1 Growth and development in organisms is controlled by a number of mechanisms that operate at the cellular level. The control elements involved in these mechanisms include hormones, the second messenger molecule cyclic AMP and regulatory genes.

- In eukaryotes the most important regulatory genes contain homeobox sequences and are called homeotic genes.

- The regulatory genes of the *lac* operon in prokaryotes are studied to help us to understand how regulatory genes and their products interact to switch structural genes on and off.

(a) Use your understanding of the biochemical identity and interactions of these control elements to complete Table 5.1 by putting a tick (✓) or a cross (✗) **in each box**.

Some of the boxes have been completed for you.

Control element	Made of protein	Binds with a protein	Codes for protein
insulin		✓	
cyclic AMP			✗
lac I (inhibitor) gene		✓	
lac O (operator) gene	✗		
homeotic gene product		✗	

[5]

Table 5.1

(b) RNA polymerase and DNA polymerase are both enzymes. RNA polymerase is involved in the action of some control elements, whereas DNA polymerase is not.

Describe and explain the difference between the **functions** of these two enzymes.

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.....

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..... **[4]**

(c) Another mechanism that can act to change the body plan of an organism during its development is **programmed cell death**.

Fill in the gaps in the following passage describing this process and the importance of its regulation.

Programmed cell death is known as ..... . Firstly, the fine network of protein filaments and microtubules known as the ..... , which gives structure to the cell, is broken down and digested by ..... .

The plasma (cell surface) membrane then changes, forming small bulges called 'blebs'. The cell breaks into membrane-bound fragments that are removed by the process of ..... so that harmful substances are not released into surrounding tissues.

Programmed cell death is a controlled process. However, mutation in a gene called p53 can prevent programmed cell death. When this occurs, the rate at which somatic cells are produced by the process of ..... becomes greater than the rate at which cells die, resulting in the formation of a mass of cells known as a ..... . **[6]**

2 Homeobox genes show astonishing similarity across widely different species of animal, from fruit flies, which are insects, to mice and humans, which are mammals. The sequences of these genes have remained relatively unchanged throughout evolutionary history and the same genes control embryonic development in flies and mammals.

(a) State what is meant by a homeobox gene.

.....

.....

.....

..... **[2]**

(b) Homeobox genes show 'astonishing similarity across widely different species of animal'.

Explain why there has been very little change by mutation in these genes.

.....

.....

.....

..... **[2]**

(c) Frogs reproduce by laying eggs in water. Each egg develops into a tadpole, which has external gills to extract oxygen from the water, and a tail to help it swim. The tadpole gradually changes into an adult frog as it grows. During this time its gills and tail disappear.

List **two** cellular processes that must occur during the development of a tadpole into a frog.

.....

..... **[2]**

(d) Name another kingdom of organisms, other than animals, that have similar homeotic genes.

..... **[1]**

[Total: 7]

