EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examinations 2024
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	**ANSWERS**

CIVICS GROUP	2	3	-			REGISTRATION NUMBER		

H2 Biology

9744/02

Paper 2 Structured Questions

11 September 2024

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.

Candidates are to answer:
All questions on the Question Paper.

Write your answers in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue, or correction fluid/tape.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
Total	

This document consists of **29** printed pages and **3** blank pages.

Answer **all** questions.

1 The unicellular fungus *Kluyveromyces lactis* is found in dairy products. It is a safe microorganism to culture for the extraction of the enzyme lactase.

Lactase catalyses the breakdown of lactose, a sugar found in milk.

The reaction catalysed by lactase is summarised in Fig. 1.1.

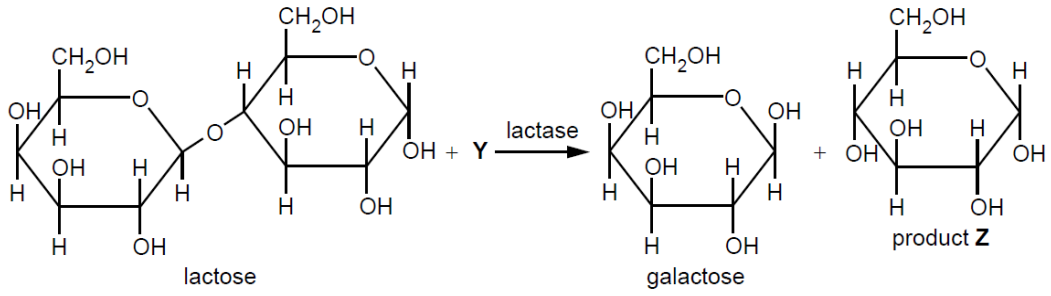


Fig. 1.1

(a) Describe the reaction that is catalysed by lactase. Use Fig. 1.1 to help you. In your answer, identify **Y** and product **Z**. [3]

1. To **hydrolyse glycosidic bond/** β-1,4 glycosidic bond broken R: if bond type is incorrectly named
2. With the **addition of Y: water;**
3. To hydrolyse **lactose to galactose and Z (α-glucose)** R: glucose

(b) On a commercial scale, immobilised lactase can be used to produce lactose-free milk.

One of the products of the reaction shown in Fig. 1.1 acts as an inhibitor of lactase. This is an example of product inhibition.

(i) Suggest why product inhibition is advantageous in *K. lactis* when lactase is acting as an intracellular enzyme but can be a disadvantage when extracted lactase is used free in solution to produce lactose-free milk. [2]

1. Advantage: It allows for homeostatic **control/ maintainance/ efficient** metabolism**;** AVP
   e.g. if, (enough) glucose/ galactose/ monosaccharides, present then no need for, uptake/ breakdown, of lactose avoids osmotic problems as no build-up of monosaccharides
2. Disadvantage: It results in **reduced productivity**/ slows rate of reaction as enzyme is unnecessarily inactivated; AVP

(ii) Suggest how using immobilised lactase for the production of lactose-free milk helps to reduce the problem of product inhibition. [1]

1. products and enzyme kept **separated** OR **product removed immediately;**

(c) When developing an enzyme-catalysed reaction for use in industry, the progress of the reaction is studied to determine the optimal conditions for product formation.

Explain how substrate concentration can affect the rate of an enzyme-catalysed reaction.[4]

1. At low substrate concentration, **substrate concentration is limiting/ the limiting factor**.
2. as substrate concentration increases, there is an **increase** in **frequency of effective collisions between enzymes and substrates** which results in a **higher rate of enzyme-substrate complex formation** as more active sites are occupied by substrates
3. At higher substrate concentration, **enzyme saturation** is reached, where **all active sites are occupied by substrate molecules at any one time**.
4. Thus, **enzyme concentration becomes limiting/ is the limiting factor** and **substrate concentration is no longer limiting**. Further increase in substrate concentration will not cause the rate of reaction to increase further.

[Total: 10]

2 Lysosomes are cell structures that contain acid hydrolases which are enzymes that work best in acidic environments.

Fig. 2.1 shows some processes that occur in neutrophils.

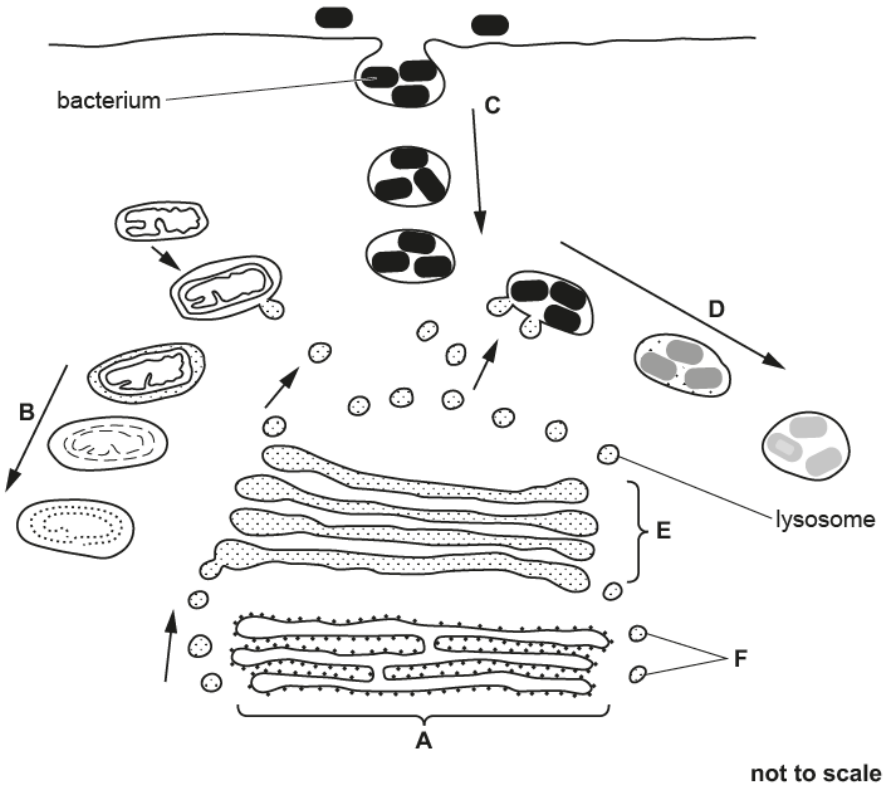


Fig. 2.1

(a) Name the cell structures labelled **A** and **E**. [1]

A - Rough endoplasmic reticulum (R: RER)
E - Golgi apparatus / Golgi body

(b) State the function of **F**. [1]

1. **Transport proteins**, such as **acid hydrolases**, from RER to Golgi apparatus (A: from A to E)
2. **compartmentalize proteins**, such as **acid hydrolases** (idea of separating from the rest of cell).
3. [Any one]

(c) Describe the role of cell surface membrane during process **C**. [3]

1. **Receptors on the cell surface membrane** of neutrophils recognize and **bind to bacteria / antigen / epitope**
   R: (constant region of) antibody on bacteria (opsonization) – not seen in Fig. 2.1
2. **Pseudopodia** of cell surface membrane **wrap around/engulf/enclose bacteria** before **fusing**
3. To **form phagosome/phagocytic vesicle/ vesicle in phagocytosis**

(R: endosome and endocytosis + cell surface membrane invaginates/infolds as neutrophil is a phagocyte)

(d) With reference to the processes occurring at **B** and at **D** in Fig. 2.1, outline the roles of acid hydrolases in lysosomes. [4]

1. Acid hydrolases in lysosomes **hydrolyse/digest/break down/destroy worn out / damaged organelles**, such as mitochondria, in **autophagy**
2. For **biological molecules** to be **recycled or reused** within the cell (OWTTE)
3. Acid hydrolases catalyse **hydrolysis/digestion/break down** of **bacteria**
4. Any named example of acid hydrolase, substrate and bond **(max 2)**: e.g.
   - **Lysozyme hydrolyses glycosidic bonds** in **peptidoglycan cell wall** of **bacteria**
   - **Nuclease hydrolyses phosphodiester bonds** in **bacterial nucleic acids**
   - **Protease hydrolyses peptide bonds** in **bacterial proteins**

   R: digest / break down bond
   R: process antigens into short peptides to be loaded onto MHC protein to form peptide-MHC complex for antigen presentation to naïve T cells (neutrophils are not antigen-presenting cells)
   The acid hydrolases in lysosomes refer to the hydrolytic enzymes found in the acidic internal environment of lysosome.

