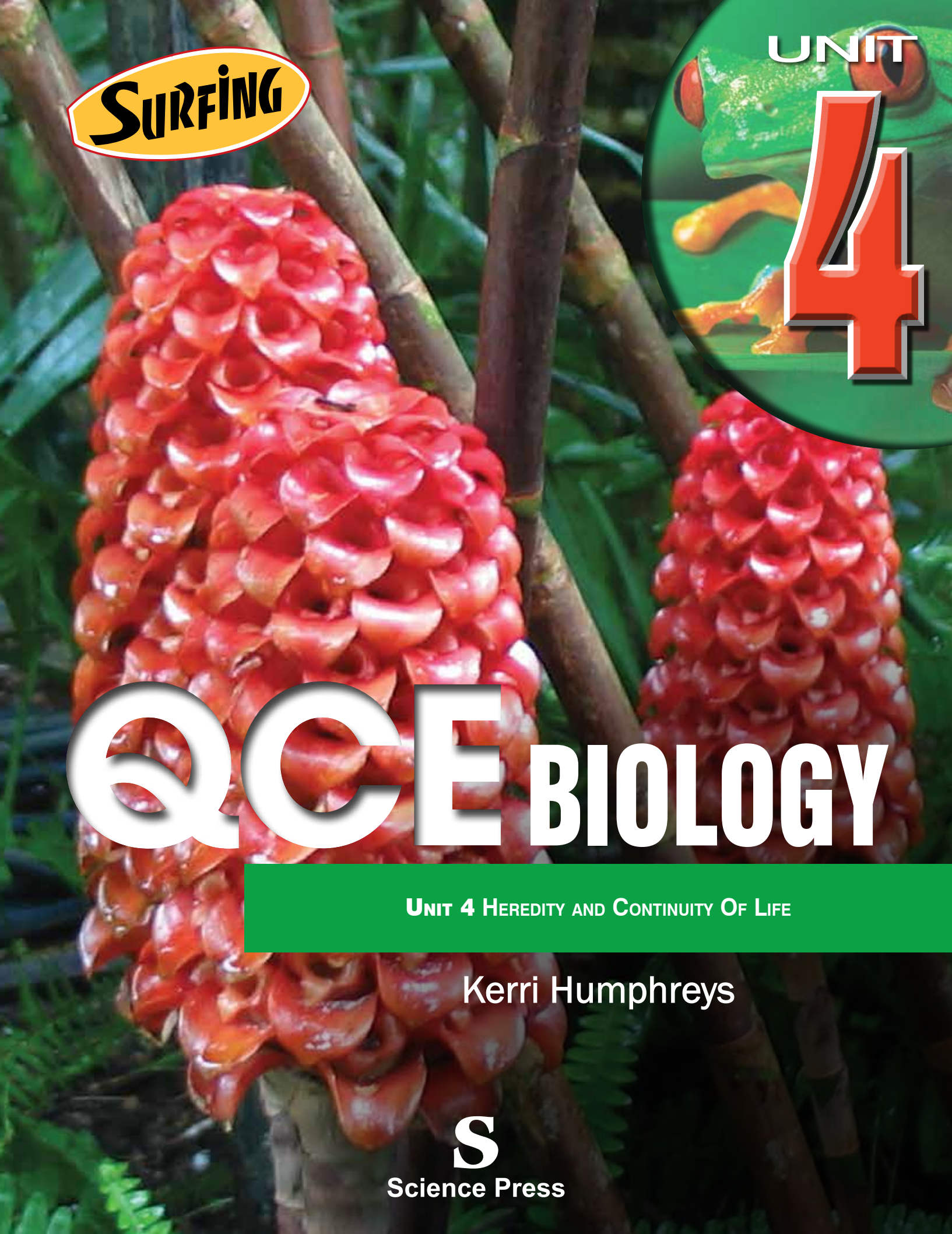
SURFING
UNIT
4
QCE BIOLOGY
UNIT 4 HEREDITY AND CONTINUITY OF LIFE
Kerri Humphreys
S
Science Press

First published 2020

Science Press
Unit 7, 23-31 Bowden Street
Alexandria NSW 2015 Australia
Tel: +61 2 9020 1840 Fax: +61 2 9020 1842
sales@sciencepress.com.au
www.sciencepress.com.au

# Contents


Introduction v
Words to Watch vi

## Topic 7 DNA, Genes and The Continuity Of Life

1 Assumed Knowledge Topic 7 4
2 Prokaryote and Eukaryote DNA 5
3 DNA In Organelles 6
4 Structure Of DNA 7
5 Activity – Making a Model Of DNA 9
6 Discovering DNA 11
7 DNA Replication 14
8 DNA Repairs Itself 16
9 DNA Replication and Continuity Of a Species 17
10 Experiment – DNA Extraction 18
11 Meiosis 19
12 Processes In Meiosis 21
13 Experiment – Investigating Meiosis 23
14 Comparing Meiosis and Mitosis 24
15 Spermatogenesis 25
16 Oogenesis 26
17 Fertilisation 27
18 Causes Of Genetic Variation Summary 29
19 Play – Cell Productions 30
20 Reproductive Technologies 34
21 Introns and Exons 36
22 RNA 38
23 Beadle and Tatum Experiment 40
24 Polypeptide Synthesis – Transcription 41
25 Polypeptide Synthesis – Translation 43
26 Activity – Making a Model Of Protein Synthesis 45
27 Importance Of Polypeptide Synthesis 47
28 Gene Expression 48
29 Phenotype 49
30 Experiment – Phenotype and Environment 51
31 Differential Gene Expression 52
32 Transcription Factor Gene 53
33 Gene Cascades and Limb Development 54
34 Mutation 56
35 Point Mutations 58
36 Block Mutations 60
37 Mutagens 62
38 Transposable Genetic Elements 64
39 Chromosome Abnormalities 65
40 Polyploidy 67
41 Case Study – Genetic Mutations 69
42 Somatic and Germ Line Mutations 71
43 Mutation and Coding and Non-Coding DNA 72
44 Variation In Genotype 74
45 Mutation and Polypeptide Synthesis 75
46 Gregor Mendel and His Experiments 76
47 Writing Genotypes 78
48 Probability Models 79
49 Incomplete Dominance 80
50 Pedigrees 81
51 Multiple Alleles 82
52 Sex Chromosomes 83
53 Morgan and Sex Linkage 84
54 Human Blood Groups and Rhesus Factor 86
55 Dihybrid Crosses 88
56 Inheritance Patterns For Autosomal Human Genetic Diseases 89
57 Polygenic Inheritance 90
58 Population Genetics 92
59 Biotechnology 93
60 Endonucleases 95
61 Activity – Restriction Enzymes 96
62 DNA Ligases 97
63 DNA Polymerase 98
64 Recombinant DNA Technology 99
65 Biotechnology and Bacteria 101
66 Recombinant Plasmids 103
67 Single Nucleotide Polymorphisms 104
68 DNA Sequencing and DNA Profiling 105
69 DNA Fingerprinting 106
70 DNA Sequencing and Evolution 107
71 Polymerase Chain Reaction 109
72 Activity – PCR 110
73 Gel Electrophoresis 111
74 Activity – Gel Electrophoresis 112
75 Using Gel Electrophoresis 113
76 Inducing Genetic Change 115
77 Cloning 117
78 Gene Cloning 119
79 Industrial Applications 120
80 Stem Cell Research 122
81 Bioinformatics and Reproduction Technologies 124
82 Human Genome Project 126
83 Genetic Screening 127
84 Other Genome Projects 128
85 Transgenic Species – Using Plasmids As Vectors 129
86 Genetically Modified and Transgenic Organisms 131
87 Implications Of Biotechnology 132
88 Biotechnology and Polyploidy 134
Topic 7 Test 136