3 Fig. 5.1 is a circular representation of the genetic code.

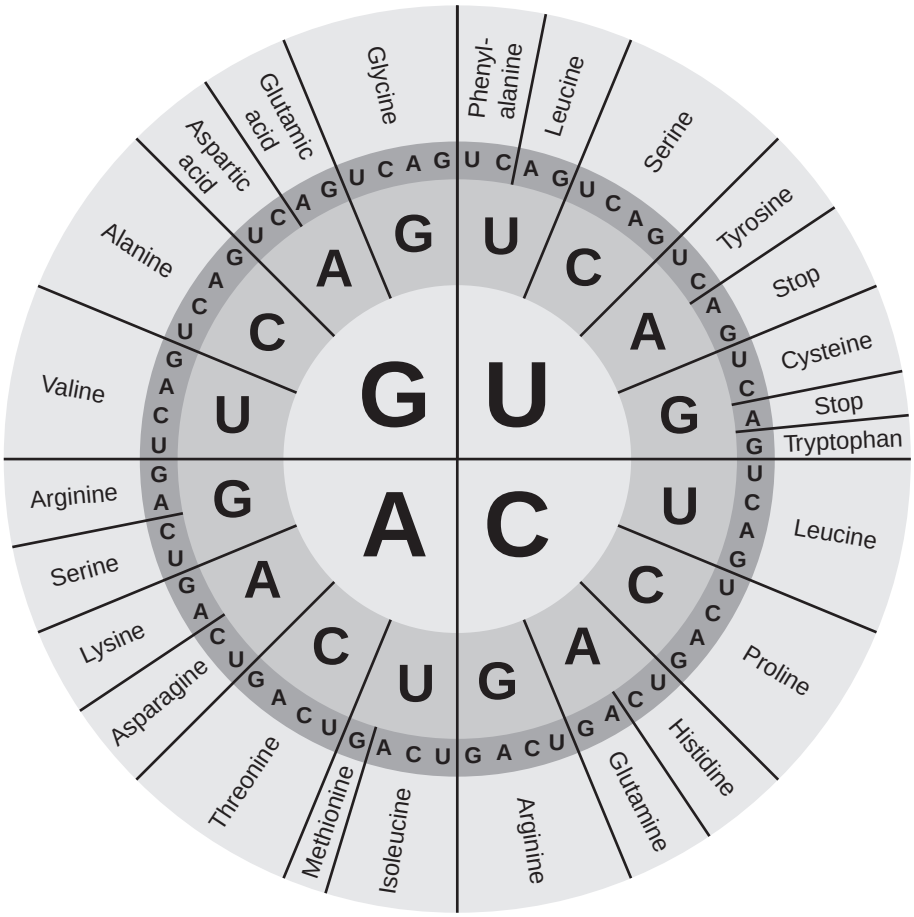

Fig. 5.1

(a) **Fig. 5.2** shows a sequence of bases coding for a sequence of amino acids. The name of the third amino acid in the sequence has been filled in.

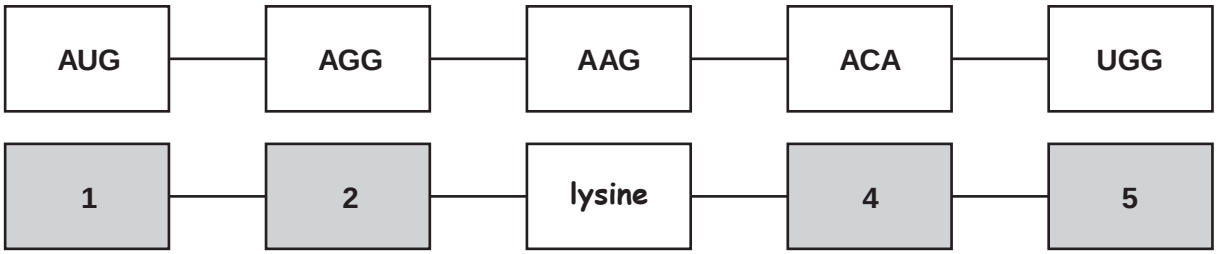

Fig. 5.2

Identify the remaining amino acids in the sequence.

1 .....

2 .....

3 lysine

4 .....

5 ..... **[2]**

(b) State the name of the stage of protein synthesis represented in Fig.5.2 **and** name the organelle in the cell where this takes place.

.....

..... **[2]**

(c) Identify the type of nucleic acid that holds the sequence of bases shown in Fig. 5.2.

..... **[2]**

(d) Using the information in **Fig. 5.1**, list the **three** triplet codons that would cause termination of a polypeptide chain (stop codons) **and** explain why these codons have this effect.

.....

.....

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.....

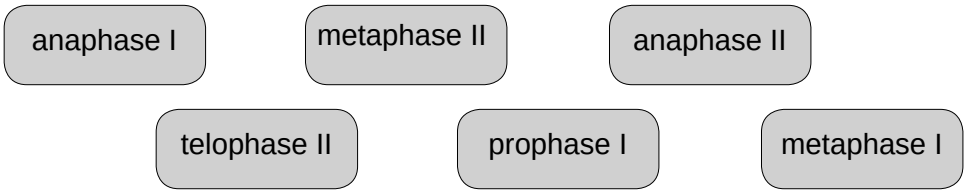
..... **[2]**

(e) What name would be given to a mutation that resulted in a change of the codon **UUU** to **UUC**?