(e) Carrier proteins in the membranes of lysosomes maintain a lower pH than the surrounding cytoplasm by moving hydrogen ions.

Suggest how the carrier proteins maintain the lower pH within the lysosomes. [1]

1. Pump hydrogen ions / protons into lysosome **against concentration gradient** via **active transport** (R: facilitated diffusion)

[Total: 10]

3 The early development of an animal involves divisions of the zygote and daughter cells by mitosis to form an embryo consisting of genetically identical cells.

Fig. 3.1 shows several cells at different stages of the cell cycle in an embryo of whitefish, *Coregonus artedi*.

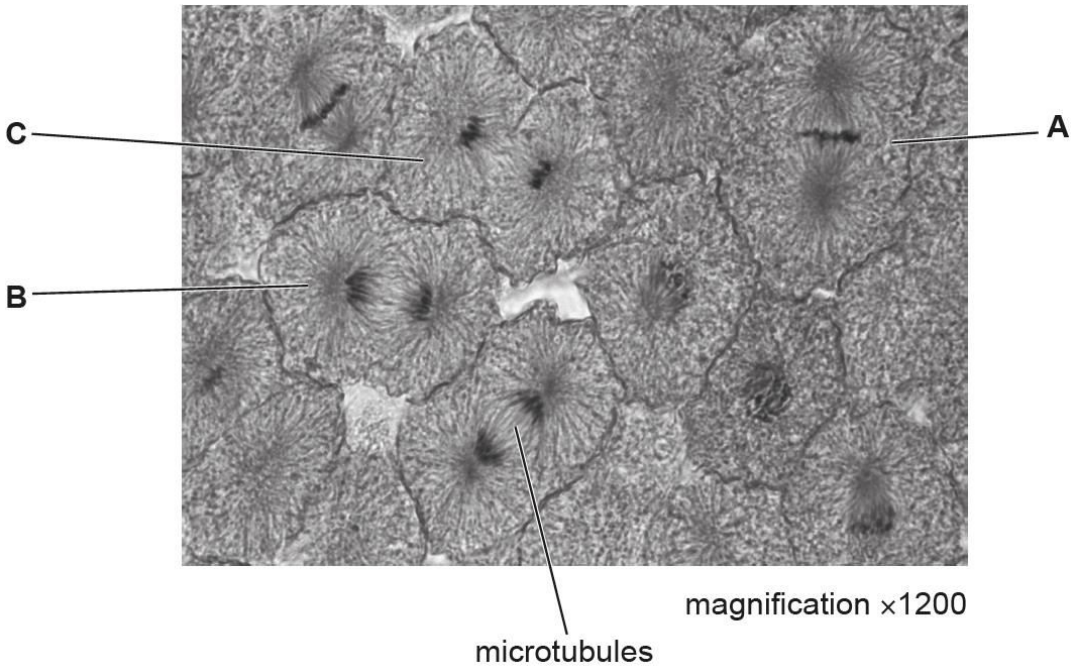


Fig. 3.1

(a) **(i)** Name the stage of mitosis in cell A and in cell C, shown in Fig. 3.1. [2]

A – Metaphase
C – Telophase (NOT anaphase or cytokinesis)

(ii) Describe the role of microtubules in cell B. [2]

1. **Shortening** of **kinetochore microtubules** to **pull daughter chromosomes** (R: sister chromatids) **apart towards opposite poles of cell**
2. **Non-kinetochore microtubules extend** to **elongate the cell**]

(b) Uncontrolled mitosis can cause cancer in humans.
Paclitaxel is a drug used in the treatment of some forms of cancer.

Researchers investigated the effect of Paclitaxel on the mitotic cell cycle of cancer cells.

- The cancer cells were grown for two days and then divided into groups.
- Each group was treated with a different concentration of Paclitaxel.

After 28 hours (one cell cycle):

- the percentage of cells in stages of mitosis was calculated
- the ratio of the number of cells in anaphase to the number of cells in metaphase was determined.

The results of the investigation are shown in Fig. 3.2.

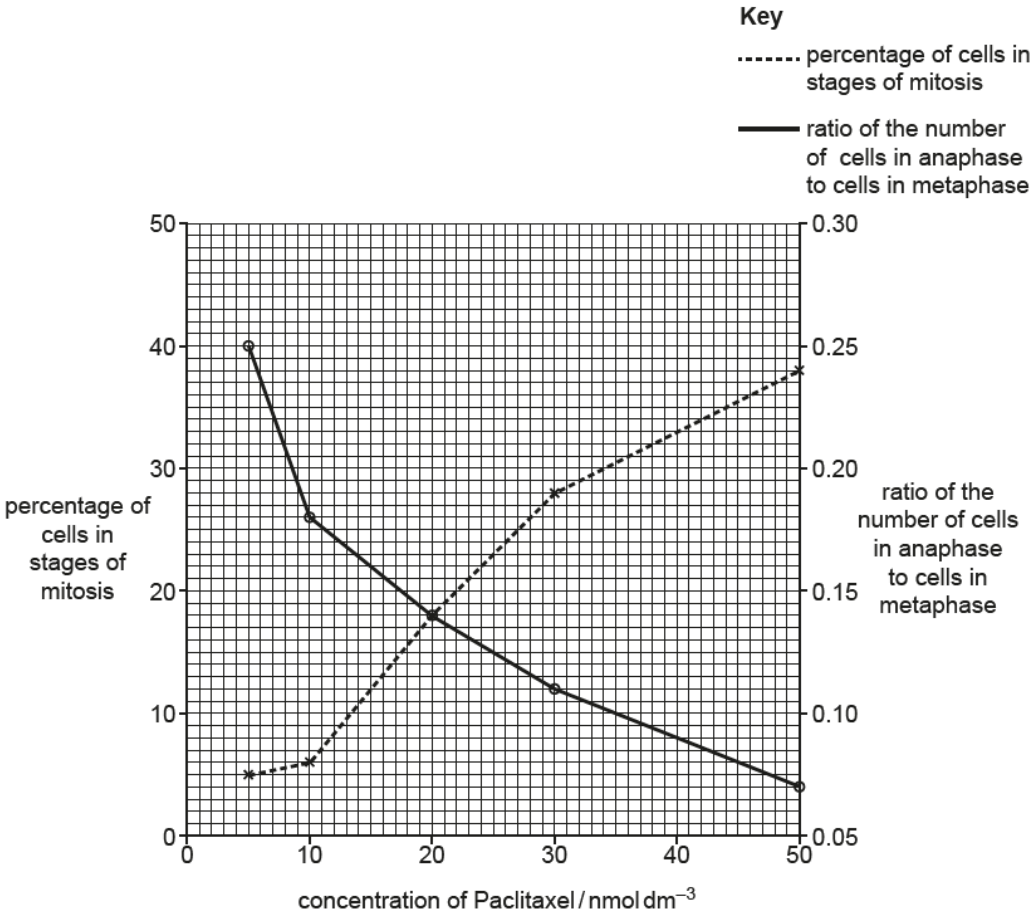


Fig. 3.2

With reference to Fig. 3.2, describe the results and suggest an explanation for the effect of Paclitaxel on the mitotic cell cycle.
[4]

