Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

9991566602 75

BIOLOGY **9700/42**

Paper 4 A Level Structured Questions **October/November 2020**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Section A: answer **all** questions.
- Section B: answer **one** question.
- 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. Blank pages are indicated.

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Section A

Answer **all** questions.

1 Fig. 1.1 shows a transmission electron micrograph of a chloroplast.

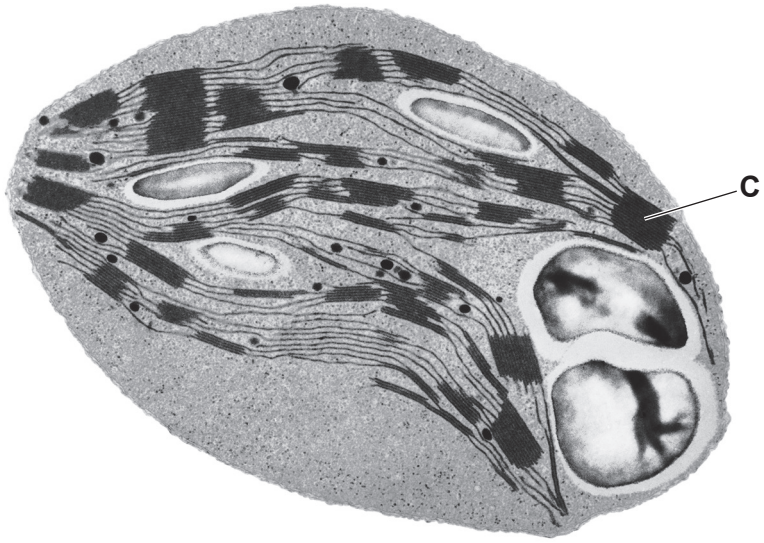


Fig. 1.1

(a) On Fig. 1.1, use label lines and letters to label:

A – the storage site of the carbohydrate product of photosynthesis

B – the site of the light independent stage.

[2]

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(b) (i) Name the structure labelled **C** in Fig. 1.1.

C ..... [1]

(ii) Explain how the structure of **C** is linked to its function.

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..... [4]

(c) (i) The anatomy of C4 plants is adapted to allow the rate of photosynthesis to remain high at high temperatures.

C3 plants do not have these adaptations and an additional reaction occurs at high temperatures that reduces the rate of photosynthesis.

Explain why the reaction that takes place at high temperatures in **C3** plants reduces the rate of photosynthesis.

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..... [2]

(ii) C4 plants have higher rates of photosynthesis than C3 plants when the ratio of atmospheric oxygen to atmospheric carbon dioxide is high.

Fig. 1.2 shows the atmospheric carbon dioxide concentration in the last 50 million years.

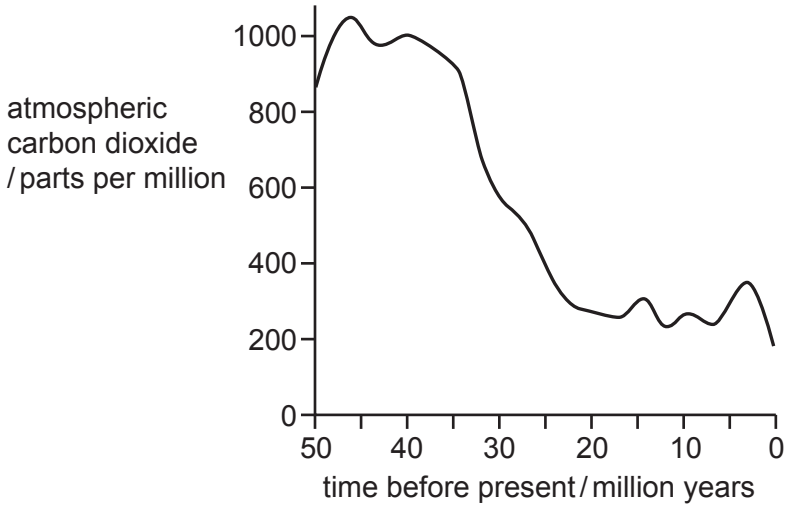


Fig. 1.2

There is evidence that C4 plants first appeared 30 million years ago.

With reference to Fig. 1.2, suggest why C4 plants first appeared 30 million years ago.

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..... [3]

[Total: 12]

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2 Domestic goats are small, herbivorous animals that provide milk for human use. This is an important source of food for people in rural South Africa.

Three Northern European goat varieties (breeds) have been imported to South Africa because they have higher milk yields than the native South African goats.

