NAME : _____ CLASS : _____

JURONG PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination 2024

BIOLOGY
Higher 2

9744/02
27 August 2024

Paper 2 Structured Questions

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your class and name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

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 **19** printed pages and **1** blank page.

Section A

Answer **all** questions

1 (a) Fig. 1.1 shows a single-celled organism called *Chlamydomonas*.

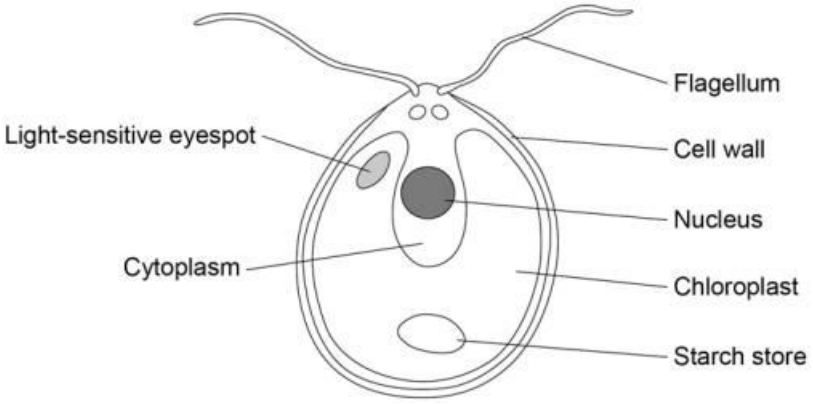


Fig. 1.1

(i) Name **two** structures that could be present inside the nucleus.

[2]

1. **nucleolus ;**
2. **DNA / rRNA / mRNA / chromatin / nucleosome / histones / ribosomal subunits**

(ii) *Chlamydomonas* lives in freshwater ponds. It uses its flagella to swim towards light of moderate intensity but away from very bright light.

Using information in Fig. 1.1, explain the advantage of this behaviour.

[2]

1. **(compulsory) Presence of chloroplast in Chlamydomonas, allowing Chlamydomonas to photosynthesise ;**
2. **moves to optimum/best light intensity for photosynthesis ;**
   OR
3. **avoids damage to photosynthetic pigments due to very bright light ;**

(iii) Oligosaccharides are carbohydrates that contain three to ten monomers in their chain. *Chlamydomonas* use oligosaccharides to synthesise glycoproteins, which are transported to cell surface membranes.

Describe the roles of the rough endoplasmic reticulum and the Golgi body in synthesising glycoproteins.

[2]

rough endoplasmic reticulum

1. **Site of polypeptide/protein synthesis ;**
2. **polypeptide folding (in lumen and packaged in transport vesicles to Golgi body);**
   A protein folding

Golgi body

3. **protein is further modified, sorted and packaged (into secretory vesicles in the lumen/cisternal space of Golgi body) ;**

rough endoplasmic reticulum or Golgi body

4. **Proteins will undergo biochemical modifications including phosphorylation / glycosylation / attachment of, oligosaccharide / polysaccharide / carbohydrate ;**

(b) A Chlamydomonas cell has two flagella. These flagella contain a single type of protein. A flagellum consists of a bundle of 242 filaments. Each filament consists of 7500 protein molecules. Each protein molecule contains 900 amino acid units.

In an investigation, a culture of Chlamydomonas was treated in a way that caused them to lose their flagella without any other damage to the cells. The flagella grew back to their original length in 60 minutes.

How many amino acid molecules would be incorporated into each growing flagellum per minute?

Show your working.

amino acid molecules incorporated $= \frac{242\ x\ 7500\ x\ 900}{60}$;
$= 27\ 225\ 000$

amino acid molecules incorporated per minute 27 225 000 ;

[2]

(c) The researchers investigated the rate at which the flagella grew in two different media.

1 a medium containing puromycin, which prevents translation by attaching to ribosomes

2 a control medium

The results are shown in Fig. 1.2.

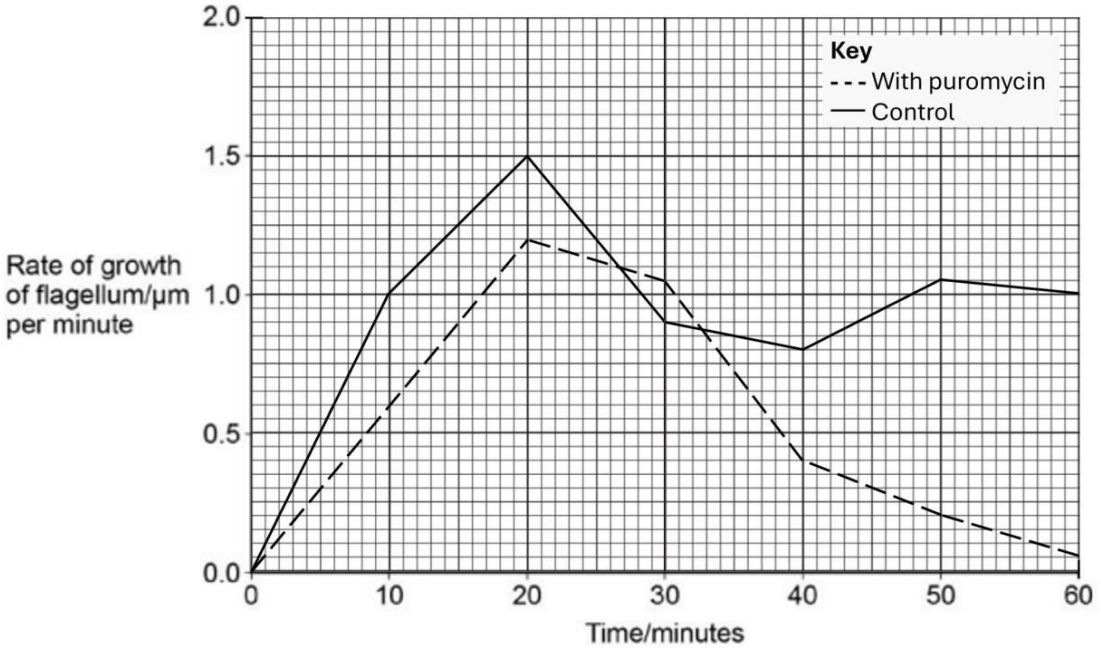


Fig. 1.2

(i) Describe how the rate of growth was affected by puromycin.

[2]

1. **In the presence of puromycin, the rate of growth is (slightly) lower / slower, in the first 27 minutes than the control ;**
   Or
2. **In the presence of puromycin, the max rate of growth of flagellum is 1.2um per min, lower than the control at 1.5um per min ;**
3. **As time increase from 27 min to 60 min, the rate of growth in the presence of puromycin decreases / is much lower than the control ;**

(ii) The researchers concluded that some of the regrowth uses protein molecules already present in the cell.

Explain the evidence for this conclusion.

[2]

1. **(re)growth only slightly affected by puromycin in the first 27 min ;**
2. **since protein synthesis was inhibited, growth continued hence it is likely to be using proteins present ;**

[Total: 12]

2 Enzymes have important roles in living organisms. Fig. 2.1a shows lactase, a crucial enzyme in the human digestive system produced by enterocytes. It is located on the surface of the microvilli, specifically within the brush border membrane.