## Topic 8 Continuity Of Life On Earth


89 Assumed Knowledge Topic 8 142
90 Evolution 143
91 Geological Time Scale 144
92 Extinction 146
93 Mass Extinctions 148
94 Comparative Genomics 149
95 Comparing Amino Acid Sequences 150
96 Molecular Homology 152
97 Developmental Biology 153
98 Molecular Systematics and Embryology 155
99 Natural Selection and Population Genetics 157
100 Charles Darwin Collected Evidence Of Natural Selection 158
101 Darwin's Finches 159
102 The Peppered Moth 160
103 Antibiotic Resistant Bacteria 162
104 Activity – Model For Natural Selection 164
105 Allele Frequencies and Population Genetics 166
106 Gene Pool Of Tasmanian Devils 167
107 Allele Frequency – Sickle Cell Anaemia 169
108 Allele Frequency – Huntington's Disease 171
109 Types Of Phenotypic Selection 172
110 Gene Flow 173
111 Genetic Drift 175
112 Microevolution 176
113 Activity – Selective Pressure and Genotypic Changes 178
114 Macroevolution 179
115 Evolution Of the Horse 180
116 Evolution Of Australian Mammals 181
117 Evolution Of the Platypus 183
118 Speciation 184
119 Patterns Of Evolution 185
120 Modes Of Speciation 186
121 Mechanisms Of Isolation 188
122 Hybridisation and Gene Flow 189
123 Case Study – Spider Orchids 191
124 Gene Flow, Allele Frequency and Speciation 193
125 Human Evolution 195
126 Population Genetics and Aboriginal Genome 197
127 Unsustainable Population Size and Reserve Area 198
Topic 8 Test 199

Answers 206
Syllabus Cross-Reference 262
Index 265

# Introduction

This book covers the Biology content specified in the Queensland Certificate of Education Biology Syllabus. Sample data has been included for suggested experiments to give you practice to reinforce practical work in class.

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of each topic contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

# Words To Watch

**account, account for** State reasons for, report on, give an account of, narrate a series of events or transactions.

**analyse** Interpret data to reach conclusions.

**annotate** Add brief notes to a diagram or graph.

**apply** Put to use in a particular situation.

**assess** Make a judgement about the value of something.

**calculate** Find a numerical answer.

**clarify** Make clear or plain.

**classify** Arrange into classes, groups or categories.

**comment** Give a judgement based on a given statement or result of a calculation.

**compare** Estimate, measure or note how things are similar or different.

**construct** Represent or develop in graphical form.

**contrast** Show how things are different or opposite.

**create** Originate or bring into existence.

**deduce** Reach a conclusion from given information.

**define** Give the precise meaning of a word, phrase or physical quantity.

**demonstrate** Show by example.

**derive** Manipulate a mathematical relationship(s) to give a new equation or relationship.

**describe** Give a detailed account.

**design** Produce a plan, simulation or model.

**determine** Find the only possible answer.

**discuss** Talk or write about a topic, taking into account different issues or ideas.

**distinguish** Give differences between two or more different items.

**draw** Represent by means of pencil lines.

**estimate** Find an approximate value for an unknown quantity.

**evaluate** Assess the implications and limitations.

**examine** Inquire into.

**explain** Make something clear or easy to understand.

**extract** Choose relevant and/or appropriate details.

**extrapolate** Infer from what is known.

**hypothesise** Suggest an explanation for a group of facts or phenomena.

**identify** Recognise and name.

**interpret** Draw meaning from.

**investigate** Plan, inquire into and draw conclusions about.

**justify** Support an argument or conclusion.

**label** Add labels to a diagram.

**list** Give a sequence of names or other brief answers.

**measure** Find a value for a quantity.

**outline** Give a brief account or summary.

**plan** Use strategies to develop a series of steps or processes.

**predict** Give an expected result.

**propose** Put forward a plan or suggestion for consideration or action.

**recall** Present remembered ideas, facts or experiences.

**relate** Tell or report about happenings, events or circumstances.

**represent** Use words, images or symbols to convey meaning.

**select** Choose in preference to another or others.

**sequence** Arrange in order.

**show** Give the steps in a calculation or derivation.

**sketch** Make a quick, rough drawing of something.

**solve** Work out the answer to a problem.

**state** Give a specific name, value or other brief answer.

**suggest** Put forward an idea for consideration.

**summarise** Give a brief statement of the main points.

**synthesise** Combine various elements to make a whole.

SURFING

# QCE BIOLOGY

UNIT 4

## UNIT 4

## Heredity and Continuity Of Life

In this unit you will:

- Explore the ways biology is used to describe and explain the cellular processes and mechanisms that ensure the continuity of life.
- Understand the processes and mechanisms of how life on Earth has persisted, changed and diversified over the last 3.5 billion years.
- Investigate different factors that influence cellular processes and gene pools.
- Examine different patterns of inheritance and the genetic basis of the theory of evolution through natural selection to analyse the use of predictive models in decision making.
- Research DNA profiling, gene therapy and genetically modified organisms and their impact on future society.
- Carry out a range of experiments and investigations to develop science inquiry skills and participate in collaborative experimental work to develop communication, interaction, character and management skills.

