H

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME			
BIOLOGY CLASS	2bi2_____	REGISTRATION NUMBER	

Biology

9744/02

Paper 2 Structured Questions

27 August 2024

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, Biology class and registration number on all the work you hand in.
Write in dark blue or black pen.
You may use an HB 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 workings or if you do not use appropriate units.

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

For Examiner's Use	
Section A	
1	**/10**
2	**/10**
3	**/10**
4	**/10**
5	**/10**
6	**/10**
7	**/10**
8	**/10**
9	**/10**
10	**/5**
11	**/5**

Total	/100

This document consists of **26** printed pages and **2** blank pages.

Answer **all** the questions.

1 Fig. 1.1 is an electronmicrograph of part of a human liver cell that contains many glycogen granules.

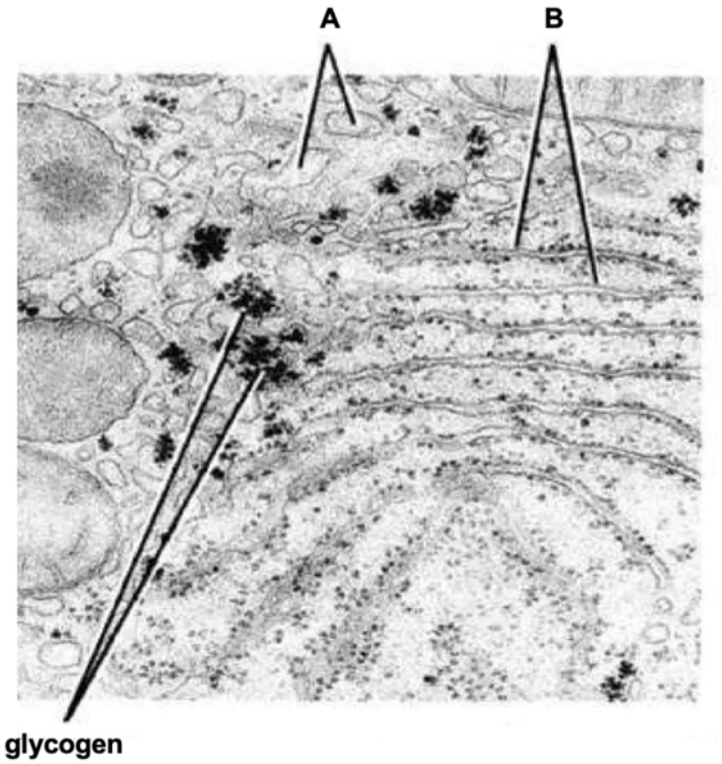


Fig. 1.1

(a) Structures **A** and **B** are interconnected sub-compartments.

Name and state the role of structures **A** and **B**.

	name	role
A	smooth endoplasmic reticulum;	site of lipid synthesis; involved in drug detoxification;
B	rough endoplasmic reticulum (reject ribosomes on rough endoplasmic reticulum);	involved in the synthesis of secretory proteins / membranal proteins; addition of carbohydrates to form glycoproteins / modifying of proteins; proteins synthesised are transported within vesicles to the Golgi body;

[4]

(b) Explain why it is important for a human liver cell to contain many glycogen granules.

Serves as a form of energy storage (reject long-term/short-term if never specify comparison);

Maintain blood glucose levels during times of high energy demands / stress / fasting;

[2]

Isolation membranes derived from structure **A** play important role in degradation of unwanted cytoplasm components.

Fig. 1.2 shows the steps involved in the degradation of unwanted cytoplasm components.

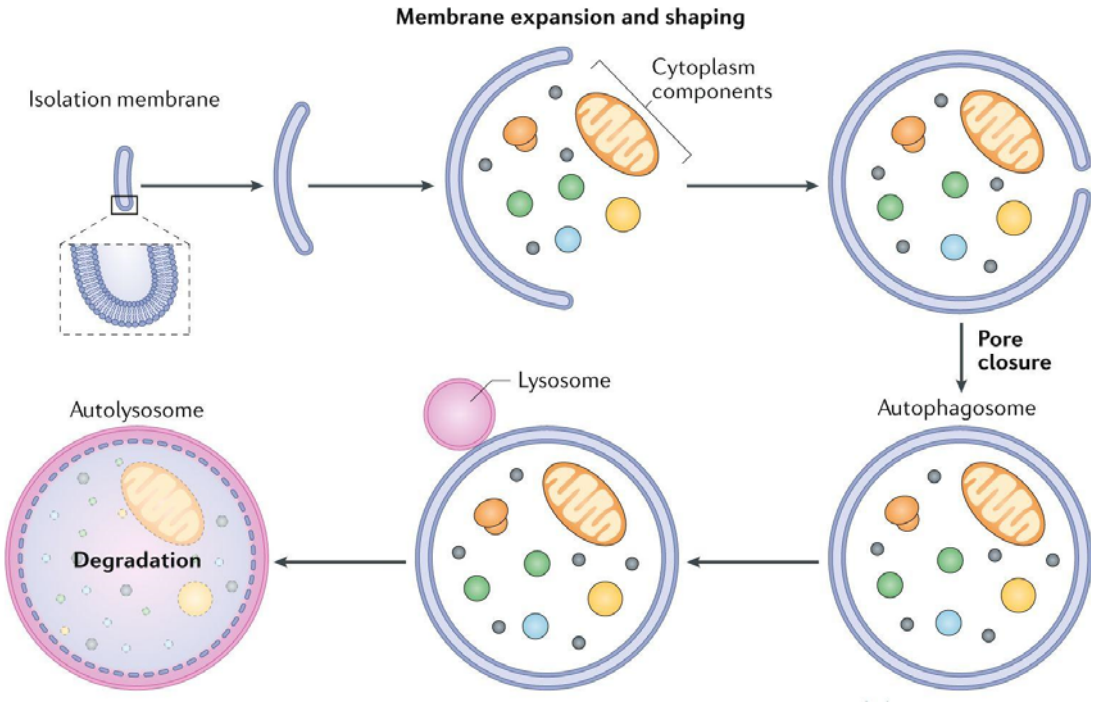


Fig. 1.2

(c) With reference to Fig. 1.2, describe how the unwanted cytoplasm components are degraded.

The isolation membrane expands to enclose the unwanted cytoplasm components such as mitochondrion;

An autophagosome is formed after pore closure;

Lysosome fuses with the autophagosome to form an autolysosome;

Hydrolytic enzymes in the autolysosome catalyse the degradation of the inner membrane / the unwanted cytoplasm components;

This process is known as autophagy;

.....

