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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

3337887198

BIOLOGY **9700/42**

Paper 4 A Level Structured Questions **October/November 2024**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **24** pages.

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[Turn over

1 **(a)** Fig. 1.1 is a diagram of part of a Bowman's capsule and a glomerular capillary.

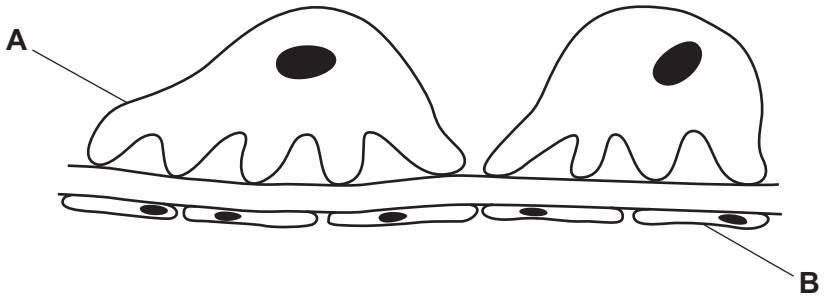


Fig. 1.1

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

A .....

B .....
[2]

(ii) The glomerular filtrate is produced in the Bowman's capsule by the process of ultrafiltration.

State the conditions required for ultrafiltration.

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(b) As the newly formed glomerular filtrate passes along the proximal convoluted tubule, selective reabsorption takes place. The fluid remaining in the proximal convoluted tubule eventually forms urine.

Table 1.1 lists three of the components of blood plasma that enter the glomerulus in a healthy person.

Complete Table 1.1 by writing:

- **increased**, if the component is present and is higher in concentration than in blood plasma
- **decreased**, if the component is present and is lower in concentration than in blood plasma
- **same**, if the component is present and is of the same concentration as blood plasma
- **not present**, if the component is absent.

You may use each response once, more than once or not at all.

Table 1.1

component of blood plasma entering glomerulus	component in newly formed glomerular filtrate	component in urine
glucose		
large plasma proteins		
urea		

[3]

(c) Sweating during exercise can lead to a response in the posterior pituitary gland and in the kidney.

State the response to sweating that occurs in the posterior pituitary gland **and** the response that occurs in the kidney.

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[Total: 9]

2 Several different processes can affect allele frequencies in populations.

(a) Outline the processes that may affect allele frequencies in wildlife populations.

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(b) The process of selective breeding changes allele frequencies in a population. Plant breeders use selective breeding to improve crop plants such as maize.

Explain how selective breeding can be used to obtain a variety of maize where the plants are vigorous and of uniform height.

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3 The treatment of many diseases has been improved by the use of genetic technology in medicine.

(a) Explain what is meant by genetic engineering.

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(b) **(i)** Leber Congenital Amaurosis (LCA) is an inherited eye disease. In LCA, the photoreceptor cells in the retina die at an early age. This causes impaired vision (reduced eyesight) in children, which can progress to blindness.

Mutations in different genes cause different forms of LCA. One form of this disease, LCA2, is caused by a mutation in the *RPE65* gene. Gene therapy has been used to treat LCA2.

Outline how an inherited eye disease, such as LCA2, is treated with gene therapy.

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(ii) Suggest why the eye is a suitable organ for gene therapy.

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(c) LCA10 is a different form of LCA caused by a recessive mutation in the *CEP290* gene. This gene codes for the protein CEP290, which is involved in the correct functioning of photoreceptor cells in the retina.

The mutation in *CEP290* causes an error to be made when the primary transcript is spliced to form messenger RNA (mRNA). The abnormal mRNA that is formed has an extra sequence of RNA nucleotides, known as exon X, between exon 26 and exon 27. Exon X contains a STOP codon.

Fig. 3.1 compares the effect of the mutation in *CEP290* with the normal gene expression.