Surfing

# QCE BIOLOGY

UNIT 4

## TOPIC 7

## DNA, Genes and the Continuity Of Life

In this topic you will:

- Describe and explain DNA structure and replication.
- Identify the processes in meiosis.
- Explain how variation occurs in the processes involved in sexual reproduction.
- Discuss implications of genetic screening technologies.
- Describe gene expression.
- Explain how mutations occur and alter genotype.
- Use probability models for inheritance problems.
- Describe recombinant DNA and its use in biotechnology.
- Explain the polymerase chain reaction and gel electrophoresis and their use in practical applications.

# 1 Assumed Knowledge Topic 7

## QUESTIONS

1. Define mitosis.
2. The diagram shows the last division of meiosis in the anther of a flower.
   (a) What is meiosis?
   (b) What would be produced, in this diagram?

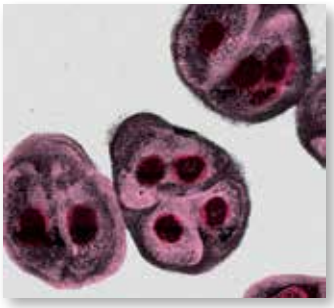

**Figure 1.1** Meiosis in an anther.

3. The diagram shows a type of human cell.

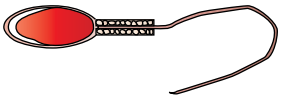

**Figure 1.2** Type of human cell.

What is the name of this cell and what is its function?

4. Define genome.
5. What is a chromosome?
6. What is meant by genotype?
7. Define fertilisation.
8. Why is it important for gametes to have half the number of chromosomes of the species?
9. How is information transferred when cells reproduce themselves?
10. What does DNA stand for?

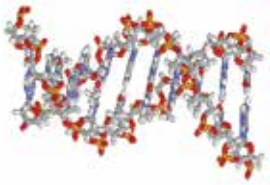

**Figure 1.3** DNA.

11. Name the basic unit of DNA.
12. Where is DNA located in cells?
13. Outline the structure of the DNA molecule.
14. What is the relationship between genes and DNA?
15. Explain the advantages of DNA replicating exactly.
16. Why is Gregor Mendel often referred to as the 'father of genetics'?
17. Identify the factors that determine the features of an organism.
18. Use an example to show how environment influences the appearance of an organism.
19. Use an example to show how genes determine the features of an organism.
20. What is the 'Watson-Crick' model of DNA?
21. Distinguish between autosomes and sex chromosomes.
22. The diagram shows the karyogram for person A.

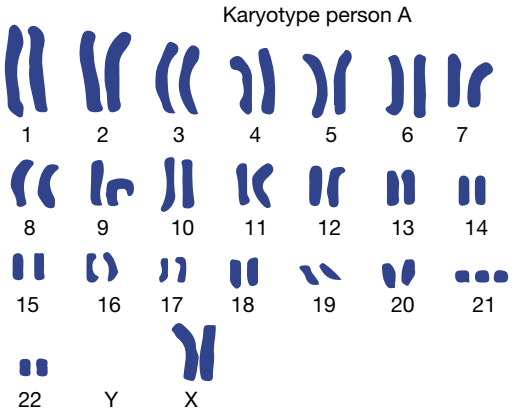


**Figure 1.4** Karyogram.

   (a) Is this person male or female?
   (b) Define trisomy.
   (c) Person A has a trisomy disorder. Name this disorder.

23. What is meant by the genome sequence?
24. Define a gene pool.
25. What is meant by allele frequency?
26. Define polyploidy.
27. What is a mutation?
28. What is comparative genomics?
29. What is a mutagen?
30. The diagram shows the electromagnetic spectrum.

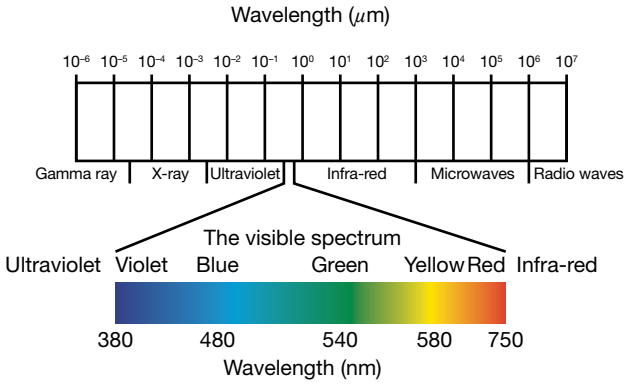


**Figure 1.5** Electromagnetic spectrum.

Which parts of the electromagnetic spectrum involve ionising radiation that causes mutation?

31. Define biotechnology.
32. Distinguish between a somatic cell and a germ line cell.
33. Distinguish between introns and exons.
34. Identify four causes of genetic variation.

# 2 Prokaryote and Eukaryote DNA

The genome of prokaryotes is structurally different to the genome of eukaryotes with the amount of DNA in a prokaryote being considerably less than the amount of DNA in an eukaryote. The process of DNA replication is fundamentally the same in prokaryotes and eukaryotes.

## Prokaryote DNA

Most prokaryotic DNA is in circular ring in the nucleoid region of the cytoplasm. They do not have the histone protein framework of eukaryote cells. Many prokaryotes also have **plasmids** which a smaller rings of DNA that contain a limited number of genes.

Prokaryote ribosomes are slightly smaller than eukaryote ribosomes and have different protein and RNA.

In DNA replication the process starts at the origin of replication site and continues from the two forks at each end of the replication bubble. There are no telomeres as prokaryote DNA is circular with no ends that can be eroded with each replication process.

When the DNA code is used in protein synthesis the process of translation starts while transcription is still in progress. When the protein has been synthesised it quickly diffuses to its site of function.

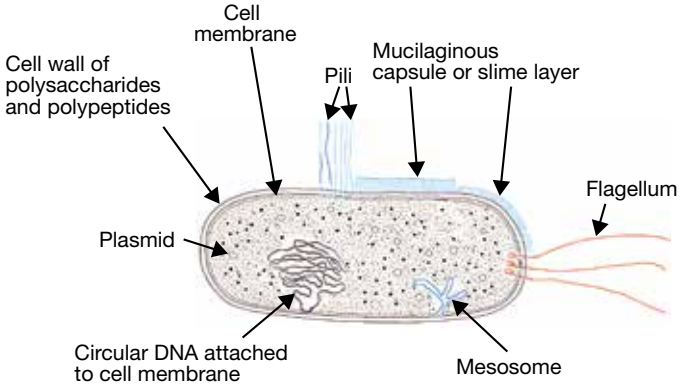


**Figure 2.1** Typical prokaryote cell.

## Eukaryote DNA

The chromosomes containing DNA of eukaryotes are found inside the nuclear membrane in the nucleus and are packaged with large amounts of protein with about one-half of the protein present being histone. The DNA-protein complex is called **chromatin**. Plasmids are found in some eukaryotes, e.g. yeast.

In eukaryotes DNA replication is initiated at many points along the chromosomes. There is also a framework of fibres throughout the nucleus that anchor the parental strands of DNA during the DNA replication process.

**Telomeres** are protective structures with repetitive codes that are found at the ends of eukaryotic chromosomes. The nucleotide sequence in telomeres is not a gene code but multiple repetitions of a short sequence that is eroded with each replication. Since eukaryotic DNA is in linear chromosomes and DNA polymerase can only add to the 3′ end of an existing chain, each replication involves the erosion of the 5′ ends of the daughter DNA strand. Telomeres act as a buffer and increase the time before genes near the ends of DNA molecules start to be eroded.

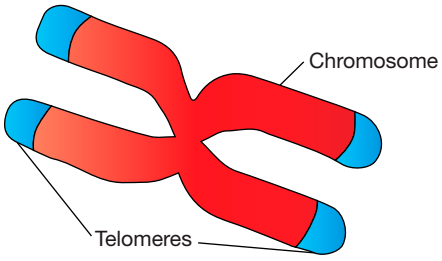


**Figure 2.2** Telomere.

When the DNA code is used in protein synthesis transcription occurs in the nucleus where the code is transcribed onto mRNA. The mRNA then has to leave the nucleus and go the cytoplasm where translation occurs. While in the nucleus there is extensive RNA processing with RNA splicing removing **introns** which are long noncoding stretches of nucleotides.

## QUESTIONS

1. Construct a table to compare the DNA of prokaryotes and eukaryotes.
2. What is a plasmid?
3. (a) What is a telomere?
   (b) Why are telomeres important?
   (c) Why are telomeres needed in eukaryotes and are not needed in prokaryotes?
4. Define chromatin.
5. In which type of cells would you *least* expect to find plasmids?
   (A) Cyanobacteria.
   (B) Methanogens.
   (C) Yeast.
   (D) Animal cells.
6. Which of the following correctly associates telomeres with their DNA code and type of cell in which they are found?

| | DNA code | Type of cell |
|---|---|---|
| (A) | Short repeating nucleotide sequence | Eukaryote |
| (B) | Short repeating nucleotide sequence | Prokaryote |
| (C) | Gene code for a polypeptide production | Eukaryote |
| (D) | Gene code for a polypeptide production | Prokaryote |

# 3 DNA In Organelles

Some organelles in eukaryotes contain DNA. The genes in these organelles are called **extranuclear genes**. These organelles can reproduce themselves.

## Mitochondrial DNA

Mitochondria are cylinder shaped organelles that vary in size from 2 to 8 micrometres in length and are the site of aerobic respiration. They have a double membrane with the inner membrane infolded to form **cristae**. They can give rise to other mitochondria by growth and division. Mitochondria contain a ring of DNA (mtDNA) like prokaryotes and the dimensions of mitochondria is similar to the size of prokaryotes. The inheritance of mtDNA from one generation to the next does not involve both parents and has been used to track ancestry and evolutionary trees. In humans the analysis of mtDNA has been used to track the migration of different human populations following the female line back through many generations.

The **endosymbiotic theory** suggests that mitochondria arose as a symbiotic relationship between a free-living heterotrophic bacterium with aerobic respiration that entered a larger cell – either a larger prokaryote or an eukaryote and both then existed in a mutualistic partnership.

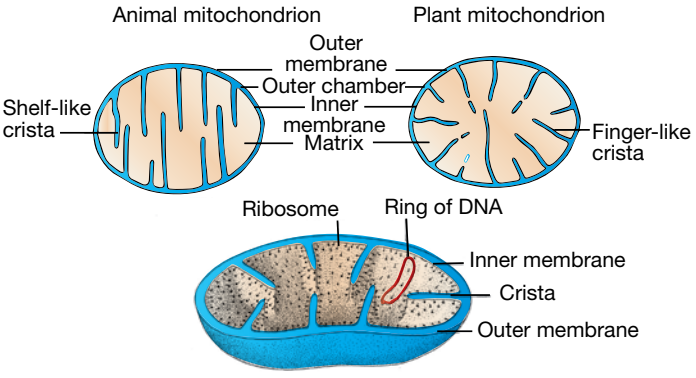


**Figure 3.1** Plant and animal mitochondria.

## DNA in plastids

Plastids are a group of closely related plant organelles that includes chloroplasts, chromoplasts and amyloplasts (leucoplasts). Plastids contain pigments such as chlorophylls and carotenoids.

**Chloroplasts** have a double membrane with the inner membrane giving rise to branching lamellae that forms **thylakoids**. They contain the green pigments chlorophyll *a* and chlorophyll *b* which trap light energy for photosynthesis. Chloroplasts contain a ring of DNA like prokaryotes and the dimension of chloroplasts is similar to the size of prokaryotes.

Chloroplasts may have arisen as a symbiotic relationship between a free-living photosynthetic bacterium that entered a larger cell – either a larger prokaryote or an eukaryote. Chloroplasts are found in algae and certain plant cells.

**Amyloplasts** are colourless plastids common in storage organs, e.g. storing starch in roots and seeds. Amyloplasts can turn in chloroplasts, e.g. potato tubers turn green in sunlight.

**Chromoplasts** are coloured plastids with non-photosynthetic pigments common in fruits and flower petals and in carrot root tissue. Chromoplasts synthesise and store pigments.

## QUESTIONS

1. What are extranuclear genes?
2. Describe mitochondria.
3. Describe mitochondrial DNA.
4. How does the endosymbiotic theory apply to mitochondria?
5. Explain how human mtDNA has been used to trace human migration across the Earth.
6. (a) What is a plastid?
   (b) Name some different types of plastids.
7. Describe chloroplasts.
8. The diagram shows one proposal about the origin of mitochondria and chloroplasts.

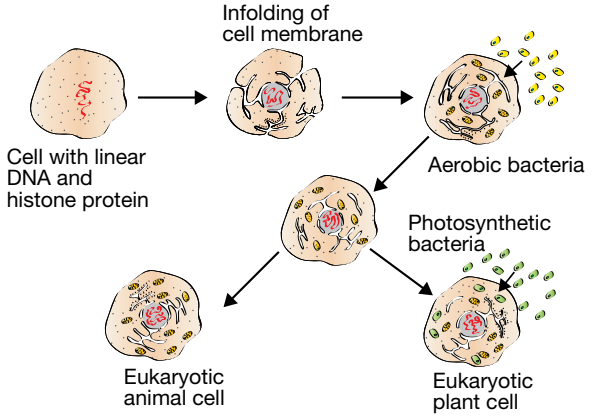


**Figure 3.2** Origin of mitochondria and chloroplasts.

   (a) Use this diagram to write out the sequence of events that has been proposed to explain the origin of eukaryotic plant and animal cells.
   (b) Explain how mitochondrial DNA and chloroplast DNA supports the endosymbiotic theory.
9. Which of the following does *not* have its own DNA?
   (A) Chromoplasts. (B) Chloroplasts.
   (C) Endoplasmic reticulum. (D) Mitochondria.
10. What is the structure of mitochondrial DNA?
   (A) Small circular ring.
   (B) Large circular ring with histone protein.
   (C) Linear chromatin.
   (D) Small circular ring linked with lipids.

# 4 Structure Of DNA

Early in the 20th century scientists tried to determine if hereditary information was passed on through proteins or deoxyribose nucleic acid (DNA).

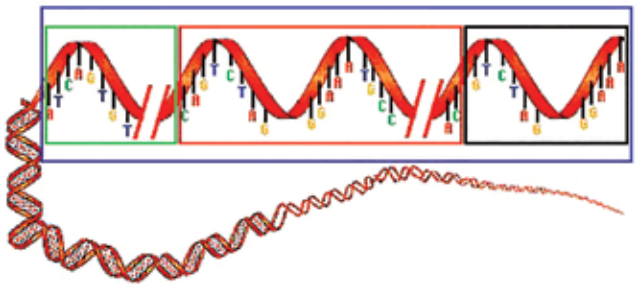

**Figure 4.1** DNA.

Eventually enough evidence was gathered to show that DNA carried the genetic material from one generation to the next. In 1944 **Oswald Avery** demonstrated that genes were made of DNA. In 1952 **Rosalind Franklin**, with **Maurice Wilkins**, showed that the DNA molecule was helical using X-ray diffraction crystallography. In 1953 **James Watson** and **Francis Crick** proposed the double helix structure for DNA.

Each chromosome consists of many genes, i.e. each **gene** is a certain length of the DNA molecule. When working out the chemical structure of genes scientists knew that the substance would have to be able to encode a large amount of information, that it must be chemically stable, that it must be able to make an accurate replication of itself, that occasional errors (mutations) could occur and that the substance controls and directs protein synthesis.

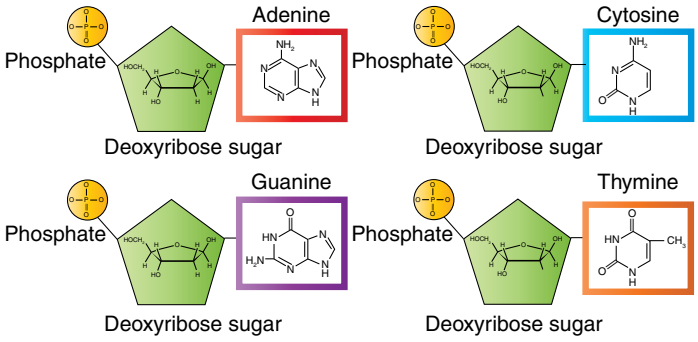


**Figure 4.2** Four different nucleotides that make up DNA.

## Nucleotides

The basic unit of DNA is the **nucleotide**. A nucleotide consists of a sugar, a phosphate and one of four nitrogenous bases – either adenine (A), guanine (G), cytosine (C) or thymine (T). To form the double helix, the sides of the ladder are made up of alternating sugar and phosphate molecules and the rungs consist of paired nitrogenous bases. Adenine always pairs with thymine and guanine always pairs with cytosine.

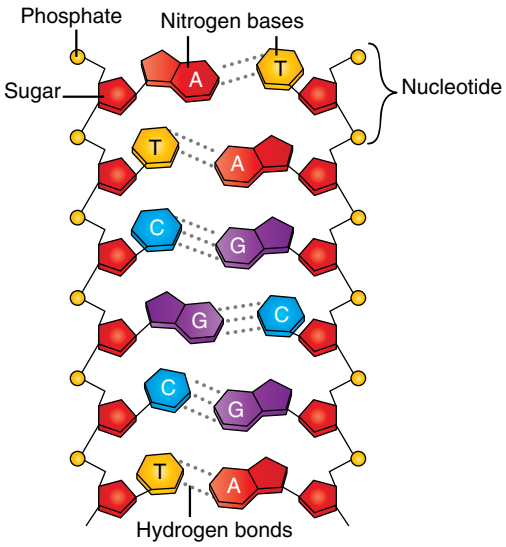


**Figure 4.3** Base pairs of DNA.

The double helix is a structure where two spirals coil around each other keeping a constant diameter of the coil. It is a right handed spiral polymer.

## Bonding in DNA

The base pairs on the rungs of the ladder are held together by hydrogen bonds and by van der Waals interactions between the stacked bases. These hydrogen bonds break during DNA replication.

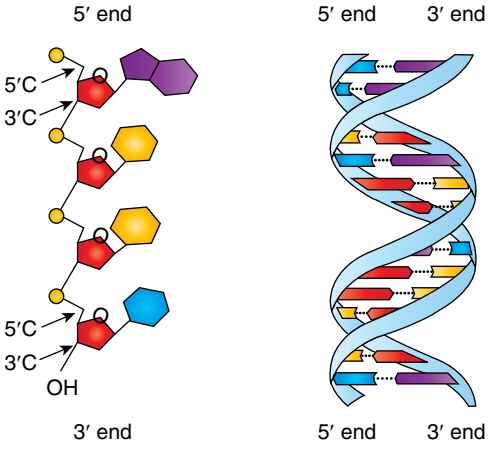


**Figure 4.4** Four different nucleotides that make up DNA.

The nucleotides are joined together by covalent bonds between the phosphate group of one nucleotide and the sugar of the next. These bonds are called **phosphodiester linkages** and occur between the –OH group on the 3′ carbon of one nucleotide and the phosphate on the 5′ carbon of the next. This means that the free ends of the DNA molecule are different to each other with one side having a phosphate attached to a 5′ carbon and the other side having a hydroxyl (OH) group on a 3′ carbon. Since the two strands of the double helix run in opposite directions, they are said to be **antiparallel** to each other. The phosphate groups give the nucleic acids their acidic properties.

## QUESTIONS

1. What is a gene?
2. What does 'DNA' stand for?
3. Use an example to show how major advances in scientific understanding have directed future biological research.
4. Describe the shape of DNA.
5. What is a nucleotide?
6. Which part of the nucleotide gives the nucleic acid its acidic properties?
7. Purines, e.g. adenine and guanine, are double ringed nitrogenous bases and pyrimidines, e.g. cytosine and thymine, are single ringed nitrogenous bases. How do these bases form complementary pairs?
8. List five features of DNA that make it a suitable genetic medium.
9. What type of bond holds the sugar of one nucleotide to the phosphate group of the next nucleotide?
10. What type of bond holds the nitrogenous bases on the 'rungs' of the ladder together?
11. Explain why the arrangement of the two strands of DNA are called antiparallel.
12. Which bonds break during DNA replication?
13. Outline the role of DNA in the transmission of genes from one generation to the next.
14. Explain the significance of DNA replication.
15. The diagram shows a short section of part of a DNA molecule.

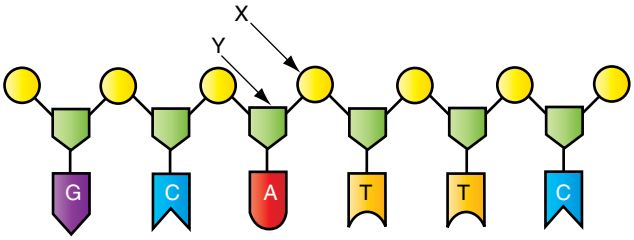


**Figure 4.5** Part of a DNA molecule.

(a) Identify parts X and Y.
(b) Draw the complementary strand of DNA.
(c) Using the given section of DNA, describe the process by which this segment controls the production of proteins and/or polypeptides.

16. Since the 1940s it has been known that genes consist of which chemical?
(A) Ribose nucleic acid.
(B) Deoxyribose nucleic acid.
(C) Dinitroadenine acid.
(D) Adenosine triphosphate.

17. Which of the following identifies the basic components of a nucleotide?
(A) Sugar, phosphate, nitrogenous base.
(B) Adenine, thymine, cytosine, guanine.
(C) Glucose, nitrate, phosphate base.
(D) Sugar, amino acid, nitrogenous base.

18. What is shown by an analysis of the DNA molecule?
(A) The 'rungs' of the 'ladder' are made of phosphate-sugar bonds.
(B) The 'sides' of the 'ladder' are made of phosphate-sugar bonds.
(C) Nucleotides of one strand are identical to the nucleotides of the opposite strand.
(D) DNA with 40% thymine will have 20% guanine.

19. A certain chromosome has 20% guanine in its structure. What would you expect to be the amount of adenine present?
(A) 20% (B) 30% (C) 60% (D) 80%

20. The diagram shows a short section of DNA.

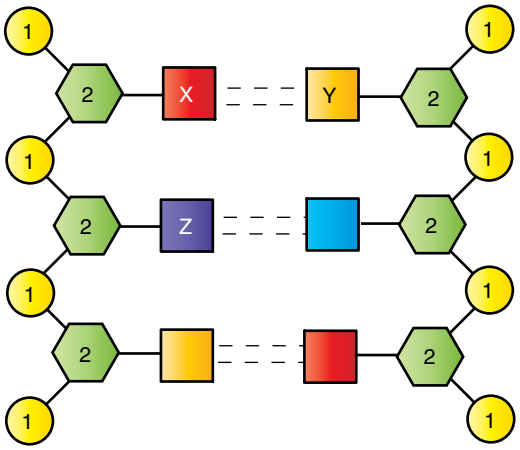


**Figure 4.6** Short section of DNA.

If X represents adenine then what could Z represent?
(A) Thymine (B) Sugar
(C) Phosphate (D) Cytosine

21. The figure below represents a single strand of DNA. What is its complementary strand?

A A C T G G

(A) AACTGC (B) GGTCAA
(C) TTGACC (D) CCAGTT

22. What type of bonds would you expect to find between the nitrogenous bases on the rungs of the DNA ladder?
(A) Hydrogen bonds.
(B) Covalent bonds.
(C) Phosphodiester linkages.
(D) Peptide bonds.

# 5 Activity – Making a Model Of DNA

In eukaryotic cells a chromosome is one extremely long linear DNA molecule. In prokaryotic cells there is a circular DNA molecule.

There are many ways you can construct a model to show the structure of DNA. Models can be made of paper, cardboard, pipe cleaners, plastic sticks, coloured balls or created using multimedia graphics. The model needs to be able to show the triplet code of DNA which is the basic instruction of the genetic code.

(a) (b) (c)

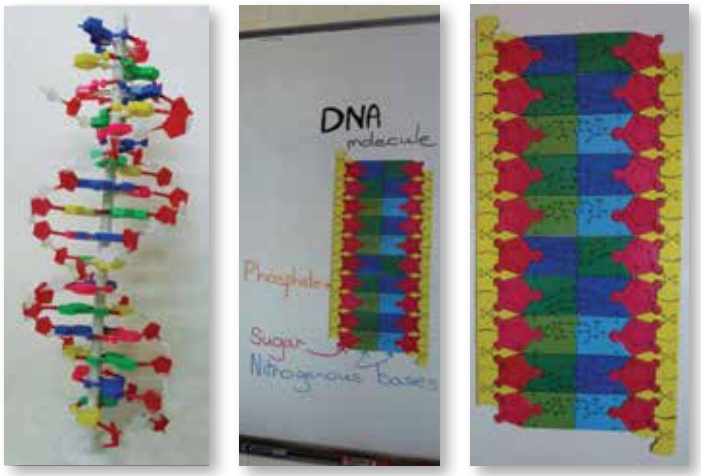


**Figure 5.1** (a) Three-dimensional model of the DNA molecule. (b) Building a two-dimensional model of DNA on a classroom whiteboard using cardboard cut-outs that have magnetic strips which stick to the whiteboard. (c) Two-dimensional jigsaw model of DNA using a purchased DNA kit.

The **triplet code** is three bases next to each other in a molecule of DNA and specifies a particular amino acid. Reading the sequence of nucleotides in the triplet code in DNA means that you are reading the sequence of amino acids which will be joined together to form a polypeptide. There are three codes that are 'stop' signals which stop the process of gene expression and the translation of the code into a polypeptide. The DNA codes ATT, ATC and ACT signal 'stop'. The DNA code TAC is the code for the amino acid methionine but also acts as a 'start' signal for translation. Note that these start and stop codes are usually given as the mRNA code (e.g. stop codes UAA, UAG and UGA) as it is the **mRNA code** that is used in definitions and used to identify different amino acids. The mRNA code is complementary to the DNA code with uracil substituting for thymine. In gene expression the mRNA code is read in the cytoplasm when the code is translated to produce a polypeptide.

In gene expression when the DNA code is translated from the mRNA code into a polypeptide it is important to read the three nucleotide bases of an amino acid in the correct **reading frame**. Any alteration of the code will affect the ability to make a particular polypeptide.

Thus it is important when making a model of DNA to know what the code means when it is translated to produce a polypeptide.

## Three-dimensional models

You can use molecular model kits with sticks and balls and make a model similar to the one built by James Watson and Francis Crick. A model using plastic sticks, coloured spheres and/or pipe cleaners has the benefit that it gives a three-dimensional vision of DNA to show the double helix structure.

Another way of showing this three-dimensional structure is to make an 'edible' DNA, e.g. using different coloured jellybeans to represent the nitrogenous bases, the phosphate and the sugar. The jellybeans can be joined with toothpicks to represent the bonds holding the nucleotides together.

## Two-dimensional models

Many models of DNA use jigsaw cut-outs of coloured paper or cardboard and align the pieces to give a two-dimensional view of the ladder and rung structure of DNA. There are DNA jigsaw kits that can be purchased to use in class or you can create your own jigsaw. The jigsaw pieces can also be used to show the process of DNA replication and protein synthesis.

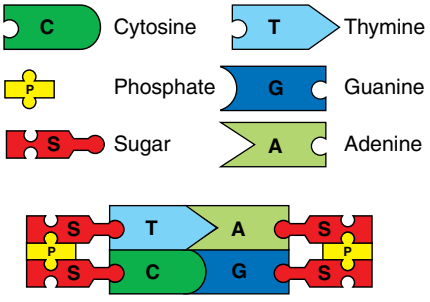


**Figure 5.2** DNA jigsaw.

## Evaluating a model of DNA

When evaluating a model the model must be consistent with known information. For example, one nucleotide of DNA must contain one phosphate, one deoxyribose sugar and one nitrogenous base, e.g. adenine (A), thymine (T), cytosine (C) or guanine (G). The nitrogenous bases must also be in complementary pairs, e.g. A-T and C-G.

# Topic 8 Test

## Section A – Multiple Choice (20 marks)

1. Which of the following is the best definition of evolution?
   (A) The change in the genetic composition of a population over generations.
   (B) Survival of the strongest animal with the most favourable features.
   (C) Change in the appearance of organisms over successive generations.
   (D) The creation of many new species from a common ancestor.
2. It is believed that crocodiles first appeared on Earth in the Cretaceous period. Some species have changed little in millions of years. What is this lack of change most likely due to?
   (A) Their strong exoskeleton which is immune to fire and nuclear radiation.
   (B) Living in a relatively unchanging habitat.
   (C) Their small size making them hard to catch by most predators.
   (D) Lack of competitors for the same food resources.
3. Which of the following is an example of a physical change in the environment that shifted the selective pressures acting on a species in the area?
   (A) The introduction of the myxoma virus affecting the rabbit population
   (B) The use of antibiotics leading to resistant strains of bacteria.
   (C) The use of insecticides led to insecticide-resistant mosquitoes.
   (D) Dark peppered moths became more numerous in polluted forests near industrial cities.
4. Which of the following is able to show evolution by natural selection?
   (A) Genetic changes in a population of organisms.
   (B) Genetic changes in the development of an individual cell.
   (C) Genetic changes of an individual organism in its lifetime.
   (D) Genetic changes in individual organisms of different species.
5. Which of the following illustrates why the common mole and the marsupial mole are an example of parallel evolution?
   (A) Both are vertebrates with notchord and gill slits at some stage of development.
   (B) Both have a pentadactyl limb with a common ancestor.
   (C) Reproductive methods are similar aiding protection of young for burrowing lifestyle.
   (D) After splitting from a common ancestor they separately evolved in a similar manner.
6. After several patients were treated with a new drug, a few returned to the hospital after a week with returning symptoms. Testing of the pathogens in these patients showed the bacteria was resistant to the drug. What can you conclude from these observations?
   (A) Some patients can develop drug resistance.
   (B) The decrease in initial symptoms allowed the pathogens to become resistant to the drug.
   (C) These patients had compromised immune systems.
   (D) At the start of treatment some bacteria were resistant to the drug and natural selection increased their numbers.

# Answers

## Topic 7 DNA, Genes and The Continuity Of Life

### 1 Assumed Knowledge Topic 7

1. Mitosis is a process during cell division in which the cell nucleus divides into two.
2. (a) Meiosis is cell division to produce haploid daughter cells.
   (b) Meiosis produces four daughter cells and in the anther will produce four pollen grains.
3. It is a sperm and it is the male reproductive sex cell (gamete).
4. The genome is the complete genetic information of an organism.
5. A chromosome is a cellular structure that holds genetic information in the coding of the DNA molecule.
6. Genotype is the genetic make-up of an organism, or a set of alleles of an organism.
7. Fertilisation is the union of two gametes.
8. Gametes fuse to form a zygote. It is essential that gametes contain only half the number of chromosomes to maintain the chromosome number of the species. Otherwise the number of chromosomes would double every generation.
13. Part A is the ovary which produces eggs (female gamete) and Part B is the uterus which is where the embryo/foetus will grow and develop until birth.
9. Information is transferred as DNA on chromosomes when cells reproduce themselves.
10. DNA stands for deoxyribose nucleic acid.
11. The basic unit of DNA is the nucleotide.
12. Most DNA is located in the nucleus. DNA is also found in mitochondria and in the chloroplasts of green plants.
13. The structure of the DNA molecule is a double helix.
14. A gene is a certain length of DNA that has the code for one characteristic.
15. DNA needs to be able to replicate itself exactly so that cell division can form identical new cells for growth, repair and maintenance of the body of a multicellular organism. Exact replication is also needed to maintain the genetic code for a species and hence keep its integrity as a distinct unit in nature.
16. Gregor Mendel experimented with pea plants and worked out the basic laws of inheritance. His work led to the study of genetics and hence he is often referred to as the 'father of genetics'.
17. Both genes and environmental factors determine the features of an organism.
18. In plants, e.g. pea plants, the environment can have a great influence on the appearance of an organism. If the plant has the genetic code to be tall, but is grown in poor soil which has few nutrients, then the plant will not reach its full height potential and may appear to be a dwarf plant.
19. In pea plants there are two alleles for plant height – tall (T) and dwarf (t). Given that all other environmental factors are the same, a plant with the genetic code TT or Tt will be tall, while a plant with the code tt will be dwarf.
20. Watson and Crick discovered that DNA had a double helix structure.
21. Autosomes are chromosomes that are not directly involved in determining sex whereas sex chromosomes are responsible for determining the sex of an individual. In humans there are two sex chromosomes X and Y. Males are XY and females are XX.
22. (a) Person A is female as they have XX.
    (b) Trisomy is the presence of 3 copies of a homologous chromosome rather than the normal 2 copies.
    (c) Person A has Trisomy 21 with 3 copies of chromosome 21 – this is Down syndrome.
23. A genome sequence is the order of the As, Ts, Cs and Gs in the DNA code.
24. A gene pool is the total aggregate of genes in a population at any one time.
25. The frequency of an allele in a population refers to the proportion of the population that have that allele.
26. Polyploidy occurs when cells contain more than two haploid (n) sets of chromosomes, e.g. triploid (3n), tetraploid (4n).
27. A mutation is a permanent change in the genetic information. This causes genetic diversity.
28. Comparative genomics studies and compares genomic features of different organisms, e.g. looking for differences and similarities in DNA sequence, genes, gene order and regulatory sequences.
29. Mutagens are environmental factors such as radiation (e.g. X-rays and UV rays) or chemical agents (e.g. benzene) that cause mutations to occur.
30. Ionising radiation includes far ultra-violet light, X-rays and gamma rays.
31. Biotechnology is the use of organisms or their parts to make useful products.
32. A somatic cell is a body cell, e.g. any cell in a multicellular organism except gametes or their precursors while germ line cells are cells that can pass on genetic information to any offspring, e.g. gametes are germ line cells.
33. Introns are non-coding segments of DNA that are removed in RNA processing while exons are coding segments of DNA that are transcribed for protein synthesis.
34. Genetic variation is due to – 1. Fertilisation. 2. Crossing over in meiosis. 3. Random segregation in meiosis. 4. Mutation.

### 2 Prokaryote and Eukaryote DNA

1.

| Feature | Prokaryote | Eukaryote |
|---|---|---|
| Amount of DNA | Considerably less than the amount DNA in eukaryotes. | Considerably more than the amount of DNA in prokaryotes. |
| Location of DNA | Most in nucleoid region in the cytoplasm. | Most inside the nuclear membrane in the nucleus. |
| Structure | Most in a single circular chromosome without histone protein framework. | Most in linear chromosomes with a DNA-protein complex. |
| Plasmids | Many prokaryotes have plasmids with accessory DNA. | Few eukaryotes have plasmids with accessory DNA, e.g. yeast has plasmids. |
| Telomeres | Not present. | Present at the ends of DNA molecules. |
| Gene expression | Translation starts while transcription is still in progress and the synthesised protein quickly diffuses to its site of function. | Transcription is compartmentalised in the nucleus and has additional steps where introns are removed. Translation occurs in the cytoplasm. |

2. A plasmid is a small ring of DNA that consists of a limited number of genes.
3. (a) Telomeres are protective structures with repetitive codes that are found at the ends of eukaryotic chromosomes.
   (b) Telomeres are important in eukaryote cells as eukaryotes have linear DNA molecules and in the process of DNA replication DNA polymerase can only add nucleotides to the 3′ end of an existing chain. This means that each replication involves some erosion of the 5′ end of the daughter DNA strand. Telomeres are a short repeating code that allows erosion of the DNA end to occur without shortening the genes near the end of the DNA molecule.
   (c) Eukaryotes need telomeres as they have linear DNA molecules while prokaryotes have circular DNA which means they do not need telomeres and do not have the problem of erosion of the ends of the molecule with each replication process.
4. Chromatin is a complex of DNA and protein in eukaryote chromosomes.
5. D
6. A