16. Inheritance

16.3 Gene Control

Paper 4

Question Paper

1 Genes have a role in determining the overall phenotype of an organism.

(c) Dwarf plants also occur if the genes controlling growth are not activated (switched on).

Explain how DELLA proteins act as repressors preventing gene expression.

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2 Stomata in leaves respond to changes in environmental conditions by opening and closing. This regulates carbon dioxide uptake and water loss.

(c) Some transcription factors increase the rate of transcription of genes involved in the closure of stomata.

State where transcription factors bind to cause an increase in the rate of transcription.

..... [1]

3 Sweet peas are garden plants that vary in height.

- Tall sweet peas grow to 200 cm in height.
- Dwarf sweet peas grow to 30 cm in height.
- Tall sweet peas contain a dominant ***Le*** allele.
- Dwarf sweet peas are homozygous for the recessive ***le*** allele.

Explain how the ***le/e*** genotype results in the dwarf phenotype in sweet peas, with reference to the effect of ***le/e*** on:

- enzyme synthesis
- hormone production
- the expression of genes affecting plant growth.

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4 Environmental conditions such as light intensity affect plant physiology.

(b) An experiment investigated how light intensity affected gene expression in kale, *Brassica oleracea sabellica*.

- Two groups of kale plants were grown, with one group in high light intensity and one group in low light intensity. All other conditions were standardised.
- After the same period of time, messenger RNA (mRNA) was extracted from each group of kale plants.
- The mRNA was used to produce cDNA.
- The cDNA was hybridised with probes for 89 621 kale genes on a microarray.
- The microarrays showed which genes were switched on (expressed) in each set of conditions.

The results showed that expression of 18% of the genes was affected by light intensity.

- 14% of the genes were switched on only in high light intensity.
- 4% were switched on only in low light intensity.

(ii) State the name of the type of proteins that control gene expression in plants.

..... [1]

5 Selective breeding has been used to improve the characteristics of crop plants, including maize and rice.

(c) Thale cress, *Arabidopsis thaliana*, is another plant that has dwarf varieties.

Scientists treated three varieties of *A. thaliana* with gibberellin:

- the wild type (normal, non-dwarf variety)
- dwarf variety **A**
- dwarf variety **B**.

Fig. 6.2 shows the responses of the three varieties to treatment with gibberellin.

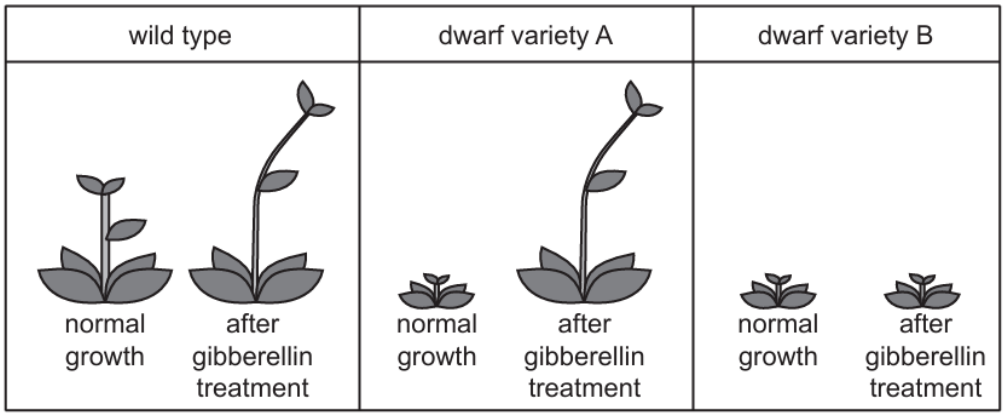


Fig. 6.2

(i) With reference to Fig. 6.2, suggest explanations for the different responses to gibberellin shown by dwarf variety **A** and dwarf variety **B**.

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(ii) BZR1 is a transcription factor that helps to regulate growth and development in *A. thaliana*.

Outline the features of a transcription factor such as BZR1.

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..... [2]

6 The bacterium, *Escherichia coli*, can use glucose or disaccharides, such as lactose, in its metabolism. Lactose needs to be hydrolysed by the enzyme β-galactosidase to form glucose and galactose, which can then be used by *E. coli*.

The production of β-galactosidase is controlled by a length of DNA called the *lac* operon.

(a) Fig. 7.1 shows the *lac* operon when lactose is **absent**.

