

2026 JC2 PRELIMINARY EXAMINATIONS

BIOLOGY

9477/01

**PAPER 1
MULTIPLE CHOICE**

**2 SEPTEMBER 2026
WEDNESDAY**

1 HOUR

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name, class and identification number on the MCQ Answer Sheet.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

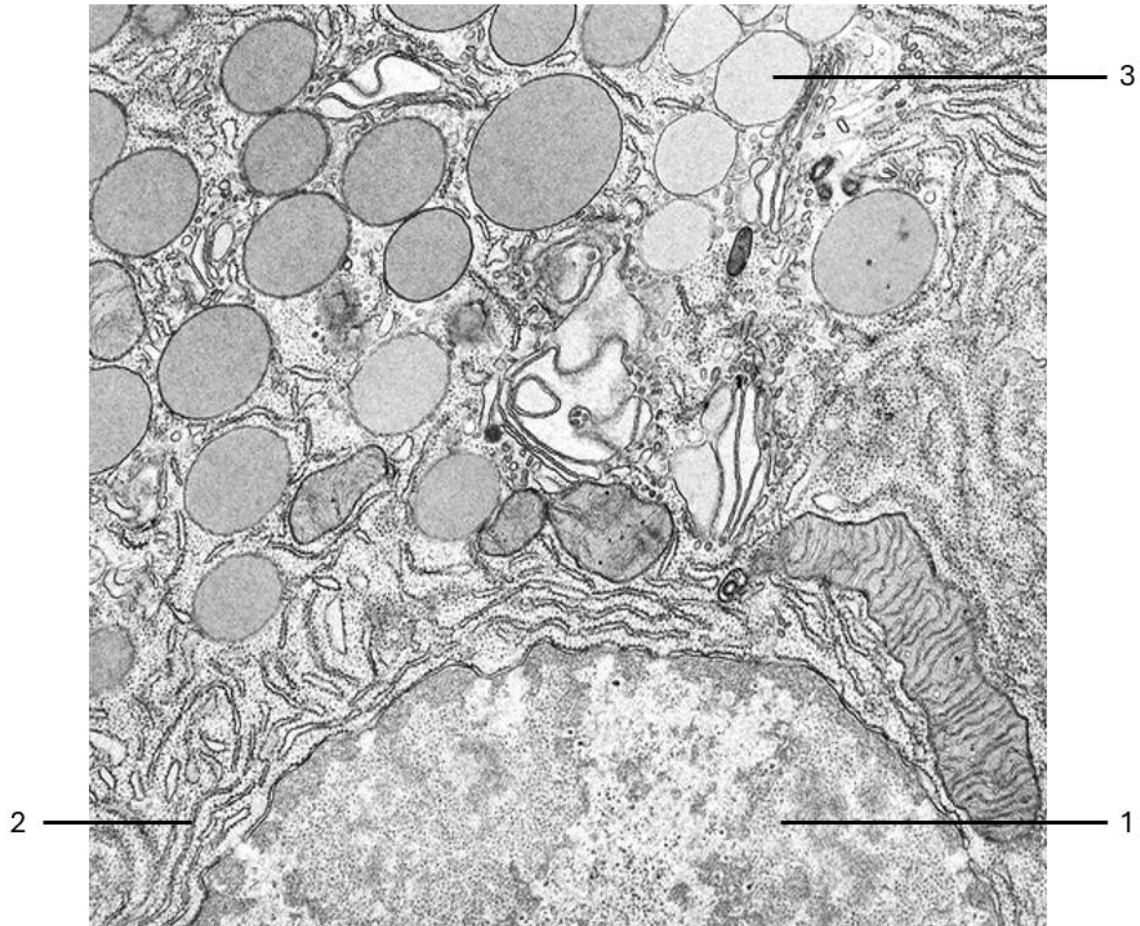
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

The use of scientific calculators is expected, where appropriate.

This document consists of **23** printed pages and **1** blank page.

- 1 An electron micrograph of a eukaryotic cell shows three structures, 1, 2 and 3.



A blue dye specific for polynucleotides was used to stain this cell.

Which of these structures will be dyed blue?

*Structure 1: nucleus (clue would be the lightly and darkly stained regions) **contains DNA** so will be stained blue.*

*Structure 2: RER (continuous with the nuclear envelope) contains ribosomes that are the site of translation using **mRNA** as a template, so will also be stained blue.*

Structure 3: secretory vesicle (numerous, and close proximity to the cell surface membrane (not shown)) only carries proteins so will not be stained blue.

- A 1, 2 and 3
- B 1 and 2 only**
- C 2 and 3 only
- D 3 only

2 Which of the following describes a lysosome?

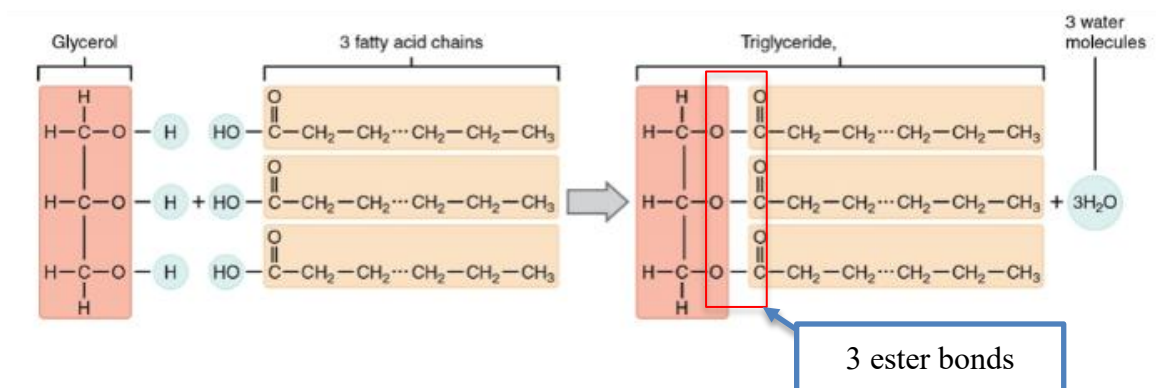
- A** a vesicle containing enzymes, enclosed by a double membrane, that is budded off the endoplasmic reticulum
*✗ Lysosome is **single** membrane, not double membrane. Lysosome also budded off from GA, not RER.*
- B** a vesicle containing hydrolytic enzymes and surrounded by a single membrane, found only in phagocytes
✗ Lysosome can also be found in other animal cells, not just in phagocytes.
- C** a vesicle enclosed by a single membrane, containing several different hydrolytic enzymes that can act inside the cell
✓ Lysosomes can fuse with other vesicles (e.g. phagosome) or worn-out organelles to digest the contents.
- D** a vesicle surrounded by a double membrane, containing enzymes which can hydrolyse damaged organelles in a cell
*✗ Lysosome is **single** membrane, not double membrane.*

3 Which statement about triglycerides is correct?

- A** Triglycerides have a higher proportion of oxygen than carbohydrates.
*Incorrect. Triglycerides have a **lower proportion of oxygen than carbohydrates**. Both contain carbon, hydrogen and oxygen, but triglycerides contain proportionally much less oxygen but more hydrogen and carbon. This contributes to triglycerides having a higher energy content per unit mass than carbohydrates.*
- B** Two triglycerides are joined together by an ester bond.
*Incorrect. Within a triglyceride, ester bonds are formed between the **hydroxyl groups of glycerol and the carboxyl groups of three fatty acids** during condensation reactions, not between two triglyceride molecules.*
- C** Triglycerides are soluble in water if they contain unsaturated fatty acids.
*Incorrect. Most triglycerides are **insoluble in water** because they contain non-polar, hydrophobic fatty acid chains and are therefore hydrophobic. Those with shorter fatty acid chains may have slightly greater water solubility. Unsaturation affects **melting point**. Unsaturated fatty acids, have C=C **double bonds**, resulting in kinks in their fatty chains. These prevent the molecules from packing closely together → lower melting point*

- D** Glycerol is joined to each fatty acid by a covalent bond.

