



Oxford Cambridge and RSA

Thursday 13 June 2019 – Morning

A Level Biology B (Advancing Biology)

H422/02 Scientific literacy in biology

Time allowed: 2 hours 15 minutes



You must have:

- the Insert (inserted)

You may use:

- a scientific or graphical calculator
- a ruler (cm/mm)



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

Last name

StemUp Model Solution

INSTRUCTIONS

- The Insert will be found inside this document.
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION

- The total mark for this paper is **100**.
- The marks for each question are shown in brackets [].
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **28** pages.

Answer **all** the questions.

- 1 This question is based on the Advance Notice article '**Learning from Iceland's model for genetic research**' in the **Insert**.

(a) The article explains how Iceland has one of the most genetically homogeneous populations in Europe.

(i) State what is meant by the following genetic terms.

1. Gene *A sequence of DNA nucleotides (bases) that codes for a polypeptide.*

2. Allele *A gene variant: a different version of the same gene.*

[2]

(ii) Allele frequencies will remain constant in a stable population. However, population changes can alter allele frequencies.

For each of the following events, give the term used to describe the effect on allele frequencies.

1. Iceland was settled by a relatively small number of explorers in the 9th century.

Founder effect

2. The Icelandic population decreased due to the two waves of plagues during the 15th century, smallpox in the early 1700s and a volcanic eruption in 1783.

Genetic bottleneck

[2]

(iii) Explain how the events described in (ii) resulted in the low genetic diversity of the Icelandic population.

Both events left only a small (decreasing) number of individuals to

reproduce, so the population had a small gene pool.

Only a limited number of alleles were passed on and many alleles were

lost from the population; geographic isolation then kept the gene pool

small.

[2]

- (b) The article describes the use of flow cytometry ('automated blood analysers') to identify genetic variants linked to the risk of developing multiple myeloma.

Explain how flow cytometry could be used to identify genetic variants linked to the risk of developing multiple myeloma.

Blood cells are labelled with a fluorescent marker.
 The fluorescence is attached to antibodies, which bind to specific antigens on the surface of the white blood cells (e.g. B cells).
 Alternatively, a fluorescent DNA probe (a labelled section of DNA complementary to the variant) binds to the genetic variant in the cells.
 The flow cytometer passes the cells one at a time through a laser, detects their fluorescence, and counts and sorts the cells with the genetic variant.
 The frequency of the variant can then be compared in people who do and do not develop myeloma.

[4]

- (c) Some genetic diseases, such as sickle cell anaemia, are caused by single mutations.

Explain how a single gene mutation causes sickle cell anaemia.

A single base (nucleotide) substitution in the gene for the β -polypeptide of haemoglobin: on the coding strand the triplet GAG becomes GTG.
 This changes the mRNA codon (GAG to GUG), so a different amino acid is attached: valine replaces glutamic acid, changing the primary structure.
 This changes the tertiary (3D) shape of haemoglobin, so the abnormal haemoglobin clumps together (crystallises) at low O_2 concentration and the red blood cells become sickle-shaped.
 The disease is only seen in homozygous recessive individuals ($H^S H^S$).

[3]

- (d) The goal of the researchers at the International Myeloma Foundation is to identify people who develop multiple myeloma after having monoclonal gammopathy of undetermined significance (MGUS).

Evaluate the advantages and disadvantages of this approach compared with pedigree analysis.

Advantages: screening for MGUS may give a more accurate diagnosis of who is at risk, so doctors can intervene and treat earlier, which may prevent or cure myeloma. It also identifies people at risk who have no family history (pedigree analysis cannot), and removes worry for people who do have a family history but no MGUS.

Disadvantages: the MGUS screening may give false positives, causing unnecessary worry, as only about 1% of people with MGUS develop myeloma each year. It is more expensive than pedigree analysis (costly flow cytometry). [4]

- (e) In MGUS, B cells produce an abnormal polypeptide called M protein.

Production of M protein involves the processes of transcription and translation.

Complete the table by putting a tick (✓) in the appropriate box to indicate whether the feature is involved in transcription, translation, both or neither.

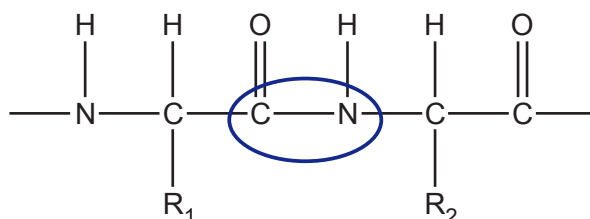
Feature	Transcription only	Translation only	Both	Neither
C pairs with G			✓	
A pairs with T	✓			
Phosphodiester bonds are made	✓			
Peptide bonds are made		✓		

[4]

- 2 Antimicrobial peptides (AMPs) are peptides found in animals and plants that destroy a wide range of pathogenic bacteria, fungi and viruses.

The α -defensins are a group of AMPs that contain 18–45 amino acids.

