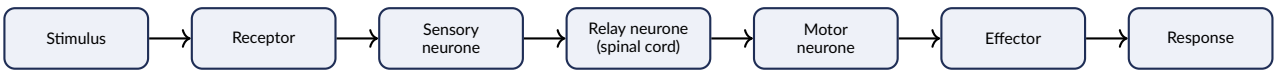
Synapse là khe hở giữa hai neuron. Khi xung thần kinh (điện) đến đầu tận cùng axon, nó kích thích giải phóng chất dẫn truyền thần kinh (neurotransmitter) – đây là chất HOÁ HỌC, khuếch tán qua khe synapse rồi gắn vào thụ thể trên màng neuron tiếp theo, tạo ra xung thần kinh mới ở đó. Vì chất dẫn truyền chỉ được giải phóng từ MỘT phía và thụ thể chỉ có ở phía CÒN LẠI, xung thần kinh chỉ có thể truyền theo MỘT CHIỀU qua synapse – đây là lý do tại sao thông tin thần kinh luôn đi đúng hướng trong cơ thể.

10.9 The Reflex Arc

A **reflex** is a rapid, automatic, and involuntary response to a stimulus, which does not require conscious thought. The pathway a reflex signal follows is a **reflex arc**:

stimulus → receptor → sensory neurone → relay neurone (in spinal cord) → motor neurone → effector → respo

A **receptor** (e.g. a pain or temperature receptor in the skin) detects the stimulus and generates an electrical impulse, carried by a **sensory neurone** to the **spinal cord**. There, the impulse passes across a synapse to a **relay neurone** (entirely within the central nervous system), which passes it across another synapse to a **motor neurone**. The motor neurone carries the impulse to an **effector** (a muscle or gland), which carries out the **response** (e.g. muscle contraction, withdrawing a hand).



The reflex arc pathway: a stimulus is detected and the resulting impulse travels through this fixed sequence of neurones to produce a rapid, automatic response.

Reflexes are fast and protective because the pathway **bypasses conscious processing in the brain** – the relay neurone in the spinal cord passes the impulse directly to a motor neurone without waiting for the brain to interpret the stimulus and decide on a response. This shorter pathway (fewer synapses, shorter distance) produces a much faster response than consciously deciding to act, allowing the body to react to potentially damaging stimuli (e.g. a hot object) before the brain has even registered pain, minimising injury.

VN **GIẢI THÍCH TIẾNG VIỆT**

Cung phản xạ (reflex arc): **kích thích** → **thụ thể** → **neuron cảm giác** → **neuron liên hợp (tuỷ sống)** → **neuron vận động** → **cơ quan đáp ứng**. Phản ứng theo sau. Phản xạ nhanh và có tính bảo vệ vì tín hiệu KHÔNG cần đi lên não để "suy nghĩ" – đường truyền ngắn hơn (ít synapse hơn, quãng đường ngắn hơn) giúp cơ thể phản ứng gần như tức thời, bảo vệ cơ thể khỏi tổn thương trước khi ta kịp "cảm nhận" cơn đau.

10.9.1 Reflex arc timing calculations

Because a nerve impulse travels at a roughly constant speed along a given neurone, the time taken for a signal to travel a known distance can be calculated:

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

Ví dụ mẫu · Basic reflex-arc timing

A sensory neurone carries an impulse a distance of $0.8\,\text{m}$ from a finger receptor to the spinal cord, at a speed of $80\,\text{m/s}$. Calculate the time taken for the impulse to travel this distance.

$$\text{time} = \frac{0.8}{80} = 0.01\ \text{s} = 10\ \text{ms}.$$

Ví dụ mẫu · Comparing myelinated and unmyelinated neurones

An unmyelinated neurone conducts impulses at $5\,\text{m/s}$; a myelinated neurone of the same length ($0.5\,\text{m}$) conducts impulses at $50\,\text{m/s}$. Calculate the conduction time for each, and state the advantage of myelination.

Unmyelinated: time $= 0.5/5 = 0.1\ \text{s} = 100\ \text{ms}$.
Myelinated: time $= 0.5/50 = 0.01\ \text{s} = 10\ \text{ms}$.
The myelinated neurone conducts the impulse **10 times faster**, illustrating why myelin sheaths substantially speed up nerve impulse transmission, allowing much quicker reflex and voluntary responses.

Ví dụ mẫu · Total reflex time across a full arc

In a simple reflex arc, impulses travel: $0.9\,\text{m}$ along a sensory neurone at $90\,\text{m/s}$; then cross two synapses, each adding a synaptic delay of $0.5\,\text{ms}$; then $0.3\,\text{m}$ along a motor neurone at $60\,\text{m/s}$. Calculate the total time from stimulus detection to the motor neurone signal reaching the effector.

Sensory neurone: $0.9/90 = 0.01\ \text{s} = 10\ \text{ms}$.
Two synaptic delays: $2 \times 0.5\ \text{ms} = 1\ \text{ms}$.
Motor neurone: $0.3/60 = 0.005\ \text{s} = 5\ \text{ms}$.

$$\text{Total time} = 10 + 1 + 5 = 16 \text{ ms}.$$

This total (a few hundredths of a second) illustrates why reflex responses feel almost instantaneous.

Ví dụ mẫu · Working backward for neurone length

An impulse takes 6 ms to travel along a motor neurone conducting at $50\,\text{m/s}$. Calculate the length of this neurone.

$$\text{distance} = \text{speed} \times \text{time} = 50 \times 0.006 = 0.3 \text{ m } (30 \text{ cm}).$$

10.10 Hormonal Coordination

Hormones are chemical messengers, produced by endocrine glands, and carried by the **blood** to target organs/cells elsewhere in the body, where they produce a specific effect.

Gland	Hormone(s)	Main effect(s)
Pancreas	Insulin, glucagon	Regulate blood glucose concentration (Section 10.6)
Adrenal glands	Adrenaline	"Fight or flight" response: increases heart rate; raises blood glucose concentration (stimulates glycogen breakdown in the liver); redirects blood flow toward muscles (dilating muscle arterioles, constricting arterioles to the gut/skin); increases breathing rate; prepares the body for vigorous physical activity
Ovaries	Oestrogen, progesterone	Development of female secondary sexual characteristics; control of the menstrual cycle (Chapter 11)
Testes	Testosterone	Development of male secondary sexual characteristics; stimulates sperm production
Pituitary gland	ADH (among others)	Controls water reabsorption in the kidney collecting duct (Section 10.4)

Major endocrine glands and their principal hormones/effects.

	Nervous (nerve impulses)	Hormonal (hormones)
Transmission method	Electrical impulse along neurones	Chemical messenger carried in the bloodstream
Speed	Very fast (impulses travel in milliseconds)	Slower (depends on blood circulation)
Duration of effect	Short-lived, rapidly switched off	Often longer-lasting
Target specificity	Direct connection to a specific effector via neurones	Travels throughout the body, but only affects cells with matching receptors
Typical use	Rapid responses (e.g. reflexes, muscle movement)	Slower, longer-term regulation (e.g. growth, blood glucose, menstrual cycle)

Nervous versus hormonal coordination – a frequently tested comparison.

VN **GIẢI THÍCH TIẾNG VIỆT**

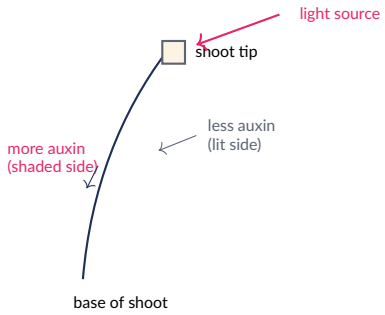
So sánh thần kinh và hormone: thần kinh truyền tin bằng XUNG ĐIỆN qua neuron, RẤT NHANH nhưng hiệu quả ngắn; hormone truyền tin bằng CHẤT HOÁ HỌC qua MÁU, chậm hơn nhưng hiệu quả thường kéo dài hơn. Thần kinh tác động đến một cơ quan đáp ứng cụ thể qua kết nối trực tiếp; hormone di chuyển khắp cơ thể qua máu nhưng chỉ tế bào có thụ thể phù hợp mới đáp ứng.

10.11 Tropisms in Plants

A **tropism** is the growth of a plant part in response to a directional stimulus. **Phototropism** is growth in response to light; **gravitropism** (geotropism) is growth in response to gravity. Shoots are typically **positively phototropic** (grow toward light) and **negatively gravitropic** (grow away from gravity, i.e. upward); roots are typically **positively gravitropic** (grow toward/downward with gravity) and show little phototropic response.

The auxin mechanism

Tropisms are controlled by a plant growth hormone, **auxin**, produced in the tips of shoots and roots and transported down toward the region of elongating cells. Light or gravity causes auxin to become **unequally distributed** across the tip: more auxin accumulates on the **shaded** side of a shoot (in response to light), or on the **lower** side of a shoot or root (in response to gravity). Critically, auxin has **opposite effects** in shoots and roots at the same concentration: in **shoot** cells, a higher auxin concentration **promotes** cell elongation; in **root** cells, the same higher auxin concentration **inhibits** cell elongation. So in a shoot, the shaded side (with more auxin) elongates faster than the illuminated side, bending the shoot **toward** the light; in a root responding to gravity, the lower side (with more auxin) elongates **more slowly** than the upper side, bending the root **downward**, toward gravity.



A shoot bending toward a unilateral light source: auxin accumulates on the shaded side, promoting greater cell elongation there and causing the shoot to curve toward the light.

(!) Lỗi thường gặp: The single most commonly tested point on tropisms is that auxin has **opposite** effects on shoot and root cells at the *same* concentration: it **promotes** elongation in shoot cells but **inhibits** elongation in root cells. This is why, when a shoot is laid horizontally, the lower (higher-auxin) side of the shoot elongates *faster*, bending it upward, while in a root laid horizontally, the lower (higher-auxin) side elongates *slower*, bending the root downward – both movements are caused by the very same unequal auxin distribution, but result in opposite directions of curvature because shoot and root cells respond oppositely to auxin.

VN **GIẢI THÍCH TIẾNG VIỆT**

Auxin có tác dụng TRÁI NGƯỢC nhau ở chồi và ở rễ tại CÙNG một nồng độ: ở **chồi**, auxin nhiều hơn ⇒ kéo dài tế bào NHANH HƠN (chồi uốn cong về phía ánh sáng, vì bên tối có nhiều auxin hơn); ở **rễ**, auxin nhiều hơn lại ỨC CHẾ kéo dài tế bào (rễ uốn cong xuống dưới theo trọng lực, vì bên dưới có nhiều auxin hơn nhưng lại kéo dài CHẬM hơn bên trên). Đây là điểm học sinh dễ nhầm lẫn nhất trong toàn bộ chủ đề hướng động.

10.12 Practice Questions

Bài tập luyện tập

Define excretion and explain how it differs from egestion.

Lời giải chi tiết

Excretion is the removal of the waste products of metabolism and substances in excess from the body (e.g. CO_2, urea, excess water/ions). Egestion is the removal of undigested food (faeces) from the gut; this material was never absorbed into the body's internal chemistry, so it is not a metabolic waste product.

Bài tập luyện tập

Where is urea produced, and by what process?

(A) In the kidneys, by ultrafiltration

(B) In the liver, by deamination of excess amino acids

(C) In the pancreas, by digestion of protein

(D) In the muscles, by anaerobic respiration

Lời giải chi tiết

Urea is produced in the liver by deamination – the removal of the nitrogen-containing amino group from excess amino acids. **(B)**.

Bài tập luyện tập

Explain why the afferent arteriole entering the glomerulus is wider than the efferent arteriole leaving it, and state the significance of this difference.

Lời giải chi tiết

The wider afferent arteriole allows more blood to enter the glomerulus than the narrower efferent arteriole allows to leave in the same time, causing blood to "back up" within the glomerular capillaries. This maintains an unusually **high hydrostatic pressure** inside the glomerulus, which is essential for forcing small dissolved substances out of the blood and into the Bowman's capsule during ultrafiltration.

Bài tập luyện tập

List four substances forced out of the blood during ultrafiltration, and two components of the blood that remain behind, with reasons.

Lời giải chi tiết

Forced out into the filtrate: water, glucose, amino acids, urea, and mineral ions (any four). Remaining in the blood: red/white blood cells and plasma proteins, because they are too large to pass through the pores of the capillary wall and basement membrane, regardless of the high pressure.

Bài tập luyện tập

Explain why glucose is normally completely absent from healthy urine, referring to both stages of urine formation.

Lời giải chi tiết

Glucose is small enough to be forced out of the blood during ultrafiltration and does enter the filtrate at the Bowman's capsule. However, during selective reabsorption in the proximal convoluted tubule, glucose is normally reabsorbed completely (100%) back into the blood by active transport, so none remains in the fluid that continues on to become urine.

Bài tập luyện tập

A patient's urine contains a significant amount of glucose. Suggest one possible explanation, referring to the normal function of the nephron.

Lời giải chi tiết

If blood glucose concentration is abnormally high (as in poorly controlled diabetes), the amount of glucose entering the filtrate may exceed the tubule's capacity to reabsorb it completely by active transport, so some glucose remains in the fluid and is excreted in the urine.

Bài tập luyện tập

(Supplement) Explain how the body responds, via ADH, to drinking a large volume of water quickly.

Lời giải chi tiết

Drinking a large volume of water dilutes the blood, raising its water potential above normal. The hypothalamus detects this and signals the pituitary gland to release **less ADH**. Lower ADH makes the collecting duct **less permeable** to water, so less water is reabsorbed back into the blood, and a larger volume of more dilute urine is produced – helping to restore blood water potential to normal.

Bài tập luyện tập

State the general sequence of a negative feedback loop, using generic terms (receptor, coordinator, effector).

Lời giải chi tiết

Receptor detects a deviation from the normal set point → coordinator processes this information → effector produces a response that counteracts the deviation → the level is corrected back toward the set point → the receptor detects the corrected level and the response is

reduced/switched off.

Bài tập luyện tập

Blood glucose concentration falls between meals. Describe the hormonal response and its effect on the liver.

Lời giải chi tiết

The pancreas detects the fall in blood glucose concentration and secretes more **glucagon**. Glucagon stimulates the liver to break down stored glycogen into glucose and release it into the blood, raising blood glucose concentration back toward normal.

Bài tập luyện tập

(Supplement) Distinguish between Type 1 and Type 2 diabetes in terms of underlying cause.

(A) Type 1: insulin resistance; Type 2: no insulin production

(B) Type 1: insufficient/no insulin production; Type 2: reduced sensitivity of cells to insulin

(C) Both types have an identical cause but different symptoms

(D) Type 1 and Type 2 both result from excess glucagon secretion

Lời giải chi tiết

Type 1 diabetes is caused by insufficient or absent insulin production; Type 2 diabetes is caused by body cells becoming less responsive (resistant) to insulin. **(B)**.

Bài tập luyện tập

Explain the body's two responses to overheating and how each helps to lower body temperature.

Lời giải chi tiết

Vasodilation: arterioles supplying skin capillaries widen, increasing blood flow near the skin surface, so more heat is lost from the blood to the surroundings by radiation. **Sweating**: sweat glands increase sweat secretion onto the skin; as sweat evaporates, it removes latent heat from the skin surface, cooling the body.

Bài tập luyện tập

Explain the body's two responses to a cold environment, other than piloerection.

Lời giải chi tiết

Vasoconstriction: arterioles supplying skin capillaries narrow, reducing blood flow near the skin surface and therefore reducing heat loss by radiation. **Shivering**: rapid involuntary contraction of skeletal muscles increases the rate of respiration in muscle cells, generating heat as a by-product and warming the body.

Bài tập luyện tập

Which structure detects deviations in body temperature and coordinates the corrective response?

(A) The pancreas
(B) The hypothalamus
(C) The Bowman's capsule
(D) The relay neurone

Lời giải chi tiết

The hypothalamus contains thermoreceptors monitoring blood temperature, receives input from skin thermoreceptors, and coordinates the appropriate corrective responses (vasodilation/sweating or vasoconstriction/shivering). **(B)**.

Bài tập luyện tập

State the function of (a) dendrites, (b) the axon, and (c) the myelin sheath of a neurone.

Lời giải chi tiết

(a) Dendrites receive nerve impulses and carry them toward the cell body. (b) The axon carries the nerve impulse away from the cell body, often over long distances, to the axon terminals. (c) The myelin sheath insulates the axon electrically and significantly speeds up conduction of the nerve impulse.

Bài tập luyện tập

Explain why nerve impulses can only cross a synapse in one direction.

Lời giải chi tiết

Neurotransmitter chemicals are stored in and released only from the axon terminal of the presynaptic (first) neurone, and the corresponding receptor molecules are located only on the membrane of the postsynaptic (second) neurone. Since the chemical is released from only one side and detected only on the other, the impulse can only cross the synaptic gap in one direction.

Bài tập luyện tập

Place the following in the correct order for a reflex arc: motor neurone, receptor, effector, relay neurone, sensory neurone, stimulus, response.

Lời giải chi tiết

Stimulus → receptor → sensory neurone → relay neurone (spinal cord) → motor neurone → effector → response.

Bài tập luyện tập

Explain why reflex responses are faster than responses that involve conscious decision-making.

Lời giải chi tiết

In a reflex arc, the relay neurone in the spinal cord passes the impulse directly to a motor neurone without the signal first travelling to the brain for conscious processing. This shorter pathway, involving fewer neurones and synapses, produces a much faster response than waiting for the brain to interpret the stimulus and consciously decide on an action – important for avoiding injury from harmful stimuli.

Bài tập luyện tập

An impulse travels 1.2 m along a sensory neurone at a speed of 60 m/s. Calculate the time taken.

Lời giải chi tiết

time $= 1.2/60 = 0.02$ s $= 20$ ms.

Bài tập luyện tập

A motor neurone conducts an impulse over 0.45 m in 9 ms. Calculate the speed of conduction in this neurone, and suggest whether it is likely to be myelinated.

Lời giải chi tiết

speed $= \dfrac{0.45}{0.009} = 50$ m/s. This speed is characteristic of a myelinated neurone (myelinated neurones typically conduct impulses tens of metres per second, far faster than the roughly 1–5 m/s typical of unmyelinated neurones), so this neurone is likely myelinated.

Bài tập luyện tập

A full reflex pathway consists of a 0.6 m sensory neurone at 60 m/s, one synaptic delay of 0.5 ms, and a 0.4 m motor neurone at 40 m/s. Calculate the total time from stimulus to signal reaching the effector.

Lời giải chi tiết

Sensory neurone: $0.6/60 = 0.01$ s $= 10$ ms.
Synaptic delay: 0.5 ms.
Motor neurone: $0.4/40 = 0.01$ s $= 10$ ms.
Total $= 10 + 0.5 + 10 = 20.5$ ms.

Bài tập luyện tập

State the gland that produces adrenaline, and describe three effects of adrenaline on the body.

Lời giải chi tiết

Adrenaline is produced by the **adrenal glands**. Effects include: increasing heart rate (pumping blood, and therefore oxygen, faster to the muscles); raising blood glucose concentration (stimulating glycogen breakdown in the liver, to provide fuel for muscles); and redirecting blood flow toward the muscles (dilating arterioles supplying muscles, constricting those supplying the gut/skin), all preparing the body for vigorous physical activity ("fight or flight").

Bài tập luyện tập

Compare nervous and hormonal coordination in terms of speed and duration of effect.

Lời giải chi tiết

Nervous coordination (electrical impulses along neurones) acts very rapidly (impulses travel in milliseconds) but its effects are typically short-lived. Hormonal coordination (chemical messengers carried in the blood) acts more slowly (limited by the speed of blood circulation) but its effects are often longer-lasting.

Bài tập luyện tập

A shoot growing on a windowsill bends toward the incoming light. Explain this response in terms of auxin distribution and its effect on cell elongation.

Lời giải chi tiết

Unequal light causes auxin (produced at the shoot tip) to accumulate on the **shaded** side of the shoot rather than the illuminated side. In shoot cells, a higher auxin concentration **promotes** cell elongation, so the shaded side elongates faster than the illuminated side. This unequal growth rate causes the shoot to curve/bend **toward** the light source (positive phototropism).

Bài tập luyện tập

A root is placed horizontally in the dark. Predict and explain the direction in which it will grow.

Lời giải chi tiết

The root will grow **downward**, curving toward the direction of gravity (positive gravitropism). Gravity causes auxin to accumulate on the **lower** side of the horizontal root. In root cells (unlike shoot cells), a higher auxin concentration **inhibits** cell elongation, so the lower side elongates more slowly than the upper side, causing the root to bend downward.

Bài tập luyện tập

In a classic agar-block experiment, a block of agar containing auxin is placed asymmetrically on one side of a decapitated shoot stump (in the dark, so light is not a factor). Predict the direction of shoot bending and explain why.

Lời giải chi tiết

The shoot will bend **away** from the side bearing the auxin-containing agar block. The side under the block receives extra auxin, promoting greater cell elongation on that side than on the opposite side; this unequal elongation curves the shoot away from the side with more auxin (more growth on one side pushes the tip toward the opposite side).

Bài tập luyện tập

Explain why auxin is described as having ”opposite effects” in shoots and roots, and why this matters for understanding gravitropism in both organs.

Lời giải chi tiết

At the same concentration, auxin **promotes** cell elongation in shoot cells but **inhibits** cell elongation in root cells. When a shoot or root is placed horizontally, gravity causes auxin to accumulate on the lower side in both cases – but because of this opposite cellular response, the shoot's lower (higher-auxin) side grows *faster*, bending the shoot *upward* (away from gravity), while the root's lower (higher-auxin) side grows *slower*, bending the root *downward* (toward gravity). The same auxin distribution therefore produces opposite curvature directions in the two organs.

Bài tập luyện tập

A doctor observes that a patient's urine contains no glucose or protein but elevated urea and salt levels after a very salty meal. Is this a normal or abnormal result? Justify your answer.