Fig 2.1b shows the enzyme anchored at its C-terminal end, with the catalytic portion extending into the intestinal lumen. This strategic positioning enables lactase to efficiently catalyse the cleavage of lactose, the major carbohydrate in milk, into its constituent absorbable monosaccharides, glucose and galactose. Lactase's function is vital for the nourishment of newborn mammals, whose primary source of nutrition is milk.

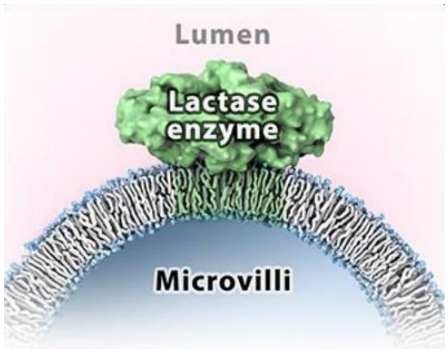


Fig. 2.1a

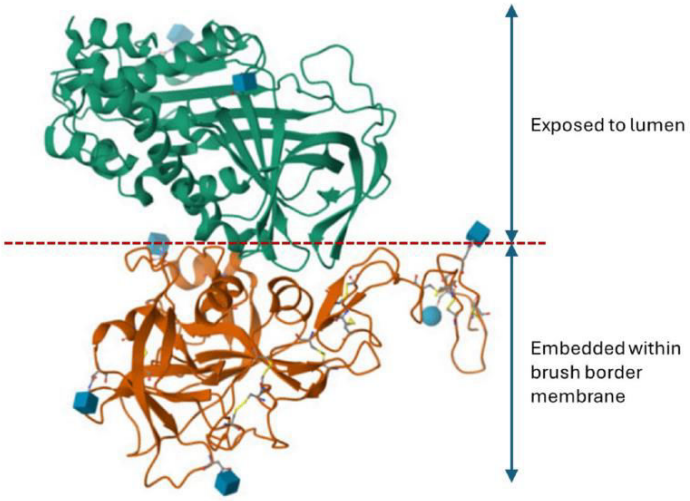


Fig. 2.1b

(a) The enzyme lactase is made up of 1023 amino acids. Fig. 2.2 shows the positions in the polypeptide chain of five amino acids found at the active site of lactase.

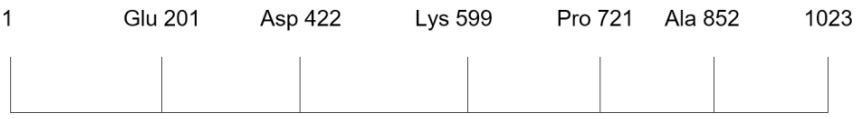


Fig. 2.2

(i) With reference to the information in Fig. 2.1 and Fig. 2.2, describe how amino acid residues at different positions in lactase may be brought together in the active site when lactase is synthesised by the cell.

[3]

1. **The polypeptide chain <u>coils and folds</u> into the (geometrically regular repeating) <u>secondary structures / α-helix and β-pleated sheet</u> respectively ;**
2. **stabilised by <u>hydrogen bonds between C=O and –NH groups</u> in the (main chain of the) polypeptide / backbone ;**
3. **The polypeptide chain / secondary structure is <u>further bent, coiled and folded</u>, to form the specific 3D conformation / tertiary structure / globular structure, of lactase, with the 5 amino acids brought together at the enzyme active site ;**
4. **Maintained by hydrogen bonds, ionic bonds, disulfide bonds and hydrophobic interactions (any 2) <u>between the R groups of amino acids</u> ;**
   (Max 3)

(ii) Suggest reasons why lactase is anchored with the catalytic portion extending into the intestinal lumen.

[2]

1. **Direct Access: This allows the lactase to be in contact with lactose present in lumen**
2. **Efficiency: Maintains stable positioning for optimal catalytic activity / break down lactose efficiently.**
3. **Proximity: Ensures immediate uptake of glucose and galactose by enterocytes.**
4. **Protection: Prevents degradation by proteolytic enzymes.**
5. **Localisation: Ensures activity where lactose digestion occurs in the small intestine.**

(b) People with lactose intolerance can drink lactose-free milk. Lactose-free milk is produced by treating milk with lactase.

There are two ways of removing lactose from milk:

- mixing a solution of lactase with the milk (free lactase)
- enclosing the lactase inside permeable beads and pouring the milk over them (immobilised lactase).

Fig. 2.3 shows these two methods.

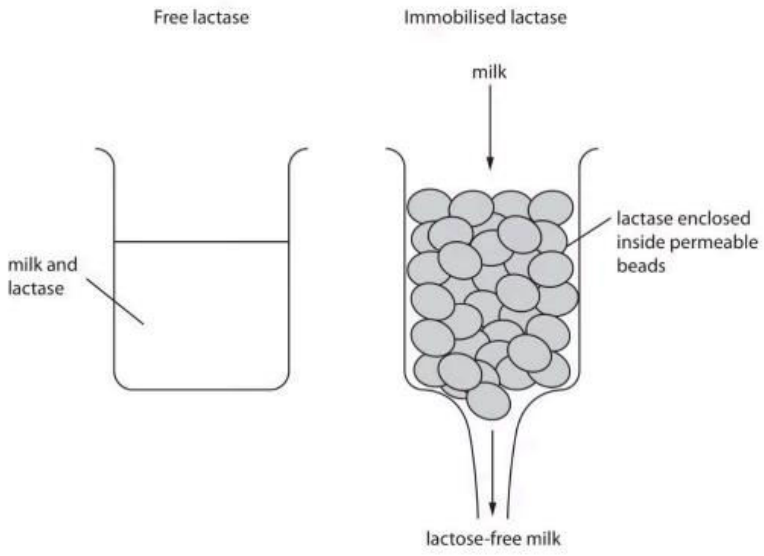


Fig. 2.3

Table 2.1 shows the effect of pH on the activity of free lactase and immobilised lactase.

Table 2.1

pH	activity of free lactase / a.u.	activity of immobilised lactase / a.u.
2	0	0
3	0	38
4	75	75
5	94	98
6	63	76
7	56	63
8	28	35

Explain the effects of pH on the activity of these two enzymes.

