

A Level Biology B (Advancing Biology)

H422/03 Practical skills in biology

Time allowed: 1 hour 30 minutes

You must have:

- the Insert (inside this document)
- a ruler (cm/mm)

You can use:

- a scientific or graphical calculator



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

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION

- The total mark for this paper is **60**.
- The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

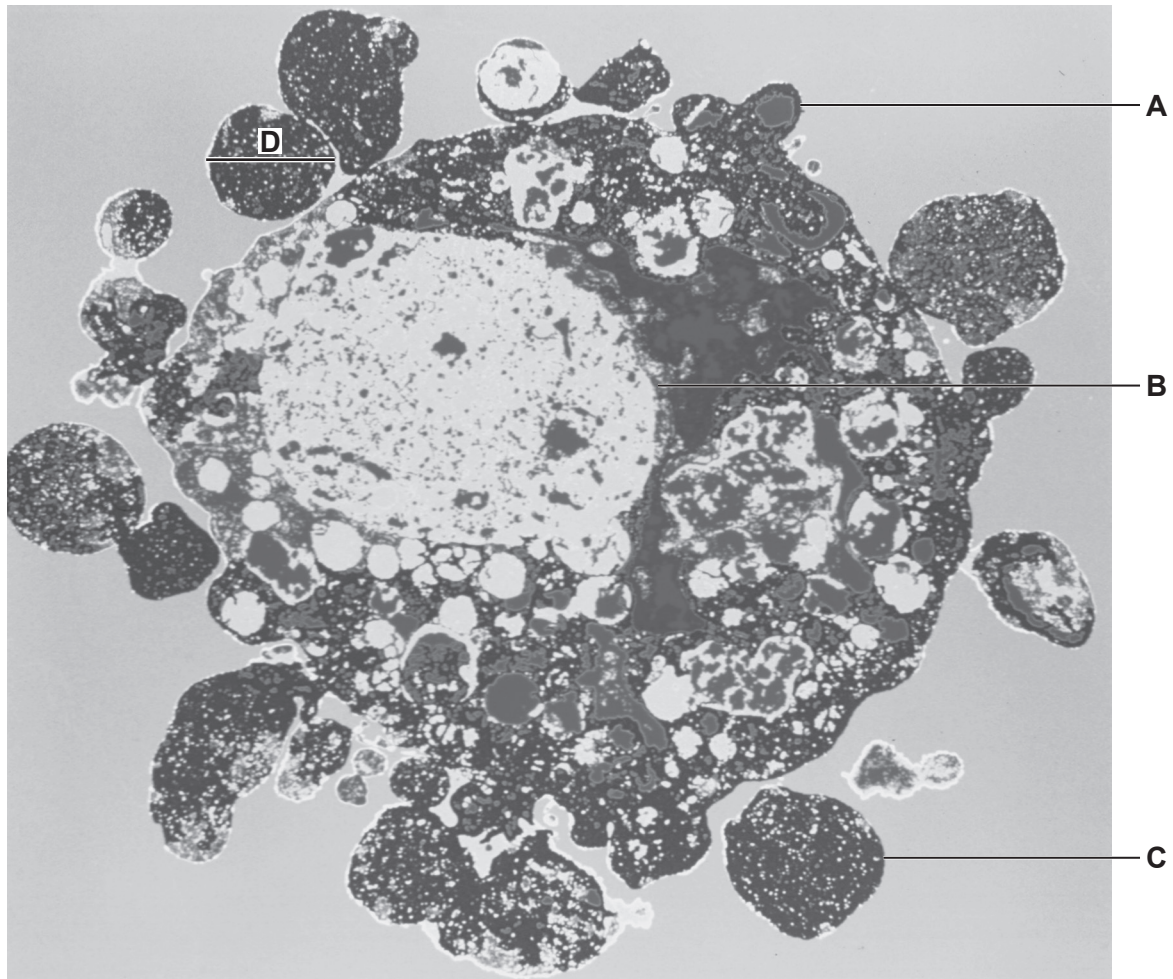
ADVICE

- Read each question carefully before you start your answer.

1 Apoptosis is the programmed cell death of damaged or unwanted cells.

(a) Fig. 1.1 shows a transmission electron micrograph (TEM) of apoptosis of a leucocyte.

Fig. 1.1



- (i) Name the following structures and processes shown in Fig. 1.1:
- the structure labelled **A** forming in the cell surface membrane
 - the process occurring to the organelle labelled **B**
 - the structure labelled **C**.