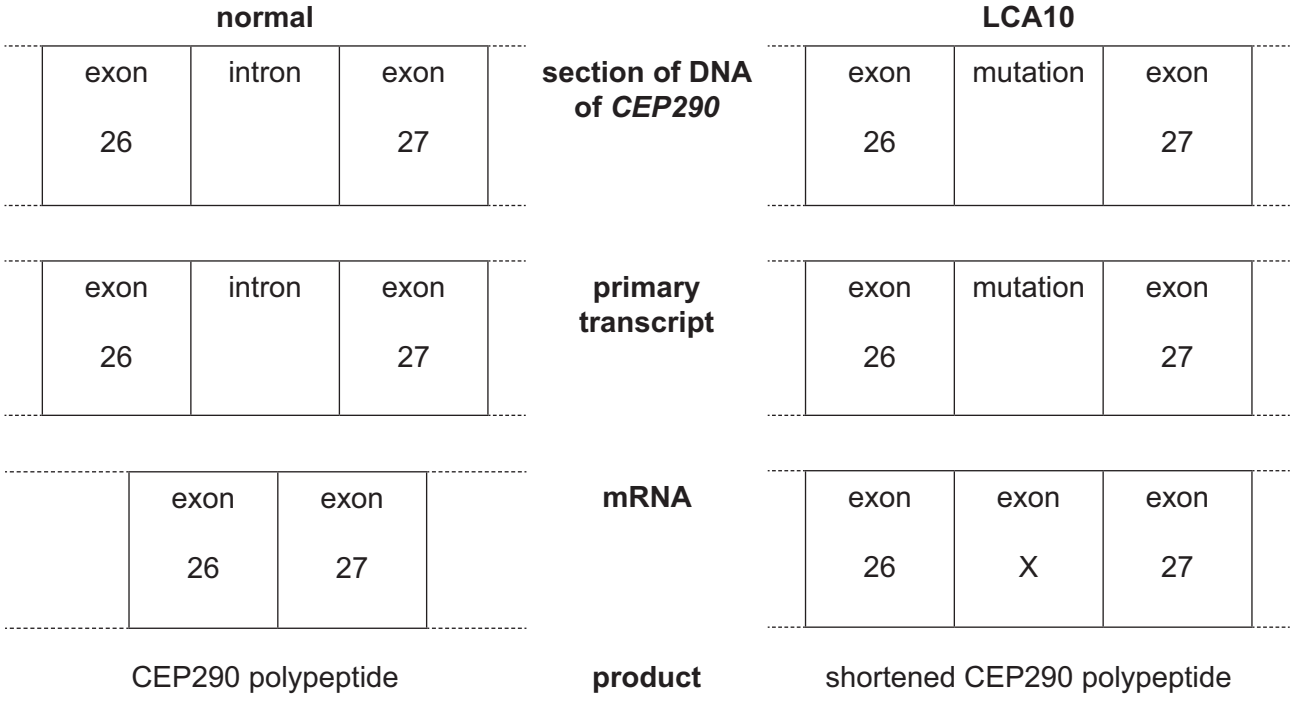


Fig. 3.1

In 2022, research was carried out into possible treatment of LCA10 using genetic technology.

(i) A human clinical trial investigated a treatment of LCA10 using a short RNA nucleotide sequence known as Sepofarsen.

Sepofarsen binds to the section of the primary transcript containing the *CEP290* mutation so that normal splicing occurs and functional CEP290 protein is synthesised.

- People in the clinical trial received regular treatment with Sepofarsen to the eye with the greatest loss of vision (treated eye) for a period of 12 months.
- Changes in the light perception (visual acuity) of both eyes were measured using a vision chart.
- A negative change in the visual acuity score shows an improvement in visual acuity.

Fig. 3.2 shows the results of the clinical trial over 12 months.