[5]

Describe

optimum pH

1. pH 5, highest lactase activity for both enzyme ;

at pH other than optimum pH

2. At pH other than pH 5, reduces / decrease, lactase activity ;
A: pH below 5/above 5

3. Quote a pair of relevant data points :
(a) 94 a.u. and 98 a.u for free lactase and immobilised lactase respectively (at pH 5)
(b) reaching 0 a.u. at pH 2, 28 a.u. and 35 a.u. for free lactase and immobilised lactase respectively at pH 8.0 ;

free lactase vs immobilised lactase

4. Immobilised lactase is active at wider range of pH values (pH 3-8 vs pH 4-8) ;

Explain (max 3)

optimum pH

5. (bonds maintaining the tertiary structure of lactase are intact) There is highest frequency of successful collisions between lactose and lactase, increasing the rate of formation of E-S complexes ;

at pH other than optimum pH

6. pH alters the ionic charge of the acidic and basic R groups on the amino acids at the active site of lactase ;
OR
pH leads to the ionic bonds and hydrogen bonds that maintained the specific conformation of the active site to be disrupted ;

7. causing a loss of the specific 3D conformation of the active site (and lactase), lactase is denatured ;

8. (lactose can no longer bind to active site of lactase) The rate of formation of E-S complexes decreases ;

free lactase vs immobilised lactase

9. Immobilisation holds the R groups of amino acids in place so active site does not change shape ;

[Total: 10]

3 The influenza virus belongs to the *Orthomyxoviridae* family. It primarily infects the respiratory tract of humans and animals. Fig. 3.1 shows an influenza virus.

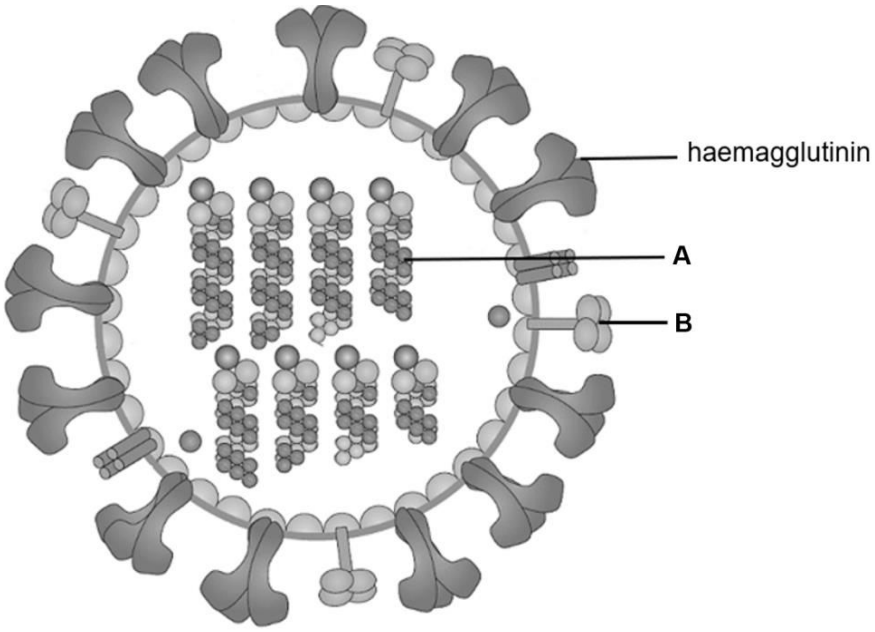


Fig. 3.1

(a) Identify the labelled structures and state their functions.

structure **A**

function

structure **B**

function

[4]

1. **A – neuraminidase ;**
2. **It (is an enzyme that) catalyses the <u>cleavage of sialic acid residues</u> from haemagglutinin, facilitating the <u>exit and release</u> of <u>newly</u> replicated influenza <u>viruses</u> from the (infected) host cell by budding ;**

3. **B – (single stranded) RNA (genome) ;** *I: double stranded*
4. **Viral RNA serves as the <u>template for the synthesis of complementary RNA (cRNA)</u>, (using the viral RNA-dependent RNA polymerase) to express viral gene products (RNA and proteins) ;**

PA, PB1 and PB2 are RNA polymerases that are found in influenza virus.

(b) Explain why the influenza virus requires its own RNA polymerases PA, PB1 and PB2.

[2]

1. **These <u>RNA-dependent</u> RNA polymerases are <u>not present in the host cell</u> (A: host cell's RNA polymerases are DNA-dependent RNA polymerases) ;**
2. **(the influenza virus possesses negative-sense RNA so) These RNA-dependent RNA polymerases are required by the virus for the synthesis of complementary RNA (cRNA) ; (A: positive sense RNA)**

Fig. 3.2 illustrates the annual influenza death toll and the number of new influenza cases in Country Z from 1925 to 1991.

In 1930, an antiviral drug designed to hinder the multiplication of the influenza virus by targeting non-envelope viral proteins was introduced for widespread use in Country Z.

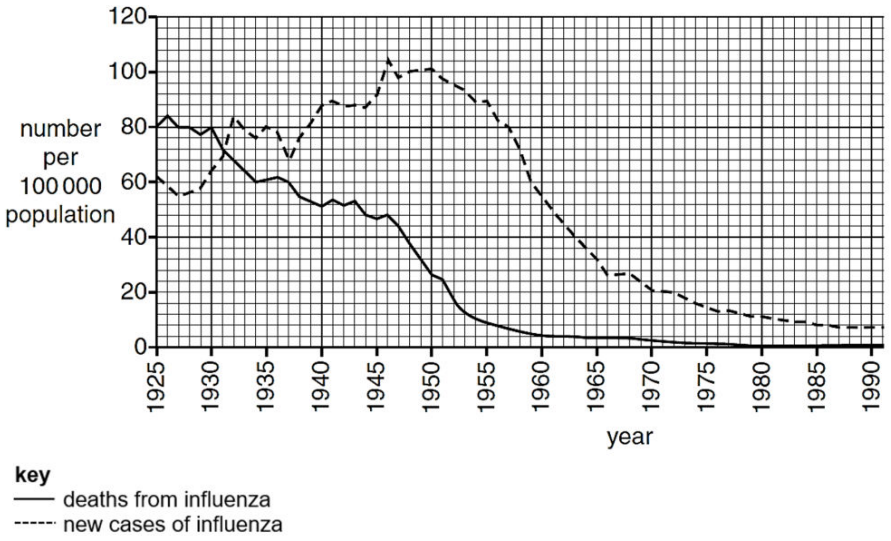


Fig. 3.2

(c) Using Fig. 3.2, account for the difference in the ten-year effect of the introduction of the antiviral drug on the number of deaths and number of new cases of influenza.

[4]

1. **Decrease by 28 deaths per 100 000 population + increase by 24 new cases per 100 000 population / Results in a <u>decrease in number of deaths</u> from 80 to 52 per 100 000 population but an <u>increase in number of new cases</u> from 64 to 88 per 100 000 population ;**

Antiviral drug reduces number of deaths by:

2. **inhibiting (RNA-dependent) RNA polymerase to prevent synthesis of complementary ssRNA /viral RNA;**
3. **reducing mRNAs for translation to form viral proteins ;**
4. **resulting in no template available to synthesise new copies of ssRNA genome ;**

5. **no new virus released which prevent damage/death of epithelial cells in respiratory tract/lungs as there is no excessive budding of new virions that depletes cell surface membrane of epithelial cells ;**

Increase in new cases of influenza as:

6. **Antiviral drug does not prevent influenza spread (as virus can be transmitted before drug takes full effect) / infection through respiratory droplets between individuals ;**
7. **Antigenic drift giving rise to new influenza strain which causes new cases of infection ;**

Max 4

[Total: 10]

4 (a) The *lac* operon is a section of DNA present in the genome of *Escherichia coli*. The structural genes of the *lac* operon are only fully expressed when the bacteria are exposed to high lactose concentrations.