Correct. Each fatty acid is joined to glycerol by a **covalent ester bond**. A triglyceride contains one glycerol molecule joined to three fatty acids, so **three ester bonds** are formed.



- 4** Collagen is a fibrous protein found in mammalian tendons.

Which feature contributes to the great tensile strength of collagen?

- A** A primary structure with covalent bonds linking a large variety of amino acids.
** Collagen has a fixed (and not variable) motif of repeated amino acids, glycine-X-Y.*
- B** A regularly folded tertiary structure held together with hydrogen bonds and ionic bonds.
** Collagen does not have a tertiary structure.*
- C** A quaternary structure with many hydrogen bonds firmly holding the α -helices.
** Collagen subunit is a triple helix, not alpha helix.*
- D** A quaternary structure of triple helix held together by hydrogen bonds between the three polypeptides.
✓ This is a correct description of the collagen subunit, tropocollagen, that is held together by inter-chain hydrogen bonds.

- 5 The components of the membranes found within and at the surface of cells contribute to their functions.

Examples of components are shown below.

- 1 glycolipids
- 2 glycoproteins
- 3 phospholipids
- 4 proteins

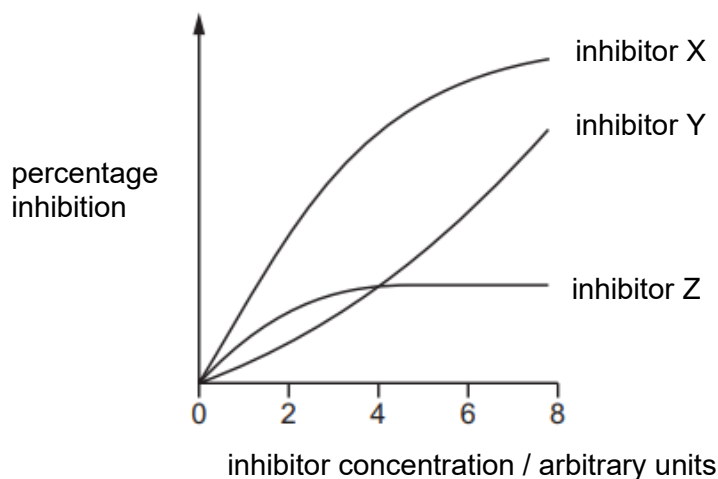
Which row matches the components with their functions?

	binding sites for toxins	recognising self from non-self	separating dissolved ions	transporting ions through membranes	binding cells together
	<i>Glycolipids and/or glycoproteins are involved in cell signaling/ receiving signals from the extracellular environment</i>	<i>Glycolipids and/or glycoproteins are involved in cell-cell recognition</i>	<i>Phospholipid bilayer forms the cell surface membrane. Phospholipid bilayer has a hydrophobic core which hydrophilic ions <u>cannot</u> pass through. Hence ions are separated on either side of the membrane.</i>	<i>Ions are hydrophilic. They cannot pass through the hydrophobic core of the cell membrane. Transport proteins are required transport ions.</i>	<i>Glycolipids and/or glycoproteins are involved in cell- cell adhesion</i>
A	1	1	4	3	2
B	3	2	3	4	1
C	1	2	4	2	2
D	1	2	3	4	1

- 6 The enzyme invertase catalyses the breakdown of sucrose to glucose and fructose.

Three different enzyme inhibitors of invertase, X, Y and Z were investigated. The percentage inhibition of invertase was measured at different concentrations of inhibitor.

The graph shows the results of the investigation.



What are valid conclusions based on the above results?

- 1 The higher the concentration of inhibitor X, the less sucrose is broken down.
✓ As concentration of inhibitor X increases, the higher the percentage inhibition of the reaction, hence less substrate (sucrose) will be broken down.
- 2 The production of glucose and fructose when using inhibitor Y is higher than when using inhibitor Z.
** Between inhibitor concentration of 4 to 8 arbitrary units, percentage inhibition of inhibitor Y is higher than Z, and hence the production of glucose of fructose will be lower.*
- 3 The production of glucose and fructose at an inhibitor concentration of 2 arbitrary units is lower than at an inhibitor concentration of 4 arbitrary units, for all inhibitors.
** Percentage inhibition for all inhibitors is lower at 2 arbitrary than at 4, hence the production of glucose and fructose should be higher, not lower.*
- 4 X is the most effective inhibitor at concentrations above 0 arbitrary units.
✓ Above 0 (up to 8) arbitrary units of inhibitor concentration, percentage inhibition of inhibitor X is always higher than inhibitor Y and Z.

- A** 4 only
B 1 and 4 only
C 2 and 3 only
D 1, 2 and 4 only

7 Which features are shared by embryonic stem cells and blood stem cells in humans?

- 1 They can divide by mitosis to give multipotent stem cells.
Pluripotent embryonic stem cells must eventually differentiate into multipotent stem cells during development (e.g., forming blood stem cell lineages), while blood stem cells (multipotent) divide to produce more multipotent stem cells.
- 2 They can divide by mitosis to replace cells that have died.
Both stem cell types divide by mitosis to produce new cells that replace dead or damaged tissue cells.
- 3 They can divide by mitosis to repair specialised cells.
Stem cells replace dead/damaged cells entirely—they do not physically repair pre-existing damaged specialised cells.
- 4 They can divide by mitosis throughout the whole lifetime of a person.
Embryonic stem cells exist only during early embryonic development, not throughout a person's entire lifetime (unlike adult blood stem cells).

A 1 and 2

B 1 and 4

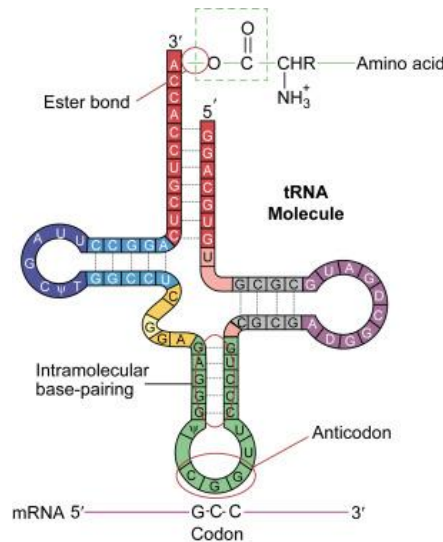
C 2 and 3

D 3 and 4

Option B was selected by a large proportion of candidates. Candidates selecting this option had not considered that there must come a point in a developmental pathway at which pluripotent stem cells give rise to multipotent stem cells, for example, in blood cell lineages. Furthermore, although stem cells are involved in the replacement of damaged cells in tissues they are not involved in the repair of damaged cells.

8 Which statement(s) about tRNA structures are correct?

- 1 There is a binding site for the attachment of a specific amino acid and a different binding site for the attachment of mRNA.
✓ 3' CCA end for the attachment of a specific amino acid and the anticodon loop for the attachment to codon of mRNA (that is bound to ribosome).
- 2 There is a ribose-phosphate backbone with strong phosphodiester bonds and areas within the polynucleotide chain where base pairing occurs.
✓ The sugar in tRNA is ribose hence the backbone is a ribose-phosphate backbone. The areas within the chain with complementary base pairing are responsible for the formation of hydrogen bonds that gives tRNA a clover-leaf structure.



- 3 There is an anticodon that contains the same triplet of bases as the triplet of DNA bases that has been transcribed to produce the mRNA codon.
✗ The anticodon sequence has the same bases as the DNA base triplet, except for uracil bases (will be thymine instead).