.....

.....

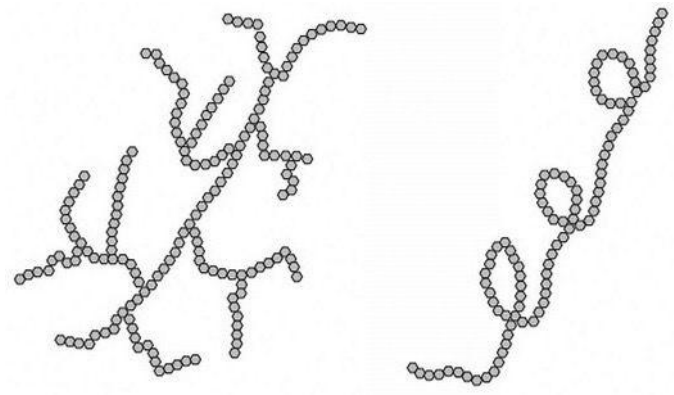
.....

.....

..... [4]

[Total: 10]

2 Fig. 2.1 shows the components of a storage molecule that is widely distributed in plants.



A **B**

Fig. 2.1

(a) Identify the components **A** and **B**.

A amylopectin;

B amylose;

[2]

(b) The presence of branches is a key structural feature of component **A**.

Explain how this structural feature enables the function of component **A**.

Branching decreases the ability of the chains to get together with one another and increases the binding of water molecules to the chains;

This allows rapid release of glucose molecules from the many ends / rapid hydrolysis of component **A** at the many ends for use in cellular respiration;

Branching also makes component **A** more compact, containing more glucose units while taking the least possible space, and is therefore ideal for its function as a storage molecule;

[2]

Fig. 2.2 shows two types of glucose that are found in plants.

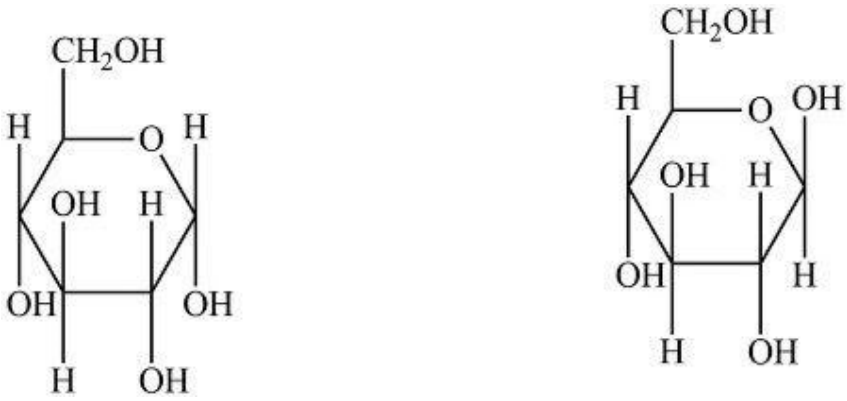
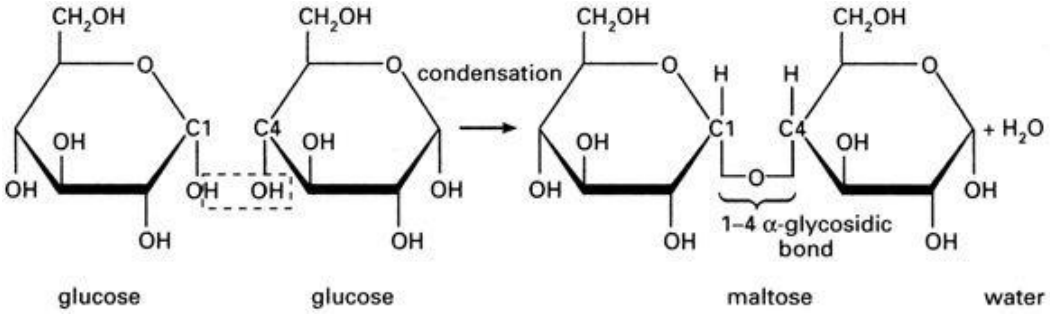


Fig. 2.2

(c) With reference to Fig. 2.2, draw a labelled diagram in the space provided to show how **two** glucose molecules react to form a branch point in component **A**.



two α-glucose drawn and labelled correctly;

1-6 α-glycosidic bond drawn and labelled correctly;

formation of one water molecule / condensation indicated;

[3]

(d) Glycolipids are generally found on the extracellular face of the eukaryotic cell surface membrane.

Describe the roles of glycolipids in eukaryotic cell surface membrane.

The carbohydrate group of glycolipids serves as a recognition site for other molecules and cells;

This forms the basis of cell-cell recognition (crucial to the immune response) / cell-cell adhesion (to form tissues) / cell signalling;

They help in determining the blood group of an individual;

Formation of myelin sheath in neurones;

They maintain the stability of the cell membrane;

[3]

[Total: 10]

3 **(a)** Fig. 3.1 shows the process of DNA replication.