Fig. 4.1 is a diagram showing the *lac* operon and a nearby region of the *E. coli* genome.

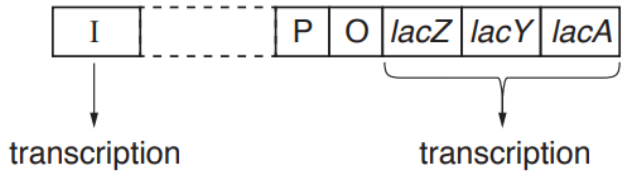


Fig. 4.1

(i) Fig. 4.1 shows how the *lac* operon consists of structural genes and regulatory sequences.

Use Fig. 4.1 to identify **two** structural genes.

Complete Table 4.1 to name each structural gene and its product.

Table 4.1

structural gene	name of gene product	
lacZ	**β-galactosidase**	**;**
lacY	***lac* / β *galactoside,* permease**	**;**
lacA	***lac* / β-galactoside, transacetylase**	**;**

Any two

[2]

(ii) Explain the role of the *lacI* gene in the regulation of the *lac* operon.

[3]

lacI gene
1. **is always expressed ;**
2. **codes for (active) repressor (that controls structural gene expression) ;**

3. **repressor recognises and binds to the operator and physically block / prevent, the attachment of RNA polymerase to the promoter ;**
4. **prevents, (structural) gene expression ;**
   OR
5. **allolactose, binds to (allosteric site) of repressor, repressor (changes its 3D conformation and) becomes inactive and, is unable to bind to / dissociate from, the operator ;**
6. **allows, (structural) gene expression by RNA polymerase ;**

(b) The *lac* operon codes for inducible enzymes. Repressible operons code for repressible enzymes.

Suggest **and** explain why it is an advantage to a prokaryote to have a repressible operon.

[3]

1. **enzymes / proteins, needed / necessary (for cell) ;**
2. **hence, enzymes / proteins, made continuously / all the time ;**
3. **repressible operon allows for, end product inhibition / product made until product concentrations too high ;**
4. **repressible operon provide a regulatory mechanism that. helps prokaryotes conserve energy and resources by inhibiting the synthesis of enzymes when their end products are abundant / prevents the cell from wasting energy and resources on producing enzymes for synthesizing a compound that is already readily available ;**

(c) Another operon found in prokaryotes is the *trp* operon.

Fig. 4.2 summarises the structure and control of the *trp* operon.

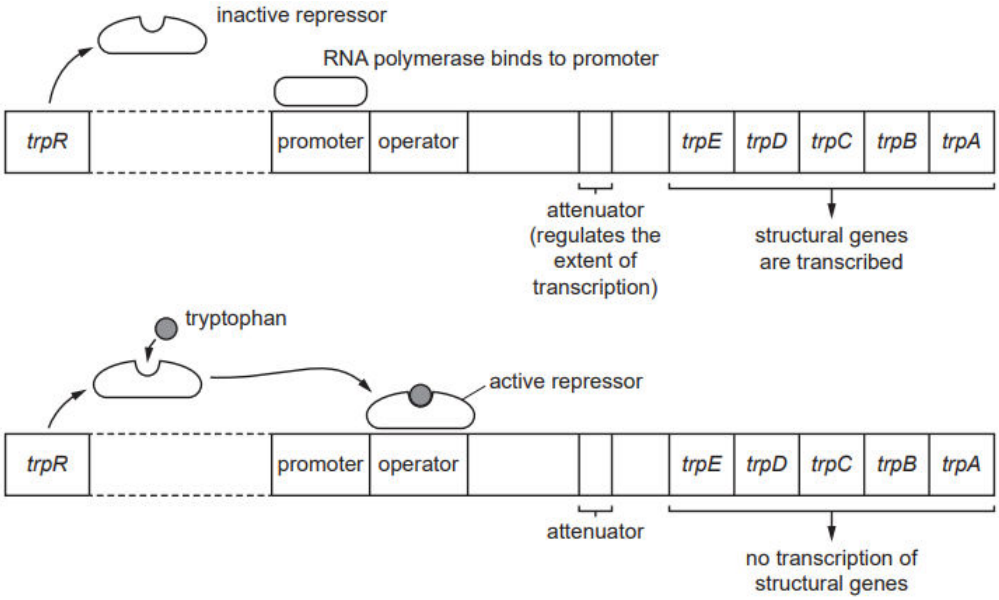


Fig. 4.2

Describe the differences in control between the *lac* operon and the *trp* operon.

[2]

	feature	*lac* operon	*trp* operon
1.	effector molecule ;	Allolactose acts as an inducer	Tryptophan acts as a co-repressor
2.	default state of repressor ;	Repressor is synthesized in the <u>active form</u>	Repressor is synthesized in the <u>inactive form</u>
3.	effect of effector molecule on operon ;	In the presence of inducer (allolactose), operon is turned ON	In the presence of co-repressor (tryptophan), operon is turned OFF
4.	default state of operon expression OR type of operon;	By default (absence of inducer), operon is switched OFF OR Trp operon is a repressible operon	By default (absence of co-repressor), operon is switched ON OR Lac operon is an inducible operon
5.	When does the repressor bind to the operator ; OR When does the repressor not bind to the operator ;	Repressor in <u>its active form</u> recognise and bind to the operator OR When <u>inducer (allolactose) binds to allosteric site of the repressor</u>, repressor does not bind to the operator	When <u>co-repressor (tryptophan) binds to allosteric site of the repressor</u>, repressor can recognise and bind the operator OR Repressor in <u>its inactive form</u> does not bind to the operator

[Total: 10]

5 There are a few mutations affecting the production of fetal haemoglobin, HbF, and normal adult haemoglobin, HbA.

- The Hb^A allele codes for the normal β-globin polypeptide of haemoglobin.
- The Hb^S allele, caused by a base substitution mutation, codes for an abnormal β-globin polypeptide.

(a) Fetal haemoglobin, HbF, is produced by the fetus until just before birth, when adult haemoglobin begins to be made. By the age of six months, adult haemoglobin has replaced most of the HbF. This change occurs when the genes coding for HbF are switched off and the genes coding for adult haemoglobin are switched on.

- A base substitution, British-198, causes fetal haemoglobin to continue to be produced.
- Normally by the age of six months, the concentration of HbF reduces to less than 1% of total haemoglobin.
- With the British-198 mutation, the concentration of HbF may be as high as 20% of total haemoglobin in an adult.
- HbF has a higher affinity for oxygen at low partial pressures of oxygen than adult haemoglobin. Individuals who have both sickle cell anaemia and British-198 mutation have reduced symptoms of sickle cell anaemia.

Suggest why having the British-198 mutation reduces the symptoms of sickle cell anaemia.

[2]

*any **two** from:*

1. **Both HbF and HbS are present ;**
2. **Presence of HbF stops / decreases HbS, fibre formation ;**
3. **fewer red blood cells, change shape / sickle / block capillaries ;**
4. **avoids very low O_2 concentration in blood / capillaries / tissues ;**

(b) Gel electrophoresis can be carried out to test individuals for the different versions of haemoglobin: HbA, HbS and HbF.