..... **[1]**

[Total: 9]

4 **(a)** The following boxes show the names of different stages that occur during meiosis



State the stage(s) in which the following events occur:

independent assortment .....

formation of the spindle apparatus .....

separation of sister chromatids .....

formation of nuclear membranes .....

chromosomes pulled to opposite poles .....

[5]

(b) Meiosis is used in many organisms for the production of gametes.

Explain why meiosis needs to have twice as many stages as mitosis.

.....

.....

.....

.....

.....

.....

[2]

(c) Meiosis is a source of genetic variation. Mutation is another source of variation.

(i) What feature of the DNA molecule is changed as a result of mutation?

..... **[1]**

(ii) Discuss the possible effects that mutation can have on the structure and function of a protein.

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..... **[3]**

[Total: 11]

5 **(a)** The Oxford Botanic Garden was founded in 1621 to grow plants for the teaching of medicine. Since that time it has seen many changes. When the ideas of Linnaeus were adopted in the 18th century, the plants were dug up and re-planted in family groups according to his new system of taxonomy.

Recently, the plants have once again had to be re-organised:

- DNA sequencing techniques, together with cladistic analysis, have provided a radical new view of plant evolutionary relationships.
- The same techniques have also improved the ability of researchers to pinpoint new cures for diseases, by examining the closest relatives of plants already known to have medicinal properties.

(i) Comment on what the different arrangements of plants in the Oxford Botanic Garden over time tell us about the nature of scientific knowledge.

.....

..... **[1]**

(ii) Suggest **two** purposes of a plant collection in a modern botanic garden.

.....

.....

.....

..... **[2]**

(b) DNA sequencing techniques have provided new information about plant relationships.

Outline the **roles** of each of the following procedures **in sequencing a genome**:

(i) the polymerase chain reaction (PCR)

.....

.....

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.....

..... **[2]**

(ii) electrophoresis

.....

.....

.....

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..... **[2]**

(iii) digestion of DNA by restriction enzymes.

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..... **[2]**

(c) Suggest why a genome has to be fragmented before sequencing.

.....

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..... **[2]**

(d) Table 5.1 lists some plants considered for genome sequencing by the 'Floral Genome Project'. The chromosome numbers and genome sizes in mega base pairs (Mbp) are shown.

One Mbp is equal to 1 000 000 base pairs of DNA.

Name	Chromosome Number(s)	Genome Size (Mbp)
Amborella	2n = 26	870
sweet rush	2n = 18	392
monkey flower	2n = 28	430
blueberry	2n = 12, 4n = 24, 6n = 36	1078

Table 5.1

(i) The sequencing method that will be used is only able to sequence fragments of DNA with a maximum length of 750 base pairs.

Calculate the minimum number of DNA fragments that would need to be sequenced to read the genome of *Amborella*.

Show your working.

Answer = ... **[2]**

(ii) Monkey flower and blueberry belong to the same taxonomic group within the plant kingdom. Only one of the pair was chosen for further sequencing work.

Using the data in Table 5.1, suggest reasons why monkey flower was chosen instead of blueberry.

.....

.....

.....

..... **[2]**

(iii) Use your knowledge of the effects of polyploidy in bread wheat to suggest one way in which the fruit of a hexaploid (6n) blueberry might differ in appearance from that of a diploid (2n) blueberry.

..... **[1]**

(e) DNA sequence information is most useful when used with the phylogenetic (cladistic) approach to classification.

How does the phylogenetic approach to classifying species differ from the biological species concept?

.....

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..... **[2]**

[Total: 18]

6 **(a)** Human populations have herded cattle for milk for around 9 000 years. Artificial selection over this time has resulted in the modern dairy cow.

(i) State **three** phenotypic traits (characteristics) that have been selected for in dairy cows.