- (a) The diagram below shows part of the structure of an α -defensin molecule.



- (i) Draw a circle around the part of the structure that represents the peptide bond.

[The response to this question should be drawn on the diagram.]

[1]

- (ii) Name the chemical reaction that joins the amino acids together in a peptide.

condensation

[1]

- (b) A student used paper chromatography to investigate the amino acid composition of a sample of α -defensin.

- (i) Suggest the importance of the following steps in the paper chromatography procedure.

1. The sample of α -defensin was heated with hydrochloric acid.

*..To..hydrolyse..the..peptide..bands,..breaking..the..protein..into..its..individual
..amino..acids..*

2. Care was taken not to touch the paper with fingers.

..To..avoid..contaminating..the..paper..with..amino..acids..from..the..skin..

[2]

(ii) Fig. 2 shows the results of one analysis.

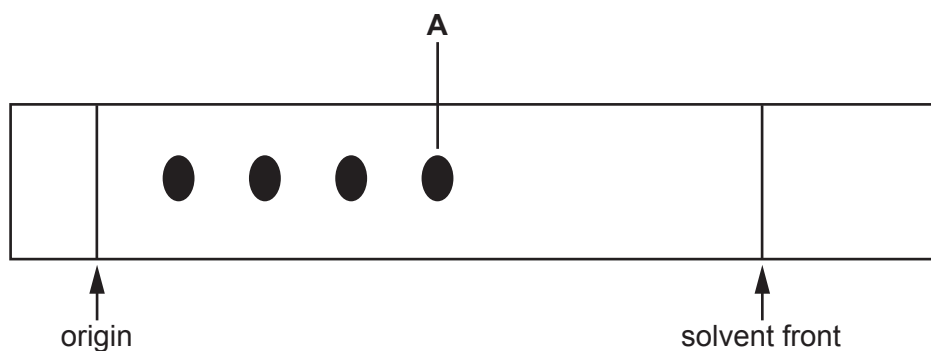


Fig. 2

Table 2 shows R_f values for six different amino acids.

Amino acid	R_f
Arginine	0.16
Cysteine	0.37
Glutamic acid	0.31
Isoleucine	0.53
Methionine	0.51
Tyrosine	0.55

Table 2

Using Fig. 2 and Table 2, calculate the R_f value for spot **A** and identify the amino acid.

distance moved by spot A = 45 mm

distance moved by solvent front = 88 mm

$$R_f = 45 \div 88 = 0.51$$

R_f value for spot **A** = ...0.51.....

amino acid = ...methionine.....

[2]

- (c)* AMPs are produced by epithelial cells in the intestines, respiratory tract, urinary tract and vagina.

The actions of AMPs include:

- destruction of many pathogenic bacteria, fungi and viruses
- stimulation of mast cells
- attraction and activation of phagocytes
- aggregation of pathogens (bacteria, fungi, viruses).

Use this information to explain how AMPs play an important role in the body's **non-specific** defence mechanisms.

AMPs are part of the first line of defence: they are made by epithelial cells at entry points such as the intestines, airways, urinary tract and vagina, with barriers such as skin, mucus and acidic vaginal pH. They destroy pathogenic bacteria, fungi and viruses before they can enter the tissues or spread, acting on many pathogens (non-specific). AMPs stimulate mast cells to release histamine (and serotonin and prostaglandins). This causes inflammation: vasodilation increases blood flow, causing redness and heat, and capillaries become more permeable, so fluid leaks out causing swelling (oedema). This brings more phagocytes and complement proteins to the site. AMPs (and cytokines) attract and activate phagocytes such as neutrophils and macrophages (monocytes differentiate into macrophages). Aggregation clumps pathogens together, so phagocytes can engulf many at once. The phagocyte engulfs the pathogen into a phagosome; lysosomes fuse with it to form a phagolysosome, and hydrolytic enzymes digest and destroy the [6]

Additional answer space if required.

pathogen. Macrophages and dendritic cells then act as antigen-presenting cells, and NK cells kill infected cells, so AMPs link several non-specific defences together.

- (d) The β -defensins are another group of peptides found in the male reproductive tract.

One β -defensin is coded for by the *DEFB126* gene. Men who are homozygous for a mutation in *DEFB126* have a normal sperm count with normal motility, but the sperm have a reduced ability to penetrate hyaluronic acid (a model for female cervical mucus).

- (i) Suggest why it is thought that the *DEFB126* mutation reduces the chance of successful fertilisation.

The sperm cannot penetrate the cervical mucus easily, so fewer sperm reach the oviduct (fallopian tube). So the sperm are less likely to reach and fertilise the secondary oocyte.

[2]

- (ii) It is estimated that 22% of all Europeans are homozygous for the recessive mutant form of *DEFB126*.

Calculate the allele frequency of the mutant form of *DEFB126* in all Europeans (men and women).