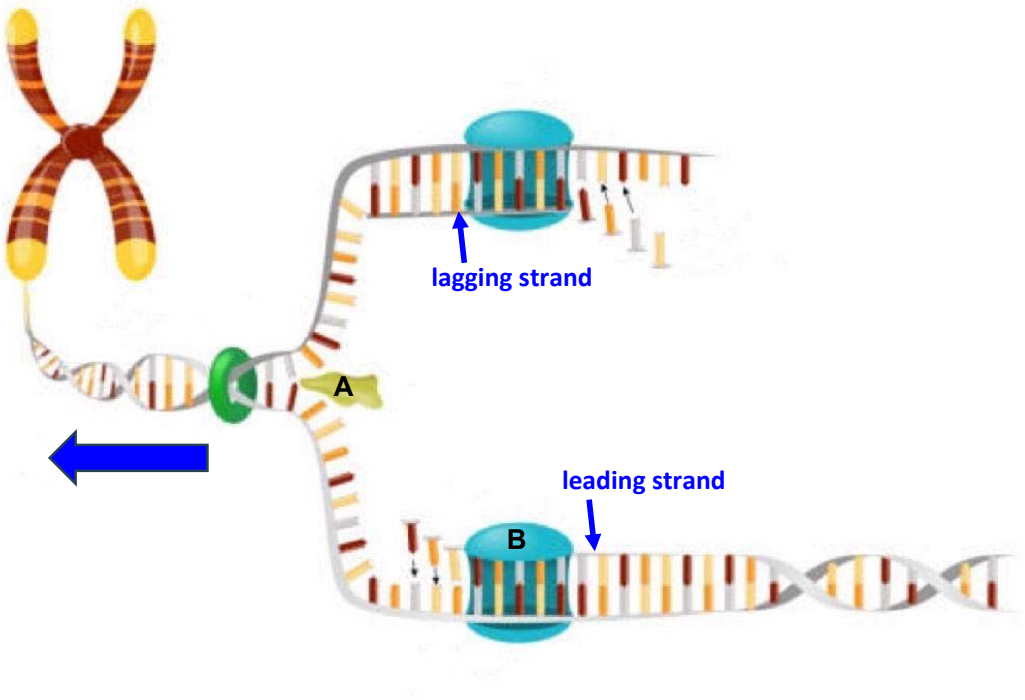


Fig. 3.1

(i) On Fig. 3.1,

- label a leading strand (1m) and a lagging strand (1m)
- draw an arrow (1m) to show the direction of movement of the replication fork.

[3]

(ii) Name the molecules **A** and **B**.

A helicase;

B DNA polymerase;

[2]

(iii) Describe how a mutation in the gene coding for molecule **B** can affect its function in DNA replication.

ref to nucleotide-pair substitution / addition / deletion;

ref to effect (e.g. missense / nonsense mutation) on mRNA produced;

ref to effect (e.g. change in active site of enzyme) on protein produced;

ref to function in DNA replication e.g. unable to polymerise / proof-read;

(accept loss or gain of function)

[3]

(b) Dideoxycytosine triphosphate (ddCTP) can bind to the active site of molecule **B**, in a similar way to deoxycytosine triphosphate (dCTP).

Fig. 3.2 shows the structure of dCTP and ddCTP.

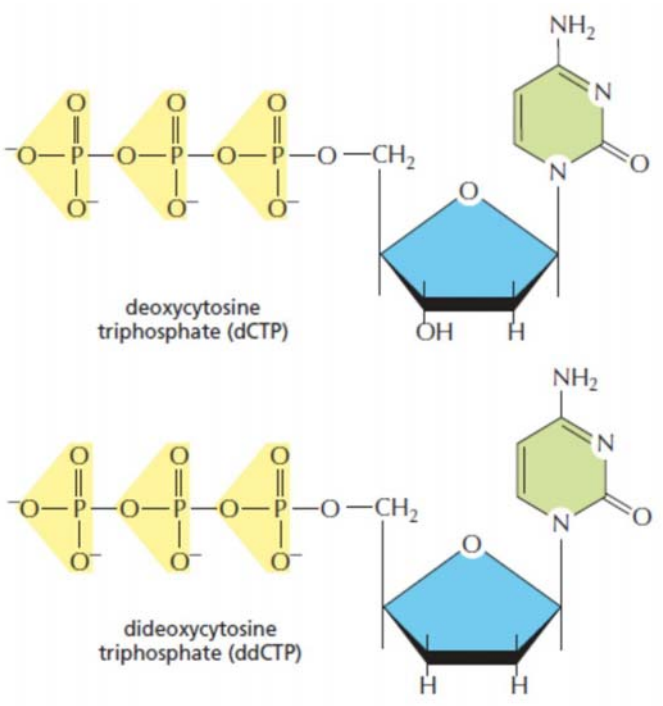


Fig. 3.2

In an *in vitro* DNA replication reaction mixture, ddCTP was added together with deoxyribonucleotides.

Suggest how the addition of ddCTP would affect DNA replication.

ddCTP competes with dCTP for the active site of DNA polymerase and forms a phospho(di)ester bond with 3' hydroxyl group of the daughter strand;

ddCTP lacks a 3' hydroxyl group on the deoxyribose / pentose sugar;

The incorporated ddCTP cannot form a phospho(di)ester bond with incoming dNTPs;

DNA replication is terminated prematurely;

[2]

[Total: 10]

4 Epstein-Barr virus (EBV) was the first virus known to cause human cancer. Human B lymphocytes are the host cells of EBV infection.

Fig. 4.1 shows the structure of EBV.

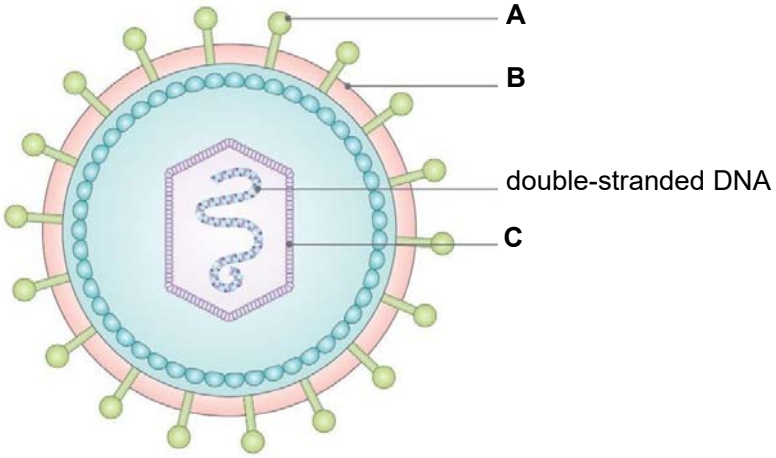


Fig. 4.1

(a) (i) Identify the structures **A** and **B**.

A (envelope) glycoprotein;

B envelope / membrane / lipid bilayer;

[2]

(ii) List **two** differences between the EBV and influenza virus genomes.

1 .....

DNA vs. RNA;

double-stranded vs. single-stranded;

one molecule / non-segmented vs. eight molecules / segmented;

2 .....

..... [2]

Fig. 4.2 shows part of the reproductive cycle of EBV starting from its attachment to a B lymphocyte.