Table 2.1 compares the mean daily milk yields of these three breeds of Northern European goat in three locations, Northern Europe, Barbados and South Africa.

Table 2.1

goat breed	mean daily milk yield / kg in different locations		
	Northern Europe	**Barbados**	**South Africa**
British Alpine	4.09	2.55	0.75
Saanen	5.17	1.73	1.45
Toggenburg	4.54	3.46	0.56

(a) Native South African goats have a mean daily milk yield of 0.25 kg.

Calculate how many times greater the mean daily milk yield will be if a native South African goat is replaced by the Northern European goat breed that gives maximum yield.

Show your working and write your answer to **two** significant figures.

answer ..... [2]

(b) (i) Explain how the data in Table 2.1 support the claim that some of the variation in mean daily milk yield in goats is due to **genetic** causes.

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..... [2]

(ii) The climate, vegetation and availability of veterinary care for goats in Northern Europe, Barbados and South Africa are different.

Explain how Table 2.1 shows that **environmental** factors can cause variation in mean daily milk yield in goats.

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..... [2]

(c) Native South African goats are better adapted to the local conditions in South Africa than a Northern European breed, such as the Saanen. However Saanen goats have the potential for very high milk yield.

Outline a programme of selective breeding that could produce a goat with a high milk yield that is adapted to the local conditions in South Africa.

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(d) Children in developing countries may drink unpasteurised goats' milk. Some may develop diarrhoea caused by live bacteria ingested in the milk.

Scientists have used genetic engineering to develop goats that produce human lysozyme in their milk. Lysozyme is an enzyme that kills bacteria and so reduces the number of bacteria in the milk.

State a social advantage **and** a social disadvantage of making these GM goats available in developing countries.

advantage .....

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disadvantage .....

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[2]

[Total: 13]

3 A subspecies is a genetically distinct population of a species that has some phenotypic differences but is not yet reproductively isolated.

500 000 years ago, the European house mouse, *Mus musculus*, evolved into two subspecies, *Mus musculus domesticus* and *Mus musculus musculus*.

(a) Suggest **and** explain how the two subspecies *M. m. domesticus* and *M. m. musculus* could have evolved from the original *M. musculus* population.

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(b) Today, *M. m. domesticus* populations are separated from *M. m. musculus* populations by a large hybrid zone. The hybrid zone formed 5000–1000 years ago when populations of the two subspecies overlapped and interbreeding occurred between the two subspecies, resulting in hybrids.

Researchers investigated the populations in the hybrid zone.

It was observed that:

- hybrid mice were infected by more intestinal worms than *M. m. domesticus* and *M. m. musculus*
- *M. m. domesticus* and *M. m. musculus* individuals frequently mate together
- hybrid male mice had a very low fertility score based on testis weight and total sperm production, whereas *M. m. domesticus* and *M. m. musculus* males had a very high fertility score
- some female hybrids were sterile
- crosses between a fertile female hybrid and a male from either subspecies produced a very low number of offspring.

M. m. domesticus and *M. m. musculus* usually have the same diploid number ($2n = 40$). Some individuals of *M. m. domesticus* have a different diploid number ($2n = 34$).

Discuss the extent to which pre-zygotic and post-zygotic isolating mechanisms maintain *M. m. domesticus* and *M. m. musculus* as two separate subspecies within the hybrid zone.

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[Total: 7]

4 Sickle cell anaemia is a non-infectious chronic disease. If not treated, sickle cell anaemia can be painful and life-threatening.

Sickle cell anaemia is caused by a base substitution mutation in the gene coding for the β-globin polypeptide of haemoglobin. This leads to a change in the primary structure of the polypeptide, as valine is present instead of glutamine. This results in abnormal sickle-shaped red blood cells, which stick together in blood vessels.

Symptoms of sickle cell anaemia include painful attacks when red blood cells block capillaries in tissues and organs.

(a) Suggest the consequences to cells when sickle-shaped red blood cells block capillaries in tissues and organs.

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..... [2]

(b) Sickle cell anaemia is an autosomal recessive inherited disorder:

- allele Hb^A codes for the normal β-globin polypeptide
- allele Hb^S codes for the sickle-cell polypeptide.

People who are heterozygous (Hb^A Hb^S) have sickle cell trait (SCT). For a child to inherit sickle cell anaemia (Hb^S Hb^S), both parents must have SCT.