Use the Hardy-Weinberg equations:

$$p + q = 1 \qquad p^2 + 2pq + q^2 = 1$$

Give your answer to **2 significant figures**.

$$q^2 = 0.22$$

$$q = \sqrt{0.22} = 0.469$$

$$= 0.47 \text{ (2 s.f.)}$$

frequency = *0.47* [2]

- (iii) The fact that the *DEFB126* mutation reduces the chances of successful fertilisation means that, in theory, the allele frequency should have fallen.

Suggest why the allele frequency of the *DEFB126* mutation remains high.

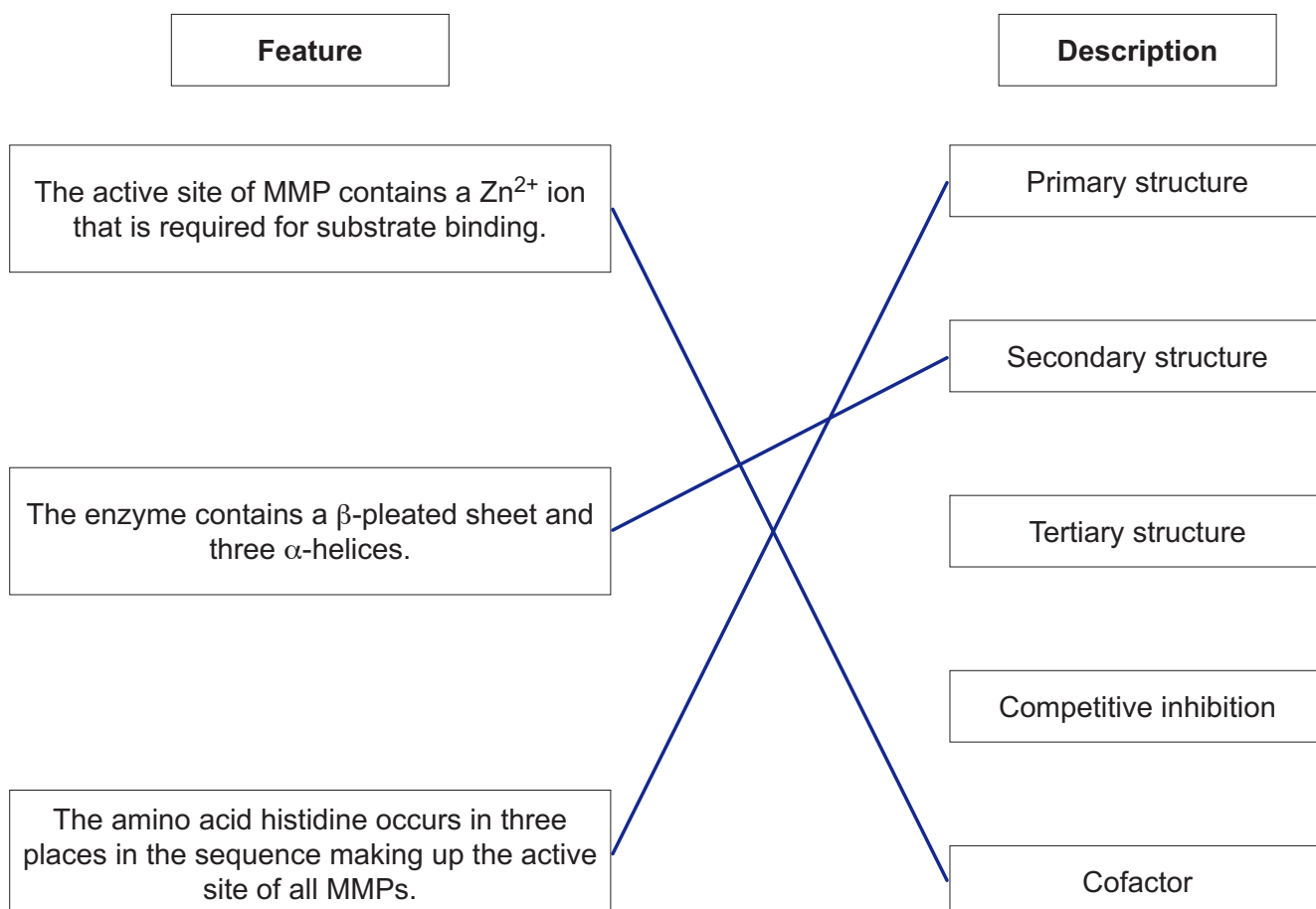
Only homozygous recessive men are affected; heterozygotes are not, so they pass on the allele (and may have a selective advantage). [1]

- 3 The extracellular matrix (ECM) can be thought of as the 'glue' that holds together the cells in a tissue. The ECM consists of water, proteins and polysaccharides.

Matrix metalloproteinases (MMPs) are a group of proteases that hydrolyse proteins in the ECM.

Each MMP consists of a single polypeptide chain.

- (a) For each of the following features of MMP structure, draw a line connecting the feature to the correct description.



[3]

- (b) MMP activity has been linked to the development of cancer.

Women with tumours in their breasts will often have biopsies (tissue samples) taken and tested to see if the tumours are malignant (cancerous) or benign (non-cancerous).