- A buffer with alkaline pH is used to make all haemoglobin molecules negatively charged.
- HbS molecules have an additional positive charge compared to HbA. HbF shows an intermediate positive charge.

(i) Describe and explain how gel electrophoresis is used to diagnose sickle cell anaemia.

[5]

1. **When placed in an <u>electric field</u> (across gel), protein / Hb moves / attracted, towards the <u>positive</u> electrode/anode ;**
2. **HbS is more positive so it moves slower through the gel ;**
3. **HbS moves a shorter distance from negative end / well ;**
4. **compare band positions to known reference bands/ ladder ;**
5. **if single band seen at HbS position, person has sickle cell anaemia ;**

(ii) Four individuals had their haemoglobin analysed by gel electrophoresis. One of the individuals was heterozygous for the Hb^A and Hb^S alleles and had a condition known as sickle cell trait (SCT). Some of the results are shown in Fig. 5.1. In Fig. 5.1, lane 1 and lane 5 are complete.

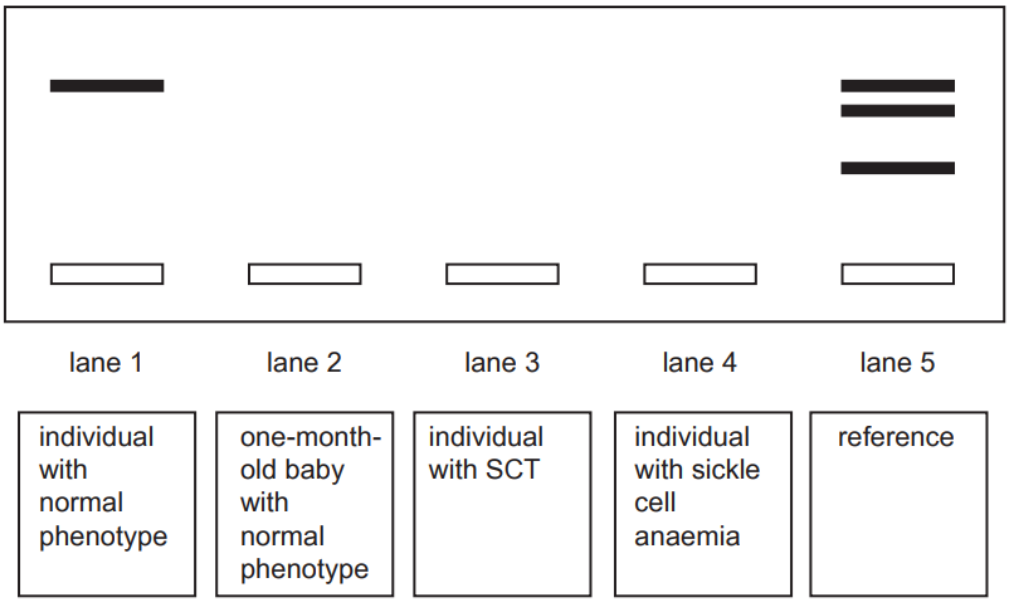
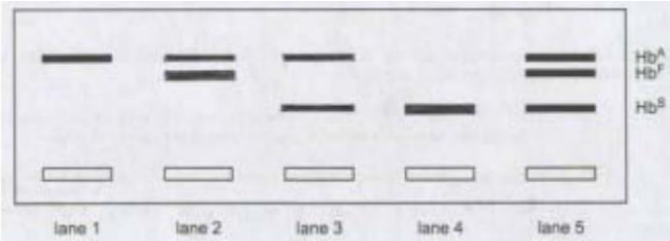


Fig. 5.1

Predict the results for the individuals analysed, by adding bands to lanes **2**, **3** and **4** on Fig. 5.1. [2]



1. **2 marks for 3 correct band patterns, 1 mark for 2 correct band patterns and 0 mark for 1 correct band pattern**

[Total: 9]

6 During interphase and mitosis of the cell cycle, the chromosomes within a cell go through several changes. Each chromosome is composed of DNA complexed with proteins.

(a) In interphase, individual chromosomes are too diffuse to be visible using a microscope. In this stage, the chromosomal material is known as chromatin.

Name the proteins that are complexed with DNA and form part of chromatin.

[1]

1. histones ;

(b) Chromosomes are most visible under a microscope during the metaphase stage of mitosis.

Fig. 6.1 shows chromosome 11 at the metaphase stage of mitosis.

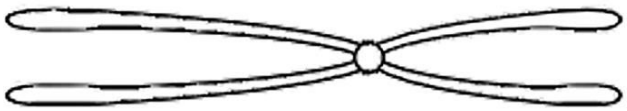


Fig. 6.1

Complete Fig. 6.2 to show the metaphase stage of mitosis with a homologous pair of chromosomes 11 in an animal cell.

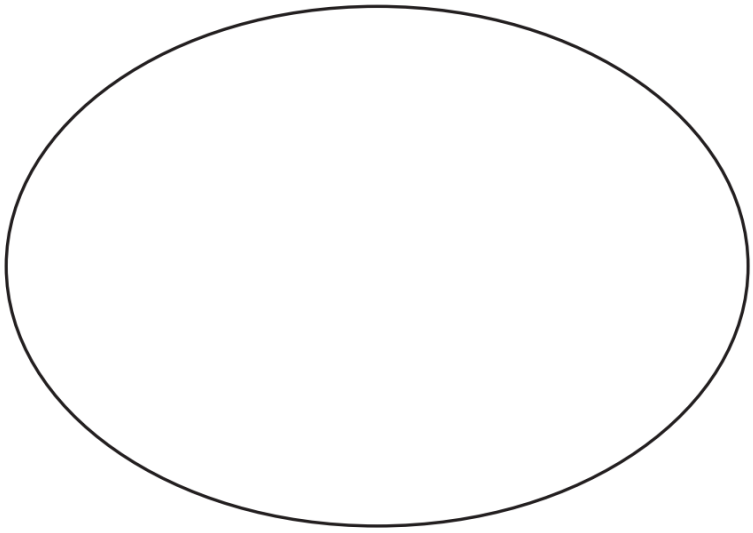


Fig. 6.2

[2]

1. two chromosomes, each with two chromatids, drawn approximately along central equator area ;
R if drawn as a, bivalent / homologous pair (close together or further apart)
A if equator is drawn across wider diameter
2. plus two other drawn feature ;

- **spindle fibres (minimum 3)**
  R continuous from pole to pole or 'cut' through chromosomes
- **spindle fibre from each pole connecting to centromere area of one chromosome**
- **<u>pair</u> of centrioles at each pole**

(c) Outline the changes that occur to the structure and behaviour of chromosome 11:

- from the start of the S phase to the end of interphase
- during prophase of mitosis.

[3]

interphase (max 2)
structure
1. DNA replicates / synthesis ;
R if stated as in, G1 / G2
2. (negatively charged) DNA wound around positively charged histone octamer to form chromatin fibre ;

behaviour
3. two sister chromatids form after (DNA) replication /during / end of, S phase ;
(note: must be clear they are formed before prophase)

prophase (max 2)
structure
4. 300 nm chromatin fibre is further coiled and compacted to form the (highly-condensed) 1400nm chromosome ;

behaviour
5. becomes visible / appears, as two identical/sister chromatids held together by a centromere ;
6. spindle fibres attach to centromere of chromosome 11 ;

(d) State how mitosis maintains genetic stability in an organism.