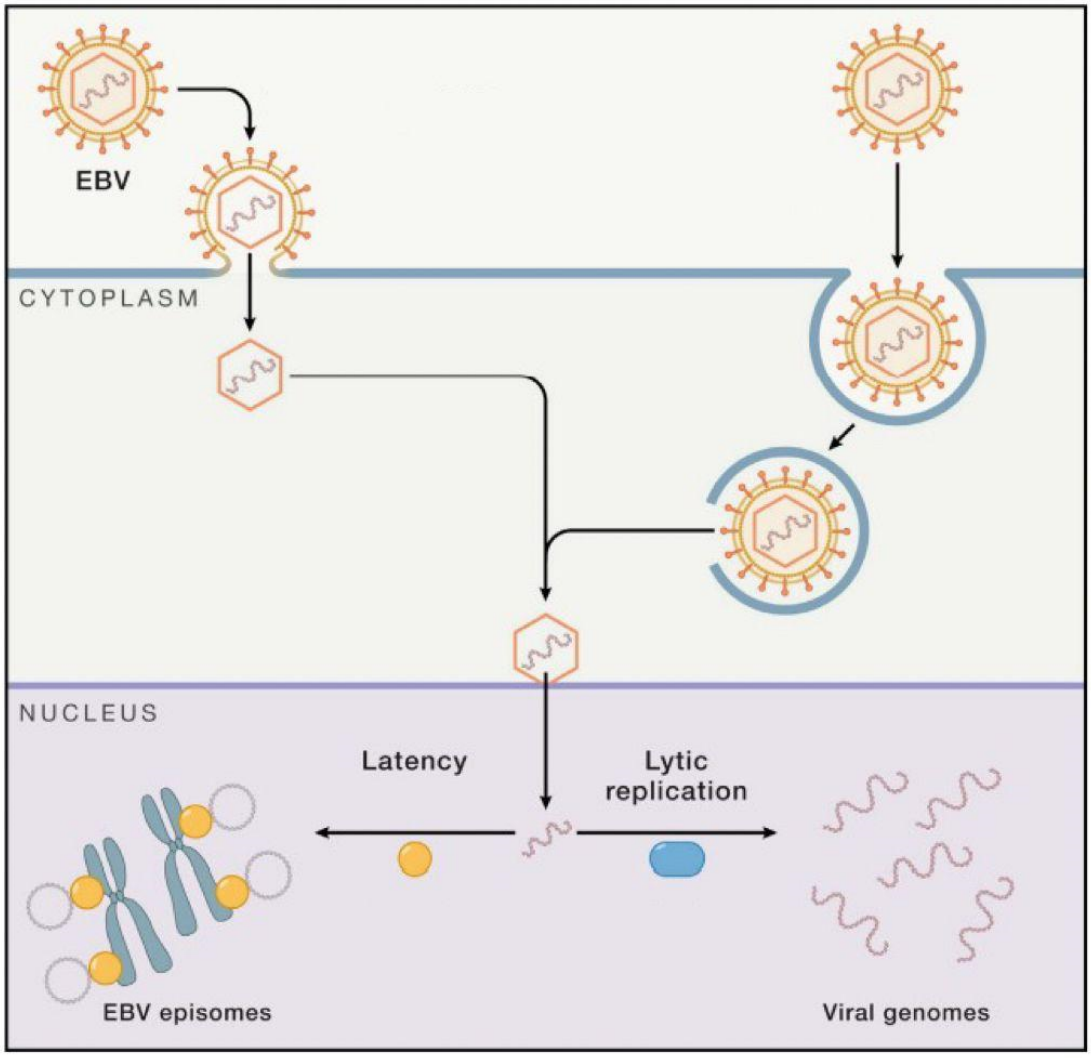


Fig. 4.2

(b) **(i)** With reference to Fig. 4.2, describe **two** ways how EBV enters the B lymphocyte.

EBV may enter via fusion of its envelope with the cell surface membrane of B lymphocyte;

EBV may also enter through (receptor-mediated) endocytosis, forming an endosome;

[2]

(ii) Besides replicating the viral genome, the synthesis of structure **C** is necessary before new EBV particles can be produced.

Describe how structure **C** is synthesised in the infected B lymphocyte.

EBV **gene** coding for capsomere / capsid protein / structure **C** is **transcribed** by the B lymphocyte's DNA-dependent **RNA polymerase**;

Ref to post-transcription modifications (at least 2);

The (+) ssRNA molecules produced are exported out of the nucleus into the cytoplasm;

where they are used as templates for **translation** into capsomeres / capsid proteins / structure **C** by **free ribosomes**;

[3]

(iii) Depending on the environmental cues, EBV may enter latency where the viral genome is retained as an extrachromosomal episome as shown in Fig. 4.2. New EBV particles are not produced.

Suggest **one** advantage of EBV entering latency.

Host cell will not lyse;

Less/no viral proteins synthesised, unlikely to trigger immune response;

Latency allows the viral genome to persist despite host immune responses to many viral antigens;

Limited viral replication can reduce the cost of infection to a level that enables mutualistic interaction with the host;

The reduced virulence associated with limited viral replication prolongs host survival and increases opportunities for transmission;

[1]

[Total: 10]

5 Increased methylation of the promoter region of a tumour suppressor gene causes one type of human lung cancer. The methylation is caused by an enzyme called DNA methyltransferase (DNMT).

Scientists have found a potential anti-cancer drug in green tea, called EGCG. EGCG is a competitive inhibitor of DNMT and enables daughter cells to produce mRNA from the tumour suppressor gene.

(a) Explain how EGCG can serve as an anti-cancer drug.

EGCG is complementary in shape and charge to active site / structural resemblance to promoter;

EGCG binds to **active site** of **DNMT**, **preventing methylation of promoter region** of tumour suppressor gene;

Promoter region of DNA will be **loosely packed**;

RNA polymerase / general transcription factors can bind to initiate transcription of tumour suppressor gene;

Ref to any 2 functions of TSG e.g. arrest cell cycle, DNA repair, induce apoptosis in cancer cells;

[4]

(b) The scientists investigated the effect of EGCG concentration on the viability of lung cancer cells grown *in vitro*.

Fig. 5.1 shows their results. The asterisk (*) indicates significant difference ($p<0.05$) compared to the control group treatment with EGCG.

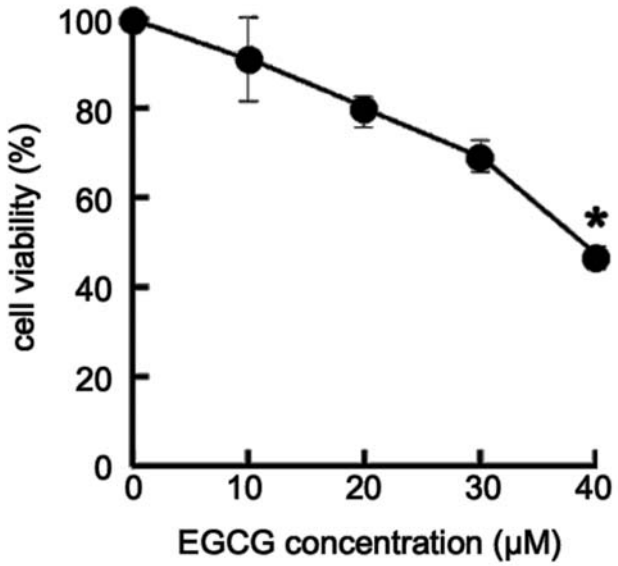


Fig. 5.1

(i) With reference to Fig. 5.1, describe the effect of increasing EGCG concentration on the viability of lung cancer cells.