In one study, the total MMP activity was measured in breast biopsies that were classed as either:

- benign
- malignant grade I (the least malignant)
- malignant grade II
- malignant grade III (the most malignant).

Table 3 shows the results of this study.

Tumour classification	MMP activity (units per μg protein)
Benign	6.58
Malignant grade I	1.34
Malignant grade II	6.80
Malignant grade III	32.29

Table 3

- (i) The researchers carried out a statistical test to compare the MMP activity in grade III tumours with the mean activity in all other tumours (benign, grade I and grade II).

Suggest a null hypothesis that the researchers would have used.

There is no significant difference in MMP activity between grade III tumours and all other tumours (benign, grade I and grade II). [1]

- (ii) The result of this test gave $p < 0.0001$.

Use the words 'probability' and 'chance' to describe the conclusion the researchers would make.

There is less than 0.01% (0.0001) probability that the difference in MMP activity between grade III and the other tumours is due to chance, so the difference is significant. [1]

- (iii) Use the data in Table 3 to evaluate the hypothesis that MMP activity increases the severity of breast cancer.

Supports: MMP activity is significantly greater in grade III (the most malignant) tumours, 32.29 units per μ g protein, almost five times grade II (6.80), and rises from grade I to III; a positive correlation.

Does not support: activity in grade II (6.80) is about the same as in benign tumours (6.58), and in grade I (1.34) it is lower than in benign tumours.

Other factors may be involved, and correlation does not imply causation.

[3]

- (c) Marimastat is an MMP inhibitor that was used in clinical trials as a potential treatment for cancer.

Suggest how marimastat could inhibit MMPs to reduce the hydrolysis of proteins in the ECM.

As a competitive inhibitor with a similar shape to the substrate, marimastat binds to (blocks) the active site of the MMP.

This prevents (competes with) the binding of the ECM proteins (substrate), so fewer enzyme-substrate complexes form and fewer proteins are hydrolysed.

[2]

- 4 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.

A diagram of the apparatus Calvin used is shown in Fig. 4.1.

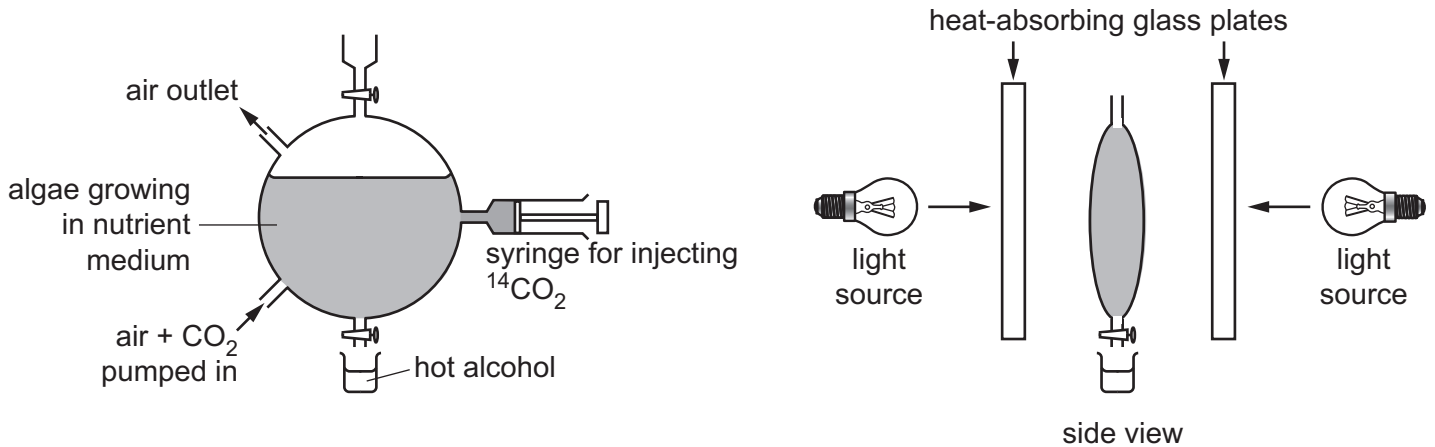


Fig. 4.1

The algae were illuminated for 30 minutes before the start of the experiment. Air and carbon dioxide were pumped into the suspension throughout.

At time zero, a small amount of radioactively-labelled carbon dioxide (¹⁴CO₂) was injected from the syringe.

At intervals after addition of the ¹⁴CO₂, samples of the suspension were run off into hot alcohol before being analysed.

(a) Suggest the reasons for the following steps in the experiment.

1. Illuminating the algae for 30 minutes before the start of the experiment.

To ensure the algae are photosynthesising at a constant rate (the suspension has equilibrated) before the $^{14}\text{CO}_2$ is added.

2. Placing heat-absorbing glass between the light sources and the flask.

To prevent the suspension overheating, which would denature the photosynthetic enzymes.