Lời giải chi tiết

This is a **normal** result. The absence of glucose and protein indicates that ultrafiltration and selective reabsorption are functioning correctly (glucose is being fully reabsorbed, and proteins were never filtered out in the first place). The elevated urea (a constant excretory waste) and elevated salt (excess mineral ions after a salty meal, appropriately not reabsorbed since the body does not need them) are exactly the expected response of a healthy kidney adjusting excretion to match dietary intake.

Bài tập luyện tập

Explain why a myelinated neurone allows a faster reflex response than an equivalent unmyelinated neurone of the same length.

Lời giải chi tiết

The myelin sheath insulates the axon and increases the speed of nerve impulse conduction along it. For neurones of the same length, a myelinated neurone therefore conducts an impulse over that distance in less time than an unmyelinated one, directly reducing the total reflex arc time and producing a faster overall response.

Reproduction in Plants and Humans

Mục tiêu Unit: So sánh sinh sản vô tính và hữu tính, ý nghĩa thích nghi của mỗi hình thức; cấu tạo hoa (nhị, nhuỵ) và quá trình thụ phấn (tự thụ phấn/thụ phấn chéo, hoa thụ phấn nhờ côn trùng/gió); thụ tinh ở thực vật có hoa, sự hình thành hạt và quả; các cơ chế phát tán hạt và điều kiện nảy mầm; cấu tạo hệ sinh sản nam và nữ ở người; (Supplement) chu kỳ kinh nguyệt và điều hoà hormone; thụ tinh, làm tổ, và vai trò của nhau thai; và tổng quan các biện pháp tránh thai.

11.1 Asexual versus Sexual Reproduction

Asexual reproduction produces new individuals from a **single** parent, using only **mitosis**, with no fusion of gametes. Offspring are **genetically identical** to the parent (and to each other) – they are **clones**. Examples include runners in strawberry plants, tubers in potato plants, bulbs in daffodils, and budding in yeast.

Sexual reproduction involves the fusion of two **gametes** (sex cells), usually from two parents, produced by **meiosis**. Offspring are **genetically different** from both parents and from each other, because of the genetic variation introduced during gamete formation and the mixing of two parents' genetic material at fertilisation.

	Asexual reproduction	Sexual reproduction
Number of parents	One	Usually two
Cell division involved	Mitosis only	Meiosis (gamete formation) + fertilisation
Genetic identity of offspring	Genetically identical to parent (clones)	Genetically different from parents and siblings
Genetic variation	None (barring rare mutation)	Substantial
Speed/resource cost	Generally fast, low resource cost	Generally slower, higher resource cost (finding a mate, producing gametes)
Examples	Runners (strawberry), tubers (potato), budding (yeast, *Hydra*)	Flowering plants producing seed via pollination; humans and most animals

Comparing asexual and sexual reproduction.

Adaptive significance: asexual reproduction allows rapid colonisation of a stable, favourable environment, since every genetically identical offspring is guaranteed to be just as well-suited to that environment as the successful parent, without the "cost" of finding a mate. Sexual reproduction produces genetically varied offspring, which is advantageous in a changing or unpredictable environment (or where disease/parasites are a threat): among varied offspring, at least some individuals are more likely to survive an unfavourable change or resist a given pathogen, providing the raw material for natural selection.

VN **GIẢI THÍCH TIẾNG VIỆT**

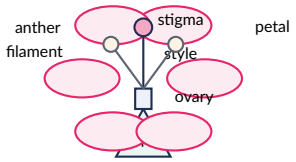
Sinh sản vô tính: MỘT bố/mẹ, chỉ dùng nguyên phân (mitosis), con giống hệt bố/mẹ về mặt di truyền (bản sao/clone) – thích hợp để nhân giống NHANH trong môi trường ổn định, thuận lợi. Sinh sản hữu tính: cần giao tử từ HAI bố mẹ (qua giảm phân/meiosis), con có biến dị di truyền – có lợi khi môi trường THAY ĐỔI hoặc có nguy cơ dịch bệnh/ký sinh trùng, vì trong một quần thể đa dạng, luôn có khả năng một số cá thể sống sót được trước điều kiện bất lợi mới.

11.2 Flower Structure

A typical insect-pollinated flower contains the following parts, in addition to protective sepals and (often) colourful petals.

Stamen (male part): consists of the **anther** (produces pollen grains, each containing a male gamete nucleus) supported on a stalk, the **filament**.

Carpel (female part, also called the pistil): consists of the **stigma** (receives pollen), the **style** (a stalk connecting the stigma to the ovary), and the **ovary** (containing one or more **ovules**, each of which contains a female gamete, the egg cell, and later develops into a seed).



Simplified structure of an insect-pollinated flower: stamen (anther + filament) is the male part; carpel (stigma + style + ovary, containing ovules) is the female part.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nhị hoa (stamen) là bộ phận SINH DỤC ĐỰC: gồm bao phấn (anther, chứa hạt phấn) và chỉ nhị (filament, cuống đỡ). Nhuỵ hoa (carpel) là bộ phận SINH DỤC CÁI: gồm đầu nhuỵ (stigma, nhận phấn), vòi nhuỵ (style, ống nối đầu nhuỵ với bầu nhuỵ), và bầu nhuỵ (ovary, chứa noãn/ovule – mỗi noãn chứa một tế bào trứng).

11.3 Pollination

Pollination is the transfer of pollen from an anther to a stigma.

Self-pollination occurs when pollen is transferred to a stigma of the *same* flower, or another flower on the *same* plant. Offspring are genetically similar to the parent plant, since both gametes come from the same individual; this guarantees reproduction even without pollinators, but reduces genetic variation and can allow harmful recessive alleles to accumulate over generations.

Cross-pollination occurs when pollen is transferred from the anther of one plant to the stigma of a flower on a *genetically different* plant of the same species. This **increases genetic variation** among offspring, generally considered advantageous for a population's ability to adapt to changing conditions or resist disease.

Feature	Insect-pollinated flowers	Wind-pollinated flowers
Petals	Large, brightly coloured (attract pollinators)	Small, dull, or absent
Scent/nectar	Present, to attract insects	Absent
Pollen quantity	Produced in smaller quantities	Produced in very large quantities (much of it wasted, since dispersal by wind is unreliable)
Pollen texture	Larger, sticky or spiky (adheres to insect bodies)	Small, smooth, and light (easily carried on air currents)
Anther position & attachment	Located inside the flower, firmly attached	Large, hanging loosely outside the flower, exposed to air movement
Stigma	Small, sticky, located inside the flower	Large, feathery, and exposed outside the flower (to catch airborne pollen)

Insect-pollinated versus wind-pollinated flower adaptations.

VN **GIẢI THÍCH TIẾNG VIỆT**

Hoa thụ phấn nhờ CÔN TRÙNG: cánh hoa to, sặc sỡ, có mùi thơm/mật hoa để thu hút; hạt phấn ÍT nhưng dính/gai để bám vào cơ thể côn trùng; nhị và đầu nhuỵ nằm BÊN TRONG hoa. Hoa thụ phấn nhờ GIÓ: cánh hoa nhỏ/không có, không mùi; hạt phấn RẤT NHIỀU, nhẹ và trơn để gió cuốn đi; nhị to lủng lẳng bên NGOÀI hoa, đầu nhuỵ to và có lông để hứng phấn trong không khí.

Ví dụ mẫu · Identifying pollination type from flower features

A flower has small, dull green petals, produces no nectar, has anthers hanging loosely outside the flower on long filaments, and has a large, feathery stigma. Identify the likely pollination method and justify your answer.

This flower is very likely **wind-pollinated**. The small, dull, scentless petals and absence of nectar indicate no investment in attracting insects. Anthers hanging outside the flower are well-positioned to release pollen into moving air, and a large feathery stigma maximises the chance of intercepting airborne pollen grains – both classic wind-pollination adaptations.

11.4 Fertilisation in Flowering Plants

Once a compatible pollen grain lands on a stigma, it **germinates**: a **pollen tube** grows out of the pollen grain and down through the tissue of the style, guided toward an ovule in the ovary. The pollen tube nucleus controls the growth of the tube, while the male gamete nucleus (or nuclei) travels down inside the tube. On reaching the ovule, the pollen tube penetrates it (via a small opening, the micropyle), and the **male nucleus fuses with the nucleus of the egg cell** inside the ovule – this fusion of gamete nuclei is **fertilisation**, producing a **zygote**.

After fertilisation: the **zygote** develops into an embryo, and the **ovule as a whole develops into a seed** (its outer layers becoming the tough seed coat, or testa). The **ovary** (containing one or more fertilised ovules) develops into a **fruit**, whose wall (pericarp) may become fleshy (aiding animal dispersal) or dry (e.g. a pod, aiding wind or explosive dispersal).

VN **GIẢI THÍCH TIẾNG VIỆT**

Sau thụ tinh ở thực vật có hoa: hợp tử (zygote) phát triển thành phôi; TOÀN BỘ noãn (ovule) phát triển thành HẠT (seed); TOÀN BỘ bầu nhuỵ (ovary) phát triển thành QUẢ (fruit). Ống phấn mọc xuyên qua vòi nhuỵ để đưa nhân giao tử đực đến gặp tế bào trứng bên trong noãn – đây là cách thực vật có hoa thực hiện thụ tinh mà không cần nước như ở một số nhóm thực vật khác.

(!) Lỗi thường gặp: Students very commonly swap these two facts: it is the **ovule** that becomes the **seed**, and the **ovary** that becomes the **fruit** – not the other way round. A useful memory check: an ovary usually contains *several* ovules, and correspondingly a fruit usually contains *several* seeds (one seed per fertilised ovule), all enclosed within the single fruit that developed from the one ovary wall.

11.5 Seed Dispersal

Seeds (and often the fruits containing them) are dispersed away from the parent plant by various mechanisms:

- **Wind dispersal**: seeds/fruits are light, and often have wing-like structures (e.g. sycamore "helicopters") or feathery, parachute-like structures (e.g. dandelion) that let air currents carry them.
- **Animal dispersal – ingestion**: fleshy, often brightly coloured or sweet fruits are eaten by animals; the tough seeds inside pass through the digestive system undamaged and are deposited elsewhere in the animal's droppings, often with a supply of natural fertiliser.
- **Animal dispersal – hooks/burrs**: fruits bear hooks or spines that catch onto the fur of passing animals (or onto clothing), and are carried some distance before falling or being brushed off (e.g. burdock).
- **Water dispersal**: seeds/fruits have a light, buoyant, waterproof structure that allows them to float and be carried by water currents (e.g. coconut).
- **Explosive (self) dispersal**: the fruit dries out and its wall builds up tension as it dries unevenly; it eventually splits open suddenly, mechanically flinging the seeds away from the parent plant (e.g. pea and broom pods).

Seed dispersal is advantageous because it **reduces competition** (for light, water, minerals, and space) between the parent plant and its own offspring, and among the offspring themselves, and it allows the species to **colonise new areas**, spreading its range and reducing the risk that a single local event (disease, fire, drought) destroys the entire population of offspring at once.

VN **GIẢI THÍCH TIẾNG VIỆT**

Phát tán hạt có lợi vì (1) giảm cạnh tranh (ánh sáng, nước, khoáng chất, không gian) giữa cây con với cây mẹ và giữa các cây con với nhau; (2) giúp loài lan rộng tới môi trường sống mới, giảm nguy cơ toàn bộ thế hệ con bị tiêu diệt cùng lúc bởi một sự kiện cục bộ (dịch bệnh, hạn hán, cháy...). Bốn cơ chế phát tán cần nhớ: gió, động vật (ăn quả hoặc móc bám), nước, và tự phát tán (quả nổ tung).

Ví dụ mẫu · Matching dispersal mechanism to fruit structure

A fruit is light, roughly disc-shaped with a single wing extending from one side, causing it to spin as it falls from the tree. State its likely dispersal method and explain the adaptation.

This is characteristic of **wind dispersal** (e.g. sycamore/maple-type fruit). The wing increases air resistance relative to the fruit's mass and causes it to spin, slowing its fall and allowing wind currents more time to carry it horizontally away from the parent tree before it lands, increasing the distance over which the seed can be dispersed.

11.6 Seed Structure and Germination

A typical seed consists of a tough outer **testa** (seed coat, protecting the contents), an **embryo** (consisting of a **plumule**, the embryonic shoot, and a **radicle**, the embryonic root), and a food store, either in one or more **cotyledons** (seed leaves) or, in cereal seeds, in a separate tissue called the **endosperm**.

Germination is the process by which a seed begins to grow into a seedling. Three conditions are required:

- **Water**: activates enzymes within the seed, softens the testa, and is needed for cell expansion and for metabolic reactions to proceed.
- **Oxygen**: required for aerobic respiration, which releases the energy needed for growth of the embryo.
- **A suitable (warm) temperature**: enzymes controlling germination work optimally within a certain temperature range – too cold and reactions proceed too slowly; too hot and enzymes may be denatured.

Light is *not* required for germination itself (though the emerging seedling will need light once it becomes photosynthetic).

Stages of germination: the seed absorbs water (imbibition) and swells; water activates enzymes that break down stored starch into sugars, providing substrate for respiration and building blocks for growth; the **radicle** emerges first, growing downward to anchor the seedling and absorb water; the **plumule** then emerges and grows upward (toward light); once the first true leaves develop and begin photosynthesising, the seedling becomes self-sufficient and no longer depends solely on its stored food reserves.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ba điều kiện nảy mầm cần nhớ: **nước** (kích hoạt enzyme, làm mềm vỏ hạt), **oxy** (cho hô hấp hiếu khí, cung cấp năng lượng), và **nhiệt độ thích hợp** (enzyme hoạt động tối ưu). Lưu ý: ÁNH SÁNG KHÔNG phải điều kiện bắt buộc để nảy mầm (dù cây con sau đó cần ánh sáng để quang hợp) – đây là điểm học sinh hay nhầm lẫn khi liệt kê điều kiện nảy mầm.

(!) Lỗi thường gặp: Do not include **light** among the essential conditions for germination – many seeds germinate perfectly well in complete darkness (e.g. buried underground), since germination relies on stored food reserves, not photosynthesis. Light only becomes essential later, once the seedling has used up much of its food store and needs to photosynthesise to continue growing.

Ví dụ mẫu · Explaining a germination failure

A gardener plants seeds in moist soil, at a warm temperature, but waterlogs the soil so heavily that it becomes saturated and airless. The seeds fail to germinate. Explain why.

Although water and a suitable temperature are present, completely waterlogged soil excludes air, so very little **oxygen** is available to the seed. Without sufficient oxygen, the seed cannot

carry out aerobic respiration at a rate fast enough to release the energy required for germination and early growth, so germination fails (or the embryo may even die from lack of oxygen, and/or from anaerobic conditions favouring rot-causing microorganisms).

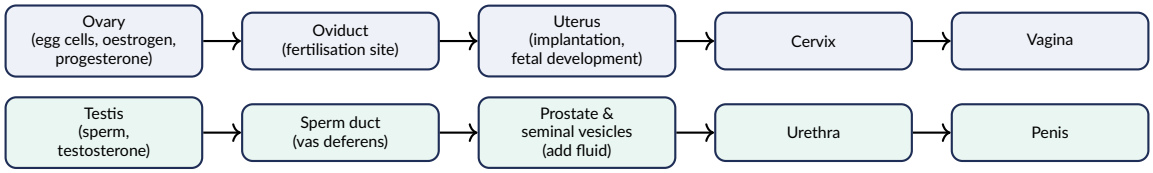
11.7 Human Reproductive Systems

11.7.1 The male reproductive system

The **testes** (singular: testis) produce **sperm** (by meiosis) and secrete the hormone **testosterone**. Sperm travel through the **sperm duct** (vas deferens) toward the urethra; along the way, fluid from the **prostate gland** and **seminal vesicles** is added, providing nutrients (e.g. fructose) and an alkaline fluid that helps neutralise the natural acidity of the vagina, together forming **semen**. The **urethra** carries semen (or, at other times, urine – never simultaneously) through the **penis**, which deposits semen into the vagina during sexual intercourse.

11.7.2 The female reproductive system

The **ovaries** produce **egg cells** (by meiosis) and secrete the hormones **oestrogen** and **progesterone**. Each month, an egg is released from an ovary into the **oviduct** (fallopian tube) – the usual site of **fertilisation**, where cilia and muscular contractions of the oviduct wall help move the egg (or embryo) toward the **uterus** (womb), the muscular organ in which a fertilised egg implants and the fetus develops. The **cervix**, a ring of muscle at the base of the uterus, holds a developing fetus in place during pregnancy and dilates to allow birth. The **vagina** receives the penis during intercourse and forms the birth canal during childbirth.



Simplified schematic pathways of the female (top) and male (bottom) reproductive systems, showing the sequence of structures involved from gamete production to release.

VN **GIẢI THÍCH TIẾNG VIỆT**

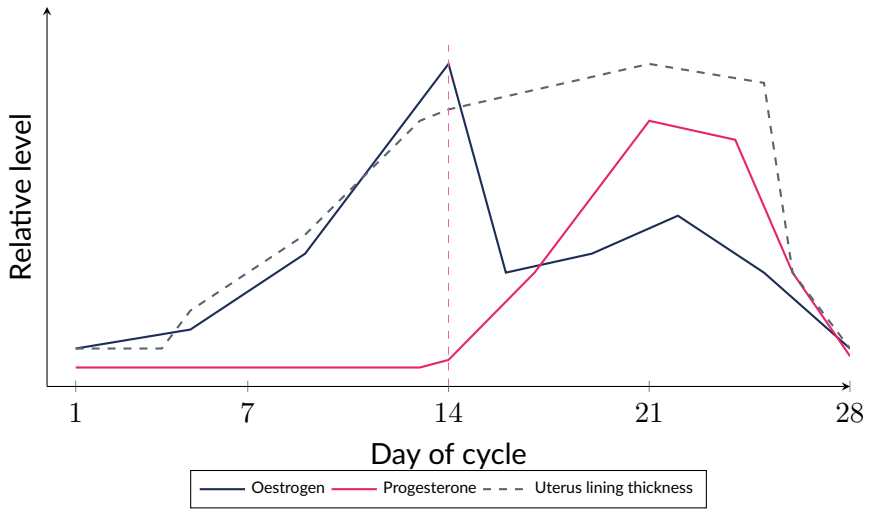
Hệ sinh dục NAM: tinh hoàn (testis) tạo tinh trùng và testosterone → ống dẫn tinh → tuyến tiền liệt/túi tinh bổ sung dịch (tạo tinh dịch/semen) → niệu đạo → dương vật. Hệ sinh dục NỮ: buồng trứng (ovary) tạo trứng và oestrogen/progesterone → ống dẫn trứng/vòi trứng (oviduct – nơi THỤ TINH xảy ra) → tử cung (uterus – nơi LÀM TỔ và phát triển thai) → cổ tử cung (cervix) → âm đạo (vagina).

11.8 (Supplement) The Menstrual Cycle

The menstrual cycle is a roughly **28-day** cycle of hormonal and physical changes that prepares the uterus for a possible pregnancy each month.

- **Day 1**: menstruation begins – the built-up uterus lining (endometrium) breaks down and is shed, since oestrogen and progesterone levels are low.
- **Days 1–13**: the pituitary gland releases **FSH** (follicle-stimulating hormone), which stimulates a follicle in the ovary to develop; the developing follicle secretes **oestrogen**, which causes the uterus lining to be rebuilt and thickened. Rising oestrogen also triggers a sharp surge of **LH** (luteinising hormone) from the pituitary gland.

- **Day 14 (approximately)**: the LH surge triggers **ovulation** – the release of a mature egg from the ovary.
- **Days 15–28**: LH converts the ruptured follicle into the **corpus luteum**, which secretes **progesterone** (and some oestrogen). Progesterone maintains and further thickens the uterus lining, preparing it for possible implantation, and inhibits further FSH/LH release (negative feedback), preventing a new follicle from developing during this phase.
- **If no fertilisation occurs**: the corpus luteum breaks down toward the end of the cycle (around days 26–28), so progesterone (and oestrogen) levels fall sharply; without hormonal support, the uterus lining breaks down, and menstruation begins again – day 1 of the next cycle.



Approximate hormone and uterus lining changes over the 28-day menstrual cycle. Oestrogen rises during the follicular phase (days 1–13) and peaks just before ovulation (day 14, dashed line); progesterone rises after ovulation (secreted by the corpus luteum) and peaks around day 21; the uterus lining thickens through most of the cycle before breaking down sharply at the end if fertilisation has not occurred.

GIẢI THÍCH TIẾNG VIỆT

VN

Chu kỳ kinh nguyệt (∼28 ngày): Ngày 1 – hành kinh (lớp niêm mạc tử cung bong ra). Ngày 1–13 – FSH kích thích nang trứng phát triển, nang trứng tiết **oestrogen** làm dày lại niêm mạc tử cung; oestrogen tăng cao gây đỉnh LH. Ngày 14 – đỉnh LH gây **rụng trứng** (ovulation). Ngày 15–28 – thể vàng (corpus luteum, hình thành từ nang trứng đã vỡ) tiết **progesterone**, duy trì niêm mạc tử cung dày. Nếu KHÔNG thụ tinh, thể vàng thoái hoá, progesterone giảm mạnh ⇒ niêm mạc bong ra ⇒ bắt đầu chu kỳ mới.

Ví dụ mẫu · Predicting hormone changes if fertilisation occurs

Explain what would happen to progesterone levels and the uterus lining if the egg released around day 14 were fertilised and successfully implanted, compared to a cycle with no fertilisation.

If fertilisation and implantation occur, the developing embryo (and later the placenta) maintains the **corpus luteum**, so **progesterone levels remain high** instead of falling around day 26–28. Because progesterone continues to maintain the uterus lining, the lining is **not shed** – menstruation does not occur, and the thickened lining continues supporting the developing embryo, in contrast to a non-fertile cycle where the corpus luteum degenerates, progesterone falls, and the lining breaks down.

11.9 Fertilisation, Implantation, and the Placenta

Fertilisation (fusion of sperm and egg nuclei) normally occurs in the **oviduct**. The resulting zygote divides repeatedly as it travels toward the uterus, and the resulting ball of cells (embryo) embeds itself into the thickened uterus lining – **implantation**.