Describe (2m)
1. As **concentration of Paclitaxel increases** from **5 nmol dm^{-3} to 50 nmol dm^{-3}**, **percentage of cells in stages of mitosis increases** from **5% to 38%**
2. and **ratio of the number of cells in anaphase to cells in metaphase decreases** from **0.25 to 0.07**

Explain (2m)
3. **Fewer cells** are able to **move into anaphase from metaphase** (or more cells stop / spend more time in metaphase)
4. **Paclitaxel prevents division** (R: splitting) **of centromeres** OR **shortening of spindle fibres / kinetochore microtubules** OR movement of daughter chromosomes to opposite poles as **cells cannot pass metaphase checkpoint**
5. AVP (e.g. Paclitaxel does not prevent more cells from undergoing mitosis)

(c) Fig 3.3 depicts a model of cancer development from a single abnormal cell.

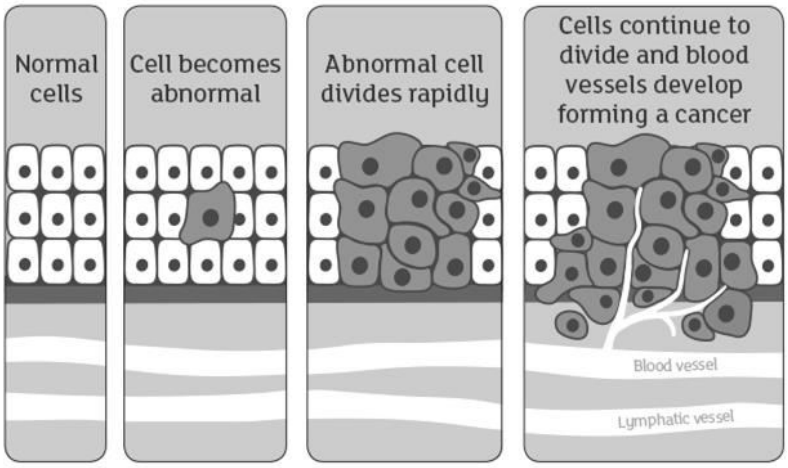


Fig 3.3

Explain what may have led to the development of this abnormal cell from a normal cell before it divides rapidly.
[2]

1. **Loss of function mutation** in **both copies of tumour suppressor gene**;
2. **Gain of function mutation** in **proto-oncogene**;
3. **Accumulation of mutations** in **genes involved in regulation of cell cycle checkpoints** (A: proto-oncogenes and tumour suppressor genes)

[Any 2]

[Total: 10]

4 In typical cells, nucleic acids are synthesised from eight different nucleotides.

Fig. 4.1 represents the three different components of a nucleotide.

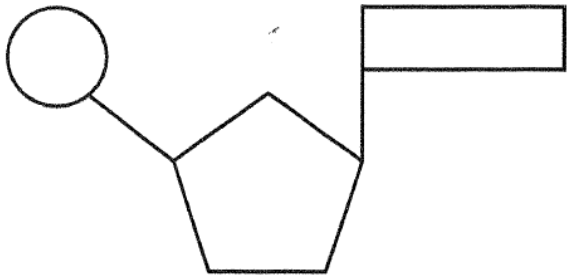


Fig. 4.1

(a) Describe how differences in these components result in the eight different nucleotides from which nucleic acids are synthesised. [2]

1. Pentose sugar in deoxyribonucleotides is **deoxyribose** while pentose sugar in ribonucleotides is **ribose**;
2. There are 4 possible deoxyribonucleotide **bases** which are **adenine**, **cytosine**, **guanine** and **thymine**, while there are 4 possible ribonucleotide **bases** which are **adenine**, **cytosine**, **guanine** and **uracil**; (A: use of abbreviation after spelling out in full first)
3. resulting in **4** different **deoxyribonucleotides** in **DNA** and **4** different **ribonucleotides** in **RNA**

[Any two]

Fig. 4.2 shows the sequence of bases in a section of a single-stranded RNA virus. The bases code for the first few amino acids of a polypeptide chain.

5' UACAUGGAUUACCCCGUUGUACAU 3'
Fig. 4.2

Each codon codes for a specific amino acid as shown in Table 4.1.

Table 4.1

UUU	phe	UCU	ser	UAU	tyr	UGU	cys
UUC	phe	UCC	ser	UAC	tyr	UGC	cys
UUA	leu	UCA	ser	UAA	STOP	UGA	STOP
UUG	leu	UCG	ser	UAG	STOP	UGG	trp
CUU	leu	CCU	pro	CAU	his	CGU	arg
CUC	leu	CCC	pro	CAC	his	CGC	arg
CUA	leu	CCA	pro	CAA	gln	CGA	arg
CUG	leu	CCG	pro	CAG	gln	CGG	arg
AUU	ile	ACU	thr	AAU	asn	AGU	ser
AUC	ile	ACC	thr	AAC	asn	AGC	ser
AUA	ile	ACA	thr	AAA	lys	AGA	arg
AUG	met	ACG	thr	AAG	lys	AGG	arg
GUU	val	GCU	ala	GAU	asp	GGU	gly
GUC	val	GCC	ala	GAC	asp	GGC	gly
GUA	val	GCA	ala	GAA	glu	GGA	gly
GUG	val	GCG	ala	GAG	glu	GGG	gly

(b) Using information from Fig. 4.2 and Table 4.1,

(i) State the third amino acid coded by the section shown in Fig. 4.2 if the virus was a positive-sense RNA virus. [1]

Tyrosine / tyr

5' UAC AUG GAU **UAC** CCC GUU GUA CAU 3' – (+)sense RNA (viral mRNA)
5' UAC AUG GAU **UAC** CCC GUU GUA CAU 3' – ribosomes translate from 5' to 3'
*met – asp – **tyr** – pro – val – val – his*

(ii) State the fourth amino acid coded by the section shown in Fig. 4.2 if the virus was a negative-sense RNA virus. [1]

Glycine / gly

3' UAC AUG UUG **CCC** CAU UAG GUA CAU **5'** – (-)sense RNA
5' AUG UAC AAC **GGG** GUA AUC CAU GUA **3'** – complementary (+) sense RNA
5' AUG UAC AAC **GGC** GUA AUC CAU GUA 3' – ribosomes translate from 5' to 3'
*met – tyr – asn – **gly** – val – ile – his – val*

A series of mutations has occurred, causing all the cytosine of the single-stranded RNA virus in Fig. 4.2 to be replaced with guanine.

Assuming that the average mass of each amino acid is 100 Da,

(iii) Estimate the mass of the entire polypeptide translated from the mutated virus if the virus was a positive-sense RNA virus. [1]

2 x 100 = **200 Da** (must include units);

5' UAG AUG GAU UAG GGG GUU GUA GAU 3' – (+)sense RNA
5' UAG AUG GAU **UAG** GGG GUU GUA GAU 3' – ribosome translate from 5' to 3'
met – asp STOP (UAG is stop codon)

(c) Some non-coding DNA can only be found in eukaryotic chromosome but not in prokaryotic chromosome.