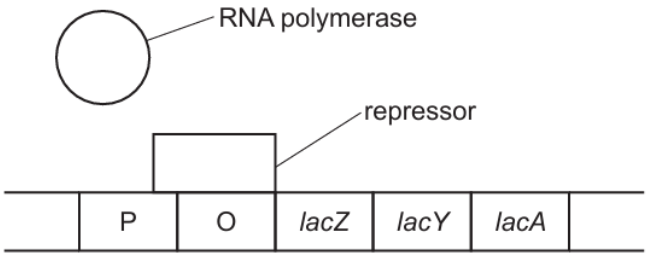


Fig. 7.1

On Fig. 7.2, draw the positions of RNA polymerase and the repressor molecule when lactose is **present**.

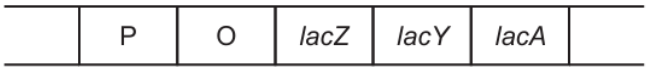


Fig. 7.2 [2]

(b) The protein coded for by *lacY* is not involved in the control of gene expression.

(i) Name the type of gene represented by *lacY*.

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(ii) Name the protein product coded for by *lacY* **and** state the precise role of this protein.

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..... [2]

(c) In an investigation into the growth of *E. coli*, a sample of the bacterium was grown in a medium that contained limited concentrations of glucose and lactose. The population size of *E. coli* was measured at regular intervals.

Fig. 7.3 shows the population growth curve obtained for this investigation.

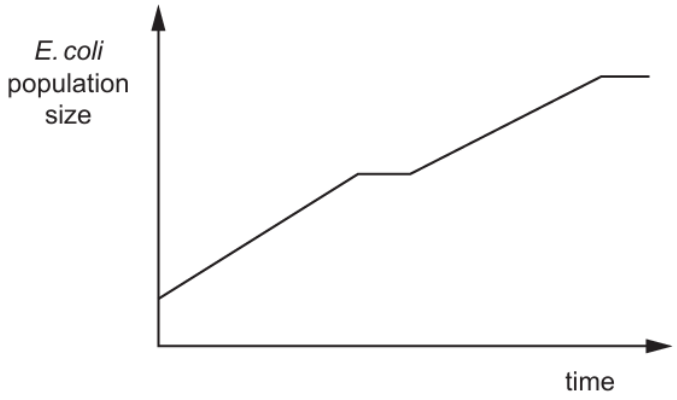


Fig. 7.3

Describe **and** suggest explanations for the population growth curve shown in Fig. 7.3.

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7 Glucagon-like peptide-1 (GLP-1) is a hormone consisting of 31 amino acids. It is secreted by specialised intestinal epithelial cells known as L cells.

Fig. 6.1 outlines the secretion of GLP-1 and its effects on the pancreas, brain and stomach.

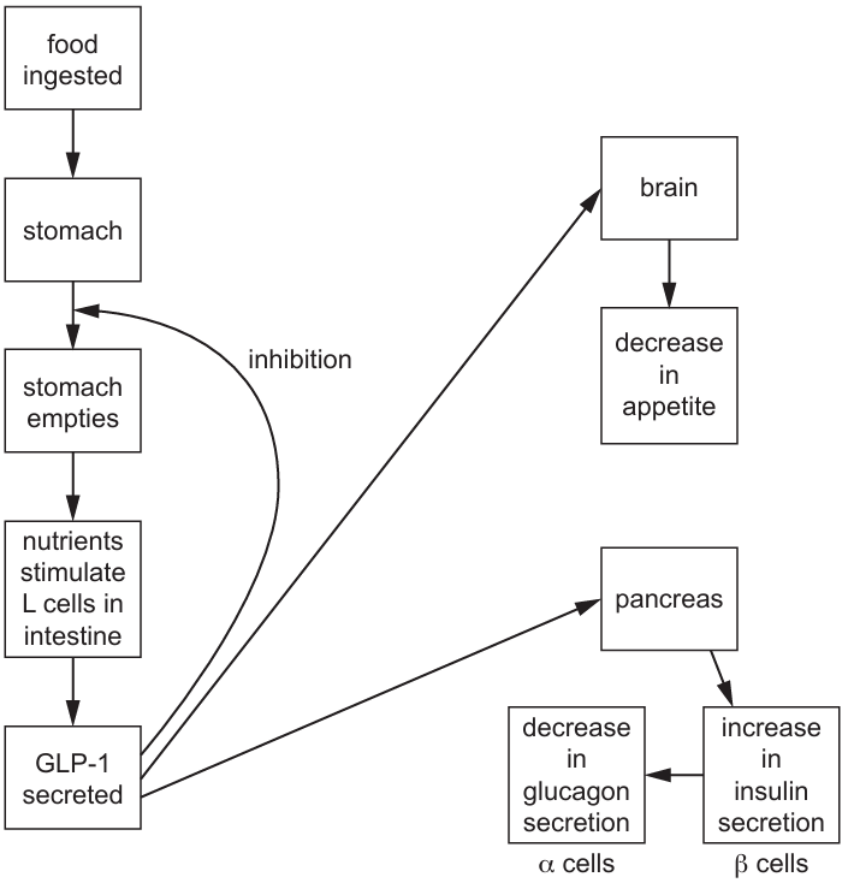


Fig. 6.1

(e) A transcription factor is involved in the production of GLP-1. An insertion mutation in the gene that codes for the transcription factor can affect the production of GLP-1.