The **placenta** is an organ that develops within the uterus wall, connected to the fetus via the umbilical cord, allowing exchange between maternal and fetal blood *without the two blood supplies mixing directly*. The placenta has a large surface area (with many finger-like projections bringing maternal and fetal blood vessels into very close proximity) across which substances diffuse:

- **Oxygen and nutrients** (e.g. glucose, amino acids) diffuse from the mother's blood into the fetus's blood.
- **Carbon dioxide and urea** (fetal waste products) diffuse from the fetus's blood into the mother's blood, to be excreted by the mother's own lungs and kidneys.

Although maternal and fetal blood do not mix directly (preventing, for example, the mother's blood pressure from damaging the more delicate fetal capillaries, and avoiding certain immune complications), the placental barrier is **not a complete barrier**: some substances can still cross it, including certain **viruses** (e.g. rubella), and harmful substances such as **alcohol** and **nicotine**. This is why pregnant women are medically advised to avoid alcohol and smoking – both can cross into the fetal bloodstream and interfere with fetal development.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nhau thai (placenta) cho phép trao đổi chất giữa mẹ và thai nhi qua KHUẾCH TÁN, nhưng máu mẹ và máu con KHÔNG BAO GIỜ trộn lẫn trực tiếp (có hai hệ tuần hoàn riêng biệt). Oxy và chất dinh dưỡng đi từ mẹ sang con; CO2 và urea (chất thải) đi từ con sang mẹ để mẹ đào thải hộ. Tuy nhiên nhau thai KHÔNG phải hàng rào tuyệt đối: một số virus, RƯỢU và NICOTINE vẫn có thể xuyên qua – đây là lý do bác sĩ khuyến cáo phụ nữ mang thai tuyệt đối không uống rượu hay hút thuốc.

Ví dụ mẫu · Identifying correct statements about the placenta

State whether each statement about the placenta is TRUE or FALSE, with a brief justification. (a) Maternal and fetal blood mix directly within the placenta. (b) Oxygen diffuses from fetal blood to maternal blood. (c) Nicotine can cross the placenta into the fetal bloodstream.

(a) FALSE – maternal and fetal blood remain in separate circulatory systems within the placenta; only substances (not whole blood) cross between them by diffusion.
(b) FALSE – oxygen diffuses in the opposite direction, from maternal blood (higher oxygen concentration) into fetal blood, to supply the fetus's respiratory needs.
(c) TRUE – nicotine is one of several harmful substances (along with alcohol and certain viruses) that can cross the placental barrier and reach the fetus.

Ví dụ mẫu · Comparing offspring variation from self- and cross-pollination

A pea plant self-pollinates every generation, while a neighbouring pea plant of a different variety consistently cross-pollinates with other plants nearby. Predict which plant's offspring will show greater genetic variation across generations, and explain why.

The **cross-pollinating** plant's offspring will show **greater genetic variation**. Self-pollination combines gametes derived from a single parent's genome, so offspring closely resemble that one parent genetically, generation after generation. Cross-pollination combines gametes from two genetically different parent plants, introducing new combinations of alleles into the off-

spring each generation – steadily increasing genetic diversity within the population over time.

11.10 Sexually Transmitted Infections and Contraception

Some infections, including **HIV** (discussed in Chapter 8), can be transmitted through sexual contact; barrier methods of contraception also reduce the risk of transmitting such infections between partners. A range of contraceptive methods can prevent pregnancy by different mechanisms:

Method	Type	Mechanism
Condom (male/female)	Barrier	Physical barrier prevents sperm from reaching the egg; also reduces transmission of sexually transmitted infections
Contraceptive pill	Hormonal	Contains oestrogen and/or progesterone that suppresses FSH/LH release from the pituitary, preventing ovulation
Intrauterine device (IUD)	Mechanical/hormonal	Placed inside the uterus; prevents implantation of a fertilised egg (some types also release hormones or copper ions affecting sperm survival)
Sterilisation (vasectomy / tubal ligation)	Surgical	Sperm duct (vasectomy) or oviduct (tubal ligation) is cut/tied, permanently preventing sperm and egg from meeting
Abstinence	Behavioural	No sexual intercourse; prevents pregnancy and STI transmission completely when consistently practised

Overview of common contraceptive methods and how each prevents pregnancy.

VN **GIẢI THÍCH TIẾNG VIỆT**

Các biện pháp tránh thai hoạt động theo cơ chế khác nhau: bao cao su (rào cản vật lý, còn giảm nguy cơ lây nhiễm bệnh qua đường tình dục); thuốc tránh thai (hormone ức chế FSH/LH, ngăn rụng trứng); vòng tránh thai (ngăn trứng đã thụ tinh làm tổ); triệt sản (cắt/thắt ống dẫn tinh hoặc ống dẫn trứng, vĩnh viễn); và kiêng quan hệ tình dục (hiệu quả tuyệt đối nếu thực hiện đúng).

11.11 Practice Questions

Bài tập luyện tập

State two differences between asexual and sexual reproduction.

Lời giải chi tiết

Asexual reproduction involves only one parent and mitosis, producing offspring genetically identical to the parent; sexual reproduction involves (usually) two parents, gametes formed by meiosis, and fertilisation, producing offspring that are genetically different from both parents and from each other.

Bài tập luyện tập

Explain why sexual reproduction can be advantageous for a species living in a changing environment.

Lời giải chi tiết

Sexual reproduction produces genetically varied offspring. In a changing (or unpredictable) environment, this variation increases the chance that at least some individuals in a population possess characteristics that allow them to survive the new conditions or resist disease, providing the raw material on which natural selection can act, whereas genetically identical (asexually produced) offspring would all share the same vulnerabilities.

Bài tập luyện tập

A strawberry plant produces new plants via runners. Explain why these new plants show no genetic variation from the parent, and suggest one advantage of this strategy.

Lời giải chi tiết

Runners are produced by mitosis from the parent plant, with no fusion of gametes, so the new plants are genetically identical clones of the parent – no genetic variation is introduced. Advantage: this allows rapid, resource-efficient colonisation of an area already known to be favourable (since the parent has already succeeded there), without the "cost" of finding a mate or the risk of producing offspring less well-adapted than the parent.

Bài tập luyện tập

Name the two parts of the stamen and the four parts of the carpel.

Lời giải chi tiết

Stamen: **anther** and **filament**. Carpel: **stigma**, **style**, **ovary**, and **ovule** (within the ovary).

Bài tập luyện tập

Distinguish between self-pollination and cross-pollination, and state one genetic consequence of each.

Lời giải chi tiết

Self-pollination: pollen is transferred to a stigma of the same flower or another flower on the same plant; offspring are genetically similar to the parent, reducing variation. Cross-pollination: pollen is transferred to a stigma on a different plant of the same species; offspring show increased genetic variation.

Bài tập luyện tập

A flower has large, sweet-scented, brightly coloured petals, produces nectar, and has pollen that is sticky and produced in relatively small quantities. Identify its pollination method.

(A) Wind-pollination
(B) Water-pollination
(C) Insect-pollination
(D) Self-pollination only

Lời giải chi tiết

Bright colours, scent, nectar, and sticky pollen in modest quantities are classic adaptations for attracting and using insects to transfer pollen. **(C)**.

Bài tập luyện tập

Explain why wind-pollinated flowers typically produce far more pollen than insect-pollinated flowers.

Lời giải chi tiết

Wind dispersal of pollen is unreliable and undirected – most pollen grains released into moving air will never reach a stigma of the same species. To compensate for this low probability of successful transfer, wind-pollinated flowers produce pollen in very large quantities, increasing the chance that at least some grains land on a suitable stigma.

Bài tập luyện tập

Describe the pathway of the male nucleus from pollen grain to fertilisation.

Lời giải chi tiết

After a compatible pollen grain lands on the stigma, it germinates and grows a pollen tube down through the style toward the ovary. The male nucleus travels down inside the pollen tube; upon reaching the ovule (via the micropyle), the male nucleus fuses with the nucleus of the egg cell inside the ovule, completing fertilisation and forming a zygote.

Bài tập luyện tập

State what the ovule and the ovary each develop into after fertilisation.

Lời giải chi tiết

The ovule develops into the **seed**; the ovary develops into the **fruit**.

Bài tập luyện tập

A fruit has hooked spines covering its surface. State its likely dispersal mechanism and explain the adaptation.

Lời giải chi tiết

This fruit is adapted for **animal dispersal by hooks/burrs**: the hooks catch onto the fur of passing animals (or clothing), allowing the fruit (and the seeds inside) to be carried some distance from the parent plant before falling off or being brushed away.

Bài tập luyện tập

Explain why seed dispersal reduces competition between a parent plant and its own offspring.

Lời giải chi tiết

If seeds germinated immediately beneath the parent plant, the seedlings would compete directly with the parent (and with each other) for the same limited light, water, minerals, and space. Dispersing seeds away from the parent spreads offspring over a wider area, reducing this direct competition and increasing each seedling's chance of obtaining sufficient resources to survive.

Bài tập luyện tập

List the three conditions required for germination and briefly state the role of each.

Lời giải chi tiết

Water: activates enzymes, softens the testa, and enables cell expansion/metabolic reactions. **Oxygen**: required for aerobic respiration to release energy for growth. **A suitable (warm) temperature**: allows enzymes controlling germination to work at an appropriate rate (not too slow from cold, not denatured from excessive heat).

Bài tập luyện tập

A batch of seeds is planted with adequate water, oxygen, and warmth, but none germinate. Suggest the most likely explanation.

Lời giải chi tiết

Since all three standard germination conditions (water, oxygen, suitable temperature) were met, the most likely explanation is that the seeds themselves were **not viable** – for example, they may have been too old, damaged, improperly stored, or never fertilised/developed properly, so the embryos inside were dead or absent.

Bài tập luyện tập

State the site of fertilisation in the human female reproductive system, and describe how the egg (or embryo) is moved toward the uterus.

Lời giải chi tiết

Fertilisation normally occurs in the **oviduct** (fallopian tube). Cilia lining the oviduct, together with muscular contractions of its wall, help move the egg (or the developing embryo, if fertilised) along the oviduct toward the uterus.

Bài tập luyện tập

Name the two hormones secreted by the testes and ovaries respectively, along with the gametes each organ produces.

Lời giải chi tiết

Testes: produce **sperm** and secrete **testosterone**. Ovaries: produce **egg cells** and secrete **oestrogen** and **progesterone**.

Bài tập luyện tập

Explain the role of fluid added by the prostate gland and seminal vesicles to sperm.

Lời giải chi tiết

This fluid provides nutrients (such as fructose) to nourish the sperm, and is alkaline, which helps neutralise the naturally acidic environment of the vagina, protecting the sperm and improving their chances of survival on the way to fertilising an egg. Together with sperm, this fluid forms semen.

Bài tập luyện tập

(Supplement) Which hormone surge directly triggers ovulation, and around which day of a typical 28-day cycle does this occur?

(A) FSH surge, around day 7
(B) LH surge, around day 14
(C) Progesterone surge, around day 21
(D) Oestrogen surge, around day 28

Lời giải chi tiết

A sharp surge in **LH** (luteinising hormone), triggered by rising oestrogen from the developing follicle, causes ovulation around **day 14** of a typical 28-day cycle. **(B)**.

Bài tập luyện tập

(Supplement) Explain the source and function of progesterone during the second half (luteal phase) of the menstrual cycle.

Lời giải chi tiết

After ovulation, the ruptured follicle is converted (under the influence of LH) into the corpus luteum, which secretes progesterone. Progesterone maintains and further thickens the uterus lining, preparing it for possible implantation of a fertilised egg, and also inhibits further FSH/LH release from the pituitary, preventing new follicles from developing during this phase.

Bài tập luyện tập

(Supplement) Explain why menstruation occurs if the egg released that cycle is not fertilised.

Lời giải chi tiết

If fertilisation does not occur, the corpus luteum degenerates toward the end of the cycle, causing progesterone (and oestrogen) levels to fall sharply. Without hormonal support, the thickened uterus lining can no longer be maintained and breaks down, being shed from the body as menstrual bleeding – marking day 1 of the next cycle.

Bài tập luyện tập

Explain why maternal and fetal blood do not mix directly in the placenta, yet substances can still pass between them.

Lời giải chi tiết

Maternal and fetal blood flow through separate, closely associated capillary networks within the placenta, kept apart by thin membranes. Because the two blood supplies are separated by only a very short diffusion distance across these thin membranes (with a large surface area of contact), useful substances (oxygen, nutrients) and waste substances (carbon dioxide, urea) can still diffuse efficiently between the two blood supplies without the bloods themselves ever mixing.

Bài tập luyện tập

State the direction of diffusion across the placenta for (a) glucose, (b) urea, (c) carbon dioxide.

Lời giải chi tiết

(a) Glucose: from mother's blood to fetus's blood. (b) Urea: from fetus's blood to mother's blood. (c) Carbon dioxide: from fetus's blood to mother's blood.

Bài tập luyện tập

Explain why doctors advise pregnant women not to drink alcohol or smoke, in terms of placental function.

Lời giải chi tiết

The placenta is not a complete barrier: alcohol and nicotine are both able to cross the placental membranes by diffusion, passing from the mother's blood into the fetal blood supply. Once in the fetal circulation, these substances can interfere with the normal growth and development of the fetus, so avoiding them during pregnancy reduces the risk of harm to the developing baby.

Bài tập luyện tập

Which contraceptive method works by suppressing FSH and LH release, thereby preventing ovulation?

(A) Condom
(B) Intrauterine device (IUD)
(C) Contraceptive pill
(D) Sterilisation

Lời giải chi tiết

The contraceptive pill contains hormones (oestrogen and/or progesterone) that suppress FSH and LH release from the pituitary, preventing ovulation. **(C)**.

Bài tập luyện tập

Explain why barrier methods of contraception, such as condoms, provide a benefit that hormonal methods do not.

Lời giải chi tiết

Barrier methods physically prevent sperm from reaching the egg, but they also form a physical barrier against the exchange of bodily fluids between partners, reducing the risk of transmitting sexually transmitted infections (such as HIV). Hormonal methods (like the pill) prevent pregnancy by suppressing ovulation but provide no barrier against infection transmission.

Bài tập luyện tập

Distinguish between vasectomy and tubal ligation as methods of sterilisation.

Lời giải chi tiết

A **vasectomy** is performed on males: the sperm duct (vas deferens) is cut and sealed, preventing sperm from being included in ejaculated semen. **Tubal ligation** is performed on females: the oviducts (fallopian tubes) are cut and sealed, preventing eggs from travelling from the ovary to meet sperm. Both permanently prevent sperm and egg from meeting, without necessarily affecting hormone production or sexual function.

Bài tập luyện tập

A student writes: "Sexual reproduction is always better than asexual reproduction because it produces variation." Evaluate this claim.

Lời giải chi tiết

This overstates the case. Sexual reproduction's variation is advantageous specifically in changing or unpredictable environments, or where disease/parasite pressure exists, because it increases the chance that some offspring survive. However, in a stable, favourable environment, asexual reproduction can be more advantageous: it is faster, requires fewer resources (no need to find a mate), and guarantees offspring just as well-suited to the environment as the successful parent. Neither strategy is universally "better" – each has advantages depending on environmental stability.

Bài tập luyện tập

Explain why a seed's testa is an important adaptive feature, and state what it develops from.

Lời giải chi tiết

The testa is a tough outer seed coat that protects the embryo and food store inside the seed from mechanical damage, drying out, and attack by microorganisms or pests, helping the seed survive potentially long periods before conditions are suitable for germination. The testa develops from the outer layers (integuments) of the ovule after fertilisation.

Bài tập luyện tập

A woman's blood test shows very low progesterone and oestrogen levels alongside a thin uterus lining. Estimate roughly which day of the menstrual cycle this sample was most likely taken, and justify your answer.

Lời giải chi tiết

This combination – both hormones low and a thin uterus lining – is most consistent with around **day 1** of the cycle (the start of menstruation), when the corpus luteum from the previous cycle has fully degenerated (progesterone and oestrogen both at their lowest) and the uterus lining has just been (or is being) shed.

Bài tập luyện tập

Explain why an ovary usually develops into a fruit containing several seeds, rather than just one.

Lời giải chi tiết

An ovary typically contains several ovules, each with its own egg cell. If more than one ovule within the ovary is successfully fertilised, each fertilised ovule develops into a separate seed, while the single surrounding ovary develops into one fruit – so a fruit commonly contains multiple seeds, one for each ovule that was fertilised.

Bài tập luyện tập

Explain why condoms are recommended alongside other contraceptive methods (such as the pill) for couples wishing to reduce the risk of sexually transmitted infections, even though the pill alone can prevent pregnancy.

Lời giải chi tiết

The contraceptive pill prevents pregnancy by suppressing ovulation, but it provides no physical barrier against the exchange of bodily fluids during intercourse, so it does not reduce the risk of transmitting infections such as HIV between partners. Condoms provide that physical barrier, reducing infection transmission risk, so using both together addresses pregnancy prevention and infection prevention, which the pill alone cannot fully achieve.

Inheritance, Variation and Selection

Mục tiêu Unit: Phân biệt chính xác nhiễm sắc thể (chromosome) – gen (gene) – alen (allele) và mối quan hệ giữa chúng; hiểu bộ nhiễm sắc thể người (46, 23 cặp) và cặp nhiễm sắc thể giới tính; nắm sơ lược cấu trúc DNA (Supplement); phân biệt nguyên phân (mitosis) và giảm phân (meiosis) về mục đích, số lần phân bào, số tế bào con và bộ nhiễm sắc thể; sử dụng thành thạo sơ đồ lai (Punnett square) cho các phép lai đơn tính (monohybrid), lai phân tích (test cross), di truyền liên kết giới tính (sex-linkage) và đồng trội (codominance) với hệ nhóm máu ABO; phân biệt biến dị liên tục và không liên tục cùng các nguyên nhân gây biến dị (đột biến, giảm phân, thụ tinh ngẫu nhiên, sinh sản hữu tính); trình bày đầy đủ cơ chế chọn lọc tự nhiên và sửa đúng ngộ nhận phổ biến về việc vi khuẩn "phát triển" khả năng kháng kháng sinh; phân biệt chọn lọc nhân tạo (chọn giống) với chọn lọc tự nhiên.

12.1 Chromosomes, Genes and Alleles

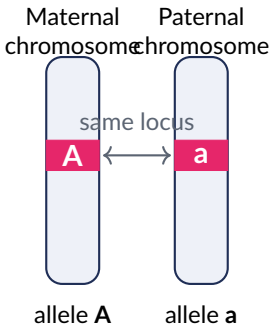
The hereditary information of every living cell is organised into structures called **chromosomes**, which are found in the nucleus.

Three core definitions

Chromosome: a long, coiled thread-like structure made of **DNA and protein**, found in the nucleus of a cell. Each chromosome carries many genes arranged along its length in a fixed order.

Gene: a length (section) of DNA on a chromosome that codes for a particular protein, and so controls the development of a particular characteristic. Genes occupy a fixed position on a chromosome called a **locus**.

Allele: one of two or more alternative versions of the same gene, occupying the same locus on a pair of homologous chromosomes, but differing slightly in their base sequence – and therefore capable of producing a different version of the characteristic (e.g. the gene for seed shape in pea plants has a *round* allele and a *wrinkled* allele).



A homologous pair of chromosomes carrying two alleles (A and a) of the same gene at the same locus.

Human chromosome number: body (somatic) cells contain **46 chromosomes**, arranged as **23 homologous pairs** – one chromosome of each pair inherited from the mother, one from the father. **22** of these pairs are **autosomes** (non-sex chromosomes); the **23rd pair** is the pair of **sex chromosomes**: **XX** in females, **XY** in males. Gametes (sperm and egg cells) contain only **23 chromosomes** (one from each pair) – they are **haploid**.

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Nhiễm sắc thể (chromosome) là cấu trúc gồm DNA cuộn với protein, nằm trong nhân tế bào. **Gen (gene)** là một đoạn DNA nằm trên nhiễm sắc thể, quy định một đặc điểm cụ thể (ví dụ: gen quy định hình dạng hạt đậu). **Alen (allele)** là các phiên bản khác nhau của CÙNG MỘT gen, nằm ở CÙNG MỘT vị trí (locus) trên cặp nhiễm sắc thể tương đồng – ví dụ alen "hạt tròn" và alen "hạt nhăn" là hai alen của gen hình dạng hạt. Học sinh Việt Nam rất hay nhầm ba khái niệm này với nhau: hãy nhớ theo thứ tự bao hàm **nhiễm sắc thể** ⊃ **gen** ⊃ **alen** (nhiễm sắc thể chứa nhiều gen; mỗi gen có thể có nhiều alen). Người có **46 nhiễm sắc thể** (23 cặp): 22 cặp thường (autosome) + 1 cặp nhiễm sắc thể giới tính (XX ở nữ, XY ở nam). Giao tử (tinh trùng/trứng) chỉ có 23 nhiễm sắc thể (đơn bội).

12.1.1 DNA structure (Supplement)

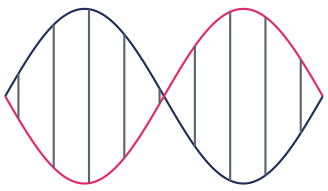
Each chromosome consists mainly of a single, extremely long molecule of **DNA (deoxyribonucleic acid)**, coiled up and associated with protein. DNA has a **double helix** structure: two strands twisted around each other, like a twisted ladder.

DNA – structure at IGCSE level

DNA is built from repeating units called **nucleotides**. Each nucleotide contains a sugar, a phosphate group, and one of four **bases**: **A** (adenine), **T** (thymine), **C** (cytosine), **G** (guanine). The sugar-phosphate groups form the two outer "backbones" of the helix (the sides of the ladder); the bases point inwards and pair up to form the "rungs" of the ladder, according to strict **complementary base pairing** rules:

A always pairs with T, **C always pairs with G**.