General trend: increased EGCG concentration results in decreased lung cancer cell viability;

Quote values: increased EGCG concentration from 0 to 40 μM, results in decreased lung cancer cell viability from 100% to 45% (accept 41-49%);

Cell viability is **significantly** reduced at 40 μM EGCG concentration;

[3]

(ii) A reporter reviewed the results of the investigation and concluded that drinking green tea could be a cure for cancer.

Suggest **three** reasons why his conclusion might **not** be valid.

Only investigated in lung cancer / Might not work for other types of cancer;

Not all cancers are caused by (increased) methylation (of a tumour suppressor gene) / ref to other causes of cancer e.g. oncogene;

Lack data on significance of reduction in cell viability;

Do not know how much EGCG is in green tea;

In vivo cells/cells in the body might respond (to EGCG) differently (from those grown *in vitro*);

[3]

[Total: 10]

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

A dihybrid cross was carried out between flies with brown body and straight wings which are heterozygous for both body colour and wing shape, and flies with black body and curved wings.

Table 6.1 shows the number of offspring of each phenotype obtained in the cross.

Table 6.1

phenotype	observed (O)	expected (E)	$(O - E)^2 / E$
brown body colour, straight wings	1695	1827	9.5369
brown body colour, curved wings	1903	1827	3.1614
black body colour, straight wings	1918	1827	4.5325
black body colour, curved wings	1692	1827	9.9753
		χ^2 =	27.21

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

The formula for chi-squared test is:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

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	3.84	6.64	10.83
2	5.99	9.21	13.82
3	7.82	11.35	16.27
4	9.49	13.28	18.47

(a) Complete Table 6.1 to

(i) show the expected number of each phenotype if the two genes are on different autosomes [1]

(ii) calculate the value of χ^2 in **two** decimal places. [1]

(iii) State and explain what can be concluded about inheritance of body colour and wing shape in fruit fly from the χ^2 value.

Degrees of freedom is **3**;

Calculated χ^2 of 27.21 is **greater than critical χ^2** of **7.82** at p=0.05;

There is **significant difference** between observed results and expected numbers;

Any difference is **not due to chance**;

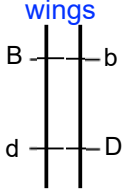
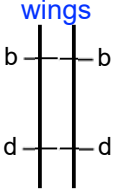
[3]

(b) Draw a genetic diagram to explain the observed results of this test cross.

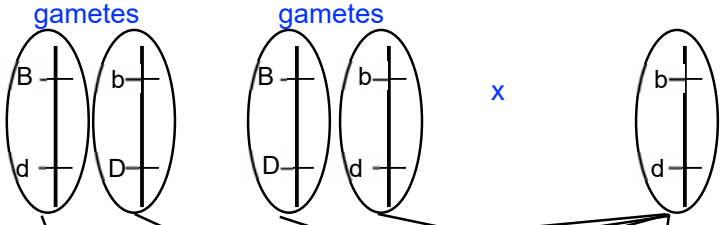
Use the symbols **B** and **b** to represent the alleles for body colour and **D** and **d** to represent the alleles for wing shape.

Test cross of F1 generation

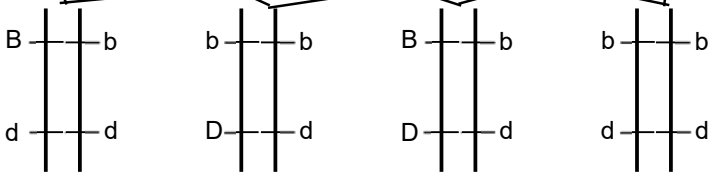
F1 phenotype: brown body colour, straight wings x black body colour, curved wings

F1 genotype:  x 

After meiosis, Gametes produced: Parental gametes, Recombinant gametes



Offspring Genotypes:



F_2 expected phenotypic ratio:	1 brown body, curved wings	:	1 black body, straight wings	:	1 brown body, straight wings	:	1 black body, curved wings
F_2 observed phenotype numbers:	1695		1903		1918		1692

[1] correct F1 phenotypes, genotypes with correct combination of alleles;
[1] correct F1 gametes, showing parental and recombinant gametes
[1] correct F_2 genotypes
[1] relate genotype to phenotype
[1] F_2 expected phenotypic ratio of 1:1:1:1 and corresponding observed numbers

[5]

[Total: 10]

7 In the 1950s, Melvin Calvin studied the series of reactions that we now know as the Calvin cycle. Calvin's 'lollipop' experiment was so called because it used a lollipop-shaped glass flask containing single-celled photosynthetic algae growing in culture.

Fig. 7.1 shows the setup of Calvin's 'lollipop' experiment.

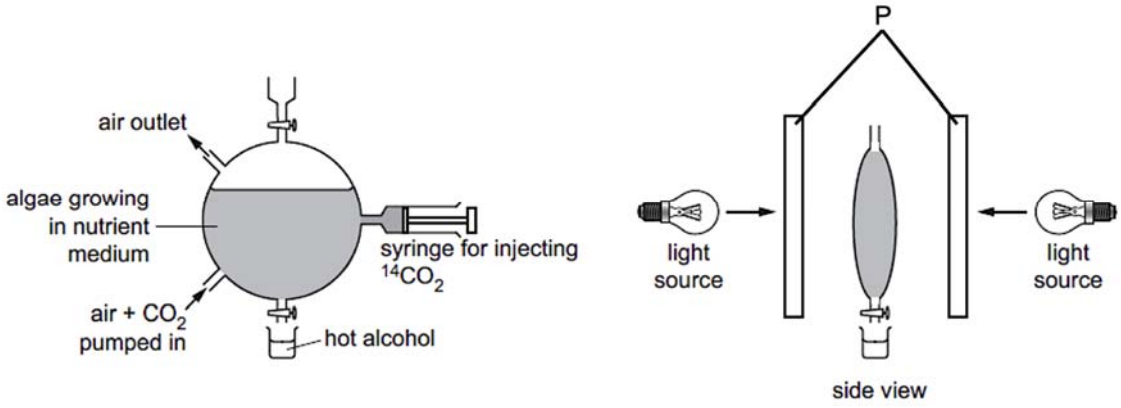


Fig. 7.1

The algae were illuminated for 30 minutes before the start of the experiment. Air containing non-radioactive carbon dioxide was pumped into the suspension throughout the 30 minutes.