Structure **A** ..*bleb*.....

Process **B** ..*nuclear fragmentation (karyorrhexis)*.....

Structure **C** ..*apoptotic body*.....

[3]

- (ii) The magnification used to produce the TEM in **Fig. 1.1** was $\times 20\,000$.

Calculate the actual diameter of the structure labelled **D** in **Fig. 1.1**.

Give your answer in standard form.

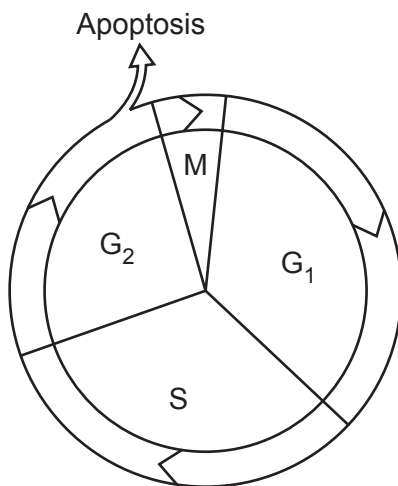
diameter of D on Fig. 1.1 = 17 mm

$$\begin{aligned} \text{actual diameter} &= \text{image size} \div \text{magnification} \\ &= 17 \text{ mm} \div 20\,000 = 0.00085 \text{ mm} = 0.85 \mu\text{m} \\ &= 0.00000085 \text{ m} \end{aligned}$$

Diameter of structure **D** = 8.5×10^{-7} m [2]

- (b) A diagram of the cell cycle is shown in **Fig. 1.2**. The diagram shows a cell entering apoptosis from the G_2 phase.

Fig. 1.2



- (i) Suggest and explain why the cell in **Fig. 1.2** entered apoptosis from G_2 .

The G2 checkpoint detected damaged DNA (or unreplicated DNA / an error made during DNA replication in S phase). [1]

- (ii) Outline a molecular mechanism that caused the cell to start apoptosis.

p53 (tumour suppressor protein) stimulates transcription factors, so the cell is labelled for destruction. [1]

- (c) Stem cells go through many cycles of cell division but remain undifferentiated.

The table shows some of the features of stem cells.

Complete the table. Use ticks (✓) to indicate the features that are observed in different types of stem cell.

Feature	Totipotent	Pluripotent	Multipotent
Can differentiate into any type of cell	✓		
Present in an embryo	✓	✓	
Present in an adult human		✓	✓

[2]

5
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2 The conditions in a plant's habitat affect its rate of photosynthesis.

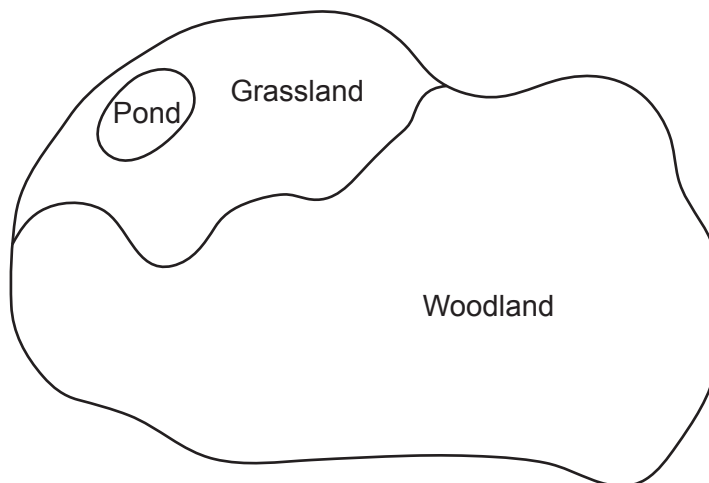
(a) Explain why plants are dependent on photosynthesis for their survival.

Photosynthesis produces triose phosphate, which is converted in the Calvin cycle into carbohydrates such as glucose and sucrose (and into lipids and amino acids).
The glucose is used in respiration to make ATP, and the light-dependent stage also produces ATP, which the plant needs to survive. [2]

(b) Black medic, *Medicago lupulina*, is a species of plant that tends to grow best in open areas, where it is exposed to high light intensities.

Lady fern, *Athyrium filix-femina*, is a species of plant that tends to grow best in damp, shaded woodland.

(i) A student observed both species of plant growing in their local area, which is shown in the diagram.



50 m

The student outlined a plan for sampling the abundance and distribution of the two species:

- Pick 10 locations on the map, 5 in the woodland and 5 in the grassland.
- Record whether the species (black medic and lady fern) are visible at each location.