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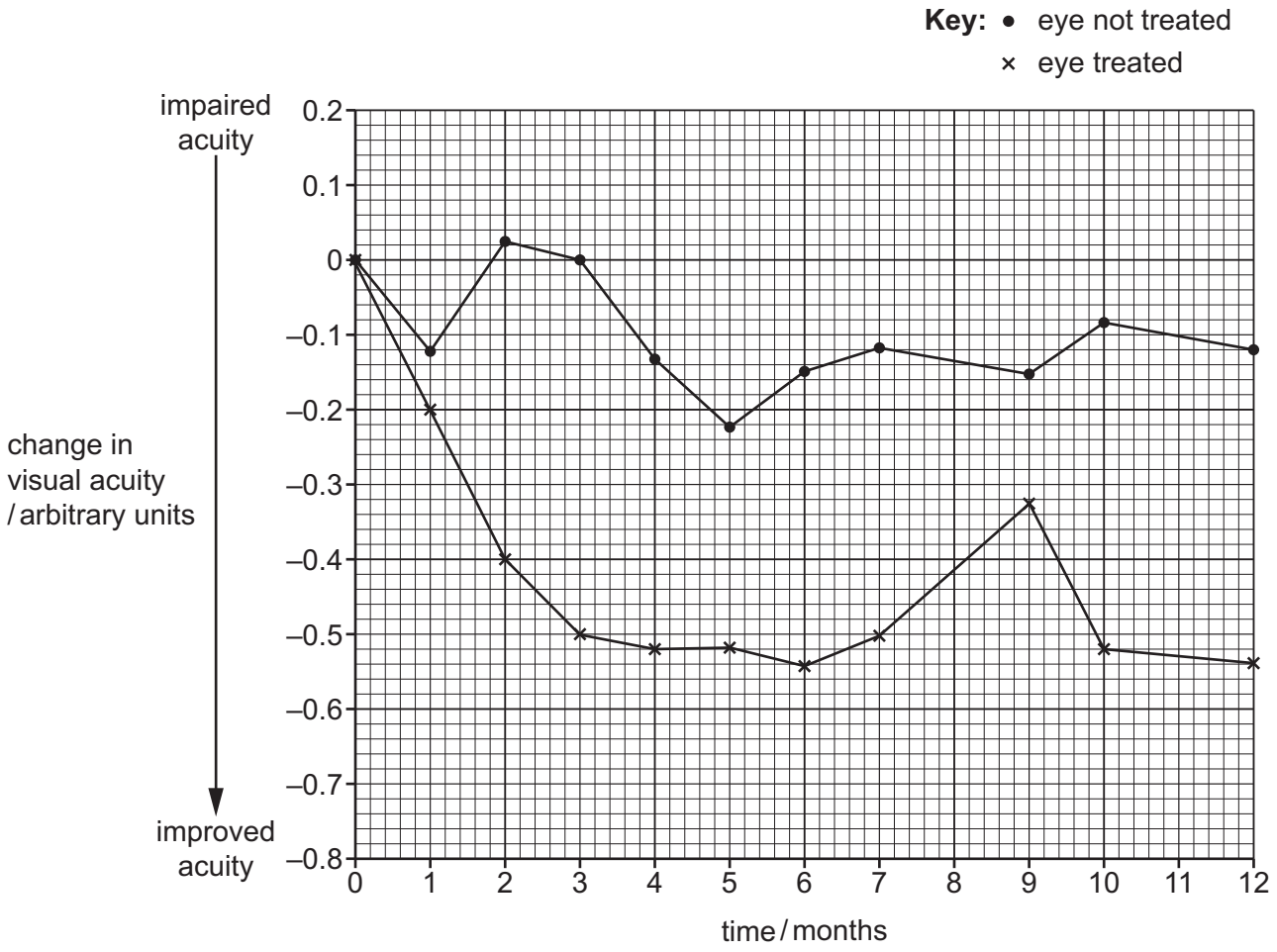


Fig. 3.2

Describe the results of the clinical trial data shown in Fig. 3.2.

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(ii) Another method being investigated to treat LCA10 is to use a gene editing tool known as the CRISPR/Cas9 system.

The CRISPR/Cas9 system uses a short length of RNA called guide RNA. Guide RNA is complementary to the target DNA and is linked to a nuclease enzyme called Cas9. Cas9 breaks phosphodiester bonds in DNA.

The cell repair mechanisms repair the cut in DNA after the modification has taken place.

- A vector delivers Cas9 and two specific guide RNAs to the photoreceptor cells.
- They act on the section of DNA which contains the mutation.
- Exon X is no longer added to the mRNA.

Explain how this method used to treat LCA10 is an example of gene editing.

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Question 4 starts on page 10

4 Genetic crosses can be used to investigate patterns of inheritance.

(a) A mutation in a gene involved in fruit colour in tomato plants, *Solanum lycopersicum*, results in the production of yellow fruits instead of red fruits.

A genetic cross was carried out between a pure breeding plant with a red fruit and a pure breeding plant with a yellow fruit to produce the F1 generation. All offspring plants produced red fruits.

The F1 plants were then crossed with each other and the seeds produced were planted to obtain the F2 generation.