3. Running each sample into hot alcohol before analysis.

To kill the algae (cells) instantly, stopping the photosynthetic reactions at that time.

[3]

- (b) Calvin measured the relative radioactivity in various compounds at 2 seconds, 10 seconds and 30 seconds after addition of the $^{14}\text{CO}_2$.

The results of the analysis are shown in Table 4. Presence of radioactivity is represented in the table as '+' and no radioactivity as '-'.

Organic compound	Relative radioactivity present at time after addition of $^{14}\text{CO}_2$		
	2 s	10 s	30 s
Amino acids	—	—	+
Glycerate-3-phosphate (GP)	+	+	+
Sucrose	—	—	+
Sugar phosphates	—	—	+
Triose phosphate (TP)	—	+	+

Table 4

- (i) Name the enzyme responsible for the initial incorporation of radioactive CO_2 into organic compounds.

Ribulose biphosphate carboxylase (rubisco) [1]

- (ii) Use the results in Table 4 to explain the order in which the organic compounds are produced during photosynthesis.

GP is produced first, because it is already radioactive (+) by 2 seconds......

TP is produced second, from GP, because it first becomes radioactive by.....

10 seconds......

Amino acids, sucrose and sugar phosphates are produced last, from TP,.....

because they only become radioactive by 30 seconds......

.....

..... [3]

- (c) Calvin isolated the compounds formed at the earliest time points and found they contained three carbon atoms.

This led him to conclude that the first reaction in the cycle was between CO_2 and a 2-carbon compound.

Explain why Calvin's conclusion was **incorrect**.

CO₂ actually reacts with RuBP (ribulose biphosphate), a 5-carbon compound, not a 2-carbon compound.

The first reaction produces an unstable 6-carbon compound that immediately breaks down to form two 3-carbon compounds (two GP), so only 3-carbon compounds were detected. [2]

Question 4(d) begins on page 16

- (d) Fig. 4.2 shows the relationship between the net rate of photosynthesis and light intensity in a plant growing at atmospheric CO_2 concentration (0.04%).

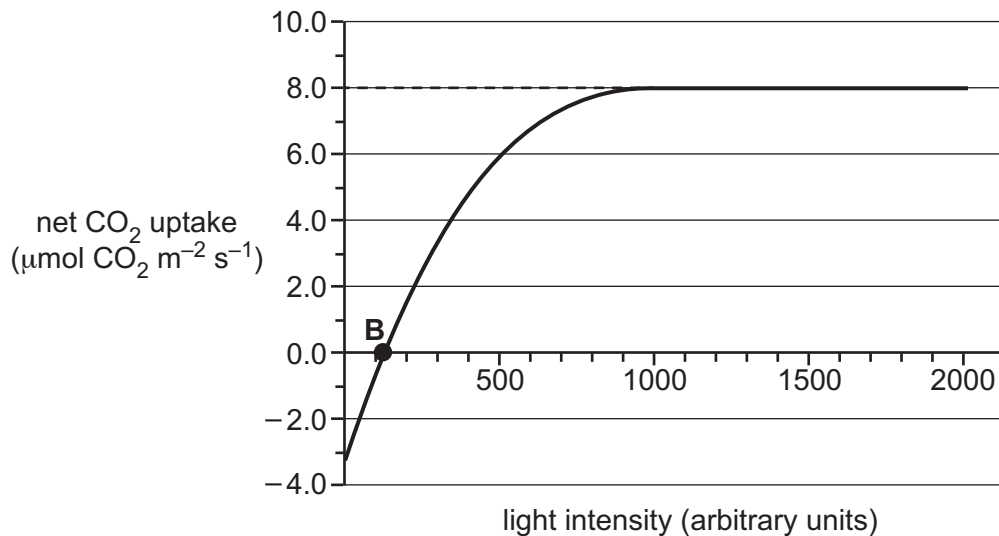


Fig. 4.2

- (i) The plant had a leaf area of 0.97 m^2 .

Calculate the maximum amount of CO_2 that the plant can take up in 1 minute.

$$\text{maximum net uptake} = 8.0 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$$

$$\text{per plant: } 8.0 \times 0.97 = 7.76 \mu\text{mol s}^{-1}$$

$$\text{in 1 minute: } 7.76 \times 60 = 465.6 \mu\text{mol}$$

$$\text{maximum amount of CO}_2 \text{ taken up in 1 minute} = \dots\dots\dots 465.6 \dots\dots\dots \mu\text{mol} \quad [2]$$

- (ii) Explain the significance of the point labelled **B** on Fig. 4.2.

Point B is the compensation point: the rate of photosynthesis equals the rate of respiration, so there is no net exchange of CO_2 (or O_2).

..... [1]

- (e) Winter wheat seeds are usually sown in the autumn and flower the following summer. Seeds sown in the spring will usually not flower.

The Russian geneticist Lysenko discovered that winter wheat seeds can be treated with cold and moisture.

Explain why winter wheat seeds treated in this way and sown in spring are able to flower.