Suggest possible roles for non-coding DNA that are not involved in regulation of gene expression in eukaryotic chromosome. [2]

Centromeres:
1. Enable **sister chromatids** to **adhere** to each other
2. Site of **kinetochore** **assembly** for **attachment of spindle fibres** at kinetochore

Telomeres:
3. **Prevent erosion of genes / loss of vital genetic** with shortening of DNA after **each round of DNA replication**
4. Serves as a **signal for apoptosis** when they are **critically short / reach critical length**
5. **Stabilise the terminal ends** of chromosomes and **prevent fusion** with other chromosomes

(d) In a typical human cell, the percentage of each type of RNA is:

mRNA 3%
tRNA 15%
rRNA 80%
others 2%

Suggest explanations for the different percentages of mRNA, tRNA and rRNA.

mRNA [1]
The **lower** % of mRNA at **3%** is due to
1. its **transient nature** as mRNA is **synthesized only when needed** for translation/protein synthesis, and then **degraded quickly**
   OR
2. Its **unfolded nature** also means that it is **more susceptible to degradation** by nucleases

tRNA [1]

The **higher** % of tRNA at **15%**

3. reflects its **continuous need during translation** to **transport amino acids to the ribosome**
   OR
4. Its **folded nature** (clover leaf shaped) also means that it is **less susceptible to degradation** by nucleases

rRNA [1]

The **highest** % of rRNA at **80%**

5. reflects the **abundance of rRNA as a major component of ribosomes** in cells and their crucial role in protein production
   OR
6. Its **folded nature** and **association with ribosomal proteins** also means that it is **protected** from nucleases

[Total: 10]

5 Fig. 5.1 shows a human immunodeficiency virus (HIV) particle about to attach to the cell surface membrane of a T-helper cell at a receptor protein called CD4. A second protein (coreceptor) called CCR5 is also necessary for the virus particle to enter and then infect the T-helper cell.

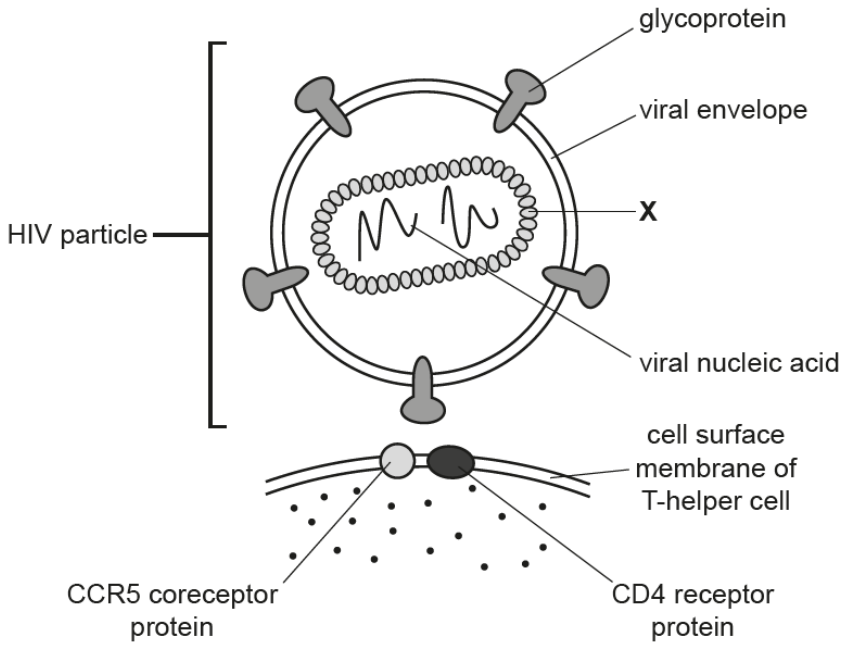


Fig. 5.1

(a) Identify structure labelled **X**. [1]

Capsid (R: capsomere / protein coat / nucleocapsid)

Fig. 5.2 shows the 4 stages of how a HIV particle enters the T-helper cell.

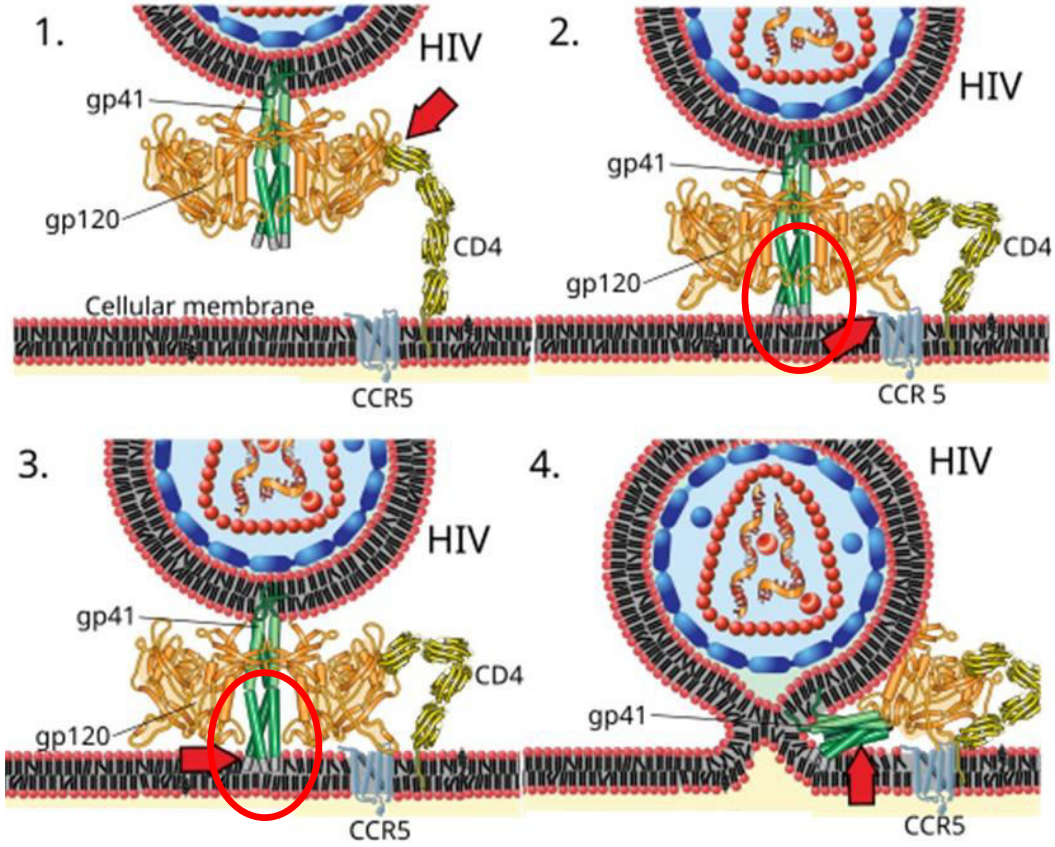


Fig. 5.2

(b) Studies have shown that some individuals did not become infected with HIV even though they were repeatedly exposed to the virus. Later discoveries indicated that these individuals had a mutation in the gene for the CCR5 coreceptor protein.

With reference to Fig. 5.2, explain how mutation of the gene for the CCR5 coreceptor protein provided protection against HIV infection. [3]

1. **gp120** becomes **no longer complementary** in **conformation** and **charge** to **binding site** of **CCR5 coreceptor**;
2. **gp41 cannot** be **inserted** / penetrated / embedded into (phospholipid bilayer of) **T-helper cell surface membrane (A: cell membrane / cellular membrane)**
3. **HIV cannot enter** the **T-helper cell** via **fusion of viral envelope with cell surface membrane** after 6-helix bundle formation of gp41**;**

(c) Acquired Immunodeficiency Syndrome (AIDS) refers to a series of symptoms and illnesses caused by HIV. There can be a latent period of up to ten years between infection and the onset of symptoms.