- A 1, 2 and 3
B 1 and 2
 C 2 and 3
 D 1 only

9 The following statements are related to the process of translation.

- 1 A peptide bond forms between adjacent amino acids.
- 2 Hydrogen bonds form between the anticodon and the codon.
- 3 The ribosome is positioned near the 3' end of the mRNA.
- 4 An ester bond forms between tRNA and specific amino acid.

In which order do the statements take place?

- A 3, 2, 1, 4
 B 3, 4, 2, 1
C 4, 2, 1, 3
 D 4, 3, 2, 1

Explanation of the correct sequence:

Statement 4: Amino acid activation occurs before translation, where a specific amino acid is attached to the 3'CCA end of the tRNA via an ester bond. (see tRNA diagram in Q8)

Statement 2: Codon recognition by anticodon next occurs as aminoacyl tRNA enters the A site of the ribosome.

Statement 1: Peptide bond formation then occurs as the amino acid carried by the aminoacyl tRNA in the A site joins the end of the growing polypeptide chain attached to the aminoacyl tRNA in the P site.

Statement 3: This is the last event in the sequence as ribosome translocates along the mRNA template from the 5' end towards the 3' end. If ribosome is found near the 3' end, it should be reaching the end of the translation process.

10 Which features of viruses explain why viruses are **not** considered to be living cells?

- 1 They have no cytoplasm.
- 2 They contain genetic material.
- 3 They have no ribosomes.
- 4 ☐ They can reproduce only inside living host cells.
- 5 They have a cell surface membrane.

A 1, 2 and 3

B 1, 3 and 4

C 2, 4 and 5

D 1, 4 and 5

- ☐ **1 ✓** Viruses are acellular and have no cytoplasm.
- ☐ **2 X** Although viruses contain genetic material, this does not explain why they are not cells; cells also contain genetic material.
- ☐ **3 ✓** Viruses lack ribosomes and therefore cannot carry out protein synthesis independently.
- ☐ **4 ✓** Viruses are obligate intracellular parasites and depend on host cells for replication.
- ☐ **5 X** Viruses do not have a cell surface membrane. Some have a **lipid envelope**, but this is not equivalent to a cell surface membrane.

11 Some events that take place during the reproductive cycle of influenza virus and HIV are listed.

- 1 Viral DNA is transcribed to mRNA.
- 2 Viral haemagglutinin bind to receptors on the host cell surface.
- 3 The virus enters the cytoplasm surrounded by a coated vesicle.
- 4 Each replicated viral RNA is given a new envelope.
- 5 Viral gp120 binds to receptors on the host cell surface.
- 6 Viral RNA is reversed transcribed by reverse transcriptase.
- 7 Translation of mRNA yields viral polyproteins which are cleaved.
- 8 Viral RNA is replicated by RNA polymerase.

Which sequence of events correctly describes the reproductive cycle of HIV?

- A 2 → 3 → 8 → 1 → 7
- B 2 → 6 → 7 → 8 → 4
- C 5 → 3 → 6 → 8 → 7
- D 5 → 6 → 1 → 7 → 4**

*HIV is a **retrovirus** with an **RNA genome**, so its reproductive cycle involves reverse transcription.*

Step	Event	Explanation
5	Viral gp120 binds to receptors on the host cell surface	gp120 on the HIV envelope binds to CD4 receptors and co-receptors on the host cell. This allows HIV to enter the cell.
6	Viral RNA is reverse transcribed by reverse transcriptase	HIV carries reverse transcriptase , which uses the viral RNA as a template to produce complementary DNA (cDNA), eventually forming viral DNA.
1	Viral DNA is transcribed to mRNA	The viral DNA becomes associated with the host cell's genetic material. Host RNA polymerase transcribes viral genes into mRNA.
7	Translation of mRNA yields viral polyproteins which are cleaved	Host ribosomes translate the viral mRNA to produce viral proteins/polyproteins. These are subsequently cleaved into functional viral proteins.
4	Each replicated viral RNA is given a new envelope	Newly assembled HIV particles acquire their lipid envelope as they bud from the host cell membrane, incorporating viral envelope proteins such as gp120.

Why the other events are not part of this sequence

- **2 — Haemagglutinin binds to receptors** → this describes **influenza virus**, not HIV. Influenza uses haemagglutinin.
- **3 — Enters surrounded by a coated vesicle** → not the characteristic entry mechanism being tested for HIV here.
- **8 — Viral RNA is replicated by RNA polymerase** → this describes an **RNA virus such as influenza**. HIV first converts its RNA genome into DNA using reverse transcriptase.

12 Some statements about bacteriophages are given.

- 1 The nucleic acid, RNA, is enclosed within a protein capsid.
- 2 During the lysogenic cycle, the phage DNA is integrated into the bacterial chromosome.
- 3 During the lytic cycle, the bacterial cell divides repeatedly while producing new phage progeny.
- 4 A prophage may be replicated when the host bacterium replicates its DNA.
- 5 During transduction, bacteriophage transfer all the bacterial DNA from one bacterium to another.

How many statements are **wrong**?

A 1

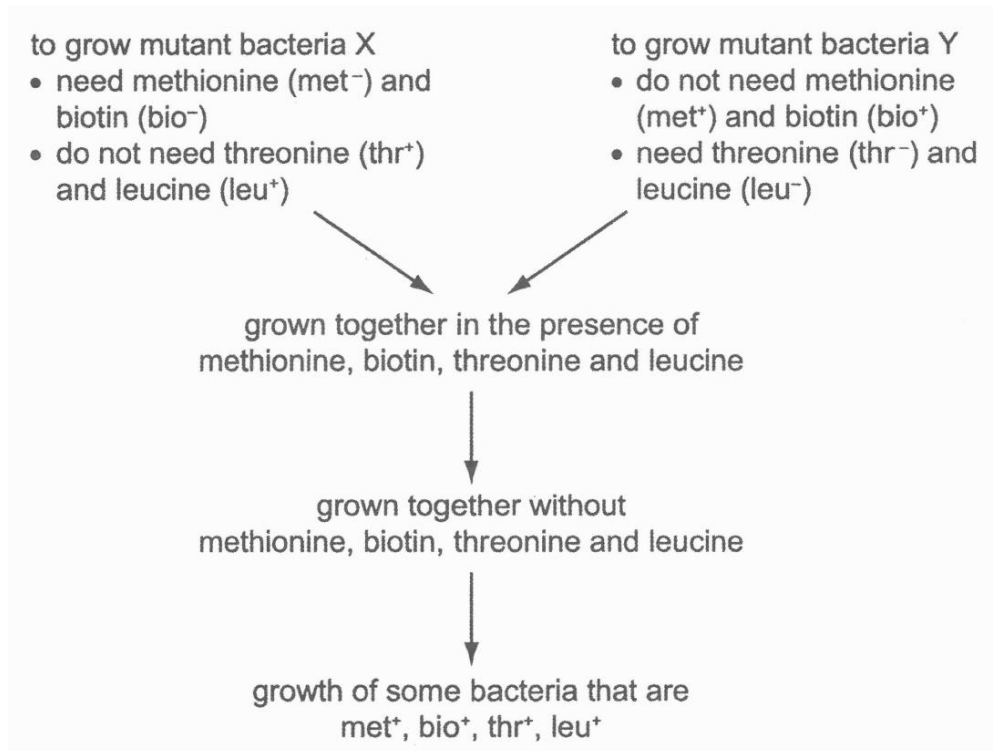
B 2

C 3

D 4

- ☐ 1 *X Virus structure: The phage genome is DNA and is enclosed within a protein capsid.*
- ☐ 2 *✓ Lysogenic cycle: In lambda phage, the viral DNA can integrate into the bacterial chromosome, forming a prophage.*
- ☐ 3 *X Lytic cycle: The host bacterium does **not** divide repeatedly. Viral components are produced, new phages assemble, and the host cell is eventually lysed.*
- ☐ 4 *✓ Lysogenic cycle: When the bacterial chromosome replicates, the integrated prophage DNA is replicated with it and can be inherited by daughter cells.*
- ☐ 5 *X Transduction: A bacteriophage can transfer some portion of the bacterial DNA, not all, from one bacterial cell to another.*

- 13 The diagram shows an investigation into bacterial genetics which involves functional alleles such as met^+ , bio^+ , thr^+ , and leu^+ and mutant, non-functional alleles such as met^- , bio^- , thr^- , and leu^- .