This precise pairing means the two strands of the double helix are **complementary** to each other – if the base sequence of one strand is known, the sequence of the other strand can be deduced. Before a cell divides, its DNA **replicates** (an exact copy of each DNA molecule is made) so that each new daughter cell can receive a complete, identical set of genetic information.



Two backbones (sugar–phosphate) twisted into a double helix; grey rungs = base pairs (A–T or C–G)

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DNA có cấu trúc **chuỗi xoắn kép** (double helix), gồm hai mạch xoắn quanh nhau như một chiếc thang xoắn. Đơn vị cấu tạo là **nucleotide**, gồm đường + phosphate + một trong bốn loại base: A, T, C, G. Các base ghép cặp bổ sung theo quy tắc cố định: **A luôn ghép với T; C luôn ghép**

với G – đây là quy tắc bắt buộc phải nhớ, không được đổi (không có A–C hay T–G). Trước khi tế bào phân chia, DNA tự nhân đôi (sao chép) để mỗi tế bào con nhận đủ một bộ thông tin di truyền hoàn chỉnh giống hệt tế bào mẹ. Ở mức IGCSE, KHÔNG cần nhớ chi tiết cơ chế enzyme của quá trình nhân đôi.

12.2 Cell Division: Mitosis and Meiosis

Body cells divide by one of two processes, depending on the purpose of the division.

12.2.1 Mitosis

Mitosis is a type of nuclear division that produces **two genetically identical diploid daughter cells** from one parent cell. Before division, the DNA of every chromosome is copied; the copies are then separated so that each of the two new cells receives one complete, identical set of chromosomes (the same chromosome number as the parent cell). Mitosis is responsible for:

- **Growth** – increasing the number of cells in a developing organism.
- **Repair** – replacing damaged or worn-out cells (e.g. skin, blood cells).
- **Asexual reproduction** – in organisms that reproduce without sex cells, the offspring produced by mitosis are genetically identical to the parent (clones).

12.2.2 Meiosis

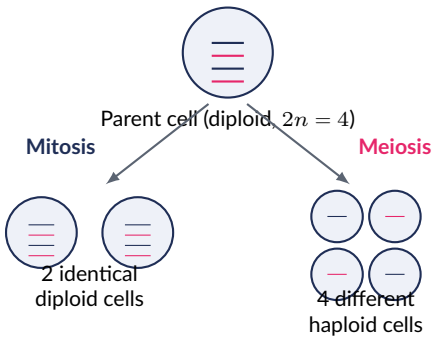
Meiosis is a type of nuclear division that produces **four genetically different haploid daughter cells** (gametes) from one diploid parent cell. It involves *two* successive divisions of the nucleus, but only *one* round of DNA copying, so each of the four resulting cells ends up with half the chromosome number of the parent cell (haploid, n). Meiosis occurs only in reproductive organs (testes/ovaries in animals; anthers/ovaries in flowering plants) to produce **gametes** for sexual reproduction.

Why meiosis produces genetically different cells (Supplement)

Two events during meiosis generate genetic variation among the four daughter cells:

Independent assortment: each homologous pair of chromosomes lines up and separates independently of every other pair, so the combination of maternal and paternal chromosomes that ends up in each gamete is essentially random – with 23 pairs in humans, an enormous number of different chromosome combinations is possible.

Crossing over: while homologous chromosomes are paired up early in meiosis, segments of DNA can be exchanged between them, creating chromosomes with new combinations of alleles that were not present on either original chromosome.



Feature	Mitosis	Meiosis
Number of divisions	1	2
Number of daughter cells	2	4
Chromosome number	Diploid ($2n$), same as parent cell	Haploid (n), half of parent cell
Genetic identity	Genetically identical to the parent cell and to each other	Genetically different from the parent cell and from each other
Purpose	Growth, repair, replacement of cells, asexual reproduction	Production of gametes (sperm, egg, pollen, ovule) for sexual reproduction

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Nguyên phân (mitosis): 1 lần phân chia → 2 tế bào con **lưỡng bội (diploid)**, giống hệt tế bào mẹ và giống hệt nhau – phục vụ **sinh trưởng, sửa chữa, sinh sản vô tính**. **Giảm phân (meiosis)**: 2 lần phân chia liên tiếp (nhưng DNA chỉ nhân đôi 1 lần) → 4 tế bào con **đơn bội (haploid)**, khác nhau về mặt di truyền – chỉ xảy ra ở cơ quan sinh dục để tạo **giao tử**. Ghi nhớ nhanh: Mitosis = 2 giống; Meiosis = 4 khác. Nguyên nhân tạo biến dị trong giảm phân (mức Supplement): **phân li độc lập** (các cặp NST tương đồng phân li ngẫu nhiên, độc lập với nhau) và **trao đổi chéo** (hai NST tương đồng trao đổi đoạn DNA cho nhau).

(!) Lỗi thường gặp: Nhiều học sinh nhớ nhầm số tế bào con hoặc bộ nhiễm sắc thể của hai quá trình. Hãy chốt chắc: nguyên phân tạo **2** tế bào **lưỡng bội, giống hệt** nhau; giảm phân tạo **4** tế bào **đơn bội, khác nhau**. Một lỗi khác là nghĩ giảm phân "nhân đôi DNA hai lần" – thực ra DNA chỉ nhân đôi **một lần** trước khi bước vào hai lần phân chia liên tiếp.

12.3 Genotype, Phenotype and the Language of Inheritance

Essential vocabulary

Genotype: the genetic make-up of an organism in terms of the alleles present (e.g. Tt).
Phenotype: the observable characteristics of an organism, resulting from both its genotype and (for some characteristics) the environment (e.g. *tall*).
Homozygous: having two identical alleles for a gene (e.g. TT or tt) – also called "pure-breeding" for that gene.
Heterozygous: having two different alleles for a gene (e.g. Tt).
Dominant allele: an allele that is expressed in the phenotype whenever it is present, whether in the homozygous or heterozygous state – represented by a **capital** letter (e.g. T).
Recessive allele: an allele that is only expressed in the phenotype when present in the **homozygous** state (i.e. no dominant allele is present to mask it) – represented by the **lower-case** version of the *same* letter (e.g. t).

VN **GIẢI THÍCH TIẾNG VIỆT**

Kiểu gen (genotype) là bộ alen mà một cá thể mang (ví dụ Tt) – KHÔNG nhìn thấy được bằng mắt thường. **Kiểu hình (phenotype)** là đặc điểm biểu hiện ra bên ngoài mà ta quan sát được (ví dụ: cây cao). Đây là cặp khái niệm học sinh Việt Nam nhầm lẫn nhiều nhất – hãy nhớ: kiểu GEN là chữ cái (Tt), kiểu HÌNH là mô tả bằng lời (cao/thấp). **Thể đồng hợp (homozygous)**: hai alen giống nhau (TT hoặc tt); **thể dị hợp (heterozygous)**: hai alen khác nhau (Tt). Quy ước chữ cái: alen **trội (dominant)** viết **IN HOA**, alen **lặn (recessive)** viết chữ **THƯỜNG** của *cùng*

một chữ cái (không được dùng hai chữ cái khác nhau, ví dụ SAI: B và r).

(!) Lỗi thường gặp: Một ngộ nhận rất phổ biến: cho rằng "trội" (dominant) nghĩa là "phổ biến hơn trong quần thể", còn "lặn" (recessive) nghĩa là "hiếm hơn". **Điều này SAI.** Trội/lặn chỉ mô tả việc alen nào được biểu hiện ra kiểu hình khi cả hai alen cùng có mặt (thể dị hợp) – KHÔNG liên quan đến tần số alen đó trong quần thể. Ví dụ: alen gây đa ngón (polydactyly) là trội nhưng lại rất hiếm; nhóm máu O (alen lặn I^O) lại rất phổ biến ở nhiều quần thể.

12.4 Monohybrid Inheritance

A **monohybrid cross** follows the inheritance of a single gene (one characteristic) between two parents. Working through a genetic cross always follows the same steps: state the alleles and what they represent; write the genotype of each parent; state the gametes each parent can produce; combine gametes in a **Punnett square**; read off the genotype and phenotype ratios of the offspring.

Ví dụ mẫu · Monohybrid cross: Tt × Tt

In pea plants, allele T (tall) is dominant to allele t (short/dwarf). Two heterozygous tall plants ($Tt \times Tt$) are crossed. Predict the genotype and phenotype ratios of the offspring.

Gametes: each Tt parent produces two types of gamete, T and t, in equal proportions.

×	**T**	**t**
T	TT	Tt
t	Tt	tt

Genotypes of offspring: $1\,TT : 2\,Tt : 1\,tt$.
Phenotypes of offspring: TT and Tt are both tall (since T is dominant); only tt is short. So the phenotype ratio is

3 tall : 1 short.

Ví dụ mẫu · Test cross: Tt × tt

A tall pea plant has an unknown genotype – it could be TT or Tt (both look tall). To find out which, it is crossed with a homozygous recessive short plant (tt); this is called a **test cross**. Suppose the unknown plant is actually Tt.

Gametes: the Tt parent produces gametes T and t; the tt parent produces only gamete t.

×	**T**	**t**
t	Tt	tt
t	Tt	tt

Result: $2\,Tt : 2\,tt$, i.e. **1 tall : 1 short**.
Interpreting a test cross: if *any* offspring show the recessive (short) phenotype, the unknown parent must have been **heterozygous** (Tt) – a homozygous dominant (TT) parent could never produce a short (tt) offspring when crossed with tt, since it has no t allele to pass on. If *all* offspring were tall, the unknown parent would most likely be TT.

VN **GIẢI THÍCH TIẾNG VIỆT**
Phép lai phân tích (test cross) dùng để xác định kiểu gen chưa biết của một cá thể mang kiểu hình trội (có thể là đồng hợp trội TT hoặc dị hợp Tt) bằng cách lai với cá thể **đồng hợp lặn** (tt).

Nếu đời con xuất hiện BẤT KỲ kiểu hình lặn nào → cá thể ban đầu chắc chắn là **dị hợp** Tt (vì TT không thể tạo giao tử t). Nếu đời con 100% mang kiểu hình trội → cá thể ban đầu nhiều khả năng là **đồng hợp trội** TT.

12.5 Sex-linked Inheritance

The 23rd pair of human chromosomes – the sex chromosomes – also carries ordinary genes, in addition to determining sex. A gene carried on the X chromosome (with no equivalent allele on the much smaller Y chromosome) shows a characteristic inheritance pattern called **sex-linkage**.

Ví dụ mẫu · Sex-linked inheritance: red-green colour blindness

Red-green colour blindness is caused by a recessive allele carried on the X chromosome. Let X^B = allele for normal colour vision (dominant), X^b = allele for colour blindness (recessive). A woman who is a carrier (X^BX^b, normal vision but carries one copy of X^b) has children with a man with normal vision (X^BY).

Gametes: mother produces X^B or X^b; father produces X^B or Y.

$\times$	X^B	**Y**
X^B	X^BX^B	X^BY
X^b	X^BX^b	X^bY

Offspring (each $\frac{1}{4}$): X^BX^B (normal-vision girl), X^BX^b (carrier girl, normal vision), X^BY (normal-vision boy), X^bY (**colour-blind boy**).
Overall phenotype ratio: 3 normal vision : 1 colour blind – but note that *only sons* can show the colour-blind phenotype in this cross; none of the daughters are colour blind (though half are carriers).

Why males are affected far more often: a male has only **one** X chromosome (X^bY), so a single copy of the recessive allele is enough to produce the colour-blind phenotype – there is no second X chromosome to carry a dominant, masking allele. A female has **two** X chromosomes, so she needs **two** copies of the recessive allele (X^bX^b) to be colour blind; with only one copy (X^BX^b) she is an unaffected carrier.

Ví dụ mẫu · Sex-linked inheritance: haemophilia (affected father × carrier mother)

Haemophilia (a blood-clotting disorder) is also X-linked recessive: X^H = normal clotting (dominant), X^h = haemophilia (recessive). An affected father (X^hY) has children with a carrier mother (X^HX^h).

$\times$	X^h	**Y**
X^H	X^HX^h	X^HY
X^h	X^hX^h	X^hY

Offspring (each $\frac{1}{4}$): X^HX^h (carrier daughter, unaffected), X^HY (unaffected son), X^hX^h (**affected daughter**), X^hY (**affected son**). This cross shows that an **affected daughter** is possible – but only when the father is affected *and* the mother is at least a carrier, since the daughter needs one X^h from each parent.

VN **GIẢI THÍCH TIẾNG VIỆT**

Gen liên kết giới tính (sex-linked) nằm trên nhiễm sắc thể X (không có alen tương ứng trên Y vì Y ngắn hơn). Vì nam giới chỉ có **một** NST X, chỉ cần **một** alen lặn là biểu hiện bệnh ngay (không có NST X thứ hai để "che" alen lặn) – đây là lý do các bệnh liên kết X (mù màu, máu khó đông/haemophilia) gặp ở nam giới nhiều hơn hẳn nữ giới. Nữ giới cần CẢ HAI alen lặn (X^hX^h) mới biểu hiện bệnh; nếu chỉ có một (X^HX^h) thì là người mang gen (carrier) không biểu hiện bệnh. Khi viết kiểu gen liên kết giới tính, LUÔN viết alen dưới dạng số mũ trên chữ X (ví dụ X^BX^b), không viết tắt thành "Bb" như phép lai thường.

(!) Lỗi thường gặp: Sai lầm thường gặp: quên viết nhiễm sắc thể Y trong kiểu gen của nam giới, hoặc viết kiểu gen nam là "X^bX^b" (nhầm nam giới có 2 NST X). Nam giới luôn có kiểu gen dạng $X^?Y$; nữ giới luôn có kiểu gen dạng $X^?X^?$. Ngoài ra, khi lập sơ đồ lai liên kết giới tính, nhớ Y không mang alen của gen đó – ô Punnett square chứa Y phải giữ nguyên "$X^?Y$", không được viết thành "YY" hay thêm alen vào Y.

12.6 Codominance and the ABO Blood Group System

Not every pair of alleles shows simple dominant/recessive inheritance. In **codominance**, both alleles present in a heterozygote are **fully expressed** in the phenotype, with neither masking the other.

Codominance: a condition in which both alleles of a gene are expressed in the phenotype of a heterozygous organism, without either being dominant or recessive to the other. The human **ABO blood group** system is the classic example: there are three alleles, I^A, I^B and I^O. I^A and I^B are **codominant** to each other; I^O is **recessive** to both I^A and I^B.

Genotype	Phenotype (blood group)
I^AI^A or I^AI^O	A
I^BI^B or I^BI^O	B
I^AI^B	AB
I^OI^O	O

Ví dụ mẫu · Codominance cross: predicting possible blood groups of offspring

One parent has blood group A with genotype I^AI^O; the other parent has blood group B with genotype I^BI^O. Predict the possible blood groups of their children.

Gametes: parent 1 produces I^A or I^O; parent 2 produces I^B or I^O.

×	I^B	I^O
I^A	I^AI^B	I^AI^O
I^O	I^BI^O	I^OI^O

Offspring genotypes (each $\frac{1}{4}$): I^AI^B (group AB), I^AI^O (group A), I^BI^O (group B), I^OI^O (group O).

Result: all four blood groups are possible, in the ratio **1 AB : 1 A : 1 B : 1 O** – illustrating that two parents who are *not* themselves group AB or group O can still produce a child of *any* of the four blood groups.

VN **GIẢI THÍCH TIẾNG VIỆT**

Đồng trội (codominance) khác với trội-lặn thông thường: CẢ HAI alen đều biểu hiện đồng thời, không alen nào lấn át alen kia. Hệ nhóm máu ABO có 3 alen: I^A, I^B (đồng trội với nhau) và I^O (lặn so với cả hai). Người có kiểu gen I^AI^B mang nhóm máu AB (biểu hiện CẢ hai kháng nguyên A và B), KHÔNG phải là "trung gian" hay pha trộn. Học sinh hay nhầm đồng trội với "trội không hoàn toàn" (incomplete dominance, tạo kiểu hình trung gian như hoa màu hồng từ hoa đỏ x hoa trắng) – ABO là đồng trội thật sự, biểu hiện CẢ hai đặc điểm cùng lúc chứ không trộn lẫn thành màu trung gian.

12.7 Dihybrid Cross (Supplement)

A **dihybrid cross** follows the inheritance of **two** genes at the same time.

Ví dụ mẫu · Dihybrid cross (Supplement): seed shape and seed colour in pea plants

In pea plants, allele R (round seed) is dominant to r (wrinkled seed); allele Y (yellow seed) is dominant to y (green seed). The two genes are on different chromosome pairs, so they assort independently. Two double heterozygotes are crossed: $RrYy \times RrYy$.

Gametes: each parent can produce four types of gamete in equal proportion: RY, Ry, rY, ry.

$\times$	**RY**	**Ry**	**rY**	**ry**
RY	$RRYY$	$RRYy$	$RrYY$	$RrYy$
Ry	$RRYy$	$RRyy$	$RrYy$	$Rryy$
rY	$RrYY$	$RrYy$	$rrYY$	$rrYy$
ry	$RrYy$	$Rryy$	$rrYy$	$rryy$

Counting phenotypes out of 16 offspring: round & yellow (genotype R_Y_, dash = either allele) $= 9$; round & green (genotype R_yy) $= 3$; wrinkled & yellow (genotype rrY_) $= 3$; wrinkled & green (genotype rryy) $= 1$.

9 round-yellow : 3 round-green : 3 wrinkled-yellow : 1 wrinkled-green

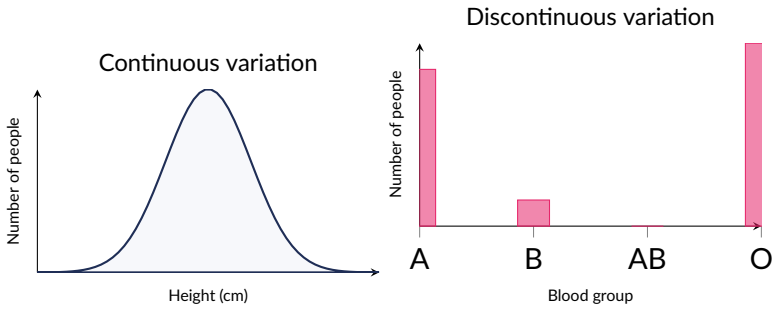
This is the classic **9:3:3:1** dihybrid ratio, which appears whenever two genes are on different chromosome pairs (so they assort independently) and both parents are heterozygous for both genes.

12.8 Continuous and Discontinuous Variation

Two patterns of variation

Continuous variation: a characteristic that shows a full, unbroken range of values between two extremes, with no distinct categories – usually controlled by **many genes** (polygenic inheritance) acting together, and often also influenced strongly by the **environment**. Examples: height, skin colour, body mass. A graph of continuous variation typically gives a **bell-shaped (normal) distribution** curve.

Discontinuous variation: a characteristic that falls into a small number of **distinct, separate categories** with no intermediates – usually controlled by a **single gene** (or a very small number of genes), and largely unaffected by the environment. Examples: ABO blood group, ability to roll the tongue, sex. A graph of discontinuous variation typically gives a **bar chart** of discrete categories.



Continuous variation (e.g. height) gives a bell-shaped distribution; discontinuous variation (e.g. ABO blood group) gives distinct, non-overlapping categories.

VN **GIẢI THÍCH TIẾNG VIỆT**

Biến dị liên tục (continuous variation): đặc điểm biến thiên liên tục, không có ranh giới rõ rệt (ví dụ chiều cao), thường do **nhiều gen** cộng gộp + **môi trường** (dinh dưỡng, luyện tập...) tác động, đồ thị dạng **hình chuông**. **Biến dị không liên tục (discontinuous variation)**: đặc điểm chia thành các nhóm **rời rạc, rõ rệt** (ví dụ nhóm máu, khả năng cuộn lưỡi), thường do **một hoặc vài gen** quyết định, ít bị môi trường ảnh hưởng, đồ thị dạng **biểu đồ cột** với các cột tách biệt.

12.9 Causes of Variation

Four processes generate genetic variation between individuals:

1. **Mutation** – a change in the base sequence of DNA (a gene), which can create a brand-new allele. Mutations can arise **spontaneously** (naturally, at low but constant background rate during DNA replication) or their rate can be **increased by mutagens** – e.g. ionising radiation (X-rays, gamma rays, ultraviolet light) or certain chemicals (e.g. some found in tobacco smoke, or industrial chemicals). Most mutations are neutral or harmful; occasionally a mutation is advantageous, and it is this rare beneficial mutation that provides the raw material for evolution by natural selection.
2. **Meiosis** – independent assortment of homologous chromosome pairs and crossing over (Supplement) shuffle existing alleles into new combinations when gametes are formed.
3. **Random fertilisation** – which particular sperm fertilises which particular egg is a matter of chance, so any one of millions of possible genetic combinations may result.
4. **Sexual reproduction** – combining genetic material from two different parents (rather than one, as in asexual reproduction) means offspring inherit a new combination of alleles not identical to either parent.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốn nguyên nhân gây biến dị: (1) **đột biến** – thay đổi trình tự base của DNA, có thể xảy ra tự nhiên hoặc do tác nhân gây đột biến (mutagen) như tia phóng xạ, tia cực tím, một số hoá chất; (2) **giảm phân** – phân li độc lập + trao đổi chéo tạo tổ hợp alen mới; (3) **thụ tinh ngẫu nhiên** – giao tử nào kết hợp với giao tử nào là ngẫu nhiên; (4) **sinh sản hữu tính** – kết hợp vật chất di truyền từ hai bố mẹ khác nhau. Lưu ý: đột biến là nguồn gốc **duy nhất** tạo ra alen HOÀN TOÀN MỚI; ba nguyên nhân còn lại chỉ xáo trộn lại các alen đã có sẵn.