Construct a genetic diagram to show the cross of the F1 generation that produced this F2 generation.

Use the symbols **R** and **r** for the alleles.

[3]

(b) A theoretical dihybrid cross involves two genes located on different autosomes. Each gene has two alleles, one dominant and one recessive.

A parent, homozygous dominant for both genes, is crossed with a parent that is homozygous recessive for both genes. This produces F1 individuals that are then crossed to produce the F2 generation.

State the phenotypic ratio of this dihybrid F2 generation **and** explain why some of these offspring phenotypes are different from the original parental phenotypes.

ratio .....

explanation .....

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[Total: 6]

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5 Phenotypic variation exists in natural populations. There are many causes of variation. Natural selection determines which phenotypes are advantageous.

(a) Variation in a particular characteristic can be described as either discontinuous or continuous.

Table 5.1 contains a list of statements that apply to discontinuous variation, continuous variation or both.

Complete both columns of Table 5.1. Put a tick (✓) in the box if the statement applies and leave the box empty if the statement does not apply.

Table 5.1

statement	discontinuous variation	continuous variation
often involves one gene only		
environmental factors may affect gene expression		
there is an additive effect of genes that contributes to the phenotype		
there are distinct differences between the various forms of a characteristic		

[4]

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(b) There is variation in the quantity of vitamin D stored in the body.

Vitamin D has an important role in keeping bones healthy. The main storage form of vitamin D in the body is serum 25-hydroxyvitamin D (serum 25-OHD).

A study was carried out on 262 healthy women to investigate if the concentration of serum 25-OHD varied between summer and winter. The women had taken no vitamin D supplements. The age range of the women in the sample was 40 to 72 years old.

Table 5.2 shows the results of the study.

Table 5.2

group	mean concentration of serum 25-OHD / ng cm^{-3}	standard deviation
sampled during summer n = 138	32.7	7.6
sampled during winter n = 124	28.5	8.3
whole sample n = 262	30.7	8.2

Additional analysis showed that there was no significant correlation between age and serum 25-OHD concentration.

(i) Explain what is meant by standard deviation.

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..... [1]

(ii) The *t*-test was used to compare the mean concentration of serum 25-OHD when sampled during the summer with the mean concentration of serum 25-OHD when sampled during the winter, as shown in Table 5.2.

Calculate the value of *t* using the formula provided.

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

key to symbols:
$\bar{x}$ = mean
s = sample standard deviation
n = sample size (number of observations)

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

There is space for your working.

t-test value ..... [3]

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(iii) The critical value at the 0.0001 probability level is 3.773.

State the conclusion that can be made about the results of the study shown in Table 5.2 **and** explain how the result of your calculation in **(b)(ii)** can be used to support this conclusion.

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(iv) Suggest the likely **causes** of variation in quantity of vitamin D stored in the body in this sample of women.

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6 **(a)** DCPIP is an indicator and can be used to determine the rate of respiration of organisms such as yeast.

(i) State the category of indicators to which DCPIP belongs.

..... [1]

(ii) Describe the colour change that occurs in DCPIP during experiments to determine the rate of respiration.

..... [1]

(b) An investigation was carried out to determine the effect of temperature on the rate of respiration of yeast.

- A suspension of yeast cells was added to a test-tube containing glucose solution.
- A further four test-tubes were set up in the same way.
- One test-tube was placed in a water-bath at 10 °C for 5 minutes.
- DCPIP was added to the test-tube and the time taken for the DCPIP to change colour was measured.
- The experiment was repeated using the other test-tubes at 20 °C, 30 °C, 40 °C and 50 °C.

The results are shown in Fig. 6.1.