Which processes could explain these results?

- 1 Conjugation could have transferred functional alleles from one bacterial strain to the other.
- 2 Transformation could have occurred when one bacterial strain took up DNA released from other bacterial strain.
- 3 The bacteria has the functional alleles met^+ , bio^+ , thr^+ and leu^+ because the four nutrients in the first medium were incorporated into their DNA.
- 4 The bacteria has the functional alleles met^+ , bio^+ , thr^+ and leu^+ because the presence of the nutrients caused the mutant alleles to be converted directly into functional alleles.

A 1 and 2

B 2 and 3

C 1 and 4

D 2, 3 and 4

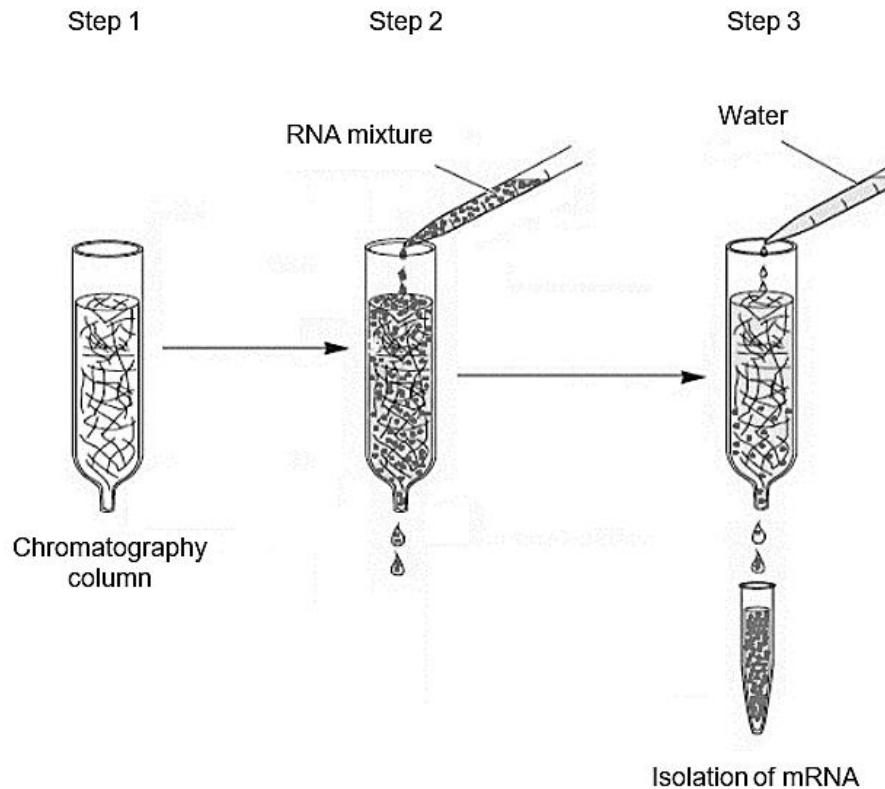
Statement

Explanation

- | | |
|---|--|
| 1 | ✓ Conjugation can transfer DNA between bacterial cells, potentially providing functional alleles that complement the mutations. |
| 2 | ✓ Transformation involves uptake of naked DNA from the environment (released by the lysed bacterial cells), which could provide functional alleles. |
| 3 | ✗ Nutrients such as methionine and biotin are not incorporated into DNA to restore functional genes. |

- 4 The nutrients do not directly convert mutant alleles into functional alleles.
 X The appearance of prototrophic bacteria must be explained by **genetic change**, such as horizontal gene transfer.

- 14 The isolation of mRNA can be done by passing an RNA mixture obtained from homogenised tissue through a chromatography column. The procedure of the mRNA isolation is as follows:



- Step 1: Set up a chromatography column which contains short lengths of uracil nucleotides attached to a solid support medium. *PolyA tail of mature mRNA will bind to the uracil nucleotides via H bonds.*
- Step 2: Add RNA mixture to the chromatography column. RNA that do not hybridise with the uracil nucleotides will pass through and leave the column. *RNA without polyA tail will not be able to bind to the uracil nucleotides and will leave the column.*
- Step 3: Add water to the chromatography column to remove and isolate the hybridised mRNA. *This breaks the H bonds between the poly A tail and the uracil nucleotides, hence releasing the mRNA from the column.*

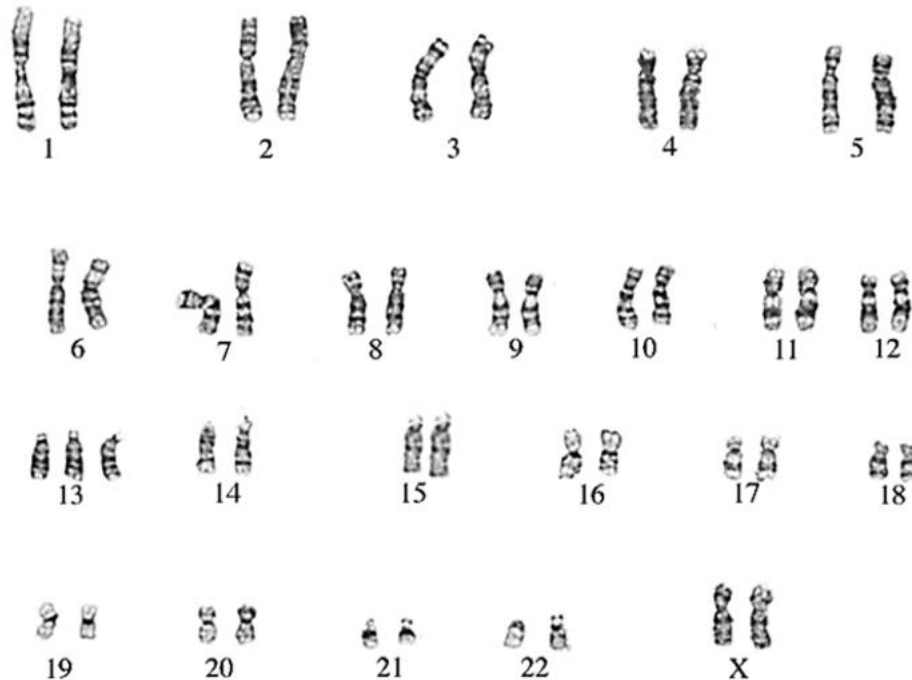
Which of the following statements is **not** true?

- A** rRNA and tRNA molecules could pass through and leave the column in Step 2.
✓ rRNA and tRNA do not have polyA tail and hence will not stay attached to the uracil nucleotides in the column.
- B** Complementary base pairing (*between the poly A tail and uracil nucleotides*) is responsible for the attachment of RNA molecules to the solid support medium.
- C** The isolated mRNA molecules in Step 3 do not contain introns.
✓ The mRNA should have completed RNA processing and hence contain poly A tail and have their introns already excised.

D The RNA molecules that attached to the chromatography column lack poly-(A) tails.

* RNA molecules that are attached to uracil nucleotides must contain poly A tails.

- 15 A newborn baby was diagnosed with Patau syndrome. The diagram below shows her chromosomes.



Which description characterises this condition?