State **two** enzymes found in HIV and describe how they contributed to the occurrence of latency.
[5]

1. **reverse transcriptase**;
2. **synthesizes** a **DNA strand** **complementary** to the **viral** **RNA strand** to **form** a **RNA-DNA hybrid**
3. **RNA strand** will be **degraded** and a second **DNA strand** **complementary** to the first one is **synthesized** to **form** a **double-stranded viral DNA**
4. **integrase**;
5. **integrates** double-stranded **viral DNA/genome** **into** **host DNA/genome** **to form provirus**;

(d) Name a bacteriophage that also undergoes latency in its reproductive cycle. [1]

Lambda / λ phage (R: *just* lambda)

[Total: 10]

6 The fruit fly, *Drosophila melanogaster*, has autosomal genes for body colour and wing shape.

Gene **B/b** is involved in the production of body colour:

- **B** = dominant allele for brown body colour
- **b** = recessive allele for black body colour

Gene **D/d** is involved in wing shape:

- **D** = dominant allele for straight wing
- **d** = recessive allele for curved wing

A dihybrid test cross was carried out between flies heterozygous for body colour and for wing
shape and flies homozygous recessive for body colour and for wing shape.

(a) Table 6.1 shows the number of offspring of each phenotype obtained in the test cross.

Table 6.1

Phenotype	Observed number	Expected number
Brown body colour, straight wings	2843	1827
Brown body colour, curved wings	855	1827
Black body colour, straight wings	842	1827
Black body colour, curved wings	2768	1827

Use Table 6.1 to calculate the expected number of each phenotype. Write your answers in the table. [1]

(b) A chi-squared (χ^2) test was carried out to compare the observed results with the results that would be expected from a dihybrid cross involving genes on different autosomes.

The value of χ^2 = 2097.836.

Table 6.2 shows the critical values for the χ^2 distribution.

Table 6.2

Degrees of freedom	p value		
	0.05	**0.01**	**0.001**
1	3.841	6.635	10.828
2	5.991	9.210	13.816
3	7.815	11.345	16.266
4	9.488	13.277	18.467

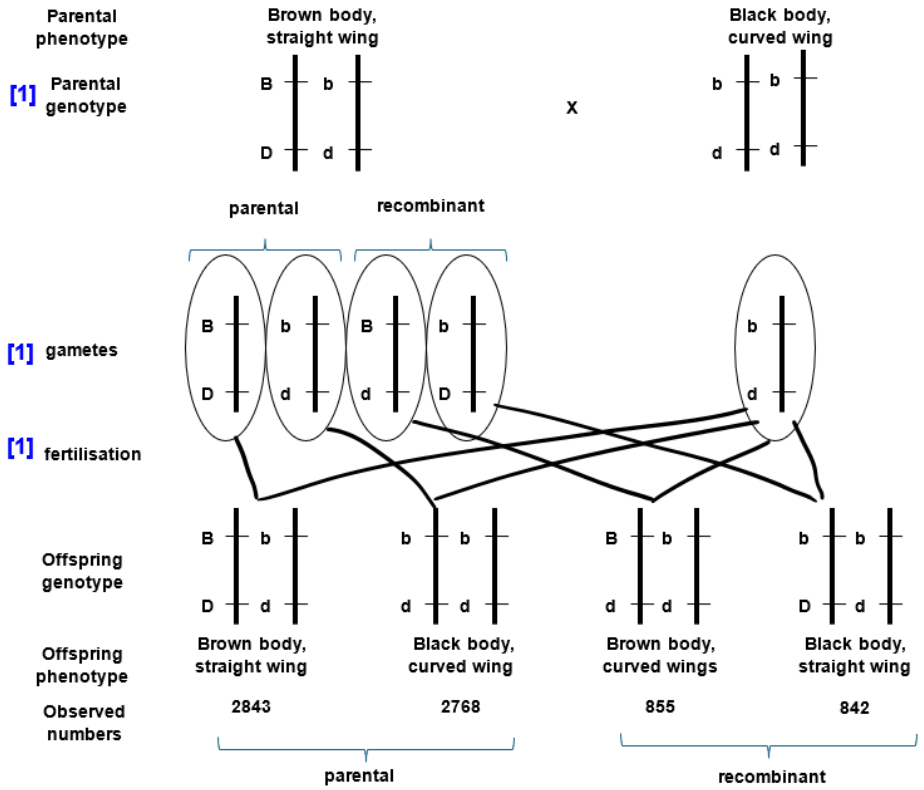
Explain how the value of χ^2 and Table 6.2 can be used to assess the significance of the difference between the observed results and the expected numbers in Table 6.1. [3]

1. The chi-squared calculated value of 2098 and **degree of freedom = 3** means **p < 0.05**.
2. Since p<0.05, at a **level of significance of 5%** we **reject the null hypothesis** that states that the expected results and observed results are not significantly different;
3. Thus, there is a **significant difference between** the **expected and observed results** and **the difference is due to some factor other than random chance**.

(c) State the type of inheritance observed in Table 6.1. [1]

1. autosomal linkage R: linkage, A: gene linkage, linked genes

(d) Draw a genetic cross to explain the observed results in Table 6.1.



[1] for correct genotypes linked to phenotypes

[1] for observed offspring numbers, and "parental" and "recombinant" types indicated

[5]

[Total: 10]

7 Extended periods of stress can cause the buildup of adenosine molecules in brain tissue.

Adenosine is a ligand that binds to a G protein-coupled receptor on brain cells. The subsequent downstream signalling response of adenosine is illustrated in Fig 7.1 below.

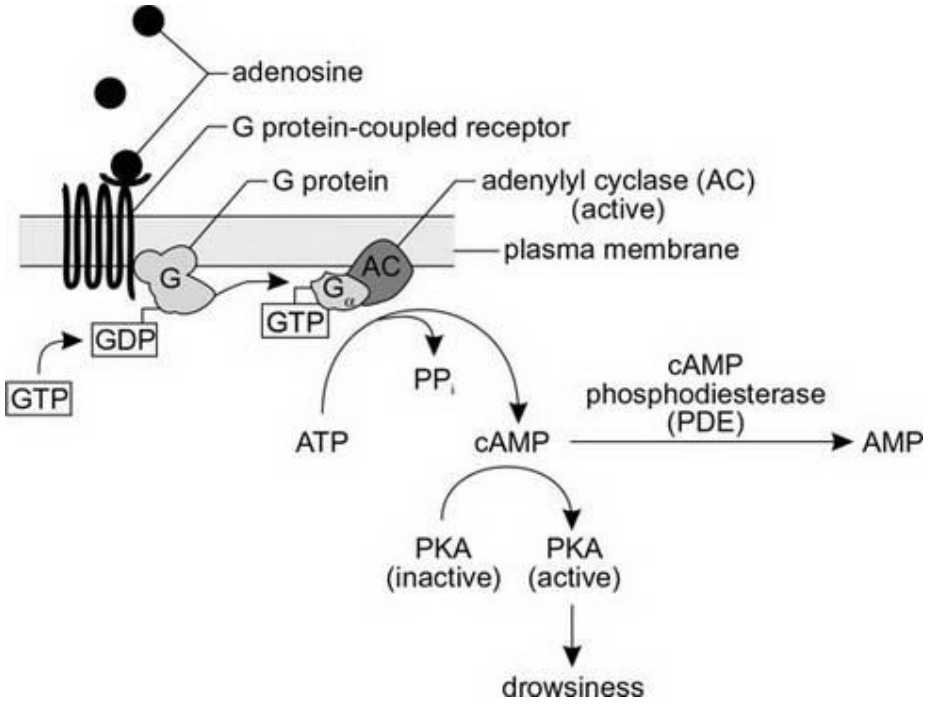


Fig. 7.1

(a) Describe how the structure of G protein relates to its function. [2]

1. It contains a **G-protein-coupled receptor binding site** so that an **inactive G protein can bind to it and be activated;**
2. It also contains a **GTPase active site** that is **complementary in conformation and charge** to **GTP** to catalyse the conversion of **GTP** to **GDP, inactivating it**;
3. It contains **amino acids** with **hydrophobic R groups** on its exterior of transmembrane domain that allows it to associate with the **hydrophobic core/ fatty acid tails/ hydrocarbon chains** of the phospholipid bilayer of cell surface membrane;

(b) A single adenosine molecule can induce a large cellular response. With reference to Fig.