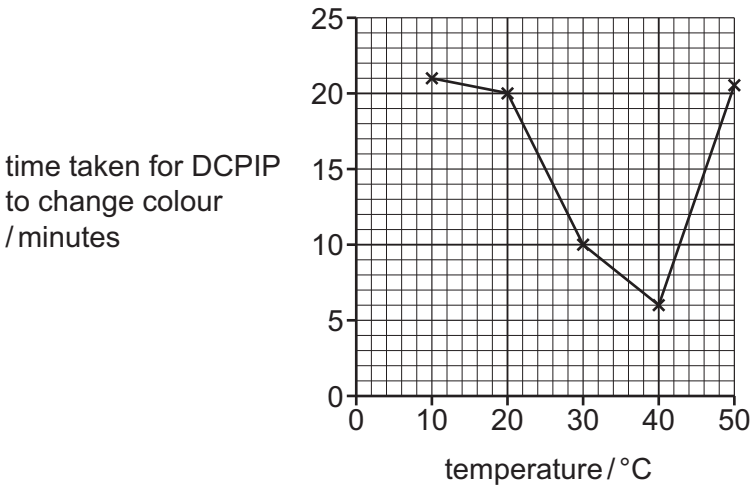


Fig. 6.1

(i) State **two** variables that need to be kept constant in this experiment.

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(ii) Explain the results shown in Fig. 6.1.

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7 **(a)** Paper chromatography is a technique that can be used to separate and identify different chloroplast pigments.

Describe how the **results** of paper chromatography can be used to identify chloroplast pigments.

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(b) Carotene and xanthophyll are chloroplast pigments.

Describe the role played by these pigments in photosynthesis.

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(c) The light-dependent stage of photosynthesis produces ATP and reduced NADP, which are used in the light-independent stage.

Describe the **light-independent** stage of photosynthesis.

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8 **(a)** Fig. 8.1 is a diagram of a motor neurone.

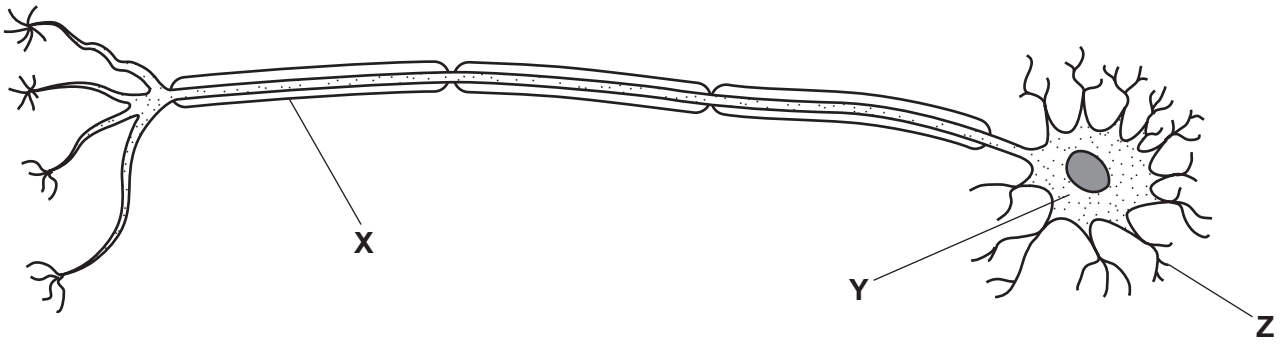


Fig. 8.1

(i) Name cell **X** and part **Y**.

X .....

Y .....

[2]

(ii) Name a type of cell that forms a synapse with structure **Z**.

..... [1]

(b) Table 8.1 shows some of the events that occur during muscle contraction.

They are **not** listed in the correct order.

Table 8.1

event	description of event
A	calcium ions diffuse out of sarcoplasmic reticulum
B	myosin heads bind to actin
C	sarcolemma depolarised
D	sarcomere shortens
E	calcium ions bind to troponin
F	T-tubule system membranes depolarised
G	binding sites on actin exposed
H	myosin heads tilt
I	tropomyosin moves
J	troponin changes shape

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Complete Table 8.2 to show the correct order of the events that occur during muscle contraction. Two of the events have been completed for you.

Table 8.2

correct order	letter of event
1	.....
2	.....
3	.....
4	.....
5	**J**
6	.....
7	.....
8	.....
9	.....
10	**D**

[4]

(c) Lambert-Eaton myasthenic syndrome (LEMS) is a rare disorder of the neuromuscular junction. A person with LEMS produces antibodies that bind to the voltage-gated calcium channels on the presynaptic knob. One symptom of LEMS is weaker muscle contraction.

Suggest **and** explain why LEMS leads to weaker muscle contraction.

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9 The red ruffed lemur, *Varecia rubra*, is a mammal found only in the rainforests of the Masoala region in north east Madagascar.

Fig. 9.1 shows a red ruffed lemur.