Outline the effect of an insertion mutation on the production of GLP-1.

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8 **(b)** Another gene, *MC1R*, interacts with *TYRP1*.

MC1R has two alleles, **E** and **e**.

- The dominant allele, **E**, allows the alleles of *TYRP1* to be expressed.
- The recessive allele, **e**, prevents the alleles of *TYRP1* from being expressed.
- When no form of melanin is produced the Labrador will have yellow fur.

(i) Construct a genetic diagram to show the ratio of possible offspring from a cross between a black male Labrador, heterozygous for both genes, and a yellow female Labrador, heterozygous for *TYRP1*.

parental phenotype	black	×	yellow
parental genotype			
gametes			
offspring genotypes			
offspring phenotypes			

ratio .....

[6]

(ii) State the term used to describe a protein that is involved in the control of gene expression in eukaryotes.

..... [1]

9 Yeast cells respond to changes in glucose concentration in their environment by using transcription factors to switch off genes.

When glucose is **present**:

- Mig1 transcription factors bind to the promoters of five genes
- Mig1 binding to the promoters stops (represses) transcription of these genes.

The genes that are repressed by Mig1 code for five enzymes that allow yeast cells to metabolise the sugar galactose when glucose is absent.

(a) Complete Table 5.1 to show **three chemical** differences between a transcription factor, such as Mig1, and a promoter.

Table 5.1

	transcription factor	**promoter**
difference 1		
difference 2		
difference 3		

[3]

(c) The repression of genes involved in galactose metabolism in yeast is similar to events at the *lac* operon in the bacterium *Escherichia coli*.

Explain how *E. coli* **represses** the production of proteins needed to metabolise lactose sugar.

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..... [3]

10 Yeast cells are unicellular eukaryotes. Yeast cells respond to changes in the concentrations of the sugars galactose and glucose by switching on genes using transcription factors.

Fig. 5.1 shows the events that occur when the sugar galactose is present and glucose is absent in the external environment.

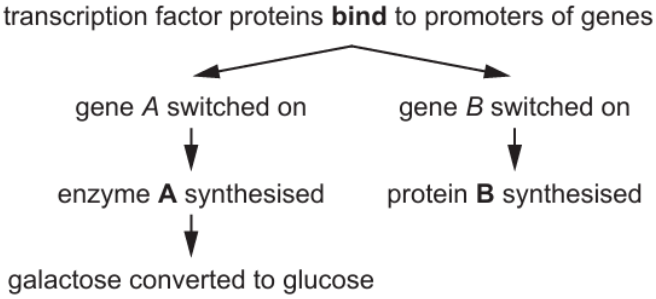


Fig. 5.1

(a) (i) Explain why enzyme **A** is described as an inducible enzyme.

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..... [3]

(ii) Protein **B** has a similar role to the protein coded for by gene *Y* of the *lac* operon.

Suggest a possible role for protein **B** that would allow yeast cells to make use of galactose.

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..... [1]

Scientists produced genetically engineered yeast cells. The gene coding for Msn2 transcription factor proteins and the marker gene coding for green fluorescent protein (GFP) are transcribed together to produce a single mRNA molecule.

The resulting Msn2 transcription factor proteins contain a GFP region as part of their structure and are called tagged Msn2 molecules. These tagged Msn2 molecules show up as green fluorescent spots when viewed using a microscope with a very high resolution.

An investigation was carried out to compare the distribution of tagged Msn2 molecules in yeast cells, when glucose is absent and when glucose is present.

The results are shown in Table 5.1.

Table 5.1

glucose availability	mean number of tagged Msn2 molecules present		
	cytoplasm	nucleus	total
glucose absent	3263	2012	5275
glucose present	1755	632	2387

(b) (i) Calculate the percentage of Msn2 molecules in the cell that are located inside the nucleus, when glucose is **absent**.

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

..... % [2]

(ii) When glucose is **present**, 26% of Msn2 molecules in the cell are located inside the nucleus.