7.1, explain why this is possible. [2]

1. **Signal amplification** can occur
2. Example
   Conversion of **ATP to cAMP** by **adenylyl cyclase** where **each adenylyl cyclase / enzyme produces many molecules of cAMP;**

OR

PKA will **phosphorylate the next protein** in the pathway where **one PKA molecule can activate many proteins in the next step;**

OR

Activation of G protein by **ligand/adenosine binding to receptor** **where one ligand/adenosine binding to the GPCR can activate many G proteins;**

(R: cAMP phosphodiesterase (PDE) converting cAMP to AMP)

The cellular response to cAMP varies widely in different types of cells. In brain cells and other cells of the central nervous system, cAMP activates a Protein Kinase A (PKA), which slows brain activity and causes drowsiness.

Normally, cAMP concentrations in the cell are kept low by the enzyme cAMP phosphodiesterase (PDE), converting cAMP to regular AMP (not cyclic). But high levels of cAMP can be attained during periods of mental fatigue or other kinds of stress.

Caffeine is an adenosine signaling antagonist, blocking the effect of adenosine. Fig. 7.2 shows the structures of adenosine and caffeine.

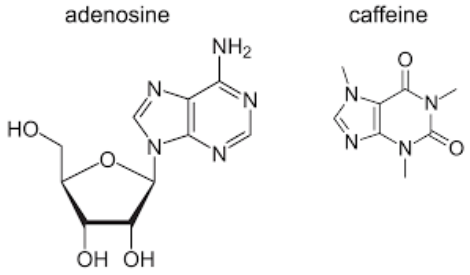


Fig. 7.2

(c) With reference to Fig. 7.1 and Fig. 7.2, explain the effect of excessive consumption of caffeinated drinks on an individual. [4]

1. The **structure of caffeine is similar to** (part of) the **structure of adenosine;**
2. Hence both molecules are **complementary in conformation and charge** to the **ligand binding site** of the **G-protein coupled/ adenosine receptor;** (note to marker: accept shape)
3. With excessive caffeine consumption, there will be a **high level of caffeine** in the body thus **caffeine is more likely to bind to the receptor and prevent adenosine from binding to it /caffeine competes with adenosine for binding to receptor;**
4. Hence the **adenosine signalling pathway is not initiated** (no activation of G protein, no activation of adenylyl cyclase, no production of cAMP, PKA is not activated)
5. **Drowsiness does not occur;**

(d) Mutations can occur in adenylyl cyclase (AC) which results in a constitutively active adenylyl cyclase enzyme. With reference to Fig. 7.1, explain why individuals suffering from such mutations are not allowed to operate heavy machinery.

[2]

1. A constitutively active adenylyl cyclase will catalyse the **excessive conversion** of **ATP to cAMP**
2. Hence **cAMP levels will increase further** which in turn will **activate PKA**, causing **excessive drowsiness** and can **pose a safety threat** to others when operating heavy machinery. (A: compromise of safety)

[Total:10]

8 Fig. 8.1 shows a transmission electron micrograph of part of a chloroplast.

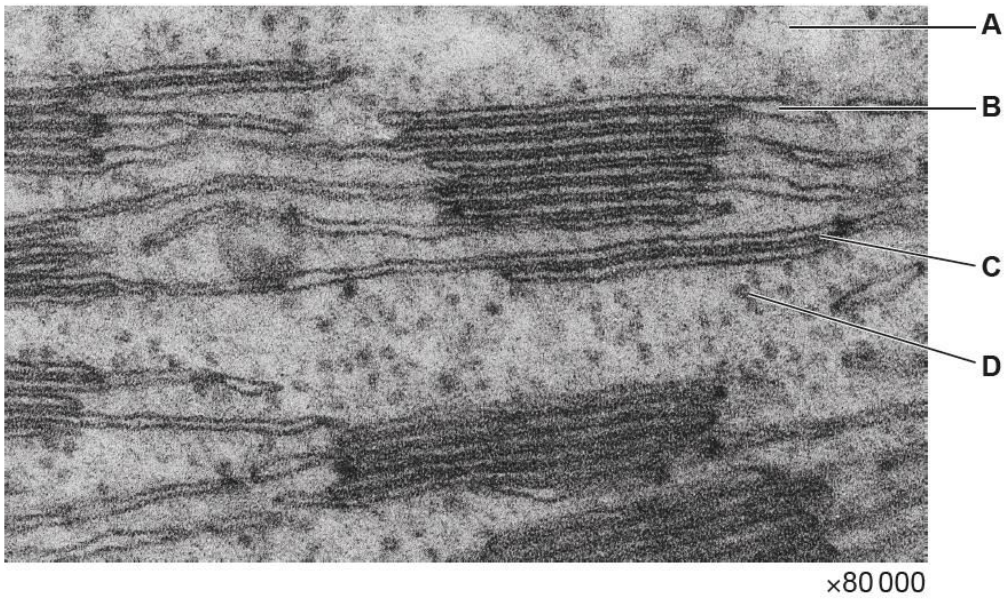


Fig 8.1

(a) Identify structures **C** and **D**. [2]

C: intergranal lamellae (R: thylakoid)
D: ribosome

(b) Explain why membrane **C** has many different coloured pigments to function efficiently. [3]

1. The coloured pigments are photosynthetic pigments such as **chlorophylls a and b and carotenoids**;
2. which are able to **absorb light energy at various wavelengths, thus increasing the range of wavelengths of light absorbed**;
3. Hence allowing **photosynthesis / light dependent reaction** to function efficiently;

(c) Fig. 8.2 is a diagram of a section through a mitochondrion.

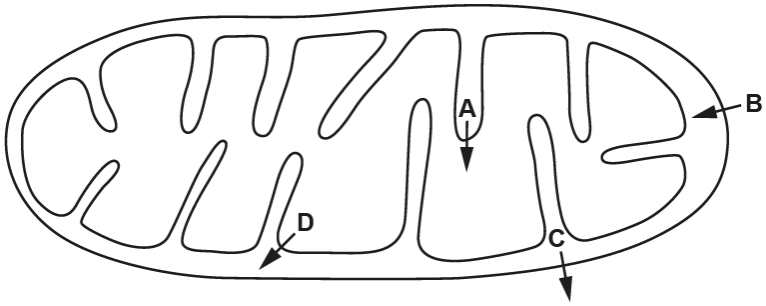


Fig 8.2

The four arrows, **A**, **B**, **C** and **D**, show the movement of molecules and ions.

Use the letters to identify **all** the arrows (one or more) that show:

(i) active transport of protons **D** [1]

(ii) diffusion of carbon dioxide **C & D** [1]

(d) Cyclical processes such as the Calvin cycle and Kreb cycle occur in during photosynthesis and respiration respectively.