*This is vernalisation: the cold, moist treatment acts like a winter.
Cold and moist conditions promote the transcription (expression) of genes
associated with flowering, e.g. by producing transcription factors, so the plants
can flower that summer.*

[2]

- (f) Chrysanthemums normally flower only in autumn.

Commercial growers obtain flowers earlier in the year by growing the chrysanthemums in greenhouses where they can use screens or curtains to provide at least 12 hours of darkness.

Explain how this method stimulates early flowering and why it will not work if the plants are exposed to a brief period of light during the 12 hours of darkness.

*Chrysanthemums are short-day (long-night) plants, and the screens give long,
uninterrupted nights.
Light converts Pr into Pfr; during darkness Pfr is slowly converted back to Pr.
During the long night most Pfr is converted to Pr. The ratio of Pfr : Pr
(relative amounts) determines when flowering occurs, so the low level of Pfr
stimulates flowering.
A brief period of light quickly converts Pr back to Pfr, so the Pfr level is
high again, the long night is broken and flowering is inhibited.*

[3]

5 Fig. 5 shows a vertical section through the human eye.

The regions labelled **C**, **D** and **E** are affected by degenerative diseases of the eye associated with ageing.

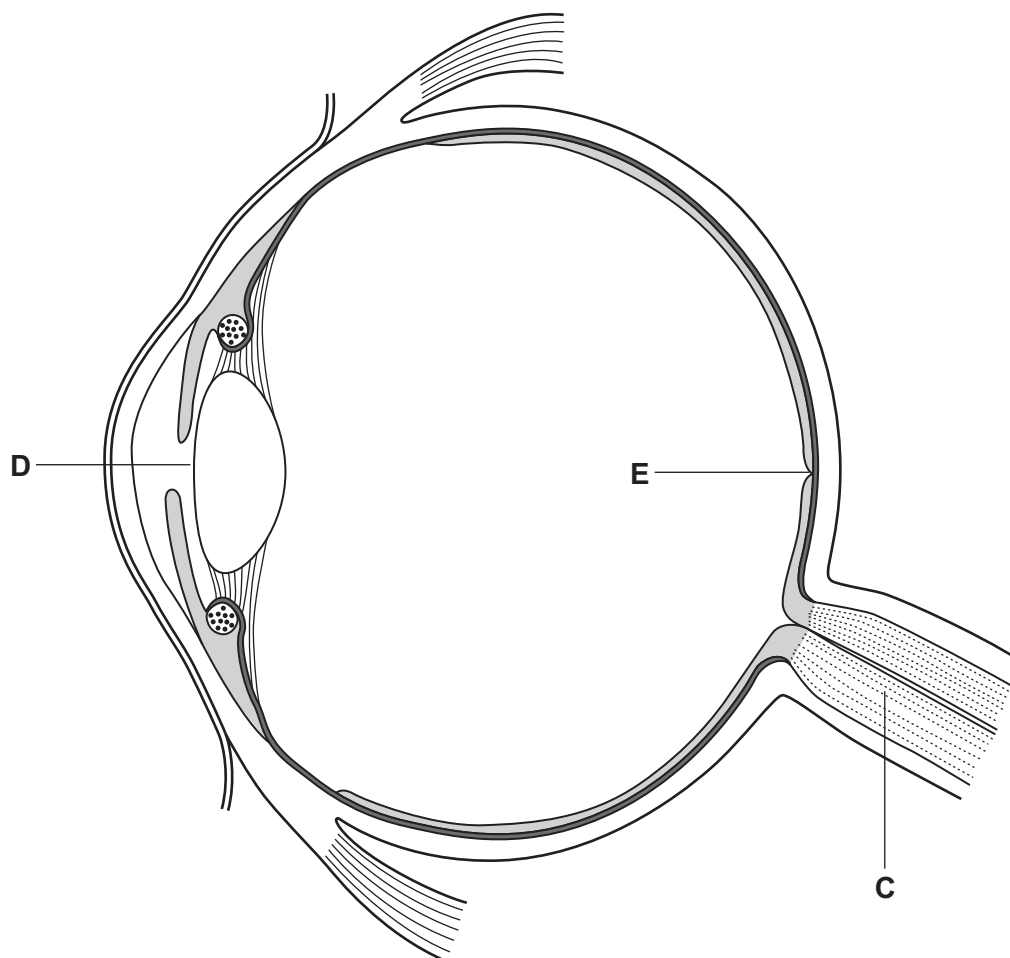


Fig. 5

- (a) (i) For regions **C** and **D** in Fig. 5, name the degenerative disease **and** explain why vision would be affected.

Region **C**

name of disease *glaucoma*

explanation *Increased pressure of the fluid (aqueous humour) in the eye damages the optic nerve, so fewer impulses reach the brain and (peripheral) vision is lost.*

Region **D**

name of disease *cataract*

explanation *The lens (protein) becomes opaque (cloudy), so less light passes through to the retina and vision becomes blurred.*

[4]

- (ii) Ranibizumab is a monoclonal antibody-based drug that inhibits the growth of new blood vessels.