At time zero, a small amount of radioactively-labelled carbon dioxide ($^{14}CO_2$) was introduced. At intervals after addition of $^{14}CO_2$, samples of the suspension were killed in hot alcohol before being analysed.

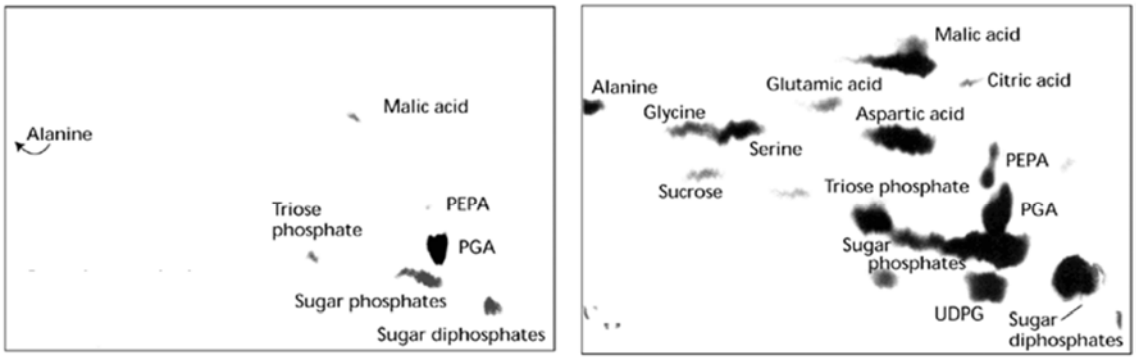
(a) **P** is placed between each lamp and the lollipop-shaped glass flask as shown in Fig. 7.1.

Suggest the purpose of **P**.

1. Ref to reduction of heat generated by lamp; [1]

The samples were analysed using chromatography and autoradiography.

Fig. 7.2 shows the results of Calvin's 'lollipop' experiment. Dark spots showed the presence of radioactive organic compounds at 5 seconds and 30 seconds after the addition of $^{14}CO_2$.



5 seconds after addition of $^{14}CO_2$ 30 seconds after addition of $^{14}CO_2$

Fig. 7.2

(b) With reference to Fig. 7.2,

(i) explain how PGA was determined to be the first intermediate in carbon fixation.

1. PGA as having largest size at 5 sec photosynthesis; [1]

(ii) explain the results at 30 seconds after addition of $^{14}CO_2$.

1. ref to reaction of CO_2 with **five–carbon** **ribulose bisphosphate** catalysed by **rubisco** (ribulose bisphosphate carboxylase/ oxygenase) to form **PGA**; [5]
2. ref to **phosphorylation and reduction** of PGA to form **G3P** (glyceraldehye-3-phosphate);
3. ref link to increased triose phosphates and sugar phosphates in Fig. 7.2;
4. ref to rearrangement of **5 G3P** to form **3 RuBP**;

5. ref link to increased sugar diphosphates in Fig. 7.2;
6. ref to increased conversion of G3P to other biomolecules such as sucrose / amino acids ;
7. ref to increased conversion of G3P to respiratory intermediates such as malic acid / citric acid;

(c) Calvin cycle requires the products of light dependent reactions.

Compare non-cyclic and cyclic photophosphorylation.

[3]

	Non-cyclic photophosphorylation	Cycle photophosphorylation
1. electron source and electron acceptor	Water (source) and $NADP^+$	Electrons are cycled through PSI
2. release of oxygen	Oxygen released from water	none
3. form in which energy is temporarily captured	ATP by chemiosmosis and NADPH	ATP by chemiosmosis only
4. photosystems involved	PS I and PS II	PS I only

[Total: 10]

8 The insulin receptor comprises two α–chains (L1, CR, L2, F1, F2 and α-CT) and two β–chains (F3, TM and TK). The extracellular portion of the receptor consists of the α–chain and F3 of

β–chain. The remainder of the β–chain includes a transmembrane helix (TM) and the intracellular tyrosine kinase (TK) domain.

Fig. 8.1 shows the steps involved in the activation of the insulin receptor.

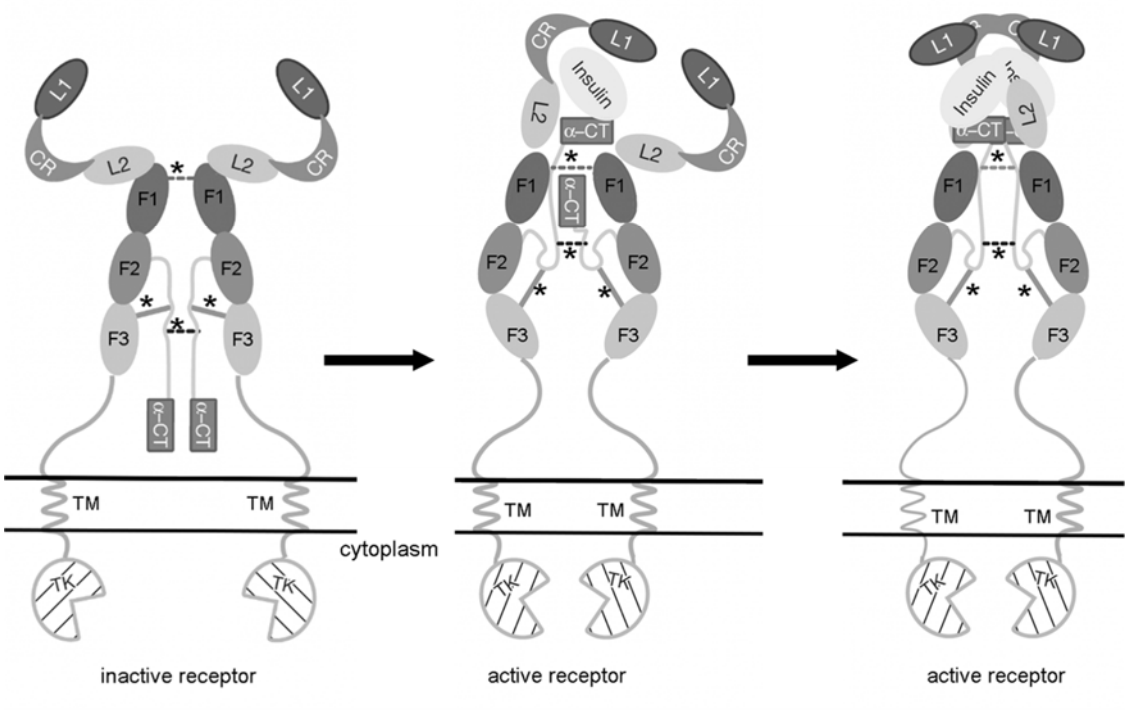


Fig. 8.1

(a) With reference to Fig. 8.1, explain how the binding of insulin leads to the activation of the insulin receptor.