Suggest why this figure is different from your answer to **(i)**.

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..... [2]

11 The interpupillary distance (IPD) is the distance in millimetres between the centres of the pupils of the eyes. Fig. 2.1 shows how IPD is measured.

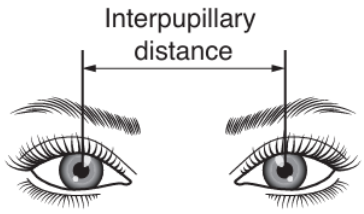


Fig. 2.1

IPD is one example of a characteristic of human facial structure that shows variation.

Fig. 2.2 shows the pattern of variation in IPD in a large sample of adults.

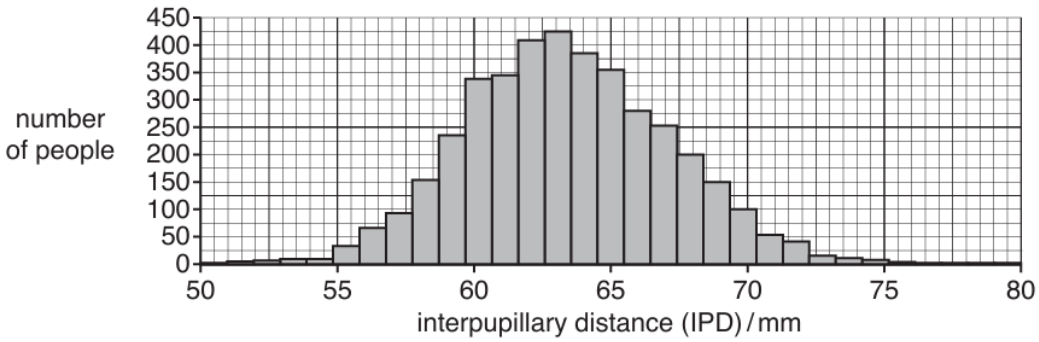


Fig. 2.2

(b) Individuals with an IPD of 70 mm or more have a mutation in the *PAX3* gene that results in less PAX3 protein being made.

The normal role of the PAX3 protein is to increase the expression of many other genes involved in embryonic development. These genes affect a range of phenotypic features such as facial structure, hearing and eye colour.

(i) State the term that is used to describe a gene, such as *PAX3*, that controls the expression of other genes **and** suggest how the PAX3 protein controls the expression of other genes.

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(iii) The chimpanzee, *Pan troglodytes*, has DNA that is 98.5% similar to humans, including possession of the *PAX3* gene. Investigations show that chimpanzees express higher levels of the PAX3 protein during embryonic development than humans.

Fig. 2.3 shows a chimpanzee, *Pan troglodytes*.



Fig. 2.3

Suggest how knowledge of the *PAX3* gene helps scientists explain how humans and chimpanzees are very different in facial structure, even though they have very similar DNA.

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12 **(a)** The *lac* operon is a section of DNA present in the genome of the bacterium *Escherichia coli*. The structural genes of the operon are only fully expressed when *E. coli* is exposed to high lactose concentrations.

(i) Fig. 3.1 is a diagram showing the *lac* operon and a nearby region of the *E. coli* genome.

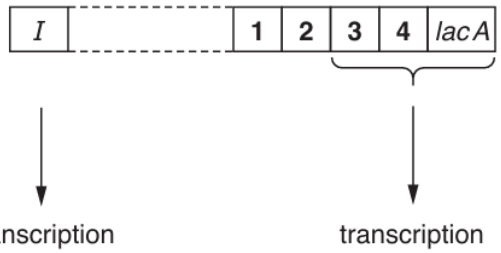


Fig. 3.1

Name sections **1**, **2**, **3** and **4** shown in Fig. 3.1.

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2 .....

3 .....

4 .....

[2]

(ii) Certain enzymes need to be present inside *E. coli* for it to be able to take up and use lactose. When the genes of the *lac* operon are expressed, the enzymes β-galactosidase and lactose permease are produced in large quantities.

Outline the functions of β-galactosidase and lactose permease.

β-galactosidase .....

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lactose permease .....

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[2]

(b) (i) Gene *I* is located a short distance away from the *lac* operon.

The product of gene *I*, a repressor protein, is a constitutive protein.

State what is meant by the term *constitutive protein*.

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.....[1]

(ii) Explain why the structural genes of the *lac* operon are **not** expressed when lactose is absent.

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.....[3]

(iii) A strain of *E. coli* has been produced with a mutation in gene *I*. Expression of this gene results in a non-functional repressor protein.

Suggest a negative effect that this mutation will have on this strain of *E. coli*.

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.....[1]