Describe how the student can improve their plan for sampling the abundance and distribution of the two species.

Use a larger sample size, e.g. 20 sites in each habitat.

Choose sample locations randomly: lay a grid over the map and use a random number generator to pick coordinates.

Use stratified sampling so the number of samples in the woodland and the grassland is proportional to their areas.

At each location use a 1 m² grid quadrat and estimate the percentage cover of each species (or use the ACFOR scale), searching thoroughly and counting plants, instead of only recording presence.

[4]

- (ii)* The student read that woodland plants, such as lady fern, might not receive all wavelengths of visible light equally.

The student planned to investigate the effect of light wavelength on the rate of photosynthesis in black medic and lady fern.

The student planned to measure rates of photosynthesis by placing each plant in a sealed, transparent container. Each container had a sensor connected to computer software to monitor carbon dioxide concentration.

Outline an experimental plan that could be used to compare the effect of light wavelength on the rate of photosynthesis in black medic and lady fern.

Your plan should include a suggestion of an appropriate statistical test, but you do **not** need to include any details of how to measure the rate of photosynthesis.

Use at least five different wavelengths (e.g. blue, green, yellow, orange and red light) by placing different coloured filters or acetate sheets over each sealed container. Use the same lamp at the same distance so light intensity stays constant.

Use several plants of each species of similar size, age and leaf area. Let each plant acclimatise for 10 minutes at each wavelength, then record the fall in CO₂ concentration over a set time.

Control variables: temperature (use a heat shield or water bath), initial CO₂ concentration, light duration and watering. Do at least three repeats at each wavelength, identify anomalies and calculate means and standard deviations.

Statistics: use an unpaired t-test to find whether there is a significant difference ($p = 0.05$) between the mean rates of photosynthesis of black medic and lady fern at each wavelength. A paired t-test could compare one species at two wavelengths. [6]

Additional answer space if required.

Safety: the lamp gets hot (risk of burns, low risk), so let it cool and keep water away from the mains supply.

(iii) The student performed the Benedict's test on solutions from the leaves of both species.

- For each of the species, the same method was used to prepare the solution.
- The Benedict's test was performed on samples of each solution using a measuring cylinder to measure the volume of each solution.
- After performing each Benedict's test, the student compared the final colour of the solution to a colour chart.
- The student repeated the Benedict's test five times.

Describe and explain **one** way to improve the precision of the student's results.

Use a colorimeter to measure the absorbance of each solution instead of comparing with a colour chart, and take more repeats and calculate a mean.

This reduces random error from judging the colour by eye, as colorimetry gives quantitative results. [2]

(iv) The student also tested for the presence of starch in various tissues of the plants.

State how to test for starch.

Add iodine in potassium iodide solution: blue-black shows starch. [1]

- (c) When a plant is exposed to high light intensities, excess light energy is absorbed by photosystem II in chloroplasts. This can potentially damage the photosystems.

A process called nonphotochemical quenching (NPQ) protects plants by converting the excess light energy absorbed by photosystem II to heat energy.

NPQ can continue even when light intensity has decreased and NPQ is no longer needed. This makes photosynthesis inefficient and reduces the rate of CO_2 fixation.

- (i) Explain why the continuation of NPQ in low light intensities reduces the rate of CO_2 fixation.

*..Fewer electrons enter the electron transport chain, so less ATP and less reduced NADP are generated and supplied to the Calvin cycle from the light-dependent stage.
So less GP is reduced to TP and less RuBP is regenerated, so less CO_2 is fixed by RuBisCO.* [2]

- (ii) Genes responsible for NPQ and other aspects of photosynthesis in plants can be identified by sequencing and analysing DNA.

DNA needs to be extracted and purified before it is analysed.

Name the substances that should be added to remove histone proteins from DNA and to precipitate the DNA.

Remove histone proteins ...*protease*.....