Suggest how ranibizumab would be effective in treating a degenerative disease that affects the region labelled **E** in Fig. 5.

Ranibizumab prevents (reverses) the growth of new blood vessels into the retina (macula / fovea), as in wet age-related macular degeneration. So it reduces damage (scarring) to the retina from leaking blood vessels, preventing further loss of central vision.

[2]

(b) The retina contains light-sensitive photoreceptor cells.

(i) Explain why photoreceptor cells in the retina are described as transducers.

They convert light energy into chemical energy (which leads to a nerve impulse). [1]

(ii) Rod cells undergo various changes when they are stimulated by light.

Complete the following table by writing 'Rest' or 'Light' in the space provided to indicate whether the description refers to a rod cell at rest or when stimulated by light.

The first row has been completed for you.

Process in rod cell	Rest or Light
Rhodopsin is broken down to form opsin and <i>trans</i> -retinal	Light
Rod cell membrane is hyperpolarised	<i>Light</i>
Neurotransmitter is released by exocytosis from the rod cell into the synaptic cleft	<i>Rest</i>
Sodium ion channels open	<i>Rest</i>

[2]

(c) Red-green colour blindness is a sex-linked inherited disorder that affects mostly males.

Suggest why red-green colour blindness affects mostly males.

The gene (allele) for red-green colour blindness is on the X chromosome, and there is no corresponding allele on the Y chromosome. Males (XY) have only one X chromosome, so only one faulty recessive allele is needed for colour blindness, whereas females need two. [2]

6 (a) Meiosis is the nuclear division that forms gametes.

(i) Explain why meiosis is referred to as a **reduction** division.

The chromosome number is halved; haploid cells are produced from diploid cells. [1]

(ii) Errors in meiosis can lead to chromosome mutations.

State the name of an event in meiosis that leads to chromosome mutations.

Non-disjunction [1]

(iii) State the name of one syndrome caused by a chromosome mutation.

Down's syndrome [1]

(iv) Some cancers that develop later in life are caused by chromosome mutation.

Suggest why these cancers are unlikely to be the result of errors in meiosis.

Body (somatic) cells divide by mitosis, not meiosis; meiosis only produces gametes. [1]

- (b)* Events before conception and during pregnancy can have a significant effect on the health of a baby.

Recently, scientists found there is only a small correlation between light alcohol consumption and small birth weight.

They found no evidence for a link between light-to-moderate alcohol consumption and the more serious effects of fetal alcohol syndrome, which can be caused when a mother drinks alcohol heavily during pregnancy.

Using this information and your own knowledge about the effects of alcohol on fetal development, evaluate this advice from the NHS website:

The Chief Medical Officers for the UK recommend that if you're pregnant or planning to become pregnant, the safest approach is not to drink alcohol at all.

Effects of alcohol: ethanol crosses the placenta into the fetal blood, and the fetal liver is less able to detoxify ethanol, so it stays in the fetus for longer. Heavy drinking can cause fetal alcohol syndrome (FAS): damage to the central nervous system, learning difficulties, psychological or behavioural problems after birth, growth deficiency and facial features such as small eye openings. Even moderate drinking can cause language and speech problems. Evaluation: the new evidence found only a small correlation between light drinking and low birth weight, and no conclusive link between light-to-moderate drinking and FAS. However, the serious effects come from heavy (excessive) drinking, and it may not be valid to extrapolate this to moderate drinking. The study may have a limited sample size or be biased (e.g. women under-reporting how much they drink), and the evidence is only recent, not long term, so later effects on children may not yet be known. Individual women and fetuses respond differently to alcohol, so no level can [6]

Additional answer space if required.

be shown to be safe for everyone. So, as harm from light drinking cannot be ruled out and FAS is severe and permanent, not drinking at all is the safest approach and the advice is justified, even though the evidence for harm from light drinking is weak.

- 7 (a) Fig. 7 is a diagram of a maize plant showing the male and female flowers.

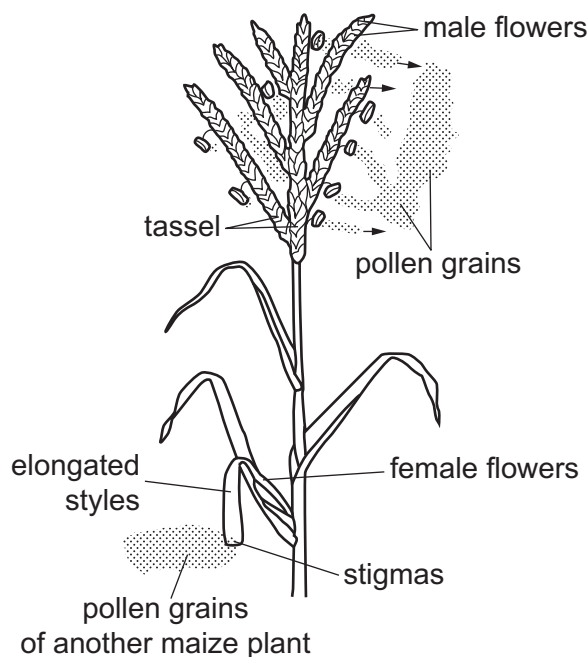


Fig. 7

Using the information in Fig. 7, identify **one** way in which maize is adapted for wind pollination.