12.10 Natural Selection

The mechanism of natural selection

Step 1 – Variation: variation already exists within a population, ultimately arising from mutation.
Step 2 – Selection pressure: a feature of the environment limits survival or reproduction – e.g. predation, disease, limited food/space, or exposure to a toxin such as an antibiotic or pesticide.
Step 3 – Differential survival and reproduction: individuals whose variation gives them an advantage under that selection pressure are more likely to survive and reproduce; individuals without the advantageous variation are more likely to die before reproducing.
Step 4 – Change in allele frequency (evolution): because the advantageous allele is passed on more often than the disadvantageous one, its frequency **increases** in the population over successive generations. This gradual change in the genetic make-up of a population over time is **evolution**.

Ví dụ mẫu · Natural selection: antibiotic resistance in bacteria

A population of bacteria is treated with an antibiotic. Researchers track the percentage of bacteria carrying a resistance allele over four rounds of antibiotic exposure:

Round of exposure	0	1	2	3	4
% resistant bacteria	1%	6%	22%	58%	90%

Explanation: the resistance allele already existed at very low frequency (1%) in the population *before* the antibiotic was ever applied, having arisen earlier by random mutation. The antibiotic itself does **not** create the resistance allele or "teach" the bacteria to resist it – it simply acts as a **selection pressure**: susceptible bacteria are killed, while the rare resistant bacteria survive and multiply, passing the resistance allele to their (very numerous) offspring. Repeating this over several rounds causes the resistance allele to become steadily more common, until it dominates the population – this is evolution by natural selection, not any change that occurs *within* a single bacterium in response to the drug.

(!) Lỗi thường gặp: Ngộ nhận rất phổ biến: "vi khuẩn tiếp xúc với kháng sinh nên PHÁT TRIỂN khả năng kháng thuốc để đối phó." Đây là SAI về bản chất. Đột biến gây kháng thuốc xảy ra **ngẫu nhiên, TRƯỚC KHI** vi khuẩn tiếp xúc với kháng sinh – kháng sinh không tạo ra đột biến kháng thuốc, mà chỉ đóng vai trò là **áp lực chọn lọc**: nó tiêu diệt các vi khuẩn KHÔNG có alen kháng thuốc, để lại các cá thể ĐÃ CÓ SẴN alen kháng thuốc (dù rất hiếm) sống sót và sinh sản. Qua nhiều thế hệ, tần số alen kháng thuốc trong quần thể tăng dần. Không có cá thể vi khuẩn đơn lẻ nào "học" hay "phát triển" khả năng kháng thuốc trong đời nó để phản ứng lại kháng sinh – **chọn lọc tự nhiên tác động lên quần thể qua nhiều thế hệ**, không phải lên một cá thể trong đời nó.

Ví dụ mẫu · Natural selection: industrial melanism in the peppered moth

Before industrial pollution, most peppered moths (*Biston betularia*) had pale, speckled wings, which camouflaged them against pale lichen-covered tree bark; a rare dark (melanic) form existed at low frequency due to a pre-existing mutation. During the Industrial Revolution, soot from factories blackened tree trunks in many areas.

Explanation using the four-step mechanism: (1) both pale and dark forms already existed (*variation*, from a pre-existing mutation); (2) soot-darkened bark made pale moths highly visible to bird predators while dark moths were now camouflaged (*selection pressure* = predation); (3) dark moths survived and reproduced more often than pale moths in polluted areas (*differential survival*); (4) the frequency of the dark allele increased sharply in polluted populations over successive generations (*evolution*). The dark form did not appear *because* the environment changed – it was already present at low frequency and was simply favoured once the environment changed.

VN **GIẢI THÍCH TIẾNG VIỆT**

Cơ chế chọn lọc tự nhiên gồm 4 bước: (1) **biến dị** đã tồn tại sẵn trong quần thể (từ đột biến); (2) có **áp lực chọn lọc** từ môi trường (kẻ săn mồi, bệnh tật, nguồn sống hạn chế, kháng sinh...); (3) cá thể mang biến dị có lợi sống sót và sinh sản nhiều hơn (**sinh sản khác biệt**); (4) alen có lợi tăng tần số qua các thế hệ = **tiến hoá**. Ví dụ bướm đêm *Biston betularia*: dạng màu sẫm đã tồn tại từ trước (do đột biến), chỉ là hiếm gặp; khi ô nhiễm công nghiệp làm thân cây sẫm màu, dạng sẫm được nguỵ trang tốt hơn nên tần số của nó tăng lên – môi trường KHÔNG tạo ra đột biến màu sẫm, môi trường chỉ chọn lọc nó.

12.11 Selective (Artificial) Breeding

Selective breeding (artificial selection) is the process by which humans choose parent organisms with desired characteristics to breed together, repeating this process over many generations to steadily increase the frequency of the desired characteristic(s) in the population.

Agricultural examples: dairy cattle selectively bred over many generations for ever-higher milk yield; wheat and rice varieties selectively bred for resistance to fungal disease and for higher grain yield; chickens bred for faster growth or higher egg output.

Key contrast with natural selection: both processes rely on heritable variation and differential reproduction, but they differ in *what determines which individuals reproduce*. In **natural selection**, the *environment* determines which individuals survive and reproduce (via predation, disease, competition, etc.). In **selective breeding**, a *human breeder* deliberately chooses which individuals are allowed to breed, based on desired traits.

Downside (Supplement): because breeders repeatedly select from a narrow set of "best" individuals, selective breeding reduces **genetic variation** within the population. A genetically uniform population is more vulnerable to being wiped out by a single new disease or environmental change, since there may be no individuals left with the resistance alleles needed to survive it.

VN **GIẢI THÍCH TIẾNG VIỆT**

Chọn lọc nhân tạo (selective/artificial breeding) là việc CON NGƯỜI chủ động chọn cá thể bố mẹ mang đặc điểm mong muốn để lai tạo qua nhiều thế hệ (ví dụ: bò cho năng suất sữa cao, giống lúa kháng bệnh). Điểm khác biệt cốt lõi với chọn lọc tự nhiên: chọn lọc nhân tạo do **con người** quyết định cá thể nào được sinh sản; chọn lọc tự nhiên do **môi trường** quyết định (qua khả năng sống sót). Nhược điểm (Supplement): chọn lọc nhân tạo làm **giảm biến dị di truyền** trong quần thể (vì chỉ một số ít cá thể "tốt nhất" được chọn lặp lại), khiến quần thể dễ bị tổn hại nếu xuất hiện dịch bệnh mới mà không có alen kháng bệnh nào còn sót lại.

12.12 Practice Problems

Bài tập luyện tập

In guinea pigs, black coat colour (B) is dominant to white coat colour (b). Two heterozygous black guinea pigs are crossed ($Bb \times Bb$). Draw the Punnett square and state the phenotype ratio of the offspring.

Lời giải chi tiết

Gametes from each parent: B or b.

$\times$	**B**	**b**
B	BB	Bb
b	Bb	bb

Genotypes: $1\,BB : 2\,Bb : 1\,bb$. Since B is dominant, BB and Bb are both black; only bb is white. Phenotype ratio: **3 black : 1 white**.

Bài tập luyện tập

A pea plant of unknown genotype has purple flowers (purple P is dominant to white p). It is crossed with a white-flowered plant (pp), and the offspring are 52 purple and 49 white. State the genotype of the original purple-flowered plant and justify your answer using a Punnett square.

Lời giải chi tiết

This is a test cross. Since roughly half the offspring are white (pp, recessive phenotype), the unknown parent must be able to produce a p gamete, so it must be **heterozygous,** Pp (a homozygous PP parent could never produce a white offspring, since it carries no p allele).

$\times$	**P**	**p**
p	Pp	pp
p	Pp	pp

Expected ratio $1\,Pp : 1\,pp$, i.e. 1 purple : 1 white – consistent with the observed $52 : 49$ (approximately 1:1).

Bài tập luyện tập

(A) Chromosome
(B) Gene
(C) Allele
(D) Nucleotide

Which term describes "a section of DNA that codes for a particular protein / characteristic"?

Lời giải chi tiết

(B) Gene. A chromosome is the whole DNA+protein structure; a gene is a specific section of it coding for one characteristic; an allele is one version of a gene; a nucleotide is the basic repeating chemical unit of DNA.

Bài tập luyện tập

State the number of chromosomes found in (a) a human skin cell, (b) a human sperm cell. Explain the difference.

Lời giải chi tiết

(a) A human skin cell (a body/somatic cell) contains **46 chromosomes** (23 homologous pairs) – it is diploid, produced by mitosis.
(b) A human sperm cell (a gamete) contains **23 chromosomes** – it is haploid, produced by meiosis, which halves the chromosome number so that when two gametes fuse at fertilisation, the normal diploid number (46) is restored in the offspring.

Bài tập luyện tập

A cell with genotype $AaBb$ (two genes on different chromosome pairs) undergoes meiosis. List all the different gamete genotypes that could be produced, and explain why more than one type is possible.

Lời giải chi tiết

Four possible gamete genotypes: AB, Ab, aB, ab. More than one type is possible because of **independent assortment**: the Aa pair of homologous chromosomes separates independently of the Bb pair, so any combination of the two chromosomes can end up together in the same gamete.

Bài tập luyện tập

(A) The daughter cells are genetically identical
(B) The daughter cells are haploid
(C) Four daughter cells are produced
(D) DNA replicates before division

Which of these statements applies to mitosis but NOT to meiosis?

Lời giải chi tiết

(A) The daughter cells are genetically identical. Mitosis produces 2 genetically identical diploid daughter cells. Statement (B) and (C) describe meiosis. Statement (D) is true of BOTH mitosis and meiosis (DNA always replicates once before any nuclear division), so it does not distinguish them.

Bài tập luyện tập

In a species of flower, red (R) is dominant to white (r). A red-flowered plant of unknown genotype is crossed with a white-flowered plant. All 40 offspring have red flowers. Deduce, with a Punnett square, the most likely genotype of the red-flowered parent.

Lời giải chi tiết

The white parent is rr. Since *all* offspring are red (no white offspring appeared), the red parent is most likely homozygous dominant RR (if it had been Rr, roughly half the offspring would be expected to be white).

×	**R**	**R**
r	Rr	Rr
r	Rr	Rr

All offspring are Rr (red), consistent with the observed result.

Bài tập luyện tập

A colour-blind man (X^bY) has children with a woman of normal vision who is homozygous (X^BX^B). Use a Punnett square to predict the vision of their sons and daughters.

Lời giải chi tiết

Gametes: father gives X^b or Y; mother gives only X^B.

×	X^b	**Y**
X^B	X^BX^b	X^BY

All daughters are X^BX^b (carriers, normal vision); all sons are X^BY (normal vision). None of the children are colour blind, but **all daughters** are carriers (each carries one copy of X^b inherited from the father).

Bài tập luyện tập

Explain, in terms of alleles, why males are much more likely than females to be affected by X-linked recessive conditions such as haemophilia.

Lời giải chi tiết

Males have only one X chromosome ($X^?Y$), so a single copy of a recessive allele on that X chromosome is sufficient to produce the affected phenotype – there is no second X chromosome carrying a possible dominant allele to mask it. Females have two X chromosomes, so they need **two** copies of the recessive allele (homozygous recessive) to be affected; a female with only one copy is an unaffected carrier.

Bài tập luyện tập

Two parents, both blood group AB (I^AI^B), have children. Use a Punnett square to find the possible blood groups of their children and the expected ratio.

Lời giải chi tiết

Gametes: each I^AI^B parent produces I^A or I^B.

×	I^A	I^B
I^A	I^AI^A	I^AI^B
I^B	I^AI^B	I^BI^B

Offspring genotypes: $1\,I^AI^A$ (group A) : $2\,I^AI^B$ (group AB) : $1\,I^BI^B$ (group B). Note: group O is **not** possible from this cross, since neither parent carries the I^O allele.

Bài tập luyện tập

Both parents are blood group O ($I^O I^O$). Their child is found to be blood group A. Explain whether this is possible.

Lời giải chi tiết

This is **not possible**. Each $I^O I^O$ parent can only produce I^O gametes, so every child must be $I^O I^O$ (group O). A child cannot show a blood group allele that neither parent possesses (ignoring rare new mutations), so a group A child from two group O parents indicates either a recording error or that one listed parent is not the biological parent.

Bài tập luyện tập

(A) One gene, discrete categories

(B) Many genes plus environment, unbroken range of values

(C) Environment only, no genetic component

(D) A single mutation only

What typically causes continuous variation, such as human height?

Lời giải chi tiết

(B). Continuous variation is usually produced by **many genes acting together** (polygenic inheritance), often combined with **environmental** influence (e.g. nutrition), producing an unbroken range of values with no distinct categories (bell-shaped distribution).

Bài tập luyện tập

State whether each of the following shows continuous or discontinuous variation, and give a reason: (a) ABO blood group; (b) body mass in adult humans; (c) ability to roll the tongue.

Lời giải chi tiết

(a) **Discontinuous** – controlled by one gene with a small number of alleles, giving distinct categories (A, B, AB, O) with no intermediates.
(b) **Continuous** – influenced by many genes plus environmental factors (diet, exercise), giving an unbroken range of values.
(c) **Discontinuous** – controlled by a single gene, giving two distinct categories (roller / non-roller).

Bài tập luyện tập

A student states: "Mutations are always harmful to the organism." Evaluate this statement.

Lời giải chi tiết

The statement is not accurate. Most mutations are indeed neutral (no noticeable effect) or harmful, but a small proportion are **beneficial** – giving the organism some advantage in its environment. Beneficial mutations are rare, but they are the ultimate source of the heritable variation that natural selection acts on to produce evolutionary change.

Bài tập luyện tập

Name two mutagens that can increase the rate of mutation, and state the type of mutagen each one is.

Lời giải chi tiết

Any two of: **ultraviolet light** or **X-rays/gamma rays** (types of *ionising radiation*); certain **chemicals** (e.g. some found in tobacco smoke or industrial chemicals) (*chemical mutagens*).

Bài tập luyện tập

A population of insects is sprayed repeatedly with the same pesticide over several years. Over time, the pesticide becomes far less effective at killing the insects. Explain this observation using the four steps of natural selection.

Lời giải chi tiết

(1) **Variation**: a small number of insects already carried a resistance allele (from earlier random mutation) before the pesticide was ever used. (2) **Selection pressure**: the pesticide kills susceptible insects. (3) **Differential survival/reproduction**: resistant insects survive and reproduce, passing the resistance allele to their offspring, while susceptible insects die before reproducing. (4) **Change in allele frequency**: over successive generations (which are short for insects), the resistance allele becomes much more common in the population, so the pesticide kills an ever-smaller proportion of the population – it appears "less effective," even though the pesticide itself has not changed. The pesticide did not cause the resistance mutation; it selected for insects that already had it.

Bài tập luyện tập

Explain why natural selection cannot act on variation that is caused only by the environment (e.g. a suntan) and not by genes.

Lời giải chi tiết

Natural selection only causes evolutionary change if the favoured variation is **heritable** (passed from parent to offspring via genes/alleles). A suntan is caused by environmental exposure (sunlight) and is not encoded in the DNA passed to offspring, so even if tanned individuals somehow survived better, this would not change the allele frequencies of the next generation – the offspring would not inherit the tan.

Bài tập luyện tập

(A) Chromosome number changes

(B) One parent chooses which alleles to combine

(C) A human breeder decides which individuals reproduce

(D) The environment decides which individuals reproduce

What is the key difference between selective (artificial) breeding and natural selection?

Lời giải chi tiết

The correct pairing is: in **artificial selection**, (C) a human breeder decides which individuals reproduce, based on desired traits; in **natural selection**, (D) the environment (predators, disease, competition, resources) determines which individuals survive and reproduce. Both processes rely on the same underlying requirements: heritable variation and differential reproduction.

Bài tập luyện tập

Give one agricultural example of selective breeding, state the trait selected for, and explain one disadvantage of relying heavily on selective breeding.

Lời giải chi tiết

Example: dairy cattle bred over many generations for increasingly **high milk yield**, by repeatedly breeding from the highest-yielding cows and bulls. Disadvantage (Supplement): repeatedly breeding from a narrow set of "best" individuals reduces **genetic variation** in the population, making it more vulnerable – if a new disease appears, there may be few or no individuals with resistance alleles left to survive it.

Bài tập luyện tập

A recessive genetic disorder is caused by allele h; the dominant allele H gives the unaffected phenotype. Two unaffected (but carrier) parents, both Hh, have four children. Predict, using a Punnett square, the probability that any one child is affected by the disorder.

Lời giải chi tiết

Gametes: each Hh parent produces H or h.

$\times$	**H**	**h**
H	HH	Hh
h	Hh	hh

Genotype ratio $1\,HH : 2\,Hh : 1\,hh$. Only hh is affected, so the probability that any one child is affected is $\frac{1}{4}$ (25%). Note that this probability applies independently to *each* child – having one affected child does not change the 1-in-4 probability for the next child.

Bài tập luyện tập

(A) $I^A I^A$

(B) $I^A I^O$

(C) $I^B I^O$

(D) $I^O I^O$

Which genotype below, if present in a parent of blood group A, would make it possible (though not certain) for that parent to have a child of blood group O?

Lời giải chi tiết

(B) $I^A I^O$. A parent with this genotype (blood group A, heterozygous) can pass on either an I^A or an I^O gamete. If the other parent also contributes an I^O gamete, the child could be $I^O I^O$ (group O). A parent with genotype $I^A I^A$ (choice A) can only ever pass on I^A, so could never have a group O child.

Bài tập luyện tập

Distinguish between homozygous and heterozygous, giving one example genotype of each for a gene with alleles E (dominant) and e (recessive).

Lời giải chi tiết

Homozygous means having two identical alleles for a gene – e.g. EE (homozygous dominant) or ee (homozygous recessive). **Heterozygous** means having two different alleles for a gene – e.g. Ee.

Bài tập luyện tập

A study of a wild plant population finds that individual plant height varies smoothly from 20 cm to 85 cm, with most individuals clustered around 50–55 cm. State the type of variation this represents and sketch the expected shape of a graph of number of plants against height.

Lời giải chi tiết

This is **continuous variation** (an unbroken range of values with a central cluster and tapering extremes). A graph of number of plants (y-axis) against height (x-axis) would be expected to show a **bell-shaped (normal distribution) curve**, peaking around 50–55 cm and tapering off towards both the 20 cm and 85 cm extremes.

Bài tập luyện tập

Explain the difference between a gene mutation occurring and that mutation becoming common in a population.

Lời giải chi tiết

A gene mutation **occurring** is a single, random chemical change to the DNA sequence in one individual (or one cell) – this happens by chance, independent of whether the environment currently favours it. A mutation **becoming common** in a population is a separate process (natural selection): it requires the mutant allele to give a survival/reproductive advantage under current environmental conditions, so that individuals carrying it out-reproduce those without it, generation after generation, gradually raising its frequency.

Bài tập luyện tập

A dihybrid cross $RrYy \times RrYy$ (round yellow seeds, both traits independently assorting) is set up in pea plants. Out of 160 offspring, predict the expected number showing each of the four phenotypes.

Lời giải chi tiết

The expected ratio is $9:3:3:1$ (total 16 parts) for round-yellow : round-green : wrinkled-yellow : wrinkled-green. Each "part" $= 160 \div 16 = 10$.

$$\text{Round-yellow} = 9 \times 10 = 90, \quad \text{Round-green} = 3 \times 10 = 30,$$

$$\text{Wrinkled-yellow} = 3 \times 10 = 30, \quad \text{Wrinkled-green} = 1 \times 10 = 10.$$

Expected: **90 round-yellow, 30 round-green, 30 wrinkled-yellow, 10 wrinkled-green.**

Bài tập luyện tập

State two differences between mitosis and meiosis, other than the number of daughter cells produced.

Lời giải chi tiết

Any two of: (1) mitosis involves **one** nuclear division, meiosis involves **two** successive nuclear divisions; (2) mitosis produces **diploid** daughter cells (same chromosome number as the parent cell), meiosis produces **haploid** daughter cells (half the chromosome number); (3) mitosis produces daughter cells that are **genetically identical** to each other and to the parent cell, while meiosis produces daughter cells that are **genetically different** from each other and from the parent cell.

Bài tập luyện tập

A woman with normal colour vision, whose father was colour blind, has children with a man who has normal colour vision. Determine the woman's genotype and predict the possible phenotypes of her children.

Lời giải chi tiết

Since the woman's father was colour blind (X^bY), he must have passed his only X chromosome (carrying X^b) to *every* daughter, so the woman must be a **carrier**, genotype X^BX^b (she has normal vision because X^B is dominant). Crossing X^BX^b (mother) $\times$ X^BY (father, normal vision):

$\times$	X^B	**Y**
X^B	X^BX^B	X^BY
X^b	X^BX^b	X^bY

Offspring: $\frac{1}{4}$ normal-vision girl (X^BX^B), $\frac{1}{4}$ carrier girl (X^BX^b, normal vision), $\frac{1}{4}$ normal-vision boy (X^BY), $\frac{1}{4}$ colour-blind boy (X^bY). Overall: 3 normal vision : 1 colour blind, with the colour-blind individual necessarily male.

Bài tập luyện tập

Explain why selective breeding and natural selection can both be described as "differential reproduction," yet only one of them is typically called "evolution" in the everyday sense used for wild populations.

Lời giải chi tiết

Both processes involve **differential reproduction**: in each generation, some individuals reproduce more than others, based on which alleles they carry. This changes allele frequencies over time in both cases, which technically fits the definition of evolution (a change in allele frequency in a population over generations). In everyday use, however, "evolution" is usually reserved for **natural selection acting on wild populations**, where the *environment* (not a human breeder) is the selective agent – selective breeding is instead described using the specific term "artificial selection" or "selective breeding," to make clear that a human, not the environment, controlled which individuals reproduced.

Bài tập luyện tập

A recessive allele c causes cystic fibrosis; C is the dominant normal allele. Two unaffected parents already have one child with cystic fibrosis (cc). What are the genotypes of the parents, and what is the probability their next child is also affected?

Lời giải chi tiết

Since the affected child is cc, each parent must have contributed a c allele; since both parents are unaffected (not cc themselves), both parents must be **heterozygous carriers,** Cc.