A genetic screening program is available for sickle cell anaemia and SCT:

- when a mother is screened and found to have SCT, the father is then screened
- if the mother becomes pregnant, the fetus is screened for both sickle cell anaemia and for SCT
- the test is done either by amniocentesis or by chorionic villus sampling, both of which carry a small risk of the pregnancy failing.

(i) Outline **two** advantages of genetic screening for sickle cell anaemia and SCT.

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..... [2]

(ii) To test for the presence of Hb^S, DNA is extracted and the polymerase chain reaction (PCR) is carried out with two specific primers.

One mutation to produce Hb^S is a base substitution in the sixth codon of the β-globin gene. The normal codon GAG changes to GTG. The normal-specific primer detects GAG whereas the mutant-specific primer detects GTG.

Explain:
- why primers are used in PCR
- how the use of two specific primers allows the amplification of the normal, sickle cell anaemia and SCT genotypes.

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(iii) Gel electrophoresis is carried out on the products of the PCRs.

Fig. 4.1 includes the results for two individuals, **A** and **B**, tested for the sickle cell allele.

- Each lane has an 860 base pair (bp) band to indicate the test is valid.
- Lane 1 is a control lane with a 207bp band for an individual with known normal phenotype.
- Lane 2 is a control lane with a 207bp band for an individual with known sickle cell anaemia phenotype.
- Lanes 1, 3 and 5 contain DNA from the PCR that used normal-specific primer.
- Lanes 2, 4 and 6 contain DNA from the PCR that used mutant-specific primer.

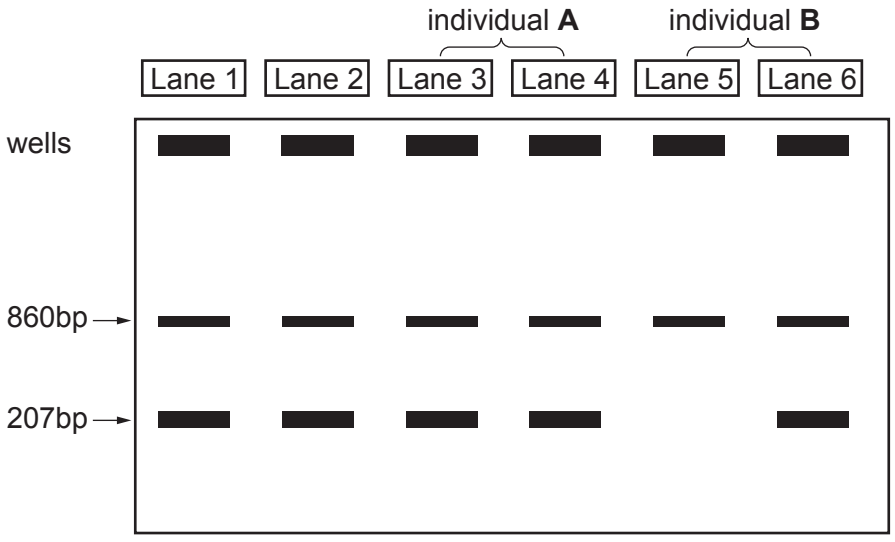


Fig. 4.1

Deduce the genotypes and phenotypes of individuals **A** and **B** in Fig. 4.1.

A .....

B .....
[2]

(c) The number of cases of sickle cell anaemia is highest in sub-Saharan Africa, the Middle East and India. These areas also have a high incidence of malaria.

People with SCT (heterozygotes) are either unaffected or may have mild symptoms of sickle cell anaemia. One advantage of SCT is an increased resistance to malaria.

(i) Explain how natural selection operates to maintain the presence of the sickle cell allele in populations in areas with malaria.

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..... [4]

(ii) Parents who use IVF to produce embryos may decide to have embryos genetically screened by a test known as pre-implantation genetic diagnosis (PGD). Only embryos that do not have sickle cell alleles are transferred to the woman's uterus.

Discuss **two** ethical reasons why parents using IVF may choose **not** to have PGD.

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..... [2]

[Total: 15]

5 Tyrosinase is an enzyme found in mammals. It is involved in the synthesis of melanin pigment. Mutations in the tyrosinase gene affect a mammal's hair colour.

Table 5.1 compares DNA sequences for codons 974–985 of:
- the normal tyrosinase gene of humans (human)
- the normal tyrosinase gene of cats that have pigmented hair (normal cat)
- the tyrosinase gene of cats that show an albino phenotype (albino cat).

The corresponding amino acid sequences of each tyrosinase are shown in the shaded rows.