A frameshift mutation

*Frameshift mutation refers to the effect of a **gene** mutation: addition or deletion of bases not in multiple of three. Diagram does not show bases being added or deleted.*

B chromosomal translocation

*In chromosomal translocation, a segment of a chromosome **breaks off** and becomes **attached** to a **non-homologous** chromosome. Diagram does not show a homologue of particular pair of chromosome becoming shorter and another homologue of another pair of chromosome becoming longer.*

C aneuploidy

*This is a condition where **one or several chromosomes** are present in extra copies or deficient in numbers. In this case, **chromosome 13** is observed to have 3 chromosomes - **an extra chromosome**, while in normal cases, each chromosome should only exist in pairs.*

D polyploidy

*A condition where there is **extra set/s** of chromosomes. E.g. if Patau syndrome is due to triploid (3 sets of chromosomes), then the diagram should show all her chromosomes (chromosome 1 to 23 and sex chromosome), existing in threes.*

- 16 The diagram shows a stage of mitosis in a cell. The amount of DNA present is 8 picograms (pg).



Which row correctly identifies the number of DNA molecules and amount of DNA in each nucleus at the end of telophase of mitosis and telophase II of meiosis respectively?

	Telophase of mitosis		Telophase II of meiosis	
	number of DNA molecules per nucleus	amount of DNA per nucleus/ pg	number of DNA molecules per nucleus	amount of DNA per nucleus / pg
A	12	8	6	4
B	6	4	3	4
C	6	4	3	2
D	6	8	3	4

The stage is prophase of mitosis.

6 chromosomes = 12 DNA molecules = 8 pg

At telophase, 2 nuclei are formed, thus 6 DNA molecules per nucleus; amount of DNA also halves, which is 4 pg.

At telophase I of meiosis, 2 haploid nuclei are formed with 3 chromosomes per nucleus. Note that the correct answer is 6 DNA molecules per nucleus as centromeres have not divided, chromosomes occur as a pair of chromatids. Amount of DNA also halves, which is 4 pg.

At telophase II of meiosis, 2 more haploid nuclei are formed with 3 chromosomes per nucleus as centromeres have divided during anaphase II. The amount of DNA also halves from 4 pg to 2 pg.

17 Which statements explain why sexual reproduction involves meiosis?

- 1 Meiosis prevents the chromosome number doubling from one generation to the next.
Meiosis reduces the chromosome number by half to ensure that when fusion of gametes occurs during fertilisation, the resulting offspring maintains the correct diploid number rather than doubling the chromosomes every generation.
- 2 Meiosis produces haploid cells.
Meiosis produces haploid gametes (containing a single set of chromosomes, n), which are necessary for sexual reproduction to combine genetic material from two parents to form a diploid zygote.
- 3 Meiosis enables chromosomes to replicate.
Chromosome replication occurs during Interphase (specifically the S phase) before meiosis begins; meiosis itself does not cause or enable replication.
- 4 Meiosis allows segregation of chromosomes into paternal and maternal sets.

During Metaphase I, homologous chromosome pairs align randomly along the equator of the cell in a process called independent assortment. Because each pair's orientation is entirely random and independent of the others, this leads to a random assortment of maternal and paternal chromosomes into the resulting daughter cells. As a result, gametes end up with a unique mixture of both maternal and paternal genetic material, rather than neatly segregating chromosomes into separate, pure paternal and maternal sets.

A 1 and 2

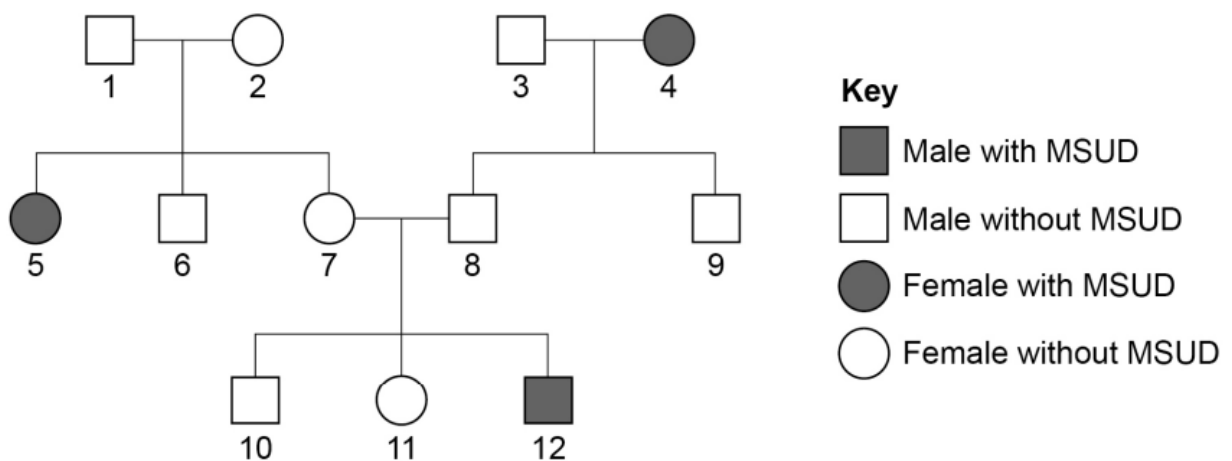
B 1 and 4

C 2 and 3

D 3 and 4

- 18** Maple syrup urine disease (MSUD) is a rare inherited human condition. MSUD is usually diagnosed early in childhood and can be controlled by having a low-protein diet.

The figure below shows the inheritance of MSUD in one family.



What is the probability of person 7 and person 8 having another son who has MSUD?

A 0.125

B 0.25

C 0.50

D 0.75

*Step 1: MSUD is **autosomal recessive**.*

Why is it recessive?

*Look at the pedigree where **two unaffected parents have an affected child**.*

If the parents do not show the condition but produce an affected child (example is parent 1 and 2 having children 6 and 7:

*The affected child must have received an allele from **both** parents.*

Let:

- **M** = normal allele
- **m** = allele causing MSUD

If persons 7 and 8 have already had a child with MSUD, that child must be *mm* and persons 7 and 8 must each be a **carrier of the recessive allele** ie genotype *Mm*.

Why is it autosomal?

Look at the **sex of the affected individuals** in the pedigree.

Both **males and females** can be affected.

More importantly, if the pedigree shows an **affected female whose father is unaffected**, this rules out a typical **X-linked recessive inheritance**.

Since both parents 7 & 8 must have contributed an *m* allele:

→ *Mm* x *Mm*

So for each pregnancy: $P(\text{child has MSUD}) = 1/4$

Step 2: The question asks for another son

Even if the child has MSUD, there is a separate probability that the child is male:

$P(\text{son}) = 1/2$

Therefore: $P(\text{another son with MSUD}) = P(\text{son}) \times P(\text{MSUD}) = \frac{1}{2} \times \frac{1}{4} = \frac{1}{8} = 0.125$

19

Two genes involved in coat colour of goats are at loci on different chromosomes.

The colour gene C causes the hairs to have uniform colour and has three alleles.

- C^{DB} giving dark brown hairs
- C^B giving black hairs
- C^{MB} giving medium brown hairs

A dominant allele of the agouti gene (A) causes the development of white hairs between the coloured hairs giving the coat a shaded appearance.

The table shows the results of crosses between a male goat and two female goats.

parents	offspring
black agouti male x uniformly dark brown female	50% uniform, 50% agouti; 50% dark brown, 50% black
black agouti male x medium brown agouti female	all agouti; 50% black, 50% medium brown

Which row shows the possible genotypes of the male and female goats?

	black agouti male	uniformly dark brown female	medium brown agouti female
A	$C^B C^{MB} AA$	$C^B C^{DB} Aa$	$C^{MB} C^{MB} AA$
B	$C^B C^{MB} Aa$	$C^B C^{DB} aa$	$C^B C^{MB} AA$
C	$C^B C^{DB} AA$	$C^{DB} C^{MB} Aa$	$C^B C^{DB} Aa$
D	$C^B C^{MB} Aa$	$C^B C^{DB} aa$	$C^{MB} C^{MB} AA$

Step 1: deduce parental genotype

Step 2: eliminate A & C → **uniform means aa; agouti means AA / Aa**

Step 3: from $C^B C^{DB}$ (2nd column) dark brown female → $C^{DB} > C^B$

Step 4: from $C^B C^{MB}$ (1st column) black male → $C^B > C^{MB}$

Step 5: $C^{DB} > C^B > C^{MB}$

Detailed explanation

1. Work out the agouti gene first

The allele **A** is dominant and causes agouti hairs.

