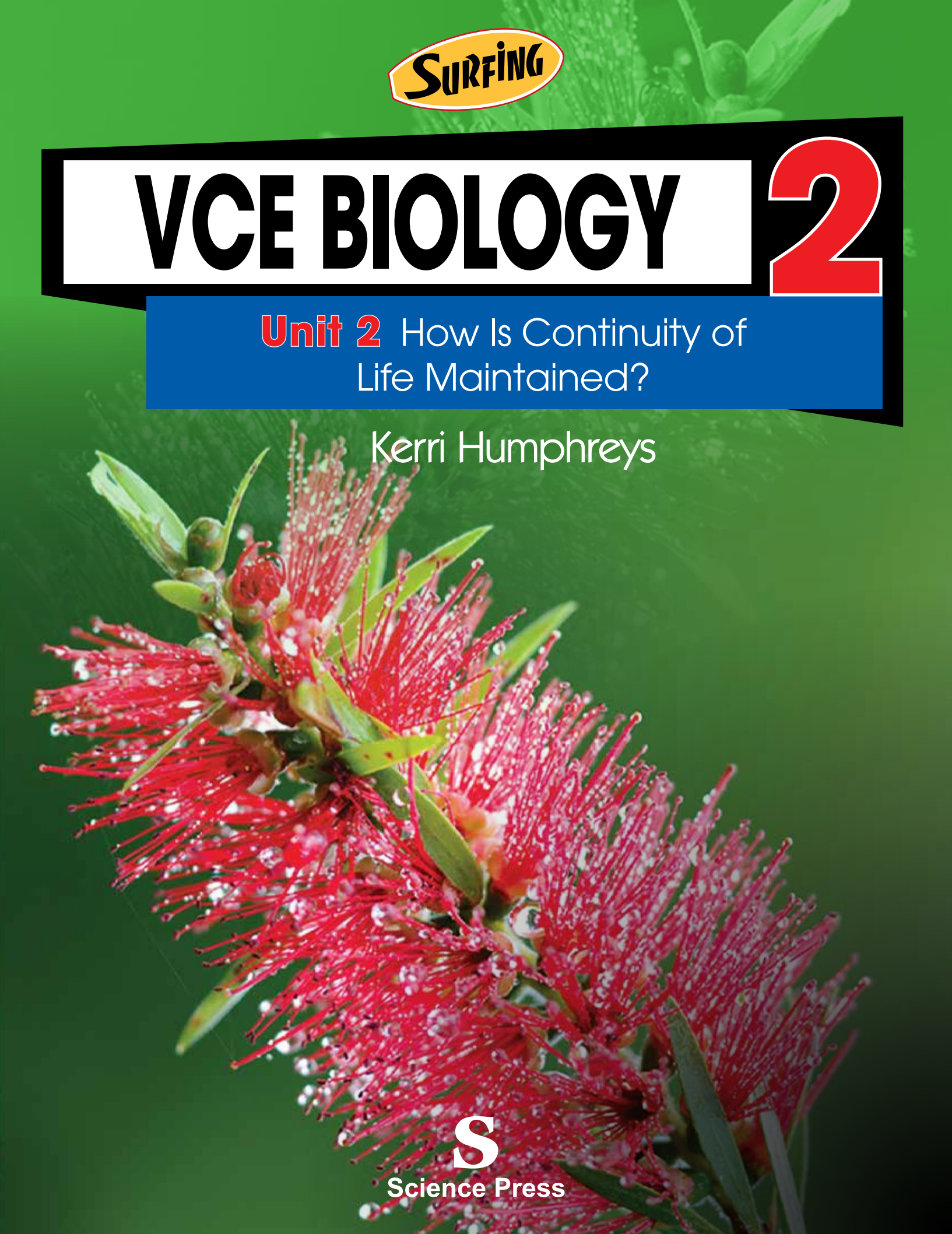
SURFING

VCE BIOLOGY 2

Unit 2 How Is Continuity of Life Maintained?

Kerri Humphreys



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Contents

Introduction

This book covers the Biology content specified in the Victorian Certificate of Education Biology Study Design. 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 the book 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

VCE BIOLOGY 2

Area of Study 1

How Does Reproduction Maintain Continuity of Life?

1 Assumed Knowledge

QUESTIONS

1. Define mitosis.
2. The diagram shows the last division of meiosis in the anther of a flower.

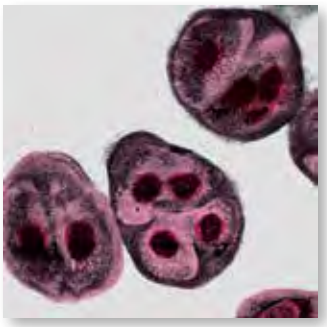

Figure 1.1 Meiosis in an anther.

   (a) What is meiosis?
   (b) What would be produced, according to this diagram?
3. How is information transferred when cells reproduce themselves?
4. What does DNA stand for?

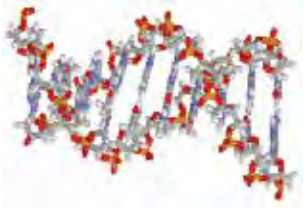

Figure 1.2 DNA.