$\times$	**C**	**c**
C	CC	Cc
c	Cc	cc

Genotype ratio $1\,CC : 2\,Cc : 1\,cc$. The probability that the next child is affected (cc) is $\frac{1}{4}$ (25%) – and this probability is the same for every pregnancy, regardless of the outcome of previous pregnancies.

Organisms and Their Environment, Human Influences and Biotechnology

Mục tiêu Unit: Sử dụng chính xác các thuật ngữ sinh thái học (quần thể, quần xã, môi trường sống, hệ sinh thái, bậc dinh dưỡng); phân biệt vai trò của sinh vật sản xuất, sinh vật tiêu thụ (bậc 1/2/3) và sinh vật phân giải; phân biệt chuỗi thức ăn và lưới thức ăn; giải thích vì sao tháp năng lượng luôn có dạng thẳng đứng thu hẹp dần và tính toán hiệu suất chuyển hoá năng lượng (khoảng 10%) giữa các bậc dinh dưỡng; so sánh tháp năng lượng với tháp sinh khối và tháp số lượng (Supplement); trình bày đầy đủ chu trình carbon (và sơ lược chu trình nitrogen – Supplement); phân tích ảnh hưởng của con người lên hệ sinh thái (phá rừng, hiệu ứng nhà kính, phú dưỡng hoá) và các biện pháp bảo tồn; giải thích ứng dụng vi sinh vật trong công nghệ sinh học (men làm bánh mì/rượu, vi khuẩn làm sữa chua) và cơ chế kỹ thuật di truyền (Supplement) qua ví dụ sản xuất insulin người và một ứng dụng nông nghiệp.

13.1 Key Ecological Terms

Core vocabulary

Population: a group of organisms of the *same species*, living in the same area, at the same time, that can potentially interbreed.
Community: all the populations of *different species* living and interacting together in the same habitat at the same time.
Habitat: the place where an organism lives – defined by its physical and biological surroundings (e.g. a rock pool, a hedgerow, the surface of a leaf).
Ecosystem: a unit made up of all the living organisms (the community) in a given area, together with the non-living (abiotic) parts of the environment, all interacting with each other (e.g. a pond ecosystem, a woodland ecosystem).
Trophic level: the position an organism occupies in a food chain, defined by the number of energy-transfer steps to reach it from the producers (e.g. producer, primary consumer, secondary consumer).

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Quần thể (population): các cá thể CÙNG một loài, sống trong cùng khu vực, có thể giao phối với nhau. **Quần xã (community)**: tất cả quần thể của các loài KHÁC NHAU cùng sống và tương tác trong một môi trường sống. **Môi trường sống (habitat)**: nơi ở cụ thể của sinh vật. **Hệ sinh thái (ecosystem)**: quần xã sinh vật + các yếu tố vô sinh (đất, nước, ánh sáng...) trong một khu vực, tương tác qua lại với nhau. **Bậc dinh dưỡng (trophic level)**: vị trí của sinh vật trong chuỗi thức ăn, tính theo số bước chuyển năng lượng kể từ sinh vật sản xuất. Học sinh hay lẫn "quần thể" và "quần xã" – ghi nhớ: quần thể = 1 loài, quần xã = nhiều loài.

13.1.1 Sampling populations: quadrats (Supplement)

The size of a population of a slow-moving or non-moving organism (e.g. a plant, a limpet) within a habitat can be estimated using **quadrats** – square frames of known area placed randomly within

the habitat. The number of individuals inside each quadrat is counted, and the mean number of individuals per quadrat is used to estimate the total population:

$$\text{Estimated population} = \text{mean number of individuals per quadrat} \times \frac{\text{total habitat area}}{\text{area of one quadrat}}.$$

Ví dụ mẫu · Estimating population size using quadrats

Ten $1\ \text{m}^2$ quadrats are placed randomly across a $500\ \text{m}^2$ field to estimate the population of daisy plants. The numbers of daisies counted in the ten quadrats are: $6,\ 4,\ 8,\ 5,\ 7,\ 3,\ 6,\ 5,\ 9,\ 7$.

Step 1 – mean number per quadrat:

$$\text{mean} = \frac{6+4+8+5+7+3+6+5+9+7}{10} = \frac{60}{10} = 6 \text{ daisies per } 1\ \text{m}^2.$$

Step 2 – scale up to the total area:

$$\text{Estimated population} = 6 \times \frac{500}{1} = 3000 \text{ daisies}.$$

Ví dụ mẫu · Quadrat sampling with a non-standard quadrat size

A student samples snails using eight quadrats, each measuring $0.5\ \text{m} \times 0.5\ \text{m}$, in a garden with total area $120\ \text{m}^2$. The numbers of snails counted are: $2, 1, 3, 0, 2, 4, 1, 3$. Estimate the total snail population in the garden.

Step 1 – find the area of one quadrat:

$$\text{quadrat area} = 0.5\ \text{m} \times 0.5\ \text{m} = 0.25\ \text{m}^2 \quad \text{(convert dimensions to area } \textit{before} \text{ scaling up)}.$$

Step 2 – mean number per quadrat:

$$\text{mean} = \frac{2+1+3+0+2+4+1+3}{8} = \frac{16}{8} = 2 \text{ snails per } 0.25\ \text{m}^2.$$

Step 3 – scale up to the total area:

$$\text{Estimated population} = 2 \times \frac{120}{0.25} = 2 \times 480 = 960 \text{ snails}.$$

A common error is to forget to convert the quadrat's side lengths into an *area* first, or to divide by the side length instead of the area – always confirm the units of the quadrat area match the units of the total habitat area before scaling up.

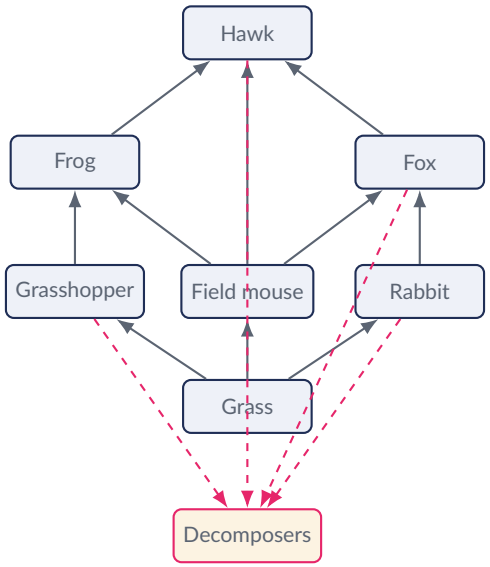
13.2 Producers, Consumers, Decomposers and Feeding Relationships

Roles in an ecosystem

Producers are organisms (mainly green plants and algae) that make their own organic food from simple inorganic substances using light energy – **photosynthesis**. They form the base of every food chain.
Consumers are organisms that obtain energy by feeding on other organisms. A **primary consumer** feeds directly on producers (herbivore); a **secondary consumer** feeds on primary consumers (carnivore/omnivore); a **tertiary consumer** feeds on secondary consumers.
Decomposers (mainly bacteria and fungi) break down dead organisms and waste (faeces, fallen

leaves) into simple inorganic substances, releasing nutrients back into the ecosystem for producers to reuse.

A **food chain** shows a single feeding pathway, with an arrow showing the direction of energy flow (e.g. grass → grasshopper → frog). A **food web** is a more realistic picture formed by **interconnected food chains**, showing that most consumers feed on – and are fed on by – more than one other species.



A food web: solid arrows = feeding relationships (energy flow); dashed pink arrows (a sample only) = decomposers breaking down dead organisms/waste from every trophic level.

(!) Lỗi thường gặp: Chú ý chiều mũi tên trong chuỗi/lưới thức ăn: mũi tên luôn chỉ theo **chiều dòng năng lượng di chuyển**, tức là từ sinh vật BỊ ĂN sang sinh vật ĂN nó (ví dụ: cỏ → châu chấu nghĩa là năng lượng đi từ cỏ sang châu chấu khi châu chấu ăn cỏ). Nhiều học sinh vẽ ngược mũi tên vì nhầm rằng mũi tên chỉ "ai ăn ai". Ngoài ra, sinh vật phân giải (decomposer) không phải là "sinh vật tiêu thụ bậc cuối cùng" trong chuỗi thức ăn thông thường – chúng nhận năng lượng từ TẤT CẢ các bậc dinh dưỡng (qua xác chết và chất thải), nên thường được vẽ tách riêng, không nằm trên một đường thẳng của chuỗi thức ăn.

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Sinh vật sản xuất (producer): tự tổng hợp chất hữu cơ qua quang hợp (chủ yếu thực vật, tảo). **Sinh vật tiêu thụ (consumer)**: ăn sinh vật khác – bậc 1 (ăn sinh vật sản xuất), bậc 2 (ăn sinh vật tiêu thụ bậc 1), bậc 3 (ăn sinh vật tiêu thụ bậc 2). **Sinh vật phân giải (decomposer)**: vi khuẩn, nấm phân giải xác chết và chất thải thành chất vô cơ đơn giản, trả lại dinh dưỡng cho môi trường. **Chuỗi thức ăn** chỉ MỘT đường đi của năng lượng; **lưới thức ăn** là NHIỀU chuỗi thức ăn nối với nhau, phản ánh thực tế rằng một sinh vật thường ăn/bị ăn bởi nhiều loài khác nhau.

13.3 Energy Flow Through Ecosystems

Why pyramids of energy are always upright

At *every* trophic level, only a fraction of the energy taken in is transferred to the next trophic level, because energy is lost from the food chain at each stage:

- **Respiration:** most energy taken in is used for respiration and is ultimately lost from the organism as **heat** (especially in mammals and birds, which maintain a constant body temperature).
- **Movement:** energy used for muscular activity is eventually lost as heat.
- **Egestion:** not all food eaten is digested/absorbed – undigested material is egested (as faeces) and never enters the organism's own biomass or metabolism.
- **Excretion:** some absorbed energy-containing waste products (e.g. nitrogenous waste, urea) are excreted rather than incorporated into new biomass.

Because energy is lost at *every* stage, the amount of energy available to each successive trophic level is always *less* than the level before it – a **pyramid of energy** is therefore always **upright** (widest at the base) and **never inverted**. On average, only about **10%** of the energy at one trophic level is transferred to (and stored in the biomass of) the next trophic level; roughly 90% is lost as described above. (The actual efficiency measured in real ecosystems varies somewhat between about 5% and 20% depending on the species and ecosystem involved, but **10%** is used as the standard estimate for calculations unless a question gives different data.)

Ví dụ mẫu · Calculating energy transfer efficiency

The producers in a grassland ecosystem store $200\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}$ of energy. The primary consumers in this ecosystem store $18\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}$. Calculate the percentage efficiency of energy transfer from producers to primary consumers.

$$\%\ \text{efficiency} = \frac{\text{energy in level } n+1}{\text{energy in level } n} \times 100 = \frac{18\,000}{200\,000} \times 100 = 9\%.$$

This is close to the typical value of about 10%, reflecting energy losses to respiration, movement, egestion and excretion between the two trophic levels.

Ví dụ mẫu · Predicting energy available at a higher trophic level

Producers in a lake ecosystem store $500\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}$. Assuming a typical transfer efficiency of 10% between each trophic level, estimate the energy available to (a) primary consumers, (b) secondary consumers, (c) tertiary consumers.

$$\text{(a) Primary consumers} = 500\,000 \times 0.10 = 50\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}.$$
$$\text{(b) Secondary consumers} = 50\,000 \times 0.10 = 5\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}.$$
$$\text{(c) Tertiary consumers} = 5\,000 \times 0.10 = 500\ \text{kJ m}^{-2}\ \text{yr}^{-1}.$$

After only three transfers, only $500\ \text{kJ m}^{-2}\ \text{yr}^{-1}$ remains out of the original $500\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}$ – just 0.1% of the original energy captured by producers. This rapid loss of usable energy is the main reason food chains rarely extend beyond four or five trophic levels: there is usually too little energy left to support a viable population at a higher level.

Ví dụ mẫu · Comparing efficiency at two different steps in the same food chain

In a woodland ecosystem, producers store $300\,000\,\text{kJ m}^{-2}\,\text{yr}^{-1}$, primary consumers store $27\,000\,\text{kJ m}^{-2}\,\text{yr}^{-1}$, and secondary consumers store $2\,430\,\text{kJ m}^{-2}\,\text{yr}^{-1}$. Calculate the percentage efficiency of energy transfer at each step, and comment on the results.

$$\text{Producers} \to \text{primary consumers: } \frac{27\,000}{300\,000} \times 100 = 9\%.$$

$$\text{Primary} \to \text{secondary consumers: } \frac{2\,430}{27\,000} \times 100 = 9\%.$$

Both transfer steps are close to the typical 10% value, showing that roughly the same proportion of energy is lost (to respiration, movement, egestion and excretion) at each successive trophic level in this food chain – the percentage efficiency does not have to change from level to level, even though the *absolute* amount of energy transferred decreases sharply each time.

Ví dụ mẫu · Working backwards from a consumer to estimate producer energy

Secondary consumers in a lake ecosystem store $600\,\text{kJ m}^{-2}\,\text{yr}^{-1}$. Assuming a typical 10% transfer efficiency at each step, estimate the energy that must have been captured by the producers to support this.

Working backwards means *dividing* by 0.10 at each step (the reverse of multiplying forwards):

$$\text{Primary consumers} = \frac{600}{0.10} = 6\,000\,\text{kJ m}^{-2}\,\text{yr}^{-1}.$$

$$\text{Producers} = \frac{6\,000}{0.10} = 60\,000\,\text{kJ m}^{-2}\,\text{yr}^{-1}.$$

So the producers must have captured approximately $60\,000\,\text{kJ m}^{-2}\,\text{yr}^{-1}$ to ultimately support $600\,\text{kJ m}^{-2}\,\text{yr}^{-1}$ of energy at the secondary consumer level – a useful check is that this larger producer value, multiplied forward by 0.10 twice, returns the original $600\,\text{kJ m}^{-2}\,\text{yr}^{-1}$.

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Ở MỖI bậc dinh dưỡng, phần lớn năng lượng bị mất đi qua **hô hấp** (toả nhiệt), **vận động**, **chất thải chưa tiêu hoá (phân)** và **bài tiết** – chỉ khoảng **10%** năng lượng được chuyển sang bậc dinh dưỡng kế tiếp. Vì luôn bị mất năng lượng qua từng bậc, **tháp năng lượng luôn có dạng thẳng đứng, thu hẹp dần lên trên** và KHÔNG BAO GIỜ bị đảo ngược – đây là điểm khác biệt quan trọng so với tháp sinh khối/tháp số lượng (có thể đảo ngược trong một số trường hợp). Công thức tính hiệu suất: (năng lượng bậc sau ÷ năng lượng bậc trước) $\times 100\%$.

13.4 Ecological Pyramids: Energy, Biomass and Numbers (Supplement)

A **pyramid of biomass** represents the total mass of living material at each trophic level; a **pyramid of numbers** represents the number of individual organisms at each trophic level. Unlike a pyramid of energy, pyramids of biomass and numbers can occasionally be **inverted** (narrower at the base than above):

- A **pyramid of numbers** can be inverted when a single large producer supports many smaller consumers – e.g. one large tree (1 producer) supporting thousands of insects (many primary consumers).
- A **pyramid of biomass** can be inverted in some situations involving parasites – e.g. many small parasites (high numbers, low total biomass) living on one large host (low numbers, high biomass) sit "above" the host if drawn by numbers, though this is a less common example at this level.

A **pyramid of energy**, in contrast, is never inverted – energy is always lost at each trophic level (never gained), so each level must always contain less energy than the level below it.

Energy and biomass pyramids are typically upright, narrowing at each higher trophic level; a pyramid of numbers can sometimes be inverted, as when one large producer (e.g. a tree) supports many small consumers.

(!) Lỗi thường gặp: Học sinh hay áp dụng máy móc quy tắc "tháp luôn thu hẹp dần lên trên" cho CẢ BA loại tháp sinh thái. Chỉ có **tháp năng lượng** là LUÔN LUÔN thẳng đứng, không bao giờ đảo ngược (vì năng lượng luôn bị mất qua mỗi bậc). **Tháp sinh khối** và **tháp số lượng** CÓ THỂ bị đảo ngược trong một số trường hợp đặc biệt (ví dụ một cây lớn nuôi nhiều côn trùng nhỏ) – vì sinh khối và số lượng không tuân theo quy luật mất năng lượng một cách chặt chẽ như tháp năng lượng.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tháp sinh khối (biomass) và tháp số lượng (numbers) THỈNH THOẢNG có thể bị đảo ngược – ví dụ một cây lớn (1 sinh vật sản xuất) nuôi hàng nghìn côn trùng ăn lá (nhiều sinh vật tiêu thụ bậc 1) tạo ra tháp số lượng có đáy hẹp hơn phía trên. Nhưng **tháp năng lượng KHÔNG BAO GIỜ bị đảo ngược**, vì năng lượng luôn bị mất đi (không thể "sinh thêm") qua mỗi bậc dinh dưỡng – đây là điểm khác biệt then chốt cần nhớ khi so sánh ba loại tháp sinh thái.

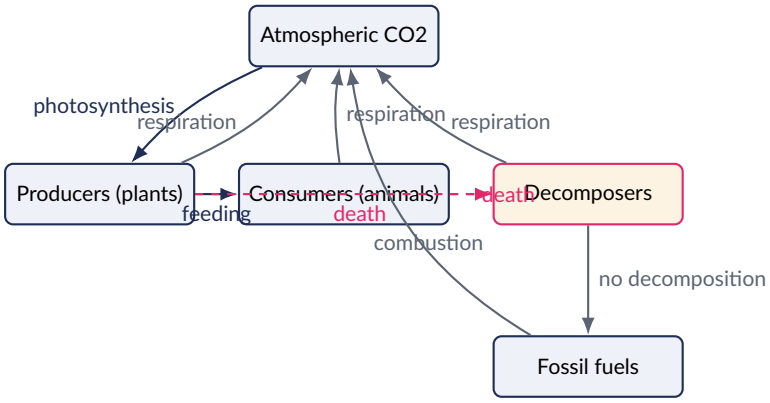
13.5 The Carbon Cycle

Carbon is continuously cycled between living organisms and the atmosphere/environment.

Processes in the carbon cycle

Photosynthesis (in producers) removes carbon dioxide from the atmosphere, converting it into organic compounds (carbohydrates) in the plant's biomass.
Respiration (in *all* living organisms – producers, consumers and decomposers) releases carbon dioxide back into the atmosphere as organic compounds are broken down for energy.
Feeding passes carbon compounds from producers to consumers along food chains.

Decomposition: when organisms die, decomposers break down the carbon compounds in their bodies (and in waste products), releasing carbon dioxide back into the atmosphere through their own respiration.
Combustion: burning of fuels (wood, or fossil fuels such as coal, oil and natural gas) releases carbon dioxide that was previously locked away, back into the atmosphere.
Fossil fuel formation: if decomposition is prevented (e.g. dead plant/animal material buried without oxygen), the carbon in that material is not released as CO2 but instead remains locked in the ground; over millions of years and under heat and pressure, this material can be slowly converted into fossil fuels (coal, oil, natural gas) – a carbon store that would otherwise have re-entered the atmosphere far sooner.



The carbon cycle: photosynthesis removes CO2; respiration (all organisms), decomposition and combustion all return CO2 to the atmosphere; fossil fuel formation locks carbon away when decomposition is prevented.

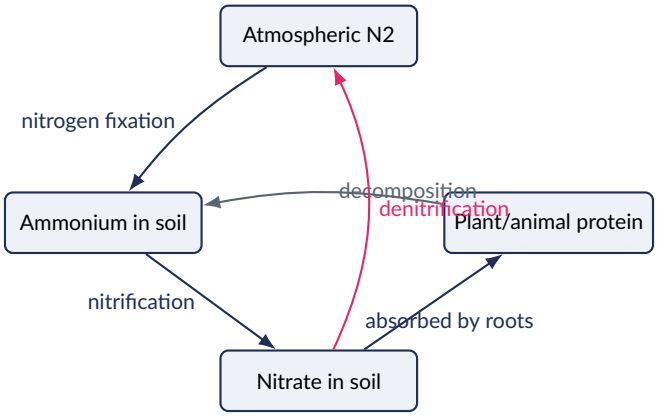
VN **GIẢI THÍCH TIẾNG VIỆT**

Chu trình carbon: **quang hợp** lấy CO2 khỏi khí quyển; **hô hấp** (ở TẤT CẢ sinh vật – sản xuất, tiêu thụ, phân giải) và **đốt cháy nhiên liệu** đều trả CO2 về khí quyển; **phân giải** xác chết bởi vi khuẩn/nấm cũng giải phóng CO2 qua hô hấp của chính chúng. Nếu quá trình phân giải bị NGĂN CHẶN (ví dụ xác sinh vật bị chôn vùi thiếu oxy), carbon không được giải phóng ngay mà bị "khoá lại", và qua hàng triệu năm dưới nhiệt độ + áp suất cao có thể biến thành **nhiên liệu hoá thạch** (than đá, dầu mỏ, khí đốt).

13.6 The Nitrogen Cycle (Supplement)

Nitrogen gas (N2) makes up about 78% of the atmosphere, but most organisms cannot use it directly – it must first be "fixed" into a usable form. Key stages:

- **Nitrogen fixation:** certain **nitrogen-fixing bacteria** (some free-living in soil, some living in root nodules of leguminous plants such as beans/peas) convert atmospheric nitrogen gas into ammonium/nitrogen compounds that plants can absorb and use to build proteins.
- **Decomposition:** decomposers break down proteins in dead organisms and waste (urea, faeces), releasing **ammonium** compounds into the soil.
- **Nitrification: nitrifying bacteria** in the soil convert ammonium compounds into **nitrates**, the form of nitrogen most easily absorbed and used by plant roots.
- **Denitrification: denitrifying bacteria** (active in waterlogged, oxygen-poor soils) convert soil nitrates back into nitrogen gas, returning it to the atmosphere and completing the cycle.