Table 5.1

	974	**975**	**976**	**977**	**978**	**979**	**980**	**981**	**982**	**983**	**984**	**985**
human	CTC	CCC	TCT	TCA	GCT	GAT	GTG	GAA	TTT	TGC	CTA	AGT
normal cat	CTC	CCC	TCC	TCT	GCT	GAT	GTG	GAA	TTT	TGC	CTA	AGT
albino cat	CTC	CCT	CCT	CTG	CTG	ATG	TGG	AAT	TTT	GCC	TAA	GTC
human	Leu	Pro	Ser	Ser	Ala	Asp	Val	Glu	Phe	Cys	Leu	Ser
normal cat	Leu	Pro	Ser	Ser	Ala	Asp	Val	Glu	Phe	Cys	Leu	Ser
albino cat	Leu	Pro	Pro	Leu	Leu	Met	Trp	Asn	Phe	Ala	STOP	–

(a) (i) A silent mutation involves a base substitution that does not result in an amino acid change.

Use Table 5.1 to identify, with reasons, a silent mutation distinguishing humans from normal cats with pigmented hair.

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..... [2]

(ii) State the changes that resulted in the premature STOP codon in the albino cat DNA sequence.

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(iii) Explain why albino cats, homozygous for the mutation that resulted in the premature STOP codon, do **not** produce melanin.

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..... [2]

(iv) Bioinformatics was used to compare the whole sequence of the tyrosinase genes of humans and cats.

Explain why bioinformatics was used to compare these gene sequences **and** suggest a conclusion that could be made from the percentage similarity data obtained.

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..... [2]

(b) Siamese cats have a temperature-sensitive tyrosinase that only functions in the cooler areas of the skin. This means they only produce a small quantity of melanin pigment. Melanin is mainly on their ears, face, paws and tail.

Fig. 5.1 shows a Siamese cat.



Fig. 5.1

The Siamese allele of tyrosinase ($\mathbf{t^s}$) is recessive to the normal allele that causes full pigmentation all over the body (**T**) but is dominant to the albino allele ($\mathbf{t^a}$).

Draw a genetic diagram to show how a cross between an albino cat and a fully pigmented cat can result in offspring that include kittens with Siamese colouring.

parent phenotypes: albino × fully pigmented

parent genotypes:

gametes:

F1 genotypes:

F1 phenotypes:

ratio:

[3]

[Total: 11]

6 **(a)** A person who has a wound to their skin may experience pain. Opioid drugs can be taken to relieve the pain.

Opioid receptors are located in the presynaptic membrane of a cholinergic synapse.

Fig. 6.1 shows the action of an opioid drug on the presynaptic membrane.

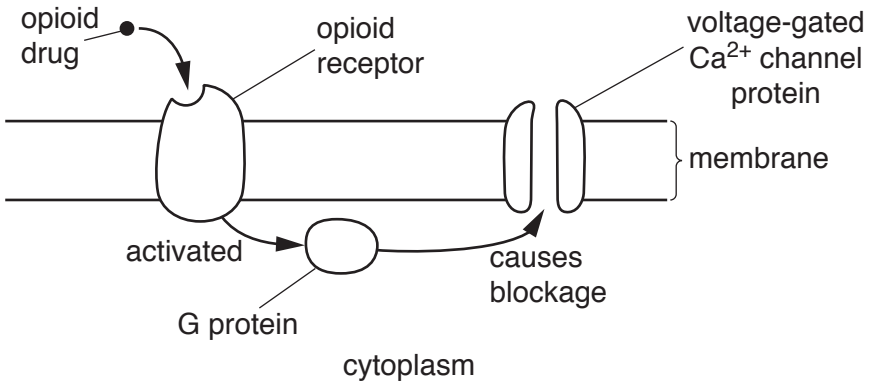


Fig. 6.1

Explain how the action of an opioid drug on the presynaptic membrane can prevent the generation of pain impulses in the postsynaptic neurone.

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..... [5]

(b) Spinal reflexes help the body to respond very quickly to potentially dangerous situations that could cause injury.

(i) State **two** features of a spinal reflex, **other than** being fast.

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..... [2]

(ii) Sensory and motor neurones are involved in a spinal reflex.

State the location of the cell body of a sensory neurone **and** a motor neurone.

sensory neurone .....

motor neurone .....
[2]

(iii) Describe the function in a spinal reflex of a sensory neurone **and** a motor neurone.

sensory neurone .....

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motor neurone .....