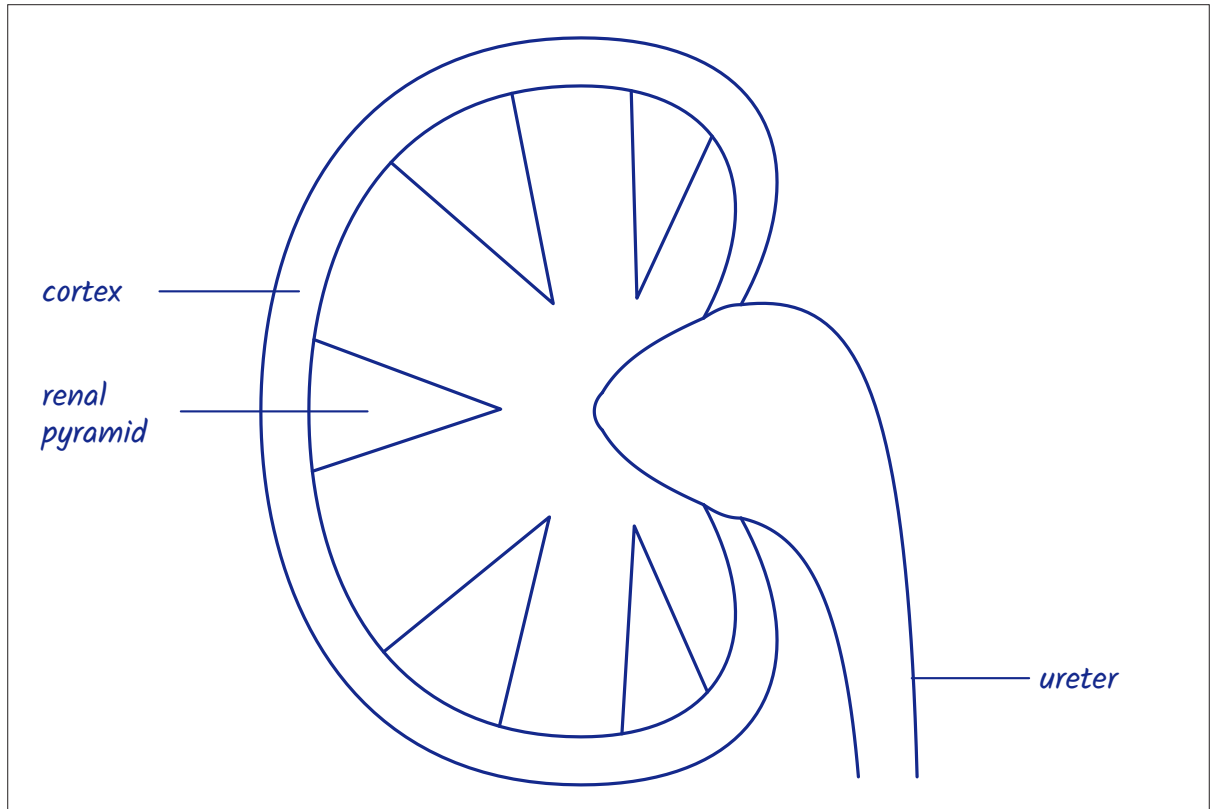
Precipitate DNA ...*ice-cold ethanol*..... [2]

- 3 The kidney is an organ of filtration and osmoregulation, but its functions can be hindered by several different diseases.

(a) A student dissected a kidney. One half of the dissected kidney is shown in **Fig. 3.1** on the **Insert**.

Draw a simple diagram of the dissected kidney, shown in **Fig. 3.1**, in the space below.

On your diagram, label the cortex, renal pyramids and ureter.



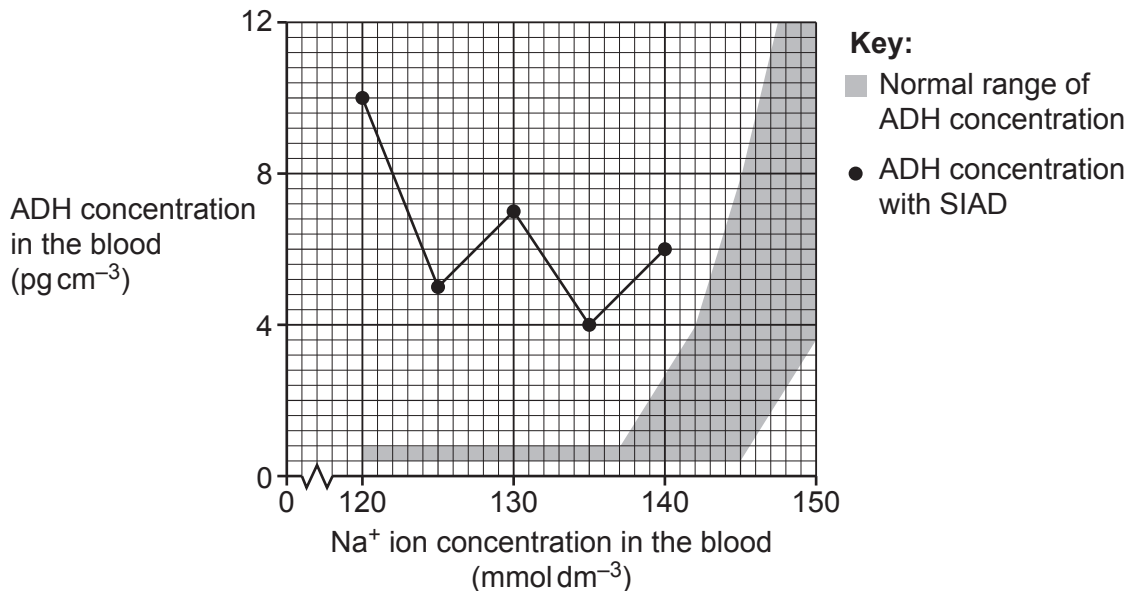
[3]