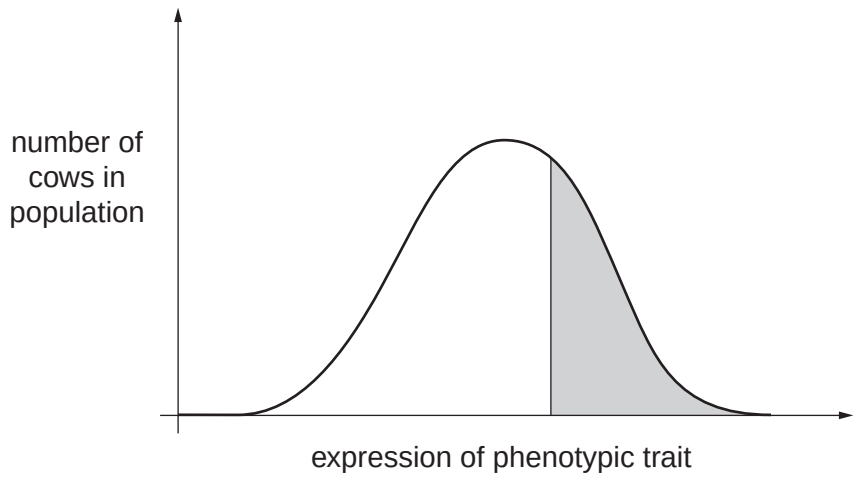
1 .....

2 .....

3 ..... **[3]**

(ii) Fig. 1.1 shows the pattern of variation of a phenotypic trait in a herd of dairy cows. The shaded part of the graph indicates those cows that are chosen to breed.

Draw, **on Fig. 1.1**, a second curve to show the pattern of variation in the next generation.



[2]

Fig. 1.1

(iii) In recent years, artificial selection of dairy cows has been helped by modern reproductive technology.

Name **two** modern techniques or procedures that can be used in the selective breeding of dairy cows.

1 .....

2 ..... **[2]**

(b) Lactase is an enzyme that is necessary to digest lactose sugar in milk.

In some parts of the world, animals are not farmed for milk and no dairy products are eaten. Adult humans that are native to these parts of the world do not produce lactase.

In areas where animals are farmed for milk, native adult humans do produce lactase. In these populations, a new allele has arisen by gene mutation.

(i) State what is meant by gene mutation.

.....

..... **[1]**

(ii) Over time, the frequency of this new allele increased in the gene pool of the human populations whose diet included milk.

Name the process by which this increase occurred.

..... **[1]**

(c) **(i)** All human babies produce the enzyme lactase. The genetic change that allows adults to produce this enzyme is thought to involve a mutation in a regulatory gene. This mutation causes the structural gene to be expressed in adults.

Distinguish between the terms 'regulatory gene' and 'structural gene'.

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..... **[2]**

(ii) Adult humans who cannot produce the enzyme lactase are described as lactose-intolerant and cannot drink milk without experiencing health problems. However, lactose-intolerant people can safely eat yogurt.

Yogurt is produced from milk that is fermented by bacteria. These bacteria perform anaerobic respiration, using carbohydrate as their respiratory substrate.

Suggest why yogurt is a suitable food for lactose-intolerant people.

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..... **[2]**

(d) The control of the expression of the *lac* operon genes, which allow uptake and digestion of lactose in the bacterium *Escherichia coli*, is well known.

Fig. 1.2 shows the arrangement of the elements of the *lac* operon.

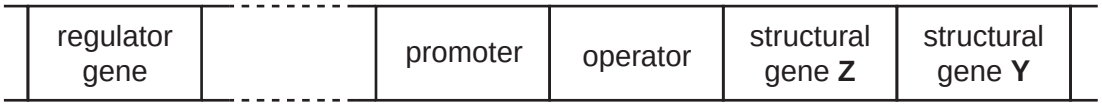

Fig. 1.2

Describe how genes **Z** and **Y** are switched on in bacteria that are moved to a nutrient medium that contains lactose.

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..... **[3]**

[Total: 16]