Therefore:

- **AA** → agouti
- **Aa** → agouti
- **aa** → uniform

First cross

The offspring are: **50% uniform, 50% agouti**

The female is **uniformly dark brown**, so she must be: **aa**

To obtain 50% agouti and 50% uniform: **Aa x aa**

So the **black agouti male must be Aa**.

Second cross

The offspring are: **all agouti**

The male is **Aa**.

Therefore, to guarantee that **every offspring receives at least one A allele**, the medium-brown agouti female must be: **AA**

because: **Aa x AA**

gives:

- 50% AA
- 50% Aa

and therefore **100% agouti - Aa**

So we already know the agouti genotypes must be:

	Male	Dark brown female	Medium brown female
Agouti genotype	Aa	aa	Aa

This immediately eliminates **A and C**, because their agouti genotypes do not give the required ratios.

2. Now work out the colour gene

There are three alleles:

- C^{DB} → dark brown
- C^B → black
- C^{MB} → medium brown

The phenotype information in the crosses allows us to infer the allele relationships.

First cross

The black male × dark brown female produces: **50% dark brown, 50% black**

The genotypes must therefore be: **Black male: $C^B C^{MB}$**

Dark brown female: $C^B C^{DB}$

The possible offspring are:

	C^B	C^{DB}
C^B	$C^B C^B$ → black	$C^B C^{DB}$ → dark brown
C^{MB}	$C^{MB} C^B$ → black	$C^{MB} C^{DB}$ → dark brown

Therefore: **50% dark brown, 50% black exactly as observed.**

So the black male is: **$C^B C^{MB} Aa$**

and the uniformly dark brown female is: **$C^B C^{DB} aa$**

- 20** A purple-flowered, tall plant with the genotype PPTT was crossed with a white-flowered, short plant with the genotype pptt. The F₁ plants were allowed to self-fertilise. A chi-squared test was carried out on the results obtained for the F₂ generation.

Part of the table of chi-squared values is shown.

degrees of freedom	p = 0.5	p = 0.1	p = 0.05	p = 0.01	p = 0.001
1	0.46	2.71	3.84	6.64	10.83
2	1.39	4.60	5.99	9.21	13.82
3	2.37	6.25	7.82	11.34	16.27
4	3.37	7.78	9.49	13.28	18.46
5	4.35	9.24	11.07	15.09	20.52

The chi-squared value in this investigation is 9.36.

What is the p-value and do the results fit the expected ratio?

	p-value	results fit expected ratio
A	between 0.01 and 0.05	no
B	between 0.01 and 0.05	yes
C	between 0.05 and 0.1	yes
D	between 0.05 and 0.1	no

*Expected F₂ phenotypic ratio is 9:3:3:1. Thus degree of freedom is 3. Calculated chi-squared value is more than the critical chi-squared value of 7.82, thus difference between observed results and expected ratio is significant, the probability that chance is causing the different is very small, hence results **do not fit** the expected ratio, **null hypothesis is rejected**.*

*For 3 degrees of freedom, a χ^2 value of 7.82 corresponds to $p = 0.05$, while a χ^2 value of 11.34 corresponds to $p = 0.01$. The calculated χ^2 value of 9.36 lies between these two values. Therefore, the **p-value must lie between 0.01 and 0.05**.*

- 21** Scientists who are trying to distinguish the contributions of genetic and environmental factors to human phenotypes often make use of studies of twins.

- Monozygotic twins grow from a single fertilised egg that splits into two.
- Dizygotic twins develop from two different eggs, each fertilised by a different sperm.

Twins can be divided into four groups, P, Q, R and S, as shown in the table.

Twins	Grow up together in the same family household	Grow up apart in different families and households
Monozygotic	P	Q
Dizygotic	R	S

For groups P, Q, R and S, which row shows the correct comparisons between the members of a pair of twins for the genetic and environmental factors that affect phenotype?

	Factors	Group P	Group Q	Group R	Group S
A	Genetic Environmental	Different Different	Different Similar	Identical Different	Identical Similar
B	Genetic Environmental	Different Similar	Identical Similar	Different Different	Identical Different
C	Genetic Environmental	Identical Different	Different Different	Identical Similar	Different Similar
D	Genetic Environmental	Identical Similar	Identical Different	Different Similar	Different Different

Compare the genetics - **Monozygotic** (identical) twins

These arise when one fertilised egg divides into two embryos. Therefore they inherit the **same alleles** (ignoring rare mutations) → **Genetic factors: Identical** → This applies to: P & Q

Dizygotic (non-identical) twins

These arise from **two different eggs fertilised by two different sperm**. They are **genetically similar** to ordinary siblings and share → Therefore their genetic factors are considered **different** → This applies to: **R & S**

Twins growing up together

If twins grow up in the **same household**, they experience broadly similar environmental influences, such as: diet, education, home conditions, socioeconomic status

Therefore: **Environmental factors: Similar** → This applies to: **P & R**

Twins growing up apart

Twins raised in different families experience different homes, diets, lifestyles

Therefore: **Environmental factors: Different** → This applies to: **Q & S**

22 Some of the events that occur during the signal transduction pathway for insulin are listed.

- 1 Auto-phosphorylation of receptor tails
- 2 Activated relay proteins activate their respective downstream transduction pathways
- 3 Dimerisation of tyrosine kinase receptors
- 4 Relay proteins bind to phosphorylated tyrosines.

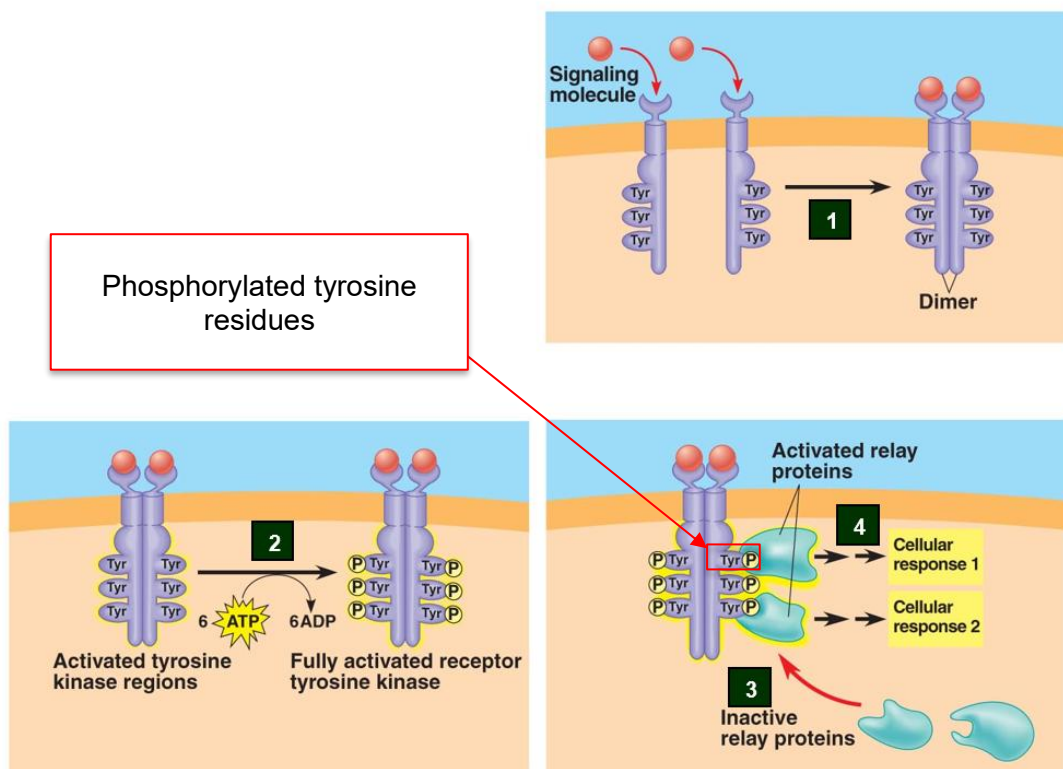
Which row shows the correct sequence?