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[4]

[Total: 13]

7 Insulin is transported around the body in the blood. The cells of the liver, muscle tissue and adipose (fat) tissue have receptors for insulin.

(a) State:
- the precise cellular location of the insulin receptors
- the type of biological molecule that forms an insulin receptor.

location .....

type of biological molecule .....
[2]

(b) Insulin stimulates the activity of the enzyme glycogen synthetase in liver cells.

Fig. 7.1 shows the activity of glycogen synthetase in liver cells for 210 seconds after glucose has been injected into the bloodstream.

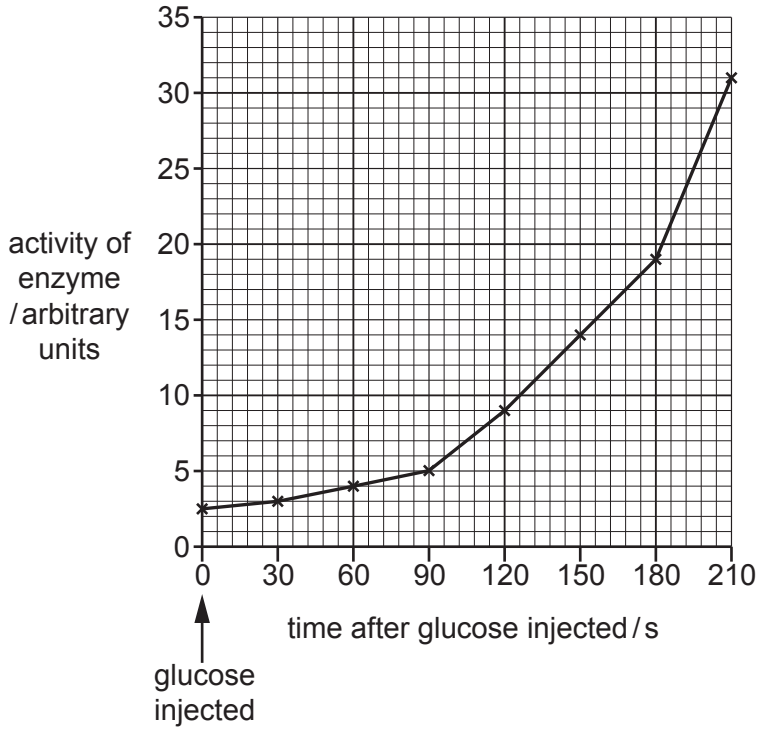


Fig. 7.1

(i) Calculate the percentage increase in glycogen synthetase activity between 90 s and 180 s after glucose was injected into the blood.

Show your working and write your answer to the nearest whole number.

answer .....% [2]

(ii) Suggest the role of glycogen synthetase in the regulation of blood glucose concentration.

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..... [1]

[Total: 5]

8 **(a)** Describe a method that could be used to estimate the population size of a mobile animal, such as a brown rat.

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..... [5]

(b) The soft rush plant, *Juncus effusus*, grows in many habitats in Northern Europe. An investigation was carried out to assess whether there was a relationship between the height of soft rush plants and the altitude at which they grow on exposed hillsides.

The mean height of 10 soft rush plants was calculated at each of eight different altitudes.

The results are shown in Table 8.1.

Table 8.1

altitude / m	mean height of soft rush plants / cm
100	85
150	86
200	83
250	79
300	72
350	74
400	68
450	63

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The statistical test, Spearman's rank correlation (r_s), was applied to find out if there was a relationship between the altitude and the mean height of the soft rush plants.

(i) The formula for calculating Spearman's rank correlation is:

$$r_s = 1 - \left(\frac{6 \times \Sigma D^2}{n^3 - n}\right)$$

- ΣD^2 is the sum of the differences between the ranks of the two samples
- n is the number of samples.

In this investigation the value of ΣD^2 is 164.

Calculate the value of r_s.

Show your working and write your answer to **two** decimal places.

r_s = ... [2]

(ii) Use your value for r_s to evaluate the relationship between the altitude and the mean height of the soft rush plants.

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..... [2]

[Total: 9]

Section B

Answer **one** question.

9 **(a)** Using named examples, describe the differences between structural and regulatory genes **and** the differences between repressible and inducible enzymes. [9]

(b) Explain the function of transcription factors in gene expression in eukaryotes. [6]

[Total: 15]

10 **(a)** Describe how a molecule of glucose is converted to pyruvate and then to acetyl CoA. [9]

(b) Explain how ATP is formed during oxidative phosphorylation. [6]

[Total: 15]

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