Fig. 9.1

(a) The International Union for Conservation of Nature (IUCN) Red List of Threatened Species™ states that the red ruffed lemur is critically endangered.

Suggest why the red ruffed lemur has become critically endangered.

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(b) Many zoos around the world operate captive breeding programmes for the red ruffed lemur.

Fig. 9.2 shows the numbers of captive-born red ruffed lemurs in North American zoos from 1970 to 2020.

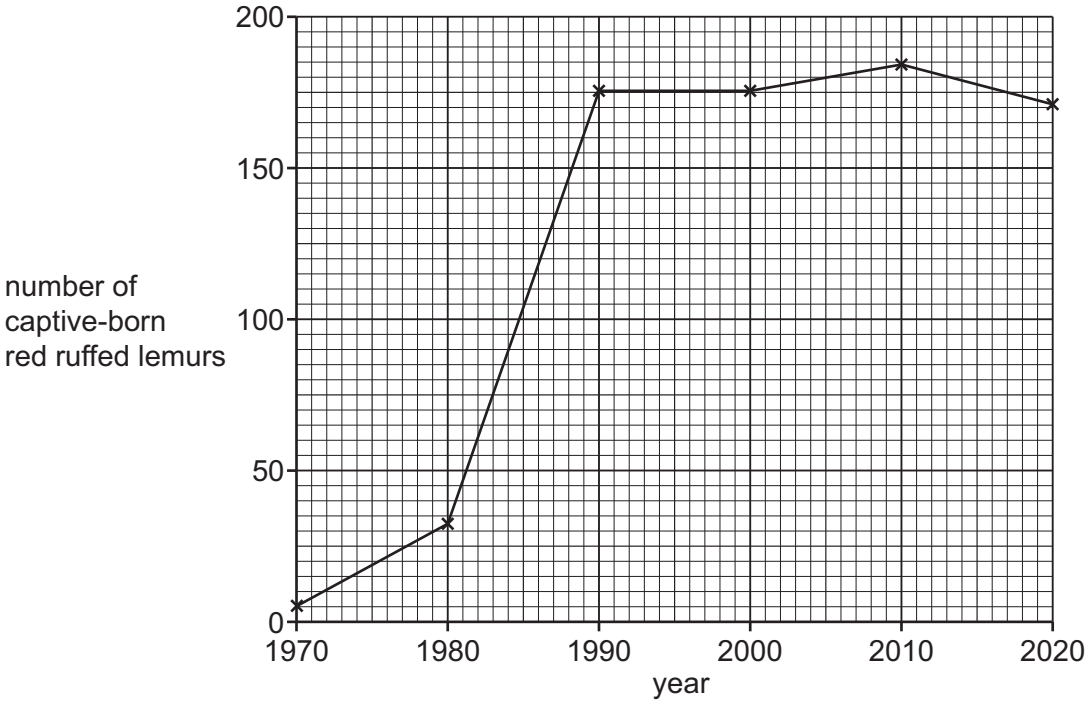


Fig. 9.2

Describe the results shown in Fig. 9.2.

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(c) Captive breeding programmes for endangered mammals such as the red ruffed lemur can vary in their success rate.

(i) Suggest problems that may affect the success of captive breeding programmes of mammals like the red ruffed lemur.

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(ii) Occasionally, wild-caught red ruffed lemurs are introduced into captive breeding programmes.

Suggest why this is done.

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10 (a) Blood glucose concentration is maintained around a set point by homeostasis.

Explain the principles of homeostasis.

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(b) Glycogen phosphorylase catalyses the conversion of glycogen to glucose in liver cells. The production of glycogen phosphorylase is coded for by the gene *PYGL*.

A mutation in *PYGL* leads to a condition called glycogen storage disease type VI (GSDVI), in which glycogen is not broken down efficiently.

Suggest **and** explain why cell signalling by glucagon is likely to be affected in the liver cells of a person with GSDVI.

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(c) Glycogen synthase catalyses the conversion of glucose to glycogen in liver cells. The production of glycogen synthase is coded for by the gene *GYS2*.

A mutation in *GYS2* leads to a condition called glycogen storage disease type 0 (GSD0) in which glycogen is not formed efficiently.

Suggest what the consequences would be if a person with GSD0 has a meal rich in glucose.

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