A 1 → 3 → 2 → 4

B 1 → 3 → 4 → 2

C 3 → 1 → 2 → 4

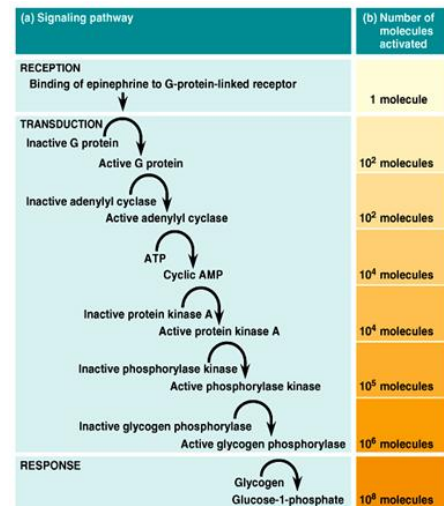
D 3 → 1 → 4 → 2



23 Which of the following statements does **not** describe the advantages of the signal transduction stage in G-protein coupled receptor (GPCR) signalling?

- A** The activated adenylyl cyclase converts intracellular ATP into cAMP and this increased cAMP level serves to amplify glucagon signal to produce stronger response.

*Advantage. Activated adenylyl cyclase catalyses the conversion of **many ATP molecules into many cAMP molecules** (**second messenger**). The large number of cAMP molecules activates many protein kinase A (PKA) molecules, resulting in a **signal amplification**.*

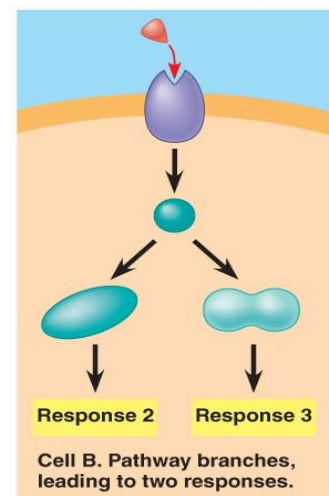


- B** The G-protein system and phosphorylation cascade in the liver cells with GPCR serves as many potential checkpoints for regulation of the GPCR signalling, ensuring that every glucagon signal produces the same cellular response.

***NOT an advantage:** The multiple steps do provide **checkpoints for regulation**, but their purpose is to allow the response to be **controlled, adjusted, enhanced, or inhibited**—not to ensure that every glucagon signal produces the same response.*

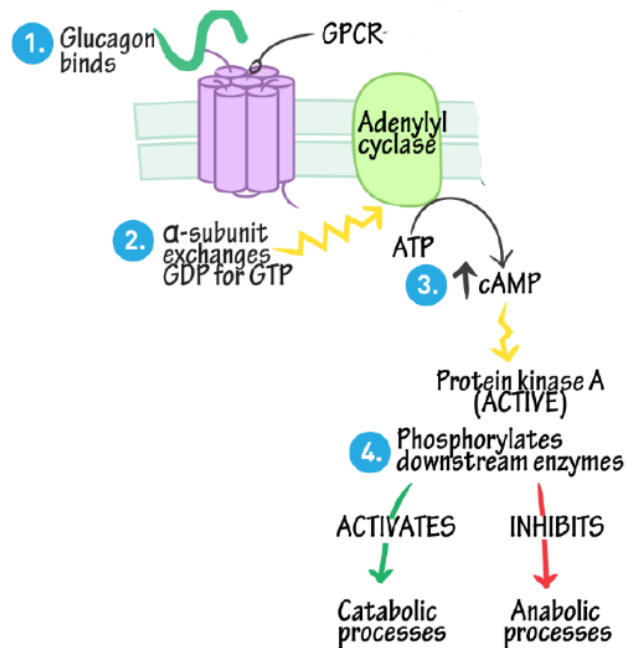
- C** One single glucagon ligand molecule can result in many cellular responses through different pathways.

*Advantage: Signal transduction can involve **branching/divergence**, so one extracellular signal can influence multiple downstream processes.*



- D** Extracellular glucagon binds GPCR at the cell surface membrane to result in the activation of genes in the nucleus.

*Advantage: Signal transduction allows an extracellular, hydrophilic, large signalling molecule such as glucagon that **cannot pass through the CSM**, to cause **intracellular effects**, including changes in gene expression, without glucagon itself entering the cell.*



- 24 Mature red blood cells have no mitochondria and use glucose as their respiratory substrate in the same way that can occur in muscle cells.

What are the final products of respiration in mature red blood cells?

- A** ATP, lactate, NAD
B ATP, pyruvate, NAD
C acetyl coenzyme A, ATP, CO₂, reduced NAD
D acetyl coenzyme A, ATP, reduced NAD

Mature red blood cells **do not contain mitochondria**, so they cannot carry out the link reaction, Krebs cycle or oxidative phosphorylation. They rely entirely on **glycolysis followed by lactate fermentation** in the cytoplasm.

During glycolysis:

- glucose is phosphorylated and eventually split into pyruvate
- **ATP is produced**
- **reduced NAD (NADH) is produced**

However, because there is no mitochondrial electron transport chain, the reduced NAD cannot be oxidised by oxidative phosphorylation. Instead:

pyruvate + reduced NAD → lactate + NAD

The regeneration of **NAD** is essential because NAD is needed for glycolysis to continue. Thus the final products include **ATP, lactate and NAD**.

Option

Why it is wrong

- A** ☒ Glycolysis produces ATP and reduced NAD; pyruvate is converted to lactate, regenerating NAD. Thus the final products include **ATP, lactate and NAD**.
B ☒ Glycolysis produces ATP, **reduced NAD** and pyruvate.

- C** ✗ *Acetyl CoA and CO₂ are produced during the link reaction, which occurs in the mitochondrial matrix. Red blood cells have **no mitochondria**.*
- D** ✗ *Again, **acetyl CoA** requires the link reaction in mitochondria. Also, reduced NAD is not a final product because it is oxidised during lactate formation.*

25 Whales are mammals, whereas snakes are reptiles. Both do not have any hind limbs, but their skeletons still have small bones that are part of the pelvic girdle in other vertebrates. The pelvic girdle is important in the functioning of hind limbs. Whales and snakes do not move in the same way as each other.

What does this suggest about the evolution of whales and snakes?

- 1 Their movement involves the same adaptations of the skeleton.
- 2 As their ancestors evolved and adapted to different habitats, the pelvic girdle lost its function.
- 3 They are descendants of different groups of animals that used their hind limbs for movement.
- 4 They share a common ancestor that used hind limbs for movement.

A 1, 2 and 3

B 1, 2 and 4

C 2, 3 and 4

D 3 and 4 only

Statement 1: ✗

The question states that whales and snakes **do not move in the same way**:

- Whales **swim** using powerful tail flukes.
- Snakes **slither** using muscles and ribs.

Therefore, they **do not have the same skeletal adaptations** for movement.

Statement 2: ✓

The pelvic girdle supporting hind limbs are **vestigial**.

This suggests that their ancestors possessed functional hind limbs, but as whales adapted to aquatic habitats and snakes adapted to limbless locomotion, the pelvic girdle became reduced and vestigial, losing its original function.