AOA; LO: 3(m)

[5]

	Ref to structure in Fig.	**Relate to function**
1.	**L1, CR, L2 domains** form complementary binding site for insulin	Allows only insulin to bind;

2.	**Receptor spans across the phospholipid bilayer / has intracellular and extracellular domains**	Allows an extracellular ligand to stimulate cellular response / transmit signal into the cell;
3.	**Transmembrane helix (TM)** containing **hydrophobic amino acids that interact with phospholipids tails** of cell surface membrane	Allows insulin receptor to be stably **anchored in the membrane**;
4.	**Tertiary structure** of insulin receptor is **maintained by weak bonds** such as hydrogen bonds, ionic bonds, hydrophobic interactions	Allows TM domains to be brought closer/ allows TK domains to be brought closer ;
5.	**Flexible carbon skeleton of** polypeptide chains	Allows ⟨**-CT domain** to interact with insulin/ allows extracellular domains to deform to bind insulin more tightly;
6.	**Tyrosine kinase (TK) domain** can be activated	Allows **phosphorylation** of cytoplasmic proteins to trigger downstream signal propagation;

(b) The lines marked by asterisks (*) represent a type of strong bond holding the polypeptide chains together.

(i) Name the bond.

Disulfide bonds; [1]

(ii) With reference to Fig. 8.1, describe the significance of these bonds.

1. Allows conformation changes on the extracellular domain to be **transmitted/propagated** to the intracellular domains; [1]
2. Allows all polypeptide chains to be held together **even with large conformation changes** in one chain;

(c) Suggest why the active receptor with two insulin molecules bound may be more effective in triggering downstream signal propagation.

1. Ref to more contact surface between insulin and insulin receptor domains + more stable conformation that with one bound insulin; [1]

(d) Describe **two** cellular responses when insulin binds to the receptors in muscle cells.

1. Ref to more glucose transporters translocated to the cell surface membrane for increased uptake of glucose;
2. Ref to more glucose being converted to glycogen for storage;
3. Ref to increased protein synthesis;
4. Ref to (more long chain fatty acid transporters translocated to cell surface membrane for) increased uptake of fatty acids;

[2]

[Total: 10]

9 Green lacewings of the genus *Chrysoperla* are insects commonly used for biological pest control as their larvae are predatory and feed on aphids.

Different *Chrysoperla* species may be identical in terms of morphology, but can be readily separated based on their courtship songs, which are vibration signals used to attract mates.

Fig. 9.1 shows the characteristics of courtship songs of four *Chrysoperla* species, namely, North American *C. calocedrii* and European *C. carnea*, *C. mediterranea* and *C. pallida*.

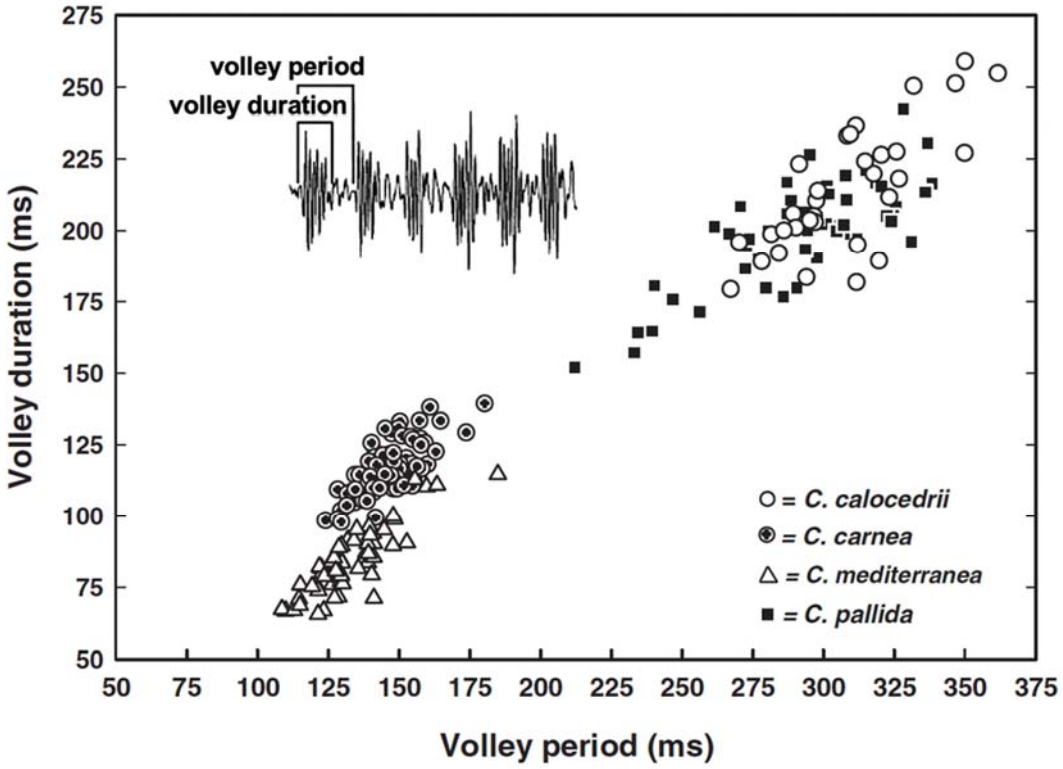


Fig. 9.1

(a) Explain how the European *C. carnea*, *C. mediterranea* and *C. pallida* may have evolved from a common ancestor.

Ref to **sympatric** speciation;

Variation in population due to **different random mutations** ;

Ref to **different courtship songs**, insects are **attracted to those with similar songs**, resulting in different preference for mates and hence **behavioural isolation**;

Leading to **disruption of gene flow** between two subpopulations;

Over many generations, the two subpopulation **accumulate genetic differences separately** and become different species;

[5]

(b) Different *Chrysoperla* species that are isolated from each other on different continents are not constrained to sing differently, so there may be occasional instances where nearly identical songs have evolved independently.