[2]

1. **Semi-conservative DNA replication occurs during S phase of interphase to form sister chromatids which are <u>genetically identical to parent DNA</u> ;**
2. **During metaphase, each chromosome is arranged on the metaphase plate such that each sister chromatid of a chromosome faces the opposite pole of the cell ;**
3. **Separation of sister chromatids during anaphase leads to formation of genetically identical daughter chromosomes, <u>ensures an even distribution of daughter chromosomes into daughter nuclei</u>, hence forming two genetically identical nuclei in daughter cells ;**
4. **There is no crossing over / no exchange of segments between non-sister chromatids of homologous chromosomes and thus there is no genetic recombination / no genetic variation ; (vs meiosis) (extra pt if qn is [4])**

Reject: double DNA content ; no genetic variation

[Total: 8]

7 *Thespesia populnea*, a flowering plant can be found throughout the tropical regions of the world. It is commonly found along roadside as it can tolerate full sun, high wind and dry conditions.

The fruit colour of *Thespesia populnea* is either yellow or brown, and the fruit coat texture can be either smooth or wrinkled.

- The allele **A** for yellow is dominant over the allele **a** for brown.
- The allele **B** for smooth coat is dominant over allele **b** for wrinkled coat.

The inheritance of fruit colour and fruit coat texture is controlled by genes that display autosomal linkage.

(a) Explain what is meant by autosomal linkage.

[2]

1. **Autosomal: not a sex chromosome / on an autosome;**
2. **Linkage: The <u>genes</u> coding for fruit colour and texture are found <u>on the same chromosome</u> (A: the two genes do not assort independently in meiosis) and are inherited together ;**

(b) A dihybrid cross was carried out between a pure-breeding plant with yellow and smooth fruit and a pure-breeding plant with brown and wrinkled fruit to produce the F1 generation. The offspring from the F1 generation is crossed with a plant with brown and wrinkled fruit. The results of this cross are shown in Table 7.1.

Table 7.1

offspring phenotype	number of offspring
yellow and smooth fruit	125
brown and wrinkled fruit	125
yellow and wrinkled fruit	10
brown and smooth fruit	10

Suggest how the results shown in Table 7.1 supports that the genes for fruit colour and coat texture display autosomal linkage.

[2]

1. **<u>Not 1:1:1:1</u> expected ratio of a test cross ;**
2. **<u>Majority</u> of offspring (yellow and smooth fruits + brown and wrinkled fruits) exhibits <u>parental</u> phenotype / <u>Minority</u> of offspring yellow and wrinkled fruits + brown and smooth fruits) exhibits <u>recombinant</u> phenotypes ;**
3. **<u>Crossing over</u> <u>between the two linked genes</u> on non-sister chromatids of homologous chromosomes may occur, (as crossing over is a chance event,) resulting in a lower proportion of <u>recombinant gametes</u> / lower chances of getting recombinant gametes ;**

(c) Use the symbols, **A, a** and **B, b** to draw a genetic diagram to explain the results in Table 7.1. [4]

Parental phenotypes: yellow and smooth fruit **X** brown and wrinkled fruit

Parental genotypes: $\frac{AB}{ab}$ **X** $\frac{ab}{ab}$;

Gametes (AB), (ab), (Ab), (aB) ; (ab) ;

Fertilisation:

	(AB)	(ab)	(Ab)	(aB)
(ab)	$\frac{AB}{ab}$	$\frac{ab}{ab}$	$\frac{Ab}{ab}$	$\frac{aB}{ab}$

Offspring genotype : $\frac{AB}{ab}$: $\frac{ab}{ab}$: $\frac{Ab}{ab}$: $\frac{aB}{ab}$;

Offspring phenotype : Yellow and smooth fruits : brown and wrinkled fruits : yellow and wrinkled fruits : brown and smooth fruits ;

Offspring phenotypic ratio : 25 : 25 : 2 : 2

(d) Outline how you would use chi-squared test to determine whether the observed results differ significantly from the expected results. No calculations or formula are required to answer this question.

[2]

1. **Obtain critical chi-squared value at p = 0.05 and compare with calculated chi-squared value ;**
2. **Determine if the observed results are significantly different from the expected results ;**
   OR
3. **Obtain probability value and compare with p = 0.05 ;**
4. **To estimate the probability that differences between observed and expected results were due to chance ;**

[Total: 10]

8 Fig. 8.1 is a transmission electron micrograph of a chloroplast.

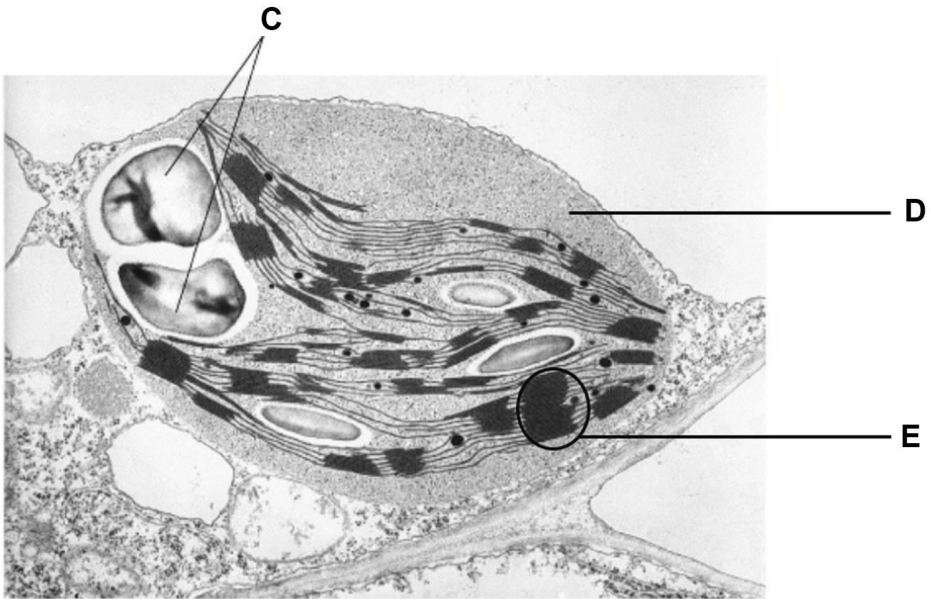


Fig. 8.1

(a) Name the structures labelled **C**, **D** and **E** in Fig. 8.1.

C

D

E

[3]

1. **C: Starch grains / starch granules ;**
2. **D: Stroma ;**
3. **E: Granum ;**

The light dependent reactions in photosynthesis involve non-cyclic and cyclic photophosphorylation.

(b) Explain how non-cyclic photophosphorylation differs from cyclic photophosphorylation.