Distinguish between these two cyclical processes. [3]

		Calvin Cycle	Kreb cycle
1	Location	**Stroma of chloroplast**	**Matrix of mitochondrion**
2	Substrate	**Carbon dioxide and RuBP**	**Acetyl CoA and oxaloacetate**
3	Products	For every **3 carbon dioxide**, one **Glyceraldehyde-3-phosphate/ Triose Phosphate** is formed	Each glucose gives rise to 2 **ATP**, 2 **$FADH_2$**, 6 **NADH**, 4 **carbon dioxide**
4	Compound regenerated	RuBP	Oxaloacetate
5	Fate of ATP	ATP is **used** during **reduction of Glycerate Phosphate /PGA and regeneration of RuBP**	ATP is **produced** via **substrate-level phosphorylation**
6	**Electron carriers / donors**	Uses **NADPH / reduced $NADP^+$** to **reduce** glycerate-3-phosphate to triose phosphate by serving as **electron donors**	Use **NAD^+ and FAD** for the **oxidation** of the intermediates of the cycle by serving as **electron acceptors**
7	**Role of CO_2**	Required for **carbon fixation**. CO_2 is used to **convert Ribulose bisphosphate (RuBP) to form an unstable 6C compound** that breaks down to form glycerate-3-phosphate	CO_2 is **released** as a result of **decarboxylation** reactions
8	**Role of O_2**	Does not require O_2	Occurs only when O_2 is present

[Any 3]

R: catabolic vs anabolic (too generic)

[Total: 10]

9 The sea blush, *Plectritis congesta*, is a flowering plant that grows on the west coast of North America.

Individual sea blush plants produce fruit that is either winged or wingless. Investigations have shown that this characteristic is controlled by a single gene with two alleles:

- a dominant winged fruit allele
- a recessive wingless fruit allele.

Fig. 9.1 shows the difference in structure between winged fruit and wingless fruit phenotypes.

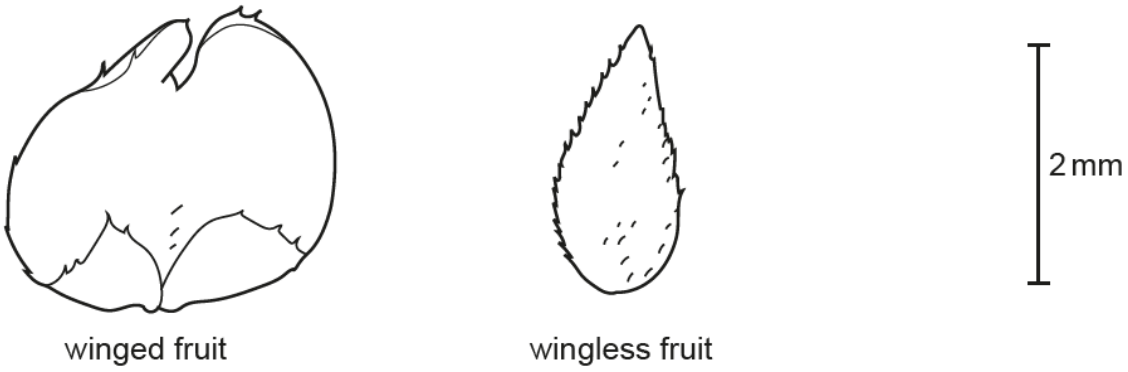


Fig 9.1

(a) A large sample of sea blush fruits was collected and their fruit-wing characteristic was recorded.

Name the type of variation that is shown for the fruit-wing characteristic of the sea blush. [1]

1. **Discontinuous variation**

(b) Early taxonomists classified sea blush plants with winged fruits as a different species to sea blush plants with wingless fruits.

Since this time, evidence from observations and experiments has confirmed that the plants belong to the same species.

Suggest **three** examples of the evidence obtained that helped to confirm that these sea blush plants belong to the same species. [3]

1. Ability of plants to **interbreed** to produce **fertile viable offspring**
2. Plants occupy the **same/ overlapping ecological niche**
3. **Similarity** in **morphology** (beyond fruit wing, shape, etc.) due to **inheritance from a common ancestor**/ **homologous structures**
4. **Similarity** in **molecular sequences** which include DNA, RNA and protein

[Any 3]

The west coast of North America also used to have an extensive lake system.

Approximately 20 000 years ago, the lakes started to dry up and they now consist of isolated small pools. Four different species of the desert pupfish have been found living in these pools. Evidence indicates that over 20 000 years ago, there was only one species of pupfish living in the lake system.

Fig. 9.2 shows a desert pupfish.

Fig 9.2

(c) Explain how the change from an extensive lake system to just a few pools could have resulted in the evolution of four species of desert pupfish. [4]

1. The **pools** are **geographically isolated** as they are broken up by **land/ shallow water** that acts as a physical barrier preventing interbreeding. This results in the **disruption of gene flow;**
2. Different pools will present **different selection pressures** and **individuals best adapted to the environment (or individuals with favourable trait)** will have a
3. **selective advantage** and will be **selected for** (or **more likely to survive and reproduce**). Their **alleles will be passed on to the next generation**, thus **increasing the frequency of favourable alleles.**
4. Over **many generations,** each population of pupfish **evolve independently on different islands** with change in allele frequencies due to **natural selection**, **genetic drift** and **accumulation of genetic mutations**.
5. The different populations became **reproductively isolated** / **can no longer interbreed to produce viable, fertile offspring**, resulting in **allopatric speciation**.

[Any 4]

(d) Due to the different soil composition of the various pools, the nutrient content of the pools may differ. Table 9.1 shows the length of pupfish in two different lake pools A and B.

Table 9.1

No.	Lake pool A	Lake pool B
1	22.9	13.7
2	19.8	18.2
3	24.4	17.5
4	27.9	15.1
5	23.1	21.6
6	25.7	19.2
7	28.2	21.6
8	25.6	24.8
9	28.7	25.2
10	31.5	27.8
11	26.2	25.2
12	37.0	34.0
	Mean = 26.75	Mean = 21.99

A research scientist was interested in finding out if the nutrient content of the lake pools influenced the length of pupfish and decided to carry out a t-test analysis.

Given that the t-test value is 2.26, examine the data in Table 9.1 and use the information given in Table 9.2 on the next page to decide whether the nutrient content of the different pools affected the length of pupfish. [2]

1. With **degrees of freedom** (v) = 12 + 12 - 2 = **22**, **0.02 < p < 0.05;**
2. Since **p < 0.05 at 5% level of significance, we reject the null hypothesis**. There is **significant difference** between the length of pupfish in lake pools A and B. Hence the **nutrient content does have an influence on the length of pupfish**.

Table 9.2

Degrees of freedom	Significance level					
	20% (0.20)	10% (0.10)	5% (0.05)	2% (0.02)	1% (0.01)	0.1% (0.001)
1	3.078	6.314	12.706	31.821	63.657	636.619
2	1.886	2.920	4.303	6.965	9.925	31.598
3	1.638	2.353	3.182	4.541	5.841	12.941
4	1.533	2.132	2.776	3.747	4.604	8.610
5	1.476	2.015	2.571	3.365	4.032	6.859
6	1.440	1.943	2.447	3.143	3.707	5.959
7	1.415	1.895	2.365	2.998	3.499	5.405
8	1.397	1.860	2.306	2.896	3.355	5.041
9	1.383	1.833	2.262	2.821	3.250	4.781
10	1.372	1.812	2.228	2.764	3.169	4.587
11	1.363	1.796	2.201	2.718	3.106	4.437
12	1.356	1.782	2.179	2.681	3.055	4.318
13	1.350	1.771	2.160	2.650	3.012	4.221
14	1.345	1.761	2.145	2.624	2.977	4.140
15	1.341	1.753	2.131	2.602	2.947	4.073
16	1.337	1.746	2.120	2.583	2.921	4.015
17	1.333	1.740	2.110	2.567	2.898	3.965
18	1.330	1.734	2.101	2.552	2.878	3.922
19	1.328	1.729	2.093	2.539	2.861	3.883
20	1.325	1.725	2.086	2.528	2.845	3.850
21	1.323	1.721	2.080	2.518	2.831	3.819
22	1.321	1.717	2.074	2.508	2.819	3.792
23	1.319	1.714	2.069	2.500	2.807	3.767
24	1.318	1.711	2.064	2.492	2.797	3.745
25	1.316	1.708	2.060	2.485	2.787	3.725
26	1.315	1.706	2.056	2.479	2.779	3.707
27	1.314	1.703	2.052	2.473	2.771	3.690
28	1.313	1.701	2.048	2.467	2.763	3.674
29	1.311	1.699	2.043	2.462	2.756	3.659
30	1.310	1.697	2.042	2.457	2.750	3.646
40	1.303	1.684	2.021	2.423	2.704	3.551
60	1.296	1.671	2.000	2.390	2.660	3.460
120	1.289	1.658	1.980	2.158	2.617	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.291

[Total: 10]

10 Measurements of the surface temperature of land and oceans can be taken from locations around the world. The mean global surface temperature for land and ocean combined can be calculated for a fixed time period.