Summary of the nitrogen cycle: nitrogen-fixing bacteria convert atmospheric N2 into ammonium; decomposers release ammonium from dead matter; nitrifying bacteria convert ammonium to nitrate for plant uptake; denitrifying bacteria return nitrate to the atmosphere as N2.

VN **GIẢI THÍCH TIẾNG VIỆT**

Chu trình nitrogen (tóm tắt): vi khuẩn **cố định đạm** chuyển N2 khí quyển thành hợp chất amoni cho cây hấp thụ; vi khuẩn phân giải giải phóng amoni từ xác sinh vật/chất thải; vi khuẩn **nitrat hoá** chuyển amoni thành **nitrat** (dạng cây hấp thụ tốt nhất); vi khuẩn **phản nitrat hoá** chuyển nitrat trở lại thành N2 khí quyển, khép kín chu trình.

13.7 Human Influences on Ecosystems

Deforestation (large-scale removal of forest, often for timber or to clear land for farming) causes: loss of **habitat** and **biodiversity** for forest species; increased **soil erosion** (tree roots no longer bind soil, and the canopy no longer intercepts heavy rain); disruption of the local **water cycle** (less transpiration from trees means less local rainfall); and an increase in atmospheric CO2, both from **burning** felled vegetation (releasing stored carbon immediately) and from the **loss of photosynthesis** that would otherwise have removed CO2 from the atmosphere.

The greenhouse effect and climate change: certain atmospheric gases (called **greenhouse gases** – notably carbon dioxide and methane) absorb infrared (heat) radiation re-radiated from the Earth's surface, and re-radiate some of it back downward, trapping heat within the atmosphere (analogous to heat trapped inside a greenhouse). Human activities – burning fossil fuels, deforestation, and (for methane) livestock farming and rice paddies – have increased the concentration of these gases, **intensifying** the greenhouse effect. This enhanced greenhouse effect is linked to **global warming**, and its consequences include **rising sea levels** (from melting polar ice and glaciers, and from thermal expansion of seawater as it warms), **changing rainfall patterns** (some regions becoming wetter, others drier, and more frequent extreme weather events), and shifts in the geographic ranges and habitats of many species as temperatures change. A further consequence linked to rising atmospheric CO2 is **ocean acidification**: oceans absorb a large proportion of atmospheric CO2, which dissolves to form a weak acid, gradually lowering the pH of seawater and affecting organisms (such as corals and shellfish) that build shells or skeletons from calcium carbonate.

Human activity	Main effect(s) on the environment
Deforestation	Habitat/biodiversity loss; soil erosion; disrupted local water cycle; increased atmospheric CO2 (from burning and lost photosynthesis)
Burning fossil fuels	Increased atmospheric CO2; enhanced greenhouse effect; global warming and climate change
Excess fertiliser use	Nutrient (nitrate/phosphate) runoff into waterways; eutrophication; oxygen depletion and death of aquatic animals
Overfishing/overhunting	Population decline or local extinction of the harvested species; disruption of food webs that depend on it

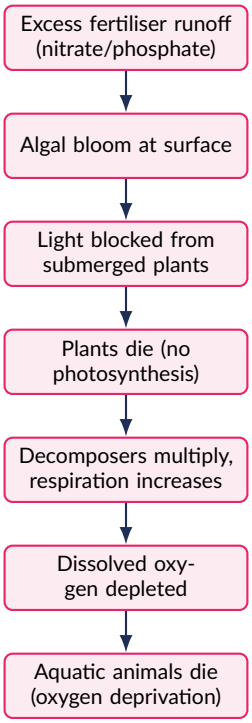
VN **GIẢI THÍCH TIẾNG VIỆT**

Phá rừng: mất môi trường sống & đa dạng sinh học, tăng xói mòn đất (rễ cây không còn giữ đất), phá vỡ chu trình nước cục bộ, và tăng CO2 khí quyển (do đốt cây VÀ mất khả năng quang hợp hấp thụ CO2). **Hiệu ứng nhà kính**: các khí nhà kính (CO2, methane) hấp thụ và bức xạ lại nhiệt (tia hồng ngoại) từ bề mặt Trái Đất, giữ nhiệt lại trong khí quyển. Hoạt động của con người (đốt nhiên liệu hoá thạch, phá rừng, chăn nuôi gia súc) làm TĂNG nồng độ các khí này, khiến hiệu ứng nhà kính trở nên mạnh hơn mức tự nhiên, dẫn đến nóng lên toàn cầu, nước biển dâng, và thay đổi kiểu mưa.

13.8 Eutrophication

The eutrophication sequence

Step 1: excess fertiliser (containing nitrate and phosphate) runs off farmland into a river or lake.
Step 2: the extra nutrients cause rapid, excessive growth of algae at the water surface – an **algal bloom**.
Step 3: the dense algal bloom blocks light from reaching submerged water plants below the surface.
Step 4: without light, submerged plants cannot photosynthesise and die; algae themselves also eventually die (e.g. once nutrients run out).
Step 5: decomposers (bacteria) multiply rapidly to feed on the large amount of dead plant/algal material, and their own **respiration rate increases** correspondingly.
Step 6: this greatly increased decomposer respiration uses up dissolved oxygen in the water faster than it can be replaced, so dissolved oxygen levels fall sharply – aquatic animals (fish, invertebrates) that need dissolved oxygen then **suffocate and die**.



VN **GIẢI THÍCH TIẾNG VIỆT**

Trình tự phú dưỡng hoá (eutrophication) PHẢI nhớ đúng thứ tự: (1) phân bón dư thừa (nitrate/phosphate) chảy tràn xuống sông hồ → (2) tảo nở hoa (algal bloom) ở bề mặt → (3) tảo che ánh sáng, thực vật chìm bên dưới không quang hợp được → (4) thực vật chết → (5) vi khuẩn phân giải sinh sôi mạnh, hô hấp tăng → (6) oxy hoà tan trong nước cạn kiệt → (7) động vật thuỷ sinh chết ngạt vì thiếu oxy. Lỗi sai phổ biến: nghĩ rằng tảo trực tiếp "đầu độc" cá – thực ra cá chết là do THIẾU OXY HOÀ TAN (gây ra bởi hô hấp mạnh của vi khuẩn phân giải), không phải do độc tố của tảo (trừ một số trường hợp đặc biệt ngoài phạm vi chương trình này).

13.9 Conservation

Why and how ecosystems are conserved

Reasons for conservation: to maintain **biodiversity** (the variety of species and genetic variation within species); to protect **ecosystem services** that humans depend on (e.g. clean water, pollination of crops, climate regulation); and to preserve resources (genetic, medicinal, food) for **future use**.

Methods of conservation: establishing **protected areas/reserves** where habitats and species are legally safeguarded from development or exploitation; **captive breeding** programmes for endangered species followed by **reintroduction** into the wild; **reforestation** (replanting trees in deforested areas); **sustainable resource use**, including fishing/hunting **quotas** that keep harvesting rates below the rate of natural population replacement; **legislation** (laws restricting hunting, pollution, or habitat destruction); and **education** to raise public awareness of conservation issues.

A resource is being used **sustainably** when it is harvested (or otherwise used) at a rate that allows the population to replace the individuals removed through its own natural reproduction, so that the resource remains available indefinitely rather than being depleted. Setting a fishing **quota** below this natural replacement rate is one practical way conservation bodies try to keep a fish stock sustainable rather than allowing it to collapse from overfishing.

VN **GIẢI THÍCH TIẾNG VIỆT**

Lý do bảo tồn: duy trì **đa dạng sinh học**, bảo vệ các **dịch vụ hệ sinh thái** (nước sạch, thụ phấn cây trồng, điều hoà khí hậu), và giữ nguồn tài nguyên cho **tương lai**. Biện pháp bảo tồn: khu bảo tồn/vườn quốc gia; nhân giống trong điều kiện nuôi nhốt rồi thả về tự nhiên; trồng lại rừng; khai thác bền vững (đặt hạn ngạch đánh bắt/săn bắt); ban hành luật pháp; và giáo dục nâng cao nhận thức cộng đồng.

13.10 Biotechnology: Microorganisms

Microorganisms are widely used by humans to produce food and drink, exploiting their natural metabolic pathways – particularly **anaerobic respiration** (covered in Chapter 9).

Yeast in bread-making: yeast (a single-celled fungus) mixed into bread dough respires anaerobically: glucose → ethanol + carbon dioxide (+ energy). The **carbon dioxide** produced becomes trapped as bubbles in the dough, causing it to rise; the small amount of ethanol produced evaporates during baking.

Yeast in brewing: the same anaerobic reaction is exploited in brewing, but here the desired product is the **ethanol** (alcohol) itself, produced from the sugars in malted grain or fruit.

Bacteria in yoghurt production: specific bacteria (e.g. *Lactobacillus* species) added to milk ferment the milk sugar **lactose** into **lactic acid** by anaerobic respiration. The build-up of lactic acid lowers the pH of the milk, causing milk proteins to coagulate (thicken) – this is what gives yoghurt its characteristic texture and sour taste.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nấm men (yeast) trong làm bánh mì và ủ rượu đều dùng chung một phản ứng hô hấp kỵ khí: glucose → ethanol + CO_2 (+ năng lượng) (xem lại Chương 9) – KHÁC với hô hấp kỵ khí ở người (chỉ tạo acid lactic, KHÔNG có CO_2). Trong làm bánh mì, sản phẩm mong muốn là CO_2 (làm bột nở); trong ủ rượu/bia, sản phẩm mong muốn là **ethanol**. Vi khuẩn *Lactobacillus* trong làm sữa chua lên men đường lactose trong sữa thành **acid lactic**, làm protein sữa đông tụ, tạo độ sánh và vị chua đặc trưng.

(!) Lỗi thường gặp: Học sinh hay nhầm sản phẩm hô hấp kỵ khí giữa các sinh vật khác nhau. Cần phân biệt rõ BA trường hợp: (1) **người (cơ)** – glucose → acid lactic (KHÔNG CO_2); (2) **nấm men** – glucose → ethanol + CO_2; (3) **vi khuẩn lactic** (làm sữa chua) – lactose → acid lactic (tương tự cơ chế người nhưng ở vi khuẩn, và cơ chất là lactose chứ không phải glucose). Đề thi thường hỏi "vì sao bánh mì nở" (do CO_2) và "sản phẩm mong muốn khi ủ rượu là gì" (ethanol) – cần trả lời đúng sản phẩm MONG MUỐN của mỗi quy trình, không chỉ liệt kê chung chung.

13.11 Genetic Engineering (Supplement)

Genetic engineering (genetic modification) is the direct transfer of a gene from one organism into a different organism, so that the second organism expresses a characteristic (usually a protein) that it would not naturally produce.

Step-by-step mechanism: producing human insulin using bacteria

Step 1: a **restriction enzyme** is used to cut out the human gene for insulin from a human chromosome. Restriction enzymes cut DNA at specific base sequences, leaving matching ("sticky") ends.

Step 2: the *same* type of restriction enzyme is used to cut open a **plasmid** (a small circular loop of DNA, separate from the main bacterial chromosome, naturally found in bacteria) – producing matching sticky ends on the plasmid.
Step 3: the human insulin gene is mixed with the cut-open plasmid; because the sticky ends made by the same restriction enzyme are complementary, the gene can slot into the gap in the plasmid. The enzyme **ligase** is then used to **join (splice)** the gene permanently into the plasmid, forming a single, closed loop of **recombinant DNA**.
Step 4: the modified (recombinant) plasmid is inserted into a **host bacterium** (commonly *Escherichia coli*).
Step 5: the bacterium now carries the human insulin gene and uses its own protein-making machinery to **express** it, producing human insulin protein. The bacteria are grown in large fermenters, and the insulin they produce is extracted and purified for use by people with diabetes.

A second example (Supplement): pest-resistant crops. The gene from the soil bacterium *Bacillus thuringiensis* (Bt) that codes for a protein toxic to certain insect pests can be transferred, using the same restriction-enzyme/plasmid/ligase approach, into crop plants such as cotton or maize. The resulting "Bt crop" produces the insect-toxic protein in its own tissues, reducing crop damage from those insect pests without needing to spray as much external insecticide. (A further example along similar lines is "golden rice", genetically engineered to produce beta-carotene, a precursor of vitamin A, in the edible part of the rice grain.)

Feature	Selective breeding	Genetic engineering
Source of the new gene/allele	Only from within the **same species** (existing variation)	Can be transferred from a **completely different species**
Timescale	Many generations (slow)	A single generation (fast, direct insertion)
Precision	Whole organisms with the best overall combination of traits are chosen	A **single named gene** is identified, cut out and inserted directly

VN **GIẢI THÍCH TIẾNG VIỆT**

Cơ chế kỹ thuật di truyền (Supplement) gồm 5 bước: (1) **enzyme cắt giới hạn (restriction enzyme)** cắt gen mong muốn (ví dụ gen insulin người) ra khỏi nhiễm sắc thể; (2) CÙNG loại enzyme cắt giới hạn đó cắt mở một **plasmid** (vòng DNA nhỏ của vi khuẩn); (3) enzyme **ligase** nối (ghép) gen vào plasmid đã mở, tạo thành DNA tái tổ hợp; (4) plasmid tái tổ hợp được đưa vào vi khuẩn chủ; (5) vi khuẩn biểu hiện gen lạ, sản xuất ra protein mong muốn (ví dụ insulin người). Lưu ý quan trọng: phải dùng CÙNG MỘT loại enzyme cắt giới hạn cho cả gen và plasmid, để tạo ra các đầu dính (sticky ends) khớp nhau. Ví dụ thứ hai: gen kháng sâu bệnh từ vi khuẩn *Bacillus thuringiensis* được cấy vào cây bông/ngô để tạo protein diệt côn trùng gây hại ngay trong mô cây.

13.12 Practice Problems

Bài tập luyện tập

(A) Population
(B) Community
(C) Habitat
(D) Ecosystem

All the different species of fish, coral, algae and other organisms living together on a coral reef, interacting with one another, are best described as a:

Lời giải chi tiết

(B) Community. A community is all the populations of different species living and interacting together in the same area. (An ecosystem would additionally include the non-living/abiotic components, such as water chemistry and light.)

Bài tập luyện tập

Explain why energy transfer between trophic levels is never 100% efficient, listing all the relevant energy losses.

Lời giải chi tiết

Energy is lost at every trophic level through: (1) **respiration**, most of which is ultimately released as heat; (2) **movement/muscular activity**, also lost as heat; (3) **egestion** of undigested food (faeces), which never enters the organism's biomass; (4) **excretion** of energy-containing waste products. Because of these losses, typically only about 10% of the energy at one trophic level becomes available to the next.

Bài tập luyện tập

A pyramid of energy shows producers storing $80\,000$ kJ m^{-2} yr^{-1} and primary consumers storing $7\,200$ kJ m^{-2} yr^{-1}. Calculate the percentage efficiency of energy transfer.

Lời giải chi tiết

$$\%\ \text{efficiency} = \frac{7\,200}{80\,000} \times 100 = 9\%.$$

This is close to the typical value of about 10% for energy transfer between trophic levels.

Bài tập luyện tập

Explain why food chains rarely have more than four or five trophic levels.

Lời giải chi tiết

Because only about 10% of energy is transferred from one trophic level to the next, the total amount of energy available decreases very rapidly at each step (e.g. from 100% at the producer level to roughly 0.01% after four transfers). Beyond four or five trophic levels, there is usually too little energy left in the system to support a viable population of organisms at the next level, so food chains rarely extend further.

Bài tập luyện tập

(A) Pyramid of energy
(C) Pyramid of numbers
(B) Pyramid of biomass
(D) All three pyramids equally

Which type of ecological pyramid can never be inverted?

Lời giải chi tiết

(A) Pyramid of energy. Energy is always lost (never gained) moving up trophic levels, so a pyramid of energy must always be upright. Pyramids of biomass and numbers can occasionally be inverted (e.g. one large tree supporting many small herbivorous insects gives an inverted pyramid of numbers).

Bài tập luyện tập

Give one example of a situation in which a pyramid of numbers would be inverted (narrower at the base), and explain why.

Lời giải chi tiết

Example: a single large oak tree (one producer) supporting a large population of aphids or caterpillars (many primary consumers). The pyramid of *numbers* is inverted because there is only one (or few) producer organism(s) but many consumer organisms feeding on it – even though, in terms of *biomass* and *energy*, the single tree still represents more mass/energy than the total mass/energy of the insects feeding on it.

Bài tập luyện tập

Ten $1\ \text{m}^2$ quadrats placed randomly in a $200\ \text{m}^2$ meadow contain the following numbers of buttercup plants: $3, 5, 4, 2, 6, 5, 3, 4, 6, 2$. Estimate the total buttercup population in the meadow.

Lời giải chi tiết

Mean number per quadrat $= \dfrac{3+5+4+2+6+5+3+4+6+2}{10} = \dfrac{40}{10} = 4$ plants per m^2.

Estimated population $= 4 \times \dfrac{200}{1} = 800$ buttercup plants.

Bài tập luyện tập

State the raw materials and products of photosynthesis and of respiration, and explain how these two processes form the core of the carbon cycle.

Lời giải chi tiết

Photosynthesis: carbon dioxide + water $\xrightarrow{\text{light energy}}$ glucose + oxygen – removes CO2 from the atmosphere and converts its carbon into organic compounds. **Respiration:** glucose + oxygen → carbon dioxide + water (+ energy) – releases CO2 back into the atmosphere. Together, photosynthesis (by producers) and respiration (by all organisms) form the main two-way exchange of carbon between the atmosphere and living things, which is then supplemented by

feeding, decomposition, combustion and fossil fuel formation to complete the full carbon cycle.

Bài tập luyện tập

Explain why burying dead organic matter in waterlogged, oxygen-poor conditions can eventually lead to fossil fuel formation, rather than the carbon simply being released as CO2.

Lời giải chi tiết

Decomposers (bacteria and fungi) need oxygen for the aerobic respiration that normally breaks down dead organic matter and releases its carbon as CO2. In waterlogged, oxygen-poor conditions, decomposition is greatly slowed or prevented, so the carbon in the dead material is not released – it remains locked in the buried material. Over millions of years, heat and pressure gradually convert this trapped carbon-rich material into fossil fuels (coal, oil, natural gas).

Bài tập luyện tập

(A) Nitrogen fixation
(B) Nitrification
(C) Denitrification
(D) Decomposition

Which term describes the conversion of ammonium compounds in soil into nitrates by bacteria?

Lời giải chi tiết

(B) Nitrification. Nitrifying bacteria convert ammonium compounds into nitrates, the form most easily absorbed by plant roots. Nitrogen fixation converts atmospheric N2 into ammonium/usable nitrogen compounds; denitrification converts soil nitrates back into atmospheric N2; decomposition releases ammonium from dead organic matter.

Bài tập luyện tập

Explain, step by step, how excess fertiliser use on farmland can lead to fish deaths in a nearby river.

Lời giải chi tiết

(1) Excess fertiliser (nitrate/phosphate) runs off the land into the river. (2) The extra nutrients cause an algal bloom at the water surface. (3) The dense algae block light from reaching submerged water plants. (4) Without light, the submerged plants cannot photosynthesise and die. (5) Decomposer bacteria multiply rapidly to break down the large amount of dead plant and algal material, and their respiration rate increases sharply. (6) This increased decomposer respiration uses up dissolved oxygen faster than it is replaced, so dissolved oxygen levels fall. (7) Fish and other aquatic animals, which need dissolved oxygen to respire, suffocate and die.

Bài tập luyện tập

A student claims: ”Algal blooms poison fish directly with toxins, which is why eutrophication kills fish.” Evaluate this statement in relation to the standard eutrophication sequence.

Lời giải chi tiết

For the standard eutrophication sequence covered in this syllabus, the statement is not the main mechanism: fish deaths are explained by **oxygen depletion**, not toxin poisoning. The chain is: nutrient runoff → algal bloom → light blocked → plants die → decomposers multiply and respire more → dissolved oxygen falls → fish die from lack of oxygen. (Some algal species can produce toxins in certain real-world blooms, but this is a separate, additional effect, not the core oxygen-depletion mechanism required here.)

Bài tập luyện tập

Explain two effects of deforestation on the carbon cycle specifically (not on soil or water).

Lời giải chi tiết

(1) Burning felled trees releases the carbon stored in their biomass immediately as CO_2 into the atmosphere. (2) Fewer trees remain to carry out photosynthesis, so less CO_2 is removed from the atmosphere than before – both effects combine to raise atmospheric CO_2 concentration.

Bài tập luyện tập

(A) It reflects sunlight back into space

(B) It absorbs and re-radiates infrared radiation from Earth's surface

(C) It increases photosynthesis rates

(D) It cools the upper atmosphere directly

How does an increased concentration of greenhouse gases such as CO_2 lead to global warming?

Lời giải chi tiết

(B). Greenhouse gases absorb infrared (heat) radiation re-radiated from the Earth's surface and re-radiate some of it back downward, trapping additional heat in the atmosphere. A higher concentration of these gases intensifies this effect, raising average global temperatures.

Bài tập luyện tập

State three consequences of increased global warming, as linked to the enhanced greenhouse effect.

Lời giải chi tiết

Any three of: rising average global temperatures; rising sea levels (melting ice and thermal expansion of seawater); changing rainfall patterns (some regions wetter, some drier); shifts in species distributions and disruption of habitats/ecosystems.

Bài tập luyện tập

Give three named reasons for conserving a threatened habitat, such as a coral reef.

Lời giải chi tiết

Any three of: to maintain **biodiversity** (protecting species and genetic variation); to protect **ecosystem services** that humans rely on (e.g. fish stocks, coastal protection, tourism); to preserve resources (e.g. potential medicinal compounds, food sources) for **future use**; to prevent irreversible loss of species that cannot be recovered once extinct.

Bài tập luyện tập

(A) Captive breeding and reintroduction
(B) Legislation
(C) Deforestation
(D) Sustainable harvesting quotas

Which of these is NOT a recognised conservation method?