- (b) Osmoregulation in the kidney can be affected by a condition called syndrome of inappropriate antidiuresis (SIAD).

Fig. 3.2 shows how ADH concentration in the blood changes with blood sodium ion (Na^+) concentration in:

- normal homeostasis
- people with one type of SIAD.

Fig. 3.2



Explain the conclusions you can make from **Fig. 3.2** about the effect of SIAD on osmoregulation.

With SIAD, more ADH is secreted than normal, and ADH is still secreted at lower Na^+ ion concentrations, therefore more ADH binds to specific receptors on the cells of the collecting duct wall. More aquaporins fuse with the collecting duct cell membranes, so the collecting duct is more permeable than normal and more water is reabsorbed into the blood plasma. This causes a higher water potential in the blood than normal.

[3]

- (c) Glucose is normally reabsorbed from the proximal convoluted tubule of the kidney.

In some conditions, such as diabetes mellitus, glucose remains in the filtrate and can be detected in urine.

Biosensors are used to detect glucose in urine.

The sentences describe how biosensors can detect glucose in urine.

Complete the sentences using the most appropriate words or phrases.

Glucose test strips contain an enzyme called*glucose oxidase*..... ,
which converts glucose to gluconic acid and hydrogen peroxide. Another enzyme,
.....*peroxidase*..... , converts hydrogen peroxide to oxygen and water. Oxygen
reacts with a chemical on the test strip to produce a colour change. In recent years, a
polarimeter device has been developed. The polarimeter gives a digital readout of the
glucose concentration in urine, in units such as*mmol dm⁻³*..... .

[3]

- (d) Kidney failure has a variety of possible causes.

This is a description of kidney failure:

The person noticed their symptoms developing over a long period of time. Unusual tissue, not normally found on a healthy kidney, could be seen on the outside of the kidney.

Suggest and give a reason for a possible cause of kidney failure in this person.

.....*Polycystic kidney disease (or kidney cancer).*.....
.....*The kidney failure was chronic, not acute, and the unusual tissue on the*.....
.....*outside of the kidney could be cysts (or tumours).*.....

[2]

- (e) Outline the possible future use of stem cells in kidney transplant surgery.

.....*In future, kidney tissue could be grown from stem cells taken from the*.....
.....*patient, e.g. induced pluripotent stem cells reset from the patient's own*.....
.....*differentiated cells, or stem cells from bone marrow.*.....
.....*This would reduce the risk of kidney rejection and the need for*.....
.....*immunosuppressants.*.....

[2]

- 4 The domestic rabbit, *Oryctolagus cuniculus domesticus*, is a subspecies of European rabbit. It is a popular pet and has been selectively bred for fur colour and other features.

(a) Complete the taxonomic ranks to show the classification of *Oryctolagus cuniculus domesticus*.

Domain: ...*Eukarya*.....

Kingdom: ...*Animalia*.....

Phylum: Chordata

Class: Mammalia

Order: Lagomorpha

Family: Leporidae

Genus: ...*Oryctolagus*.....

Species: ...*cuniculus*.....

[2]

(b) A student bred two pet rabbits several times to produce a total of 48 offspring.

One of the parental rabbits had upright ears and black fur. The other parental rabbit had floppy ears and brown fur.

The student researched the genetics of the two traits (ear position and fur colour) and the family tree of the two rabbits. The student predicted the offspring phenotypes would be:

- 25% black fur, upright ears
- 25% black fur, floppy ears
- 25% brown fur, upright ears
- 25% brown fur, floppy ears

The student used the chi squared (χ^2) test to determine whether the phenotypic ratio of the offspring was significantly different from their expectations.