[3]

	feature	non-cyclic photophosphorylation	cyclic photophosphorylation
1	photosystems involved ;	PS II and PS I	only PS I
2	pathway of electron flow ;	from water, through 2 ETCs, via 2 photosystems, to NADP	PSI to ETC and back to PS I
3	number of ETCs involved ;	two	one
4	first electron donor ;	water	special chlorophyll a / P700 of PS I
5	final electron acceptor ;	NADP	special chlorophyll a / P700 of PS I
6	products	ATP, NADPH, oxygen	only ATP
7	generation of proton gradient ;	high H^+ concentration in the thylakoid lumen due to photolysis of water (by water splitting enzyme in PSII)	high H^+ concentration in the thylakoid lumen but water splitting enzyme is absent (from PSI)

Max. 3

Laboratory experiments were carried out to investigate the effect of day length (light exposure period) on the rate of photosynthesis in common eelgrass, *Zostera marina*.

- The temperature was controlled at 4 ^{o}C.
- A fixed concentration of carbon dioxide dissolved in water was used.
- The day length was different for five groups of *Z. marina*.
- This was maintained for 10 days to allow *Z. marina* to adapt to these conditions.
- After 10 days, the rate of photosynthesis was measured for each group under the same controlled conditions.

Table 8.1 shows the results of the experiment.

Table 8.1

day length / hours	rate of photosynthesis / arbitrary units
12	2.5
14	5.0
16	7.0
18	11.0
20	18.0

(c) With reference to Table 8.1, describe **and** explain the effect of increasing day length on the rate of photosynthesis for the *Z. marina*.

[4]

1. **As day length increases from 12 hours to 20 hours, rate of photosynthesis increases from 2.5 arbitrary units to 18.0 arbitrary units.**
2. **As day length increases, more light is absorbed by the photosystems / photosynthetic pigment / chlorophyll ;**
3. **Photophosphorylation / light dependent reactions / photolysis increases ;**
4. **More oxygen / reduced NADP / ATP / triose phosphate / glucose / starch is produced ;**

Max. 3

[Total: 10]

9 Australia's unique biodiversity includes tens of thousands of native animal species, with a significant proportion being endemic.

(a) The dingo, belonging to the genus *Canis*, is a wild canine native to Australia, believed to have arrived on the continent around 4000 years ago.

The distribution of some of the species belonging to the genus *Canis* is shown in Fig. 9.1.

The dingo and the grey wolf species have distinct ranges but the ranges of the three species of jackal overlap in East Africa.

The domestic dog, *Canis familiaris*, is found worldwide and it can breed with all other members of the genus to form fertile hybrids.

Fig. 9.1

Table 9.1 shows whether members of different species of the genus *Canis* are able to breed with each other.

Table 9.1

key: ✓ = able to interbreed ✗ = unable to interbreed **?** = interbreeding unknown

	dingo	grey wolf	golden jackal	side-striped jackal	black-backed jackal	domestic dog
dingo	✓	?	?	?	?	✓
grey wolf	?	✓	?	?	?	✓
golden jackal	?	?	✓	✗	✗	✓
side-striped jackal	?	?	✗	✓	✗	✓
black-backed jackal	?	?	✗	✗	✓	✓
domestic dog	✓	✓	✓	✓	✓	✓

(i) Suggest the type of isolating mechanism **preventing**:

- the three species of jackal interbreeding

[1]

1. **Behavioural / physiological isolation ;**

- the dingo mating with all the other members of the genus *Canis* apart from the domestic dog.

[1]

1. **Geographical isolation ;**

(ii) Using the information in Fig. 9.1 and Table 9.1, state:

- **one** reason why the members of the genus *Canis* could be described as one species

[1]

1. **All members of the genus are able to interbreed with the domestic dog to produce fertile offspring ;**

- **one** reason why they should be described as separate species.

[1]

1. **(idea of) the different types of jackals unable to interbreed (to produce fertile offspring) ;**

(b) The zebra finch, *Taeniopygia castanotis*, is native to arid regions throughout Australia. The variation in clutch size of zebra finches was investigated over several years. The clutch size refers to the number of eggs a bird lays in its nest. The data from the investigations are shown in Fig. 9.2.

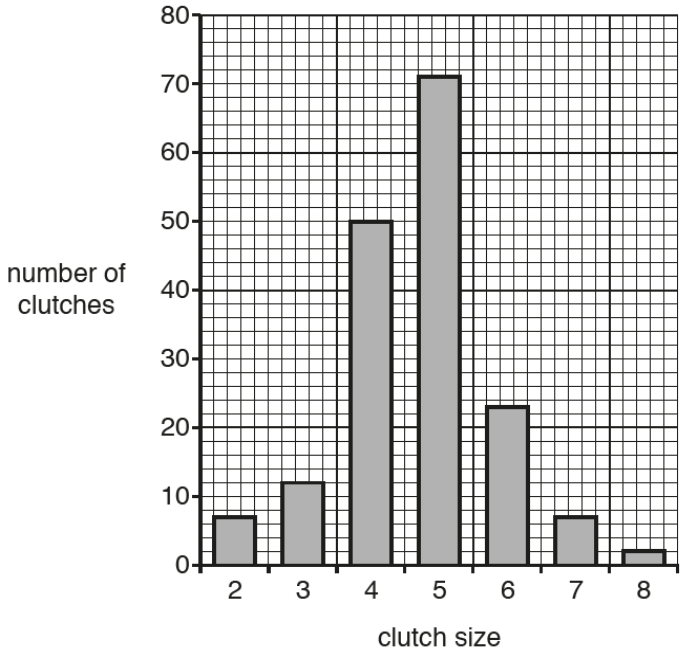


Fig. 9.2

(i) Describe the pattern shown by the data in Fig. 9.2.

[2]

1. **5 is the most common / frequent clutch size ;**
   OR
2. **Clutch size of 5 has the highest number of clutches, i.e. 71 clutches ;**

3. **Fewer clutches are very large + data (e.g. only 2 clutches with clutch size of 8)**
   OR
4. **Fewer clutches are very small + data (e.g. only 7 clutches with clutch size of 2)**
5. **Normal distribution ;**

Max. 2

(ii) The data in this investigation were collected over 60 years ago.

The same investigation, carried out today, would produce the same pattern of results.

Explain how the selection factors acting on zebra finches would maintain the same pattern of results.

[4]

1. Stabilising selection ;
2. Average / mean / clutch size of 4 to 5, has selective advantage ;
3. Low clutch size (e.g. 2 or 3) means fewer (surviving) offspring ;
4. For high clutch size (e.g. 6, 7 or 8), not all offspring will survive ;
5. High clutch size means more competition between the offspring for food ;
6. High clutch size might lead to more predation of eggs ;
7. High clutch size might link to higher chance of (viral) disease in eggs / chicks ;
Max. 2 for mp5-7

[Total: 10]

10 Fig. 10.1 is a diagram of a protein in the cell surface membrane of a macrophage from a mouse.

Macrophages use these proteins in antigen presentation. Non-self antigens bind to the proteins and are involved in the activation of specific T lymphocytes during the immune response.