Lời giải chi tiết

(C) Deforestation. Deforestation is a cause of habitat and biodiversity loss, not a conservation method. The other three (captive breeding/reintroduction, legislation, sustainable quotas) are all standard conservation methods, alongside protected areas/reserves, reforestation and education.

Bài tập luyện tập

Explain, using anaerobic respiration, why bread dough rises in a warm place, and state the equation for the reaction involved.

Lời giải chi tiết

Yeast in the dough respires anaerobically: glucose $\rightarrow$ ethanol $+$ carbon dioxide ($+$ energy). The carbon dioxide gas produced becomes trapped as bubbles within the dough, causing it to expand (rise) in a warm environment, which speeds up the rate of yeast respiration (enzyme-controlled reactions occur faster at warmer temperatures, up to the point of denaturation).

Bài tập luyện tập

State the desired product in (a) bread-making and (b) brewing, even though both processes use the same basic reaction in yeast.

Lời giải chi tiết

(a) In bread-making, the desired product is **carbon dioxide** (to make the dough rise); the ethanol produced evaporates during baking. (b) In brewing, the desired product is **ethanol** (alcohol); the carbon dioxide produced is typically released or, in some processes, used to carbonate the drink.

Bài tập luyện tập

Explain, in terms of anaerobic respiration, how bacteria convert milk into yoghurt.

Lời giải chi tiết

Bacteria (e.g. *Lactobacillus* species) added to milk respire anaerobically, converting the milk sugar lactose into **lactic acid**. The build-up of lactic acid lowers the pH of the milk, causing milk proteins to coagulate (denature and clump together), which thickens the milk into yoghurt and gives it its characteristic sour taste.

Bài tập luyện tập

(A) Restriction enzyme
(B) Ligase
(C) Amylase
(D) Plasmid

Which enzyme is used to join a human gene into a bacterial plasmid during genetic engineering?

Lời giải chi tiết

(B) Ligase. Restriction enzyme cuts DNA (both the gene from the human chromosome and the plasmid); ligase then joins (splices) the gene into the cut plasmid. Amylase is a digestive enzyme unrelated to genetic engineering; a plasmid is the DNA vector, not an enzyme.

Bài tập luyện tập

Describe, in the correct order, the main steps used to genetically engineer bacteria to produce human insulin.

Lời giải chi tiết

(1) A restriction enzyme cuts the human insulin gene out of a human chromosome. (2) The same type of restriction enzyme cuts open a bacterial plasmid, producing matching sticky ends. (3) The human insulin gene is inserted into the cut plasmid, and ligase joins (splices) it into place, forming recombinant DNA. (4) The recombinant plasmid is inserted into a host bacterium. (5) The bacterium expresses the human insulin gene, producing human insulin protein, which is then extracted and purified.

Bài tập luyện tập

Explain why the *same* type of restriction enzyme must be used to cut both the human chromosome (to remove the gene) and the bacterial plasmid.

Lời giải chi tiết

A given restriction enzyme cuts DNA at a specific base sequence, leaving a particular pattern of "sticky ends." Using the same restriction enzyme on both the gene and the plasmid ensures the sticky ends produced are **complementary** to each other, so the cut gene will fit precisely into the cut plasmid and can be joined together by ligase. Using two different restriction enzymes would likely produce sticky ends that do not match, so the gene could not be inserted into the plasmid.

Bài tập luyện tập

Describe a named agricultural application of genetic engineering, other than insulin production, and explain its purpose.

Lời giải chi tiết

Example: the gene from the bacterium *Bacillus thuringiensis* (Bt), which codes for a protein toxic to certain insect pests, has been inserted into crop plants such as cotton or maize. The modified crop produces the insect-toxic protein within its own tissues, reducing damage from those insect pests without needing to apply as much external insecticide. (Golden rice, engineered to produce beta-carotene – a vitamin A precursor – in its grain, is another accepted example.)

Bài tập luyện tập

A food chain is: grass → grasshopper → frog → hawk. Identify the trophic level (producer, primary/secondary/tertiary consumer) of each organism.

Lời giải chi tiết

Grass = **producer**; grasshopper = **primary consumer** (feeds directly on the producer); frog = **secondary consumer** (feeds on the primary consumer); hawk = **tertiary consumer** (feeds on the secondary consumer).

Bài tập luyện tập

Explain the difference between a food chain and a food web, and state one advantage of representing feeding relationships as a food web.

Lời giải chi tiết

A food chain shows a single, linear feeding pathway (e.g. grass → rabbit → fox). A food web shows many interconnected food chains, since most organisms feed on – and are fed on by – more than one species. Advantage: a food web gives a more realistic picture of an ecosystem, showing that if one food source is removed or a population changes, consumers can often be affected through multiple pathways (or may switch to alternative food sources), which a single food chain cannot represent.

Bài tập luyện tập

Producers in an ecosystem capture $1\,200\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}$ of energy. Using a typical 10% transfer efficiency at each step, calculate the energy available to secondary consumers.

Lời giải chi tiết

Primary consumers: $1\,200\,000 \times 0.10 = 120\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}$. Secondary consumers: $120\,000 \times 0.10 = 12\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}$. So secondary consumers have access to approximately $12\,000\ \text{kJ m}^{-2}\ \text{yr}^{-1}$ – only 1% of the energy originally captured by the producers.

Bài tập luyện tập

Explain why decomposers are essential to both the carbon cycle and the nitrogen cycle.

Lời giải chi tiết

In the **carbon cycle**, decomposers break down the carbon compounds in dead organisms and waste, releasing carbon dioxide back into the atmosphere through their own respiration – without decomposers, carbon would remain locked in dead material and would not be recycled. In the **nitrogen cycle**, decomposers break down proteins and other nitrogen-containing compounds in dead organisms and waste, releasing ammonium compounds into the soil, which nitrifying bacteria can then convert into nitrates for plants to reuse.

Bài tập luyện tập

(A) Nitrogen fixation
(C) Nitrification
(B) Denitrification
(D) Decomposition

Which process converts nitrate in the soil back into atmospheric nitrogen gas?

Lời giải chi tiết

(B) Denitrification. Denitrifying bacteria (active in waterlogged, oxygen-poor soil) convert soil nitrate back into nitrogen gas (N2), returning it to the atmosphere and completing the nitrogen cycle.

Bài tập luyện tập

State one similarity and one difference between the carbon cycle and the nitrogen cycle.

Lời giải chi tiết

Similarity: both cycles involve decomposers breaking down dead organisms/waste to release a key element (carbon as CO2; nitrogen as ammonium) back into the environment for reuse by producers. **Difference:** the carbon cycle mainly cycles carbon between the atmosphere (as CO2) and living organisms via photosynthesis, respiration, combustion and fossil fuel formation; the nitrogen cycle additionally requires specific bacteria (nitrogen-fixing, nitrifying, denitrifying) to convert nitrogen between its gaseous, ammonium and nitrate forms, since most organisms cannot use atmospheric N2 directly.

Ôn tập nhanh: **Bài tiết (excretion)** là loại bỏ chất thải CHUYỂN HOÁ do chính cơ thể tạo ra (ví dụ CO2, urea); **thải phân (egestion)** là loại bỏ thức ăn KHÔNG được tiêu hoá/hấp thụ (phân) – hai khái niệm này KHÔNG đồng nhất. • Thẩm thấu (osmosis): nước luôn di chuyển từ nơi có **thế nước cao hơn** sang nơi có **thế nước thấp hơn** qua màng bán thấm – không nói "nước di chuyển theo nồng độ chất tan" một cách trực tiếp mà phải quy về thế nước. • Hô hấp kỵ khí: ở **người** tạo acid lactic (KHÔNG có CO2); ở **nấm men** tạo ethanol + CO2 – hai sản phẩm khác nhau, không dùng lẫn cho nhau trong bài thi. • Enzyme ở nhiệt độ CAO bị **biến tính (denatured)** – thay đổi VĨNH VIỄN hình dạng trung tâm hoạt động, không thể phục hồi; ở nhiệt độ THẤP enzyme chỉ hoạt động **chậm lại** (chưa biến tính), có thể hoạt động lại bình thường khi nhiệt độ tăng trở lại. • Đột biến kháng kháng sinh ở vi khuẩn xảy ra **NGẪU NHIÊN, TRƯỚC KHI** tiếp xúc kháng sinh – kháng sinh chỉ chọn lọc (không tạo ra) đột biến đó. • Luôn **đổi đơn vị về cùng hệ** TRƯỚC khi tính độ phóng đại (magnification = kích thước ảnh ÷ kích thước thật, không đơn vị) hoặc tính phần trăm. • **Kiểu gen** là bộ chữ cái alen (Tt); **kiểu hình** là đặc điểm quan sát được (cao/thấp); alen **trội** viết chữ HOA, alen **lặn** viết chữ thường của CÙNG một chữ cái – và "trội" không có nghĩa là "phổ biến hơn". • **Siêu lọc (ultrafiltration)** ở cầu thận lọc theo **kích thước phân tử**: phân tử nhỏ (nước, glucose, muối khoáng, urea) lọt qua; phân tử lớn (protein huyết tương, tế bào máu) bị giữ lại. • Trình tự **phú dưỡng hoá**: phân bón dư thừa → tảo nở hoa → chặn ánh sáng → thực vật chết → vi khuẩn phân giải tăng hô hấp → oxy hoà tan cạn kiệt → động vật thuỷ sinh chết ngạt – phải nhớ ĐÚNG THỨ TỰ này, không đảo lộn các bước. • Nguyên phân tạo **2** tế bào lưỡng bội giống hệt nhau; giảm phân tạo **4** tế bào đơn bội khác nhau. • Tháp **năng lượng** luôn thẳng đứng (không bao giờ đảo ngược); tháp sinh khối/số lượng đôi khi có thể đảo ngược.

Đồng hành cùng 8020 English

Cảm ơn bạn đã học cùng bộ giáo trình quốc tế 8020. **Điểm thật · Thầy thật · Kết quả thật** — nhiều học viên chỉ cần 1–2 khoá để đạt kết quả mong muốn.

Chương trình đào tạo tại 8020 English

IELTS Academic/General · **SAT** · PTE · Duolingo · TOEFL | **AP** (College Board) · **IB** Diploma · **Cambridge** IGCSE / A-Level | săn học bổng du học.

Vì sao chọn 8020 English?

- **100% giáo viên** đạt tối thiểu 8.0 IELTS hoặc 1500 SAT — đội ngũ Giáo sư · Tiến sĩ · Thạc sĩ tốt nghiệp trường top đầu thế giới (Carnegie Mellon — #1 Hoa Kỳ về Khoa học Máy tính).
- **Kèm 1–1** mọi độ tuổi; lớp sĩ số nhỏ 2–5 bạn (đa số dưới 10 bạn/lớp).
- Lộ trình cá nhân hoá, theo sát tiến độ từng học viên; lớp OFFLINE tại TP.HCM & ONLINE toàn quốc.

Bảng vàng học viên

AP 5/5 — Calculus AB/BC	**AP** 4–5 — Biology, Chemistry	**IB** 90/100 — Economics
SAT 1590 / 1570 / 1550	**IELTS** 8.0–9.0	**Duolingo** 110 · **PTE** 90

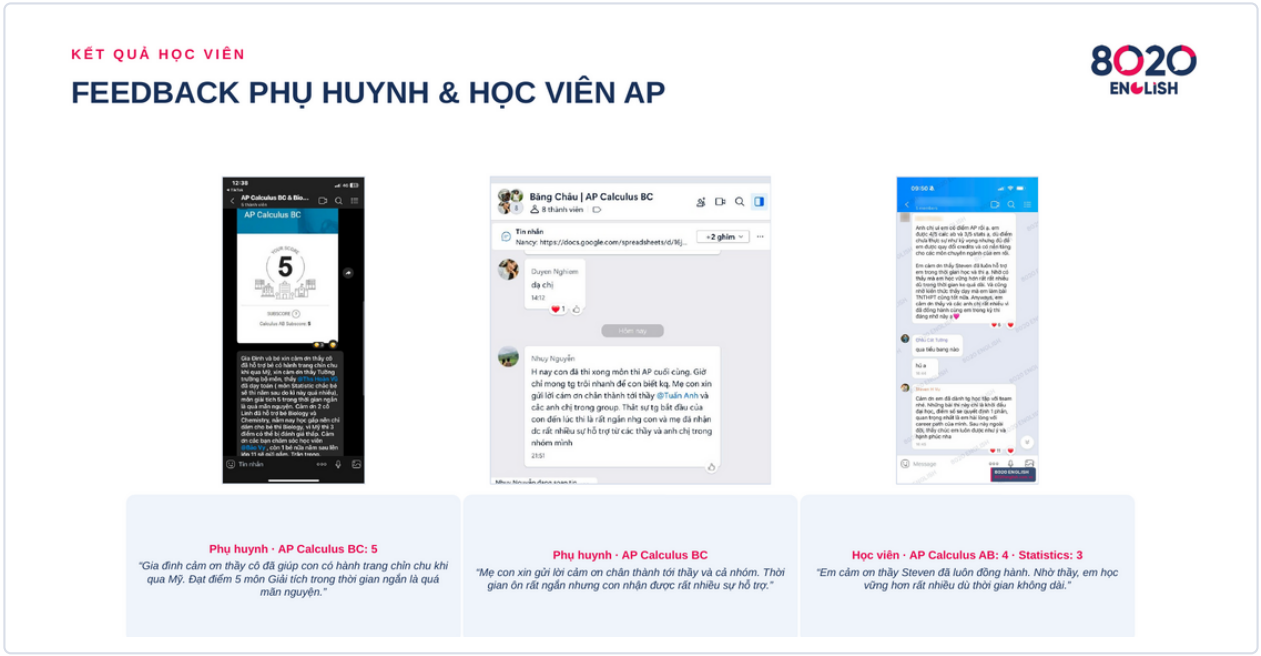
Cảm nhận học viên & phụ huynh

> *"Bạn đã cải thiện được tư duy Writing — kỹ năng từng là nỗi sợ lớn nhất — và cuối cùng đã đậu vào trường top như mong muốn. Thái độ học tập cực kỳ nghiêm túc; ngay cả khi nằm viện vẫn cố gắng học đều đặn."*
>
> — Phan Thị Thanh Hằng · IELTS Overall 8.5

> *"Cần tất cả kỹ năng trên 7.5 để xét vào trường top 1 Anh Quốc về Y học (chương trình UKFPO của NHS) — và đã đạt mục tiêu sau khi học Writing 1–1."*
>
> — Trần Hoàng Bảo Ngọc · IELTS Overall 8.0 (Writing 6.0 → 7.5)

> *"Gia đình và bé xin cảm ơn thầy cô đã giúp con có hành trang chỉn chu khi qua Mỹ. Đạt điểm 5 môn Giải tích trong thời gian ngắn là quá mãn nguyện."*
>
> — Phụ huynh · AP Calculus BC 5/5

> *"Em cảm ơn thầy đã luôn đồng hành. Nhờ thầy, em học vững hơn rất nhiều dù thời gian ôn không dài."*
>
> — Học viên · AP Calculus AB 4

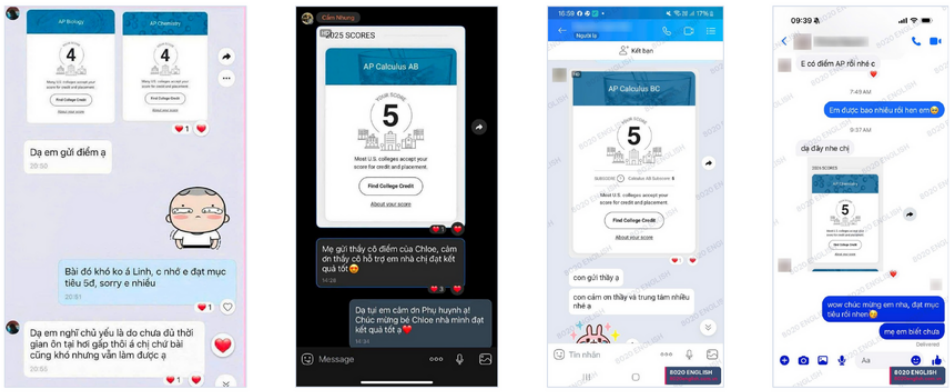


Feedback phụ huynh & học viên AP — nhiều môn đạt điểm 4 & 5

Điểm thi thật của học viên

KẾT QUẢ HỌC VIÊN

ĐIỂM SỐ AP



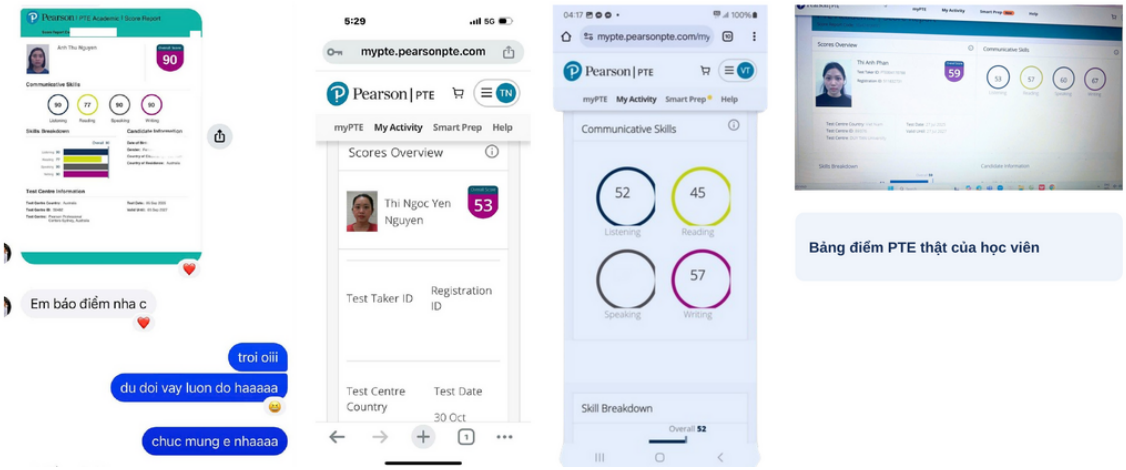
AP Biology: 4 · AP Chemistry: 4 | AP Calculus AB: 5 | AP Calculus BC: 5 | AP Chemistry: 5

Bảng điểm AP thật của học viên – nhiều môn đạt điểm 4 & 5

Bảng điểm AP thật — Calculus AB/BC 5/5 · Biology & Chemistry 4–5 (College Board)

KẾT QUẢ HỌC VIÊN

ĐIỂM SỐ PTE

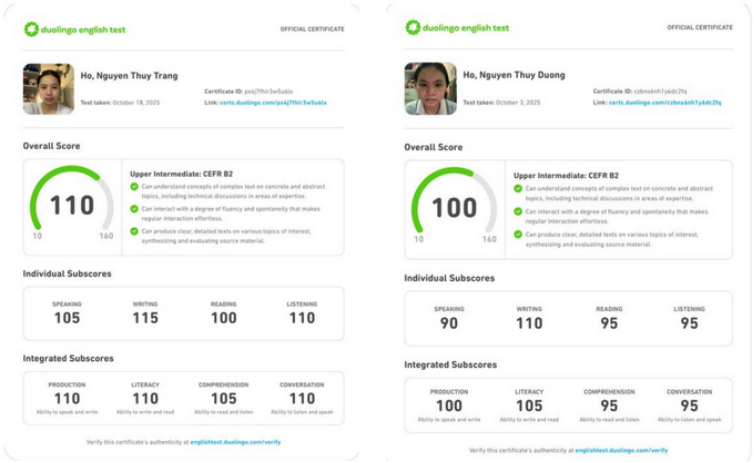


Bảng điểm PTE thật của học viên

Học viên 8020 — PTE Academic 90

KẾT QUẢ HỌC VIÊN

ĐIỂM SỐ DUOLINGO



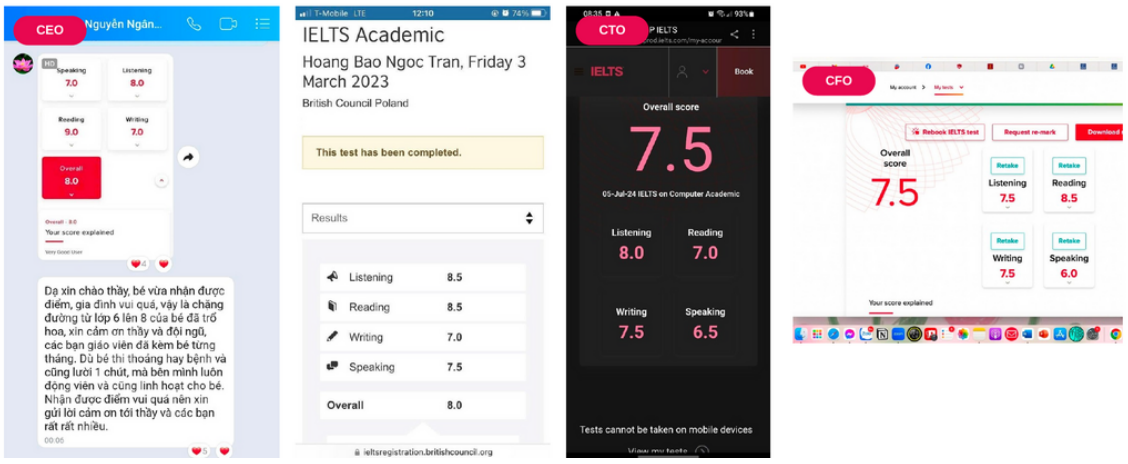
Duolingo English Test – 110 & 100

Học viên 8020 — Duolingo English Test 110 & 100

KẾT QUẢ HỌC VIÊN

THÀNH TÍCH HỌC VIÊN

Bảng điểm thi thật – chất lượng được giám sát nghiêm ngặt. Một số học viên chỉ cần 1–2 khóa để đạt kết quả mong muốn.



Học viên 8020 — IELTS 8.0 / 7.5 / 8.5 (báo điểm thật)