Their null hypothesis was:

‘There is no difference between the expected phenotypic ratio of the offspring and the observed phenotypic ratio of the offspring.’

The student’s expected and observed results are shown in **Table 4.1**.

Table 4.1

Phenotype	Expected number	Observed number
Black fur, upright ears	12	10
Black fur, floppy ears	12	17
Brown fur, upright ears	12	8
Brown fur, floppy ears	12	13

- (i) Calculate χ^2 for the results shown in **Table 4.1**. Use the formula:

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

Give your answer to **3** significant figures.

$$(10 - 12)^2 \div 12 = 4 \div 12 = 0.333$$

$$(17 - 12)^2 \div 12 = 25 \div 12 = 2.083$$

$$(8 - 12)^2 \div 12 = 16 \div 12 = 1.333$$

$$(13 - 12)^2 \div 12 = 1 \div 12 = 0.083$$

$$\chi^2 = 0.333 + 2.083 + 1.333 + 0.083 = 3.833$$

$$\chi^2 = \dots\dots\dots 3.83 \dots\dots\dots [3]$$

- (ii) A χ^2 probability table is shown in **Table 4.2**.

Table 4.2

Degrees of freedom	Probability (p)		
	0.10	0.05	0.01
1	2.71	3.84	6.64
2	4.60	5.99	9.21
3	6.25	7.82	11.34
4	7.78	9.49	13.28
5	9.24	11.07	15.09

Using your answer to (i) and the data in **Table 4.2**, state and explain what you can conclude about the student's results.

There are $4 - 1 = 3$ degrees of freedom, so the critical value at $p = 0.05$ is 7.82. The calculated value (3.83) is lower than the critical value at 3 degrees of freedom. So there is no significant difference between the observed and expected results at $p = 0.05$; there is a greater than 5% probability that the difference is due to chance. The null hypothesis can be accepted. [3]

(c) Another aspect of rabbit fur colour is colour density.

One gene controls colour density. This gene has several alleles, including:

- C^F , which results in full colour. This allele is dominant to the other two alleles.
- C^S , which results in shaded colour. This allele is dominant to C^A .
- C^A , which results in albino fur (no colour).

A pair of rabbits were bred. 50% of their offspring had full colour, 25% were shaded, and 25% were albino.

State the genotypes of the two parental rabbits that produced these offspring.

Parent 1 ... $C^F C^A$

Parent 2 ... $C^S C^A$ [2]

(d) (i) Rabbits can inherit genetic diseases.

The probability of a rabbit inheriting a genetic disease can be assessed.

Name the method used for assessing the risk of an animal inheriting a genetic disease.

... *pedigree analysis* [1]

- (ii)* Rabbits can also develop diseases such as anaemia and lymphosarcoma that affect the number of erythrocytes and leucocytes in their circulatory system.

If such a disease is suspected, the rabbit's blood can be sampled and the blood cells can be analysed.

Describe a method that could be used to observe blood cells **and** a method used to identify blood cells from the blood of a rabbit.

Observing: make a blood smear. Place a drop of blood near one end of a clean, sterile microscope slide, hold a second slide (spreader) at 30 to 45° and push it along to make a thin film one cell thick. Air dry and fix with methanol (fixative).

Identifying: use differential staining with a named stain such as Leishman's (or Wright's) stain, then rinse with buffer, dry and view with a light microscope at x400, then x1000 under oil immersion.

The stain colours nuclei purple, so leucocytes can be identified: neutrophils have lobed nuclei and granular cytoplasm, lymphocytes have a large round nucleus filling the cell, monocytes have a kidney-shaped nucleus.

Erythrocytes are pink, biconcave and have no nucleus. Cells can be counted to detect anaemia or abnormal leucocyte numbers.

Alternatively, flow cytometry can identify and count cells by sorting them by size, density and shape (or fluorescent antibody labels).

Safety: blood may carry pathogens (moderate risk), so wear gloves, [6]

Additional answer space if required.

disinfect surfaces and dispose of sharps and slides in a sharps or biohazard bin; methanol is flammable, so keep it away from flames.

.....

.....

.....

- (e) Rabbits, like all mammals, have a double circulatory system.

Explain the importance to mammals, such as rabbits, of having a double circulatory system.

*Oxygenated and deoxygenated blood do not mix, and the separate circuits can
be kept at different pressures: low pressure to the lungs to avoid damage,
high pressure to the body.
This gives more efficient delivery of oxygen and nutrients to cells and tissues.*

[2]

END OF QUESTION PAPER

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