5. Name the basic unit of DNA.
6. Where is DNA located in cells?
7. Outline the structure of the DNA molecule.
8. What is the relationship between genes and DNA?
9. Explain the advantages of DNA replicating exactly.
10. What is a mutation?
11. Explain the advantages and disadvantages of DNA mutating.
12. What is a pedigree?
13. What is biotechnology? Give an example.
14. Describe some benefits of using biotechnology.
15. Describe some social and ethical issues of using biotechnology.
16. Distinguish between sexual reproduction and asexual reproduction.
17. What is a somatic cell?
18. Define a stem cell.
19. What is a germ layer?
20. Define a mutagen.
21. Why is Gregor Mendel often referred to as the 'father of genetics'?
22. Identify the factors that determine the features of an organism.
23. Use an example to show how environment influences the appearance of an organism.
24. Use an example to show how genes determine the features of an organism.
25. What is the 'Watson-Crick' model of DNA?
26. Define genome.
27. What is a chromosome?
28. What is meant by genotype?
29. Define fertilisation.
30. Why is it important for gametes to have half the number of chromosomes of the species?
31. The diagram shows the structure of a buttercup.

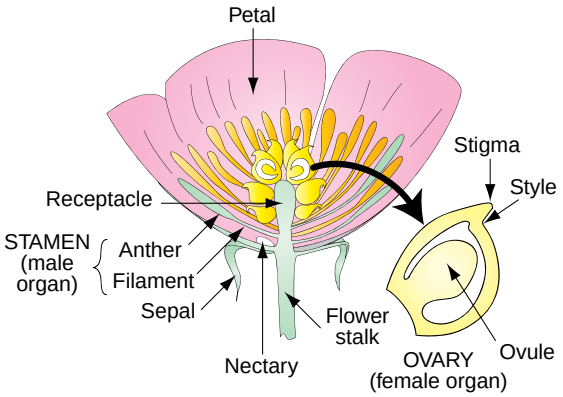

Figure 1.3 Half-flower of buttercup.

   Identify the male part of the flower and the female part of the flower.
32. Gregor Mendel has often been called the 'father of genetics'. The following picture shows Gregor Mendel.

Figure 1.4 Gregor Mendel.

   Describe Mendel's contribution to the study of genetics.
33. What is the Human Genome Project?
34. Define mutation.
35. Identify some causes of mutation.
36. Define hybrid.
37. What is a zygote?
38. What is a clone?

2 The Cell Cycle

The **cell cycle** is a series of events that occur in the life of eukaryotic cells. It consists of mitosis, cytokinesis and the stages of interphase which are G_1 stage (growth stage 1), S stage (synthesis stage) and G_2 stage (growth stage 2). Mitosis is the shortest phase of the cell cycle taking less than 10% of the time and interphase taking 90% of the time of the cycle.

Mitosis is the division of the nucleus in cell division. **Cytokinesis** is the division of the cytoplasm and follows mitosis. In growing cells most of the time is interphase when DNA, other molecules and cell components are synthesised.

The timing of the cell cycle varies for different types of cells and for different times in the life of a particular species.

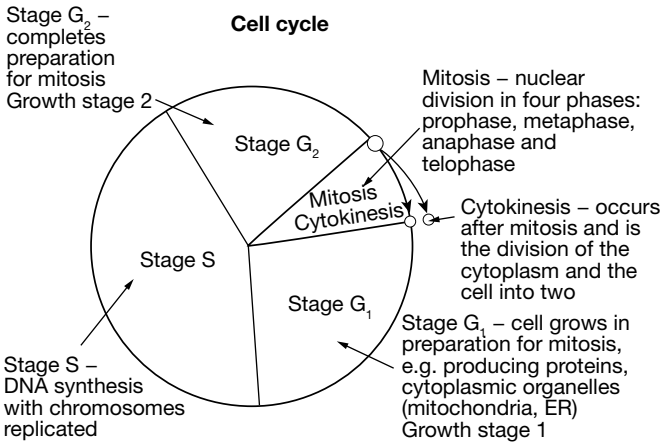

Figure 2.1 The cell cycle.

M phase

The M phase is when mitosis occurs, followed by cytokinesis and the eukaryotic cell divides to form two identical daughter cells.

G_1 phase

The G_1 phase is the 'first gap' when normal cellular activity resumes after the cell division and mitosis. The G_1 phase can be a long phase and is where cells that become differentiated leave the cell cycle and stop dividing. The cells grow by producing proteins and cytoplasmic organelles.

S phase

The S phase is a synthesis phase when DNA is replicated. The amount of DNA in the nucleus doubles in this phase. The chromosomes are not visible with a light microscope during this phase. The chromosomes exist as very long thin threads of **chromatin** which is a three-dimensional network of DNA and associated protein molecules. The associated proteins help keep the structure of the chromosome and help control the activity of the genes.

G_2 phase

The G_2 phase is the 'second gap' when there is synthesis of other cellular molecules in preparation for cell division. The G_2 phase usually involves rapid cell growth.

Cell cycle checkpoints

A checkpoint is a control point in the cell cycle where stop and go-ahead signals regulate the cycle. Three checkpoints are the G_1 checkpoint, G_2 checkpoint and the metaphase checkpoint.

The **G_1 checkpoint** is the restriction point and if it receives the go-ahead the cell will usually complete the cell cycle and divide. In mammalian cells the G_1 checkpoint determines if the rest of the cycle occurs or if the cell goes into a non-dividing state called the **G_0 phase**. The G_0 phase is a resting state and can be the state when some types of cells reach their mature form, e.g. nerve and heart muscle cells move to the G_0 phase when differentiation is complete. Some cells stay at the G_0 phase for some time and will begin to divide if needed, e.g. parenchymal cells in the liver and kidney. While other cells rarely go into the G_0 phase, e.g. epithelial cells.