(i) With reference to Fig. 9.1, identify the European *Chrysoperla* species which has similar courtship song as the North American *C. calocedrii*.

C. pallida; [1]

(ii) Suggest how the introduction of the North American *C. calocedrii* to Europe will affect the gene pool of the European *Chrysoperla* species.

C. calocedrii may **mate with *C. pallida***, resulting in: (any one point below)

- **hybridisation** of the two species / form a **new hybrid species / gene pool combined**;
- **increase genetic variation** in the population of *C. pallida* / increase types of genes/alleles in gene pool of *C. pallida*;

[1]

(c) Fig. 9.2 shows the phylogeny based on DNA sequence data for the four *Chrysoperla* species.

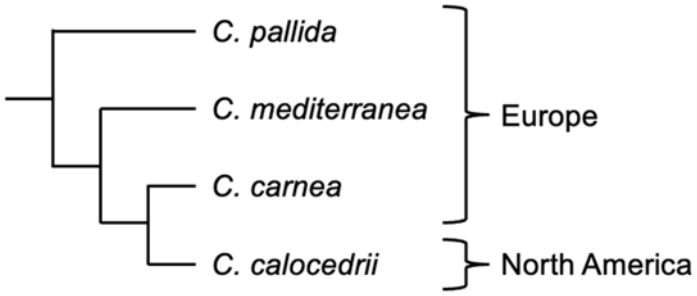


Fig. 9.2

With reference to Fig. 9.1 and Fig. 9.2 and the information provided, explain the importance of using DNA sequences, in addition to morphology and courtship songs, in reconstructing phylogenetic relationships of *Chrysoperla* species.

Chrysoperla species may be **morphologically indistinguishable** as they share a recent common ancestor (not due to convergent evolution);

C. pallida and *C. calocedrii*, which are geographically isolated, have **similar courtship songs** based on Fig. 9.1;

but *C. pallida* and *C. calocedrii* are **most distantly related based on DNA sequences / phylogeny** in Fig. 9.2;

Ref to similarity in courtship songs due to **convergent** evolution;

Molecular differences that are not reflected in morphology or courtship songs can be used to determine **evolutionary distance between species**;

[3]

[Total: 10]

10 Palm oil is a vegetable oil that is used very widely in food products. The oil is extracted from the fruit of the oil palm tree.

Oil palm trees have a higher oil yield than that of other oil-producing plants.

Fig. 10.1 shows the oil yield of four crop plants.

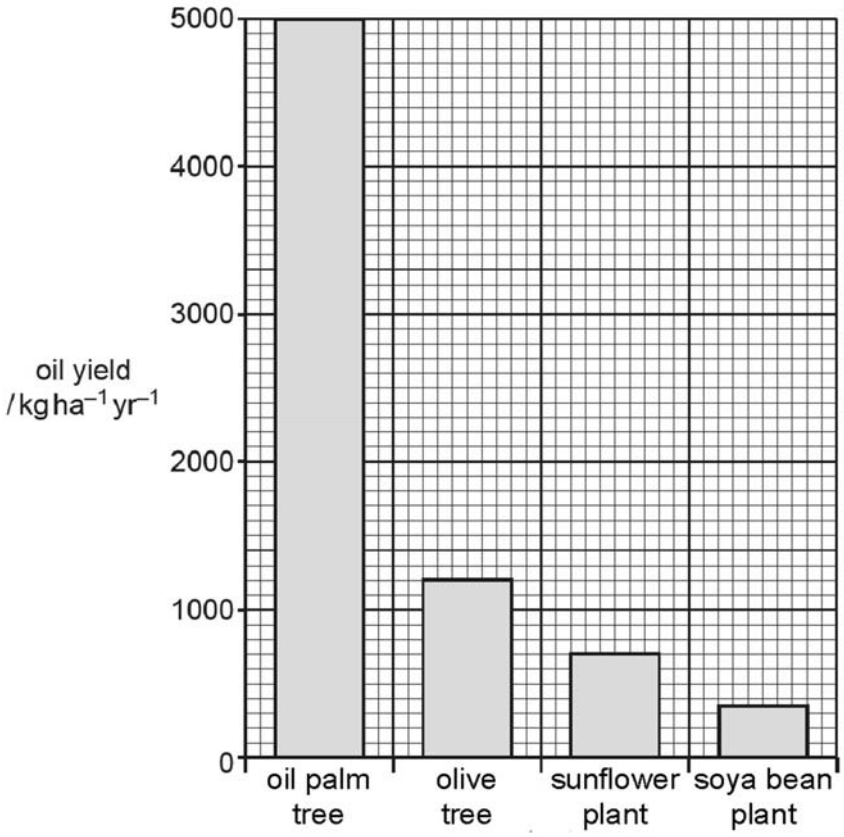


Fig. 10.1

(a) Calculate how many hectares (ha) of soya bean plants would be needed to produce the **same** yield of oil as one hectare of oil palm trees per year.

Show your working and write your answer to **one** decimal place.

5000 / 350 ;

= 14.3 ha ;

..... ha [2]

(b) Oil palm plantations in Malaysia and Indonesia have been created by cutting down rainforests. This reduces biodiversity.

State three reasons why it is important to maintain biodiversity.

- maintain large gene pool / genetic variation ;
- rich reservoir for biomedicines;
- genetic diversity for food
- maintain food webs / food chains / ecosystem ;
- AVP ;

Reject general importance of forests that is not related to biodiversity e.g. carbon sink

[3]

[Total: 5]

11 Infectious diseases can be controlled by different methods including vaccines and antibiotics.

Describe how vaccines and antibiotics can be used to control infectious diseases.

Vaccines:

by **introducing antigens of pathogen / inactivated pathogens / attenuated live pathogens** into the body;

stimulates an adaptive immune response by **activating the T/B lymphocytes / produce antibodies**;

generates a supply of **memory cells** that **protect against future infection** / **provide long-term immunity**;

confers **herd immunity** when a **large percentage of population are immunised**;

Antibiotics:

inhibiting the growth of bacteria or killing the bacteria;

E.g. inhibit peptidoglycan cell wall synthesis / inhibit translation by 70S ribosomes / inhibit nucleic acid synthesis ;

[5]

[Total: 5]

Question 2 starts/continues on page 4

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