Scientists calculated:

- the mean global temperature for the twentieth century
- the mean global temperature for each decade (ten years) from 1880 to 2020.

The mean temperature for each decade was compared to the mean for the twentieth century.
For each decade, the difference in temperature was calculated.

The calculated differences are shown in Fig. 10.1.

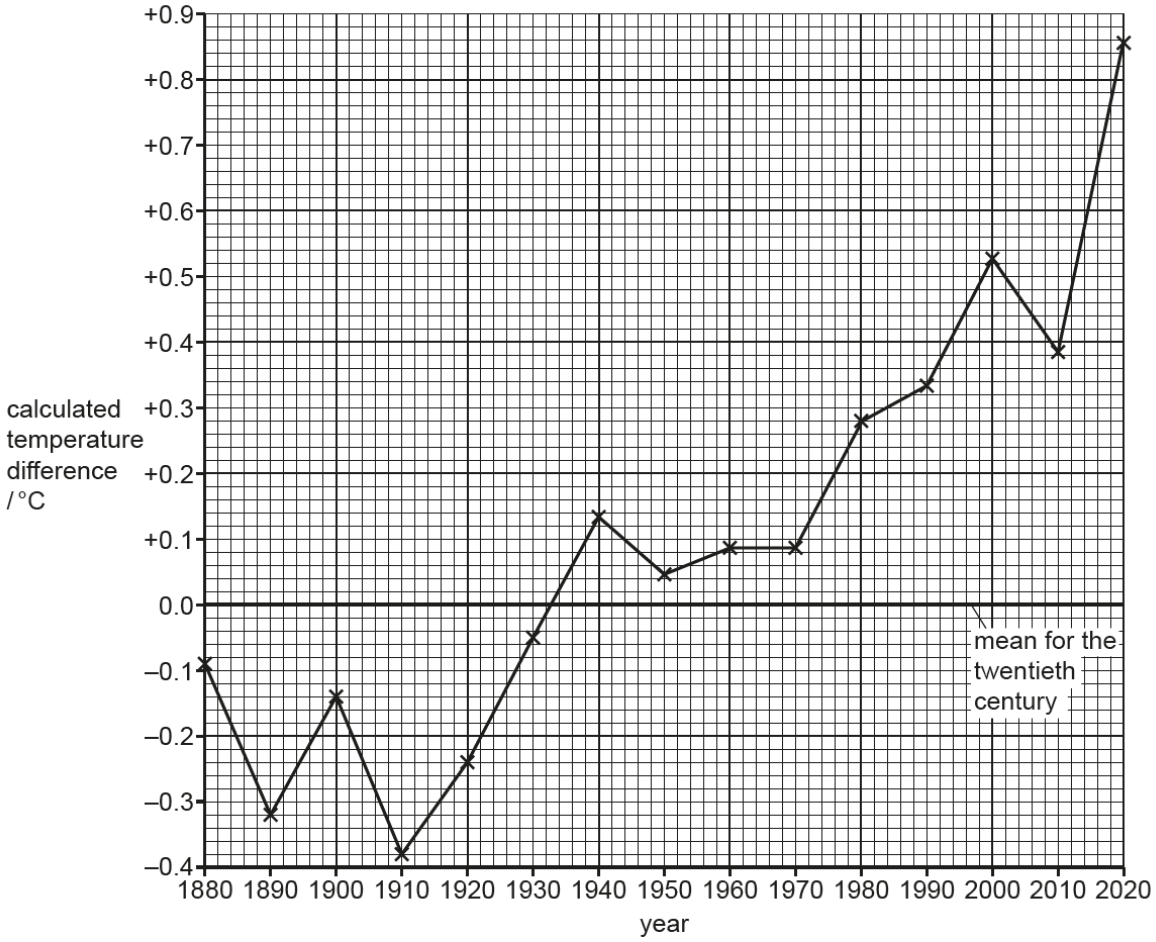


Fig. 10.1

(a) Calculate the rate of increase in temperature per **decade** between 1980 and 2020.

Show your working.

Write your answer to **two** decimal places.

$\frac{0.86 - 0.28}{4}$ **or** $\frac{0.58}{4}$; OR $\frac{0.85 - 0.28}{4}$ **or** $\frac{0.57}{4}$;

0.15 ; 0.14 ;

1. Correct working
2. Correct answer to 2 d.p. (allows ecf)

answer **0.15** / **0.14** °C per decade [2]

(b) The moose, *Alces alces*, is a large member of the deer family. It lives in temperate forests in North America and northern Europe, where snow is present for large parts of the year. The moose feeds on a plant in the lake called watermilfoil, *Myriophyllum aquaticum*.

Fig. 10.2 shows an adult male moose feeding in a lake.

Fig. 10.2

Moose populations have decreased in North America since 1980.

Suggest **and** explain reasons for the decrease in moose populations. [3]

Compulsory point
1. This could be due to **global warming**, which resulted in

Any two from below:
2. **less watermilfoil**, hence **less food** for the moose / **increased competition** due to **limited food** sources
3. **less snow cover** hence **more predation** (any one)
4. **loss of habitat** / **deforestation** hence **more predation** / **less food**
5. surfacing of (new) **disease** (with a **named example** e.g. from melting of permafrost) hence **more death**

[Total: 5]

11 Cells of the immune system respond to the presence of non-self antigens.

(a) State what is meant by a non-self antigen. [1]

1. foreign **protein** that **stimulates an immune response** / **production of antibodies** / **activation of lymphocytes** (Any one)
   (A: glycoprotein / polysaccharide / molecule / **foreign** substance / **foreign** antigen)

(b) Four different types of cells of the immune system are shown in Table 11.1.

Complete Table 11.1:
- use a tick (✓) if the description applies to the named cell of the immune system
- use a cross (✗) if the description does **not** apply.

Table 11.1

description of cell	cell of immune system		
	B-lymphocyte	**plasma cell**	**T-helper cell**
able to undergo differentiation to become effector cells	✓	✗	✗
main role is to secrete cytokine during an immune response	✗	✗	✓
present during a **primary** immune response to a virus	✓	✓	✓

each correct column one mark

[3]

(c) Some vaccination programmes have been more successful than others.

Suggest **one** factor that contribute to the success of a vaccination programme. [1]

1. idea that **reaching enough of the population** to give **herd immunity**.
2. **vaccinating** children **early enough** in their lives / **before** the **time when they are most at risk** (OWTTE).
3. **long duration of protection** given by vaccine / artificial immunity
4. **little / no mutation** of pathogen (to evade vaccine)
5. **ability to change vaccine in response to changing strain**(s) of pathogen (OWTTE)
6. **long shelf life** of vaccine / **stable vaccine** e.g. in high temperatures
7. AVP (A: accessibility / cost)

[Any 1]

[Total: 5]