□

Statement 3: ✓ **True**

Since both whales and snakes possess vestigial pelvic girdles, indicating that their **ancestors had functional hind limbs**. The question states that **whales are mammals, whereas snakes are reptiles**. Mammals and reptiles must have different evolutionary lineages (groups).

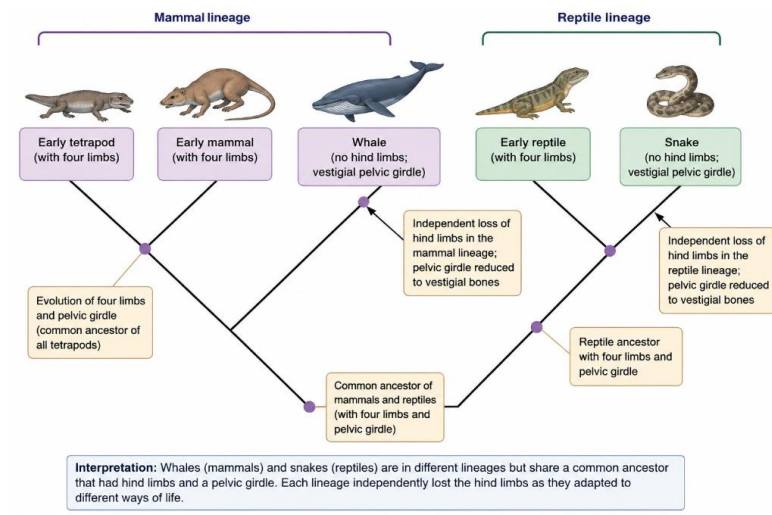
Whales must have descended from **hind-limbed mammals**, while snakes descended from **hind-limbed reptiles**.

Statement 4: ✓ **True**

Both whales and snakes possess the **same vestigial structure** (a reduced pelvic girdle).

Vestigial structures are inherited from ancestors in which they were functional.

This suggests that both lineages inherited the pelvic girdle from a **common ancestor with functional hind limbs**, providing evidence for common ancestry.



26 Organisms are classified using taxons. The scientific names of three species are below.

- Leopard – *Panthera pardus*
- Lion – *Panthera leo*
- Tiger – *Panthera tigris*

What is the highest taxon that these organisms have in common?

A class

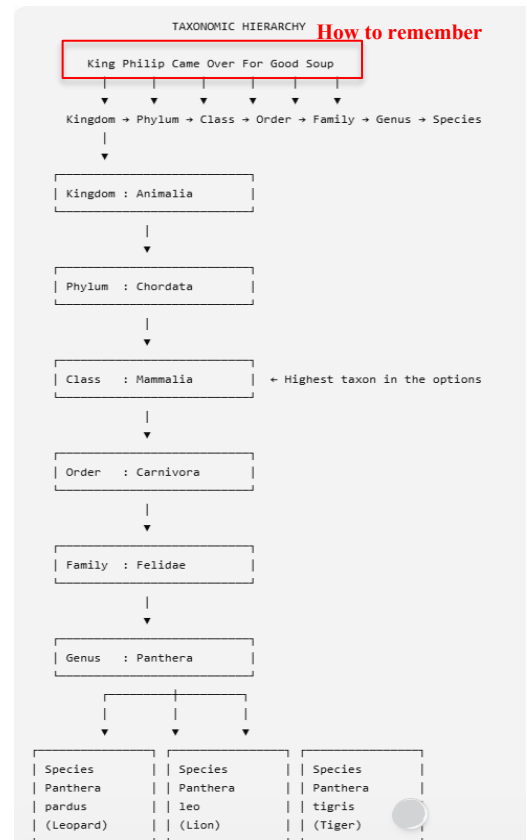
B family

C genus

D order

The first word of the scientific name is the **genus**. Since all three organisms belong to the **same genus** (*Panthera*) they **must also belong to the same family, order, class, phylum and kingdom**, because classification is **hierarchical**. Organisms classified in the same genus are automatically classified into the same higher taxonomic groups.

Note: If **Kingdom** had been included as options, **Kingdom** would have been the highest shared taxon..



27 Which statement helps to explain the role of mangrove forests in mitigating the impact of climate change?

A Mangrove roots form a dense mass that slows the flow of water, causing suspended organic material to settle out and become trapped in oxygen-poor sediments that limit further decomposition.

Mangroves act as carbon sinks by trapping carbon-rich organic matter in oxygen-poor sediments, reducing the rate at which carbon is returned to the atmosphere as CO₂. This reduces the concentration of greenhouse gases in the atmosphere and therefore helps mitigate global warming due to reduced greenhouse effect.

B The roots of mangrove trees absorb organic carbon from sediments and store it in their cell walls in biomolecules such as lignin and cellulose that are highly resistant to chemical breakdown.

** Roots of mangrove do not absorb organic carbon from sediments, they take in carbon in the form of carbon dioxide from the air via the stomata on the leaves. The roots (pneumatophores) primarily take in oxygen not carbon dioxide. While they do release a small amount of carbon dioxide as a byproduct of cellular respiration, their main function is to deliver oxygen to the submerged, oxygen-starved root system.*

C When the leaves of mangroves die and fall, they are carried quickly to the sea where the carbon fixed in photosynthesis is trapped in deep ocean sediments before it can be released in the process of decomposition.

** Leaves of mangrove are usually stored locally in the shallow, oxygen-poor mangrove soils rather than carried away to deep ocean sediments. The complex root system of the mangroves slow down tidal water, so it is difficult for 'quick' movement of water. This statement also does not address how impacts of climate change is mitigated.*

D Mangrove forests provide a buffer zone between the sea and land which reduces the rate at which sea levels can rise as a result of the melting of the polar ice caps and retreat of glaciers to higher altitudes.

** While it is true that mangroves act as a physical buffer that protects coastlines from waves, it cannot reduce the rate at which sea levels rise due to the melting of the polar ice caps.*

28 Which statement correctly explains the cause of coral bleaching?

A Expulsion of zooxanthellae due to increased water temperatures results in coral bleaching.

The presence of zooxanthellae in corals give corals the colour. When they leave due to the increased temperatures, corals lose colour and appear white (coral bleaching).

B Exposure of zooxanthellae to too much physical disturbance, such as strong currents or wave action, results in coral bleaching.

** This is not true, strong currents or wave action will not result in the expulsion of zooxanthellae from corals.*

C Ocean acidification reduces calcium carbonate available for corals to build their skeletons, resulting in coral bleaching.

** Ocean acidification only affects the formation of reef structure, it does not result in the expulsion of zooxanthellae from corals.*

D Low light intensity causes coral bleaching by reducing photosynthesis in zooxanthellae.

** Coral bleaching is caused by high water temperatures, not due to low light intensity.*

29 Which method of gaining immunity can be described as natural active immunity?

Natural active means naturally-occurring process (with no human intervention), produced by the individual's own immune system.

A Feeding on colostrum (breast milk)

Mother's antibodies are passed directly to the infant -> natural passive

B Inhaling a live virus and becoming infected

Inhaling a live virus and becoming infected (is a natural process) which results in individual's own immune system in producing the antibodies (active)

C Receiving a tetanus toxoid injection

Antibodies are produced by the individual because of the injection (not a natural process) -> artificial active

D Receiving an injection of ready-made antibodies

artificial passive

30 Which of the following statement(s) could describe both B-lymphocytes and T-lymphocytes?

1 They contain specific protein receptors in their cell surface membranes.

This is true for both cells – B cell receptors and T cell receptors.

2 They differentiate into plasma cells.

This is only true for B cells. T cells differentiate to form cytotoxic T cells or helper T cells.

3 They divide by mitosis.

This is true for both cells during clonal expansion.

A 1 and 3 only

B 1 and 2 only

C 2 and 3 only

D 2 only

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