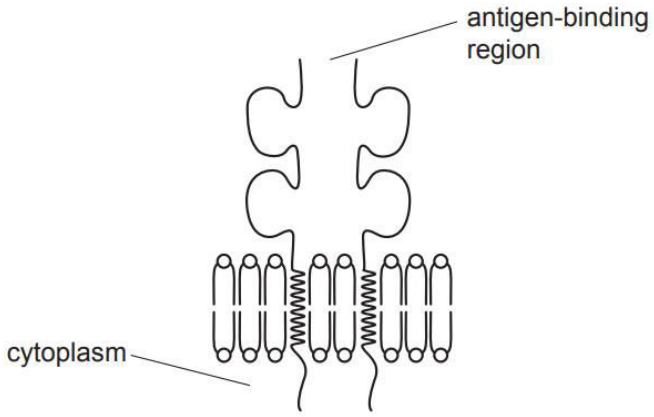


Fig. 10.1

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

[1]

1. (foreign) protein / glycoprotein, that stimulates, an immune response / production of antibodies / activation of lymphocytes ;
A polysaccharide / molecule / foreign substance / foreign antigen

(b) Some pathogens enter human cells. Macrophages partially digest these pathogens and present antigens to T lymphocytes during immune responses.

With reference to Fig. 10.1, explain how T lymphocytes respond to infection by a specific type of pathogen.

[4]

1. **T-lymphocytes, have specific TcR that recognise and bind to the <u>complementary</u> MHC-antigen complex on APC / antigen on macrophage ;**
2. **(selected) T-lymphocytes, divide many times (by mitosis) / undergo clonal expansion ;**

3. **helper T cells secrete cytokines ;**
4. **detail of effect of cytokine ;**
   (a) activation of B-cells to, proliferate / undergo clonal expansion and differentiate, into plasma cells and memory cells
   (b) stimulate ($CD8^+$) T lymphocytes to proliferate / undergo clonal expansion and differentiate into cytotoxic T cells
   (c) promote the recruitment of more monocytes and, macrophages

5. **cytotoxic T cells, bind / attach, to infected cells and destroy / kill, them ;**
6. **detail of action of cytotoxic T cells ;**
   (a) Perforin / granzyme that aid in the destruction of the infected cells via apoptosis.
   (b) Perforin forms pores in the plasma membrane of the infected cell, which allows the entry of granzymes into the cell.
   (c) Granzymes are hydrolytic enzymes that break down the cell contents, thus eradicating the infected cell and the viruses it carries

7. **production of memory T cells that quickly divide by mitosis, proliferate and undergo differentiation to develop into large numbers of effector T cells upon re-exposure to the same antigen ;**

[Total: 5]

11 The concept of climate change and global warming has been of concern to scientists for many years.

Plant biodiversity varies throughout the world and is dependent on many factors, particularly climate.

Fig. 11.1 shows the relationship between the number of plant genera and the mean annual rainfall in seven countries.

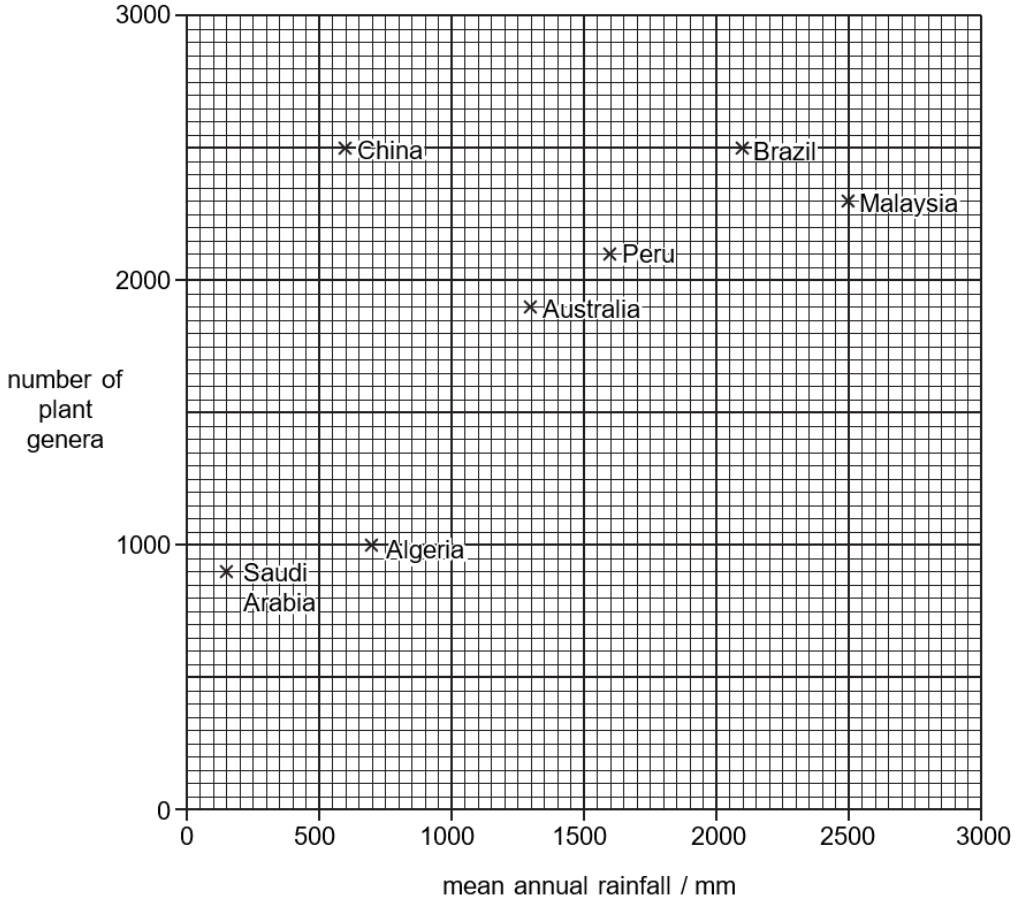


Fig. 11.1

(a) Describe the relationship between the number of plant genera and the mean annual rainfall in these seven countries.

[2]

1. **number of plant genera increases as mean annual rainfall increases / direct relationship / positive correlated ;**
2. **Ref to paired figures correctly quoted with units i.e. genera number and mean annual rainfall in 2 named countries showing the trend ;**
3. **China not fitting the trend ;**

(b) Suggest how human activity can contribute to climate change and its effect on plant biodiversity.

[4]

1. **Human activities such as burning of fossil fuels due to increasing energy usage / deforestation for agriculture or urban development / food choices linked to increased meat consumption (Any two) ;**

2. **increases the emission of greenhouse gases such as carbon dioxide and/or methane into the atmosphere ;**
3. **Increased greenhouse gas (GHGs) emissions has resulted in enhanced greenhouse effect, trapping heat in the atmosphere and resulting in global warming and increase in global average temperature ;**

4. **Increase / decrease in rainfall / increased incidence of flooding / drought, shorter / longer rainy season ;**
5. **Consequence on plants e.g. plant wilting from loss of water / plant rotting from waterlogged roots / plants infected by pests and pathogens ;**
6. **Decrease in genetic diversity / species diversity ;**

MP 1 + any 3 from MP 2-6

[Total: 6]