Pollen is produced in large amounts, and the anthers (male flowers on the tassel) and the long feathery stigmas hang outside the flower, in the air.

[1]

- (b) When maize pollen grains land on the stigma of a maize plant, a pollen tube grows towards the ovule.

Describe the events that lead to the formation of the embryo **and** the endosperm.

Double fertilisation occurs.
The pollen tube grows down the style, through the micropyle, and delivers two male gametes (sperm cell nuclei) into the embryo sac.
One male gamete fuses with (fertilises) the egg cell to form a diploid zygote, which develops into the embryo.
The nucleus of the other male gamete fuses with the two polar nuclei to form a triploid nucleus, which develops into the endosperm.

[3]

- (c) As well as being a popular food (corn on the cob), maize is a useful model for studying patterns of inheritance.

Each maize cob contains hundreds of seeds known as kernels.

In maize, one gene determines the colour of the kernels, which is either yellow or colourless.

Another gene determines the amount of endosperm in each kernel. Kernels filled with endosperm are smooth whereas kernels with shrunken endosperm appear wrinkled.

- (i) Two pure breeding strains of maize were crossed. One strain had smooth yellow kernels. The other strain had wrinkled colourless kernels.

All the kernels of the offspring (F_1) were smooth and yellow.

The plants in the F_1 generation were then crossed with plants that had pure-bred wrinkled colourless kernels.

State the parental genotypes and gametes of this cross.

Use the following to represent the alleles:

- **A** and **a** for colour (yellow or colourless)
- **B** and **b** for appearance (smooth or wrinkled).

parental genotypes: *AaBb* × *aabb*

gametes: *AB, Ab, aB, ab and ab*

[2]

- (ii) Using a genetic diagram and your answer to (c)(i), predict the phenotypic ratio that you would expect from the second cross.

parents: *AaBb* (smooth yellow) × *aabb* (wrinkled colourless)

gametes: *AB Ab aB ab* × *ab*

	<i>AB</i>	<i>Ab</i>	<i>aB</i>	<i>ab</i>
<i>ab</i>	<i>AaBb</i> yellow, smooth	<i>Aabb</i> yellow, wrinkled	<i>aaBb</i> colourless, smooth	<i>aabb</i> colourless, wrinkled

1 smooth yellow : 1 wrinkled yellow : 1 smooth colourless : 1 wrinkled colourless

phenotypic ratio: *1 : 1 : 1 : 1* [2]

(iii) The actual results of the second cross are shown in Table 7.1.

Phenotype	Number of kernels
Smooth yellow	275
Wrinkled yellow	277
Smooth colourless	235
Wrinkled colourless	213

Table 7.1

Calculate χ^2 for these data.

Use the formula: $\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$

You may use the table below for working out.

<i>Phenotype</i>	<i>O</i>	<i>E</i>	<i>O - E</i>	<i>(O - E)²</i>	<i>(O - E)²/E</i>
<i>Smooth yellow</i>	275	250	25	625	2.500
<i>Wrinkled yellow</i>	277	250	27	729	2.916
<i>Smooth colourless</i>	235	250	-15	225	0.900
<i>Wrinkled colourless</i>	213	250	-37	1369	5.476
				$\Sigma =$	11.792

$$\chi^2 = \dots 11.79 \dots [3]$$

- (iv) Table 7.2 shows a χ^2 probability table.

Degrees of freedom	Probability (p)				
	0.50	0.10	0.05	0.01	0.001
1	0.46	2.71	3.84	6.64	10.83
2	1.39	4.61	5.99	9.21	13.82
3	2.37	6.25	7.82	11.35	16.27
4	3.36	7.78	9.49	13.28	18.47

Table 7.2

What can you conclude about the results shown in Table 7.1 based on the χ^2 value you calculated in (c)(iii)?

$\chi^2 = 11.79$ with 3 degrees of freedom is greater than the critical value
11.35 ($p = 0.01$), so there is less than 1% probability that the
differences between observed and expected results are due to chance. [1]

- (v) Suggest an explanation for your conclusion in part (iv).

There is linkage between the two genes, for colour and for shape
(appearance).
The genes are on the same chromosome, so they do not assort
independently and the expected 1 : 1 : 1 : 1 ratio is not obtained. [2]

END OF QUESTION PAPER

This image shows a blank sheet of white paper designed for handwriting practice. It features a solid vertical line on the left side, creating a narrow margin. The rest of the page is filled with evenly spaced horizontal dashed lines, providing guides for letter height and placement. There are no other markings, text, or illustrations on the page.

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