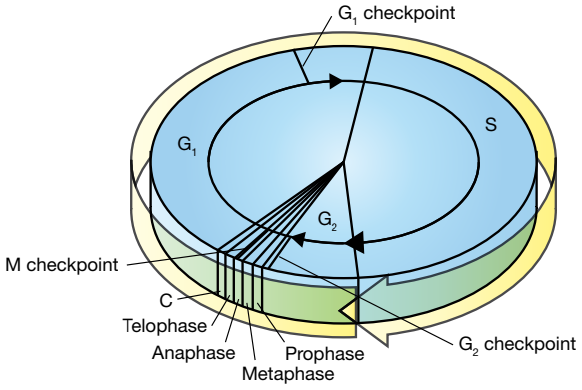

Figure 2.2 Checkpoints in the cell cycle.

The **G_2 checkpoint** triggers mitosis and makes sure chromosomes have been replicated and DNA is not damaged before mitosis. If DNA damage is detected at the G_2 phase checkpoint the cell cycle will halt until the damage is repaired.

The **M checkpoint** is the metaphase checkpoint in mitosis and is the DNA damage point to check if sister chromatids are correctly attached before anaphase. The mitotic spindle needs to be aligned correctly at this checkpoint for the rest of mitosis to occur.

Checkpoint proteins

At certain times of the cell cycle there are checkpoint proteins that keep the steps of the cycle in order and keep the cycle operating normally, e.g. the S phase promoting factor (spf) and the mitosis promoting factor (mpf). These regulatory proteins are mainly **kinases** and **cyclins** and are part of the **cell cycle control system**.

Disruption of the cell cycle

The cell cycle can be disrupted due to genetic predisposition or the action of mutagens that gives rise to uncontrolled cell division including cancer and abnormal embryonic development.

Genetic predisposition means that the genome of the person contains specific genetic variations, often inherited from a parent that gives the person an increased likelihood of developing a particular disease or disorder.

A **mutagen** is a chemical or physical agent that causes a mutation changing DNA and the genetic information.

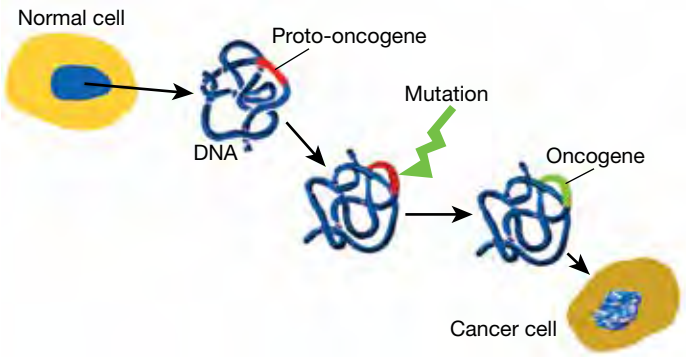

Figure 2.3 Proto-oncogenes and oncogenes.

Proto-oncogenes are a group of normal cellular genes that have the potential to become oncogenes. Proto-oncogenes code for proteins that stimulate cell growth and division, inhibit cell differentiation and cause cell death. An **oncogene** is a gene that is part of the normal genome or a gene found in viruses that triggers cancerous characteristics. Mutations can cause a proto-oncogene to become an oncogene. This means the oncogene will cause increased cell division, decreased cell differentiation and will inhibit cell death. The uncontrolled cell division will form a mass of cells called a **tumour** (neoplasm). Tumours can occur in any organ or tissue. A benign tumour is a mass of cells that will stay at the original site and have a slower growth rate than a malignant tumour. The cells of a malignant tumour detach and spread to other organs and tissues.

QUESTIONS

1. (a) What is the cell cycle?
   (b) What events make up the cell cycle?
   (c) What is the shortest phase of the cell cycle?
2. What proportion of the cell cycle is usually interphase?
3. What is mitosis?
4. What is cytokinesis?
5. Construct a table to summarise what happens during each of the phases of interphase.
6. What is a checkpoint?
7. What is the function of the G_1 checkpoint?
8. What is the function of the G_2 checkpoint?
9. What is the function of the M checkpoint?
10. If cells are given radioactively-labelled thymine the processes of the cell cycle can be investigated. Thymine is part of DNA but not part of RNA. Explain why the radioactive thymine is able to show the timing of the different phases of the cell cycle.
11. What is involved in the cell cycle control system?
12. Identify the regulatory proteins involved in the cell cycle control system.
13. What is the G_0 phase and when does it occur?
14. What is chromatin?
15. In active mammalian tissue the cell cycle can take 12 to 20 hours. The diagram shows the cell cycle for an active skin cell.

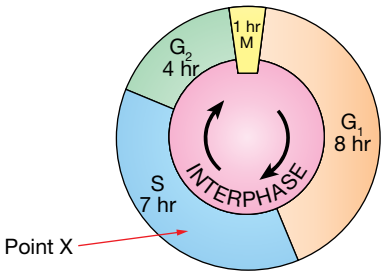

Figure 2.4 The cell cycle in an active mammalian tissue.

   (a) How long is the cell cycle for this cell?
   (b) What is the longest phase of this cycle?
   (c) What would be happening in the cell at point X of the cell cycle?
16. What can disrupt the regulation of the cell cycle?
17. What is meant by genetic predisposition?
18. What is a mutagen?
19. Define proto-oncogene.
20. Outline the function of most proto-oncogenes.
21. Define an oncogene.
22. What can cause a proto-oncogene to become an oncogene?
23. Outline what happens when a proto-oncogene becomes an oncogene.
24. What is a tumour?
25. Differentiate between a benign tumour and a malignant tumour.
26. Which of the following occurs when a proto-oncogene is mutated to become an oncogene?
   (A) Cells become specialised.
   (B) Uncontrolled cell division.
   (C) Increased cell death.
   (D) Increased cell differentiation.
27. Which of the following is least likely to disrupt the cell cycle?
   (A) Ionising radiation.
   (B) Genetic predisposition.
   (C) Chemical mutagens.
   (D) Cells entering G_2 phase.

3 Binary Fission

Prokaryotes do not have membrane-bound organelles, e.g. nucleus and include the bacteria and archaea. **Eukaryotes** have membrane-bound organelles, e.g. nucleus and mitochondria and include plants, animals and fungi. Unicellular organisms use binary fission as a means of reproduction, e.g. the prokaryotes and the unicellular eukaryotes, e.g. Protista such as the protozoans.

In most bacteria the genetic information is on a single bacterial chromosome that is a circular DNA molecule with associated proteins. The prokaryotic chromosome is in the **nucleoid region** of the bacterial cell. Most bacteria also have **plasmids** which are small rings of DNA that only contain a few genes. Plasmids give the bacteria additional capabilities, e.g. the plasmids of some bacteria give them resistance to antibiotics.

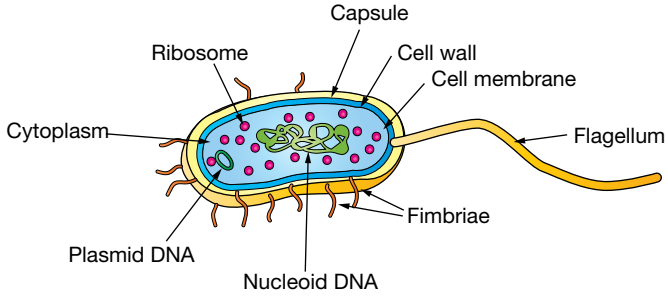

Figure 3.1 Typical bacterial cell.

Replication process in prokaryotes

Prokaryotes reproduce by binary fission when one cell splits into two. In bacteria the replication process starts at the **origin of replication** which is a specific part of the bacterial chromosome. This section is replicated and one copy of the origin moves to the other end of the cell. The nuclear material replicates and the cell elongates.

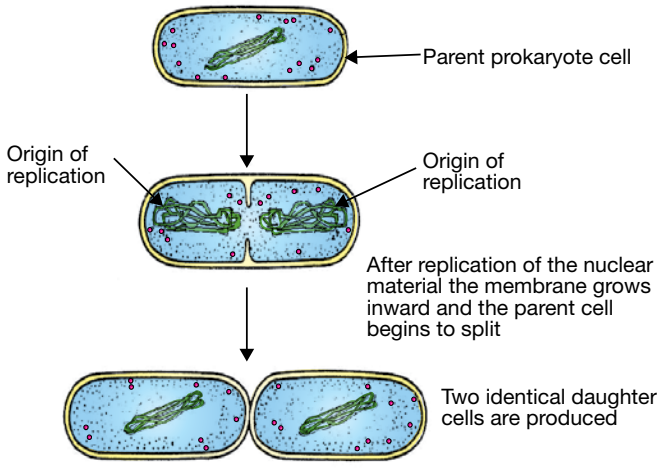

Figure 3.2 Typical bacterial cell.

When replication of the nuclear material has finished the cell membrane grows inward to split the long cell into two identical daughter cells.

The plasmids replicate independently of the main chromosome.

Binary fission in eukaryotes

In eukaryotes such as the protozoans which have a heterotrophic nutrition. The organism will have a period of growth, increasing in size until the cell undergoes nuclear division and fission splits the cell into two. Amoebas rely on binary fission for reproduction.

Evolutionary significance

Binary fission is a form of asexual reproduction as one parent gives rise to two or more individuals. Binary fission is energy efficient as the bacteria do not have to use energy or time to find a mate and they can quickly produce many numbers at an exponential rate if conditions are favourable. Since the prokaryotes preceded the eukaryotes the process of binary fission gave rise to mitosis in evolutionary history.

As binary fission produces identical offspring with no mixing of genetic information variation, in offspring relies on the process of mutation. Survival ability can be threatened if there is a small gene pool and the environment rapidly changes.

Conjugation

Conjugation is a process in prokaryotes when there is direct transfer of DNA between two cells that are temporarily joined. The fimbria form a bridge between the two cells to allow the exchange of genetic material. In some bacteria, e.g. ciliates conjugation is a sexual process with the two cells exchanging haploid micronuclei.

QUESTIONS

1. What are prokaryotes?
2. What are eukaryotes?
3. Which organisms reproduce by binary fission?
4. Where is the genetic material in prokaryotes?
5. Outline the process of binary fission in prokaryotes.
6. What is the believed origin of mitosis?
7. In organisms that rely on binary fission, how does variation occur?
8. Why are plasmids an important feature for some bacteria?
9. Which of the following organisms would *not* rely on binary fission for reproduction?
   (A) *Amoeba* (B) *Paramecium*
   (C) *Escherichia* (D) *Hydra*

4 Rates of Binary Fission

There can be a rapid procession of prokaryotic cells through their cell cycle by binary fission. Some species under favourable conditions can produce a new generation within 15 to 20 minutes, while other species can take much longer to produce a new generation, e.g. 24 hours. The spirochete bacteria *Treponema pallidum* when grown in ideal conditions reproduces in 33 hours.

Since one prokaryote divides into two, the growth rate is exponential, i.e. 2 cells become 4, then 8, 16, 32 etc.

However, in cultures and real situations a colony does not always grow at an exponential rate. When first exposed to new conditions there is often an inoculation period or lag time when the cells are adapting to the new conditions. The cells may be growing in size, increasing metabolic activity and/or synthesising new components, e.g. proteins, RNA. The cells will then reproduce by binary fission with an exponential growth rate. There is then a stationary stage as the cells use up their food supply, the release of metabolic wastes introduces toxins and poisons, the prokaryote has to compete with other micro-organisms for resources or they are consumed by other organisms. The graph shows the growth of the bacteria *Escherichia coli* in culture with explanations of why the number of cells in the culture changes over time. *E. coli* is a Gram-negative, facultative anaerobic, rod shaped bacterium found in the lower intestine of many endotherms. It is often used in laboratory experiments and is used as an indication of sewage pollution in water resources. Under favourable conditions it can reproduce in 20 minutes.

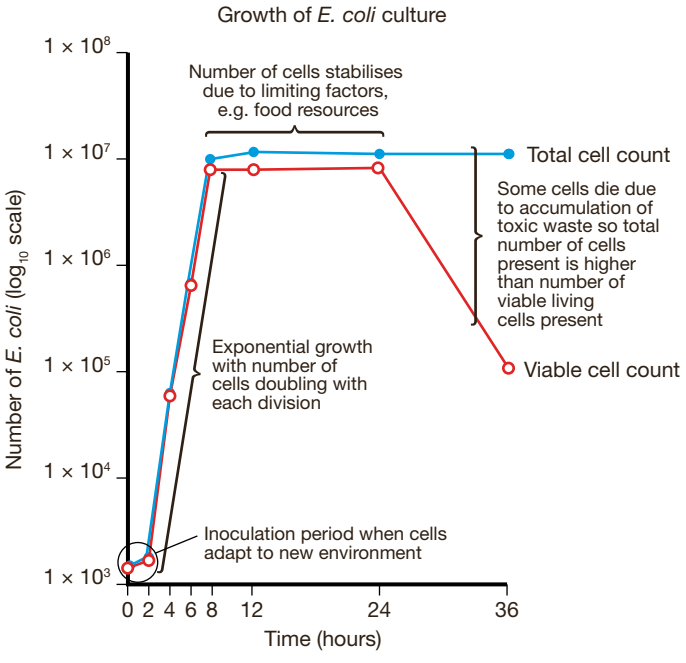

Figure 4.1 Growth rate of *E. coli* in culture.

Genetic diversity

Reproduction by binary fission means that offspring cells are genetically identical to the parent cell. However, the fast procession through the cell cycle by the prokaryotes means that errors in DNA replication, e.g. by spontaneous mutations such as point substitutions, deletions, insertions occur and can lead to increased genetic diversity of the prokaryote within a short time. In a study at Michigan State University 20 000 generations were followed over 3000 days. The results showed that the bacteria populations accumulated beneficial mutations and rapidly evolved when confronted by environmental selective pressures.

Formation of endospores

Many prokaryotes form endospores when conditions become less favourable, e.g. their environment lacks particular essential nutrients. In this process a copy is made of the original chromosome and it is surrounded by a tough, multilayered structure that forms the endospore. Water is removed from the endospore stopping its metabolism. The original cell then lyses and the endospore is released to survive the harsh conditions, e.g. many endospores can survive exposure to boiling water. The endospore stays dormant until the return of favourable conditions, e.g. suitable temperature and water availability.

QUESTIONS

1. How quickly can prokaryotes reproduce?
2. What is exponential growth?
3. Describe *Escherichia coli*.
4. Explain why *E. coli* is often used in laboratory experiments.
5. The probability of a spontaneous mutation occurring in a given *E. coli* gene averages around one in 10 million (1×10^7) per cell division.
   (a) If *E. coli* in a human intestine produce 2×10^{10} new cells each day, how many bacteria in the intestine will have a mutation in that gene?
   (b) If there are 4300 genes on the *E. coli* chromosome, how many mutations occur per human host per day?
   (c) Explain why populations of *E. coli* can rapidly evolve when confronted by new environmental selective pressures.
6. What is an endospore?
7. What is the evolutionary significance of endospores?
8. If the Gram-positive bacteria *Staphylococcus aureus* has a generation time of 30 minutes, how long would it take for one bacterium to divide by binary fission to become a colony of over one million cells?
   (A) 10 hours (C) 10 days
   (B) 20 hours (D) 20 days

5 Mitosis and Cytokinesis

Mitosis is a process during cell division in which the cell nucleus divides into two. Mitosis is needed to create new cells for growth, repair and reproduction. Since all organisms begin life as one cell, a fertilised egg, mitosis is essential to become a multicellular organism.

Mitosis increases the number of cells. Even when the organism has ceased 'growing', mitosis is still needed. Older cells need replacement as they are damaged or worn out and some parts, even in adults, are continually growing, e.g. hair and fingernails in humans and root tips and shoot tips in plants.

Genetic information is transferred to new cells as DNA and DNA is present in nuclei, mitochondria and chloroplasts. Each new daughter cell is identical to the parent cell and has a full set of chromosomes.

Interphase

Interphase is often called the 'resting' stage but it is actually a time of high activity between cell divisions, when the DNA is replicating and when other organic molecules and cell components are being synthesised. The nucleus appears as a dark-staining material called chromatin and the nucleolus is visible. Chromosomes are *not* visible. The cell cycle consists of mitosis and interphase.

The stages of mitosis

Mitosis is a continuous process that can take from fifteen minutes to several hours to complete. In mitosis a cell splits into two with each new daughter cell having the same genetic information as the parent. For convenience, mitosis has been divided into stages: prophase, metaphase, anaphase and telophase.

Prophase. The chromosomes become visible as long, thin threads which shorten and thicken. The nucleolus and then the nuclear membrane disappear. The chromosomes appear as two chromatids joined together by a centromere. In animal cells the centriole divides into two and each moves to opposite ends of the cell. Plant cells do not have centrioles.

Metaphase. The chromatids line up along the central plane of the cell and the spindle forms. Each pair of chromatids are attached to the spindle at the centromere. At this time the chromosomes have maximum shortening and thickening with individual chromatids and the centromere clearly visible.

Anaphase. Is the shortest stage in mitosis. The centromere divides and the pair of chromatids separate as each one is pulled to opposite ends of the cell by the spindle fibres as the fibres shorten.

Telophase. The spindle disappears, the sets of chromosomes at the poles condense, the nucleoli reform, and a nucleus forms around each group. At this time cytokinesis occurs and the cells split into two distinct groups. Two new cells are formed.

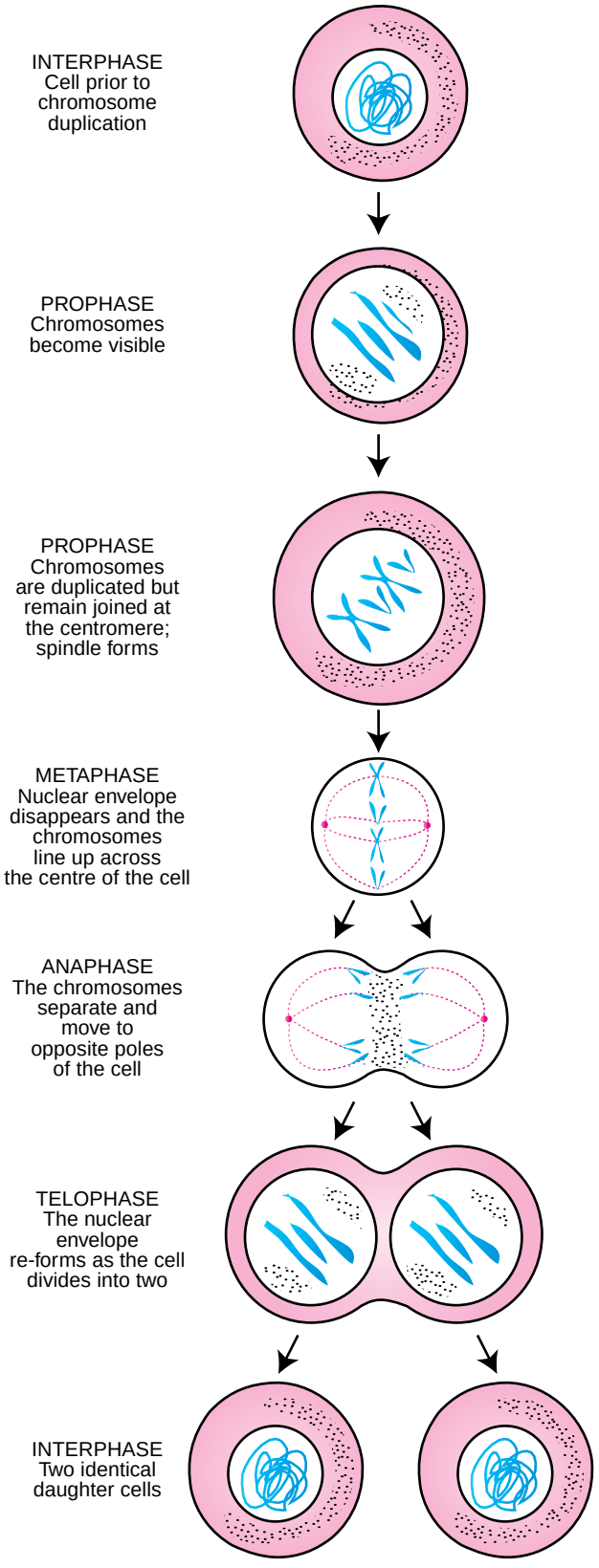

Figure 5.1 Stages of mitosis.

Cytokinesis in plant and animal cells

Cytokinesis is the division of the cell's cytoplasm following the division of the nucleus. Cytokinesis is important because it stabilises the internal concentration of materials in the two new cells.

The cell organelles are evenly divided and distributed between the two daughter cells. Each new cell needs sufficient organelles such as mitochondria, ribosomes and endoplasmic reticulum so that it can grow and carry out the processes of living.

In **animal cells** a cleavage furrow begins at the centre of the cell. The cell membrane constricts with the help of a contractile ring of microtubules and microfilaments which appear near the cell surface and contract. Cleavage continues as the cell membrane continues to be pinched in until they are separated into two segments. Plants cannot do this as they have rigid cell walls.

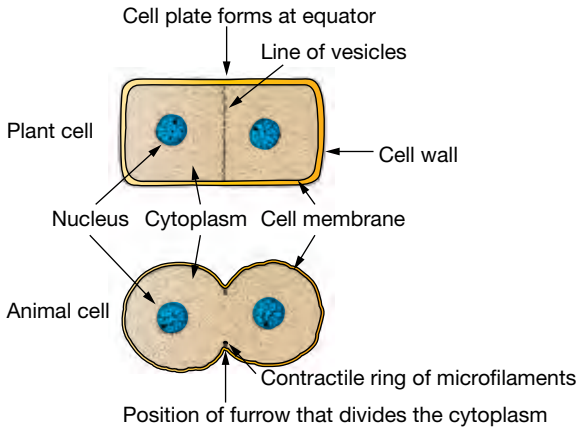

Figure 5.2 Cytokinesis.

In **plant cells**, a cell plate forms during telophase across the mid-line of the parent cell. The cell plates forms by the coalescence of tiny vesicles. These vesicles were made by Golgi bodies and contain the components of the cell wall and the cell membrane. The vesicles fuse and the plate grows outward from the centre of the cell, forming two membranes that become the two new cell membranes. The new cell walls form between these membranes.

QUESTIONS

1. (a) Define mitosis.
   (b) Explain why mitosis is vital for multicellular organisms.
2. (a) Define cytokinesis.
   (b) Explain why cytokinesis is important.
3. Outline the role of mitosis.
4. Which organelles contain DNA?
5. During the 'resting' phase of the cell cycle, is the cell really 'resting'?
6. Describe how cytokinesis is different in plants and animals.
7. How are the cell organelles divided between the two new daughter cells?
8. Describe the appearance of a cell at the beginning of mitosis.
9. Briefly outline the process of mitosis.
10. Describe spindle fibres and their function.
11. When will cells divide?
    (A) The surface area to volume ratio becomes too large.
    (B) Nutrients cannot efficiently reach all parts of the cell by diffusion.
    (C) Membrane surface area is too large to efficiently support cellular metabolism.
    (D) Wastes leave the cell too quickly.
12. A scientist was observing a cell undergoing mitosis. Which event would show it was a plant cell rather than an animal cell?
    (A) Formation of cell plate.
    (B) Cleavage of the cytoplasm.
    (C) Spindle fibres attach to centrioles.
    (D) Formation of chromatids.
13. A cell with 14 chromosomes undergoes mitosis. How many chromosomes will be in each daughter cell?
    (A) 7 (B) 14 (C) 21 (D) 28
14. The diagram shows mitosis and interphase.

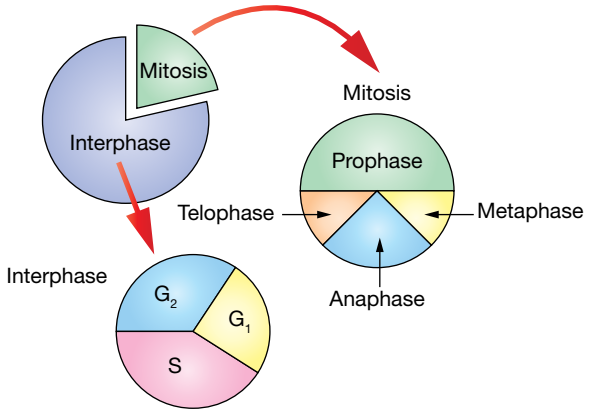

Figure 5.3 Interphase and mitosis.

From this diagram what is the longest phase of mitosis?
    (A) S phase.
    (B) Interphase.
    (C) Prophase.
    (D) Anaphase.
15. Which organelle produces the vesicles that contain the components of the cell wall and cell membrane for cytokinesis in plant cells?
    (A) Mitochondria.
    (B) Chloroplasts.
    (C) Nucleus.
    (D) Golgi bodies.

Answers

1 Assumed Knowledge

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. Information is transferred as DNA on chromosomes when cells reproduce themselves.
4. DNA stands for deoxyribose nucleic acid.
5. The basic unit of DNA is the nucleotide.
6. Most DNA is located in the nucleus. DNA is also found in mitochondria and in the chloroplasts of green plants.
7. The structure of the DNA molecule is a double helix.
8. A gene is a certain length of DNA that has the code for one characteristic.
9. 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.
10. A mutation is a change in the chemical structure of the DNA.
11. An advantage of DNA mutating is that it can lead to different phenotypes, individuals with different forms of characteristics which can be beneficial in a changing environment for natural selection and the survival of the species. A disadvantage is that mutations are often harmful and reduce the normal lifespan of the individual, e.g. mutation causing cancer.
12. A pedigree is a graphical way of picturing the ancestry of living things. It shows genetic history.
13. Biotechnology is the use of biological processes by industry or agriculture to change organisms in order to produce useful products or provide services, e.g. to brew beer and breed cattle with specific characteristics.
14. Biotechnology has helped humans develop new food sources, e.g. baking bread, making cheese, brewing beer, breeding certain strains of cereal crops to get a higher yield. This has increased food supply and hence allowed population growth.
15. Social issues arising from the use of biotechnology can involve human safety and confidentiality. For example, the production of genetically modified food is a recent development in biotechnology. Some people call them 'frankenfoods' and are worried about the effect on human health if there is long-term consumption of these foods. Biotechnology has also developed new diagnostic tests using genetic engineering. A social issue arising from these diagnostic tests involves confidentiality of the results and whether insurance companies have the right to personal genetic information about an individual. Ethical issues involving biotechnology have arisen with the recent experiments with animal cloning and whether the creation of human clones should be allowed. Another ethical issue is animal welfare. Animals are involved in many ways in genetic research and although there are guidelines (minimum number of animals to be used, the experiments are to be carried out humanely) some activists would like to ban all animal experimentation.
16. Asexual reproduction involves only one parent and the offspring have the exact same set of chromosomes as the parent, whereas sexual reproduction involves two parents and the offspring have chromosome sets different from those of either parent.
17. A somatic cell is a body cell.
18. A stem cell is a relatively unspecialised cell that can divide by cell division to produce identical daughter cells and to differentiate to form different specialised cells.
19. A germ layer is a group of cells in an embryo that will give rise to tissues and organs of the body.
20. A mutagen is a chemical or physical agent that causes a mutation changing DNA and the genetic information.
21. 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'.
22. Both genes and environmental factors determine the features of an organism.
23. Many different examples can be used to show how the environment influences the appearance of an organism. 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.
24. 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.
25. Watson and Crick discovered that DNA had a double helix structure.
26. The genome is the complete genetic information of an organism.
27. A chromosome is a cellular structure that holds genetic information in the coding of the DNA molecule.
28. Genotype is the genetic make-up of an organism, or a set of alleles of an organism.
29. Fertilisation is the union of two gametes.
30. 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.
31. The male part of the flower is the stamen and it consists of the anther and the filament. The female part of the flower is the carpel and it consists of the ovary, with ovules, the style and the stigma.
32. Gregor Johann Mendel studied the inheritance of different characteristics in pea plants in 1856. He started with many strains and bred them for several years to find easily recognisable traits that bred true. Mendel crossed purebreeding round seeds with purebreeding wrinkled seeds and found that the first generation (F_1) were all round seeds. When he crossed two of the offspring he found that the ratio was 3 round to 1 wrinkled in the second generation (F_2). Mendel concluded that there were two factors for a character and one (e.g. round seed shape) was dominant over the other (e.g. wrinkled seed shape).
33. The Human Genome Project was a program which wanted to map all the genes in the human genome.
34. A mutation is a permanent change in the genetic information.
35. There are several causes of mutation, e.g. mistakes in DNA replication, DNA damage by chemical mutagens, radiation and incorrect repair and maintenance of cells.
36. A hybrid is heterozygous for a characteristic and can be produced by crossing two different purebreeding organisms.
37. A zygote is a fertilised egg.
38. A clone is an organism that has the identical genetic make-up to the parent cell.

2 The Cell Cycle

1. (a) The cell cycle is a series of events that occur in the life of eukaryotic cells.
   (b) The cycle consists of mitosis, cytokinesis and the stages of interphase which are G_1 stage (growth stage 1), S stage (synthesis stage) and G_2 stage (growth stage 2).
   (c) Mitosis is the shortest phase of the cell cycle.
2. Interphase usually lasts for around 90% of the cell cycle.
3. Mitosis is a process during cell division in which the cell nucleus divides into two.
4. Cytokinesis is the division of the cell's cytoplasm following the division of the nucleus.
5.

Phase	What happens
G_1 phase	Normal cellular activity resumes after mitosis and cell division. In this phase cells grow in size by producing proteins and cytoplasmic organelles.
S phase	Is the synthesis phase when DNA is replicated and the amount of DNA in the nucleus doubles. Chromosomes are not visible and the DNA with its associated proteins exists as chromatin.
G_2 phase	Cell grows in size as molecules are produced in preparation for mitosis.

6. A checkpoint is a control point in the cell cycle where stop and go-ahead signals regulate the cycle.
7. The G_1 checkpoint is the restriction point and if it receives the go-ahead the cell will usually complete the cell cycle and divide.
8. The G_2 checkpoint triggers mitosis and makes sure chromosomes have been replicated and DNA is not damaged before mitosis.
9. The M checkpoint is the metaphase checkpoint in mitosis and is the DNA damage point to check if sister chromatids are correctly attached before anaphase. The mitotic spindle needs to be aligned correctly at this checkpoint for the rest of mitosis to occur.
10. Since thymine is in DNA and not RNA, radioactive thymine can be used to track the formation of new DNA. Samples taken over time will show how much radioactive thymine is incorporated into the new DNA that is being synthesised and then during mitosis the thymine can be tracked into the two new daughter cells. G_1 and G_2 will be gap stages as RNA is the messenger that takes the genetic code from the nucleus to the cytoplasm for protein synthesis and RNA does not contain thymine.
11. The cell cycle control system has checkpoint proteins that keep the cycle in order and operating normally.
12. The regulatory proteins involved in the cell cycle control system are kinases and cyclins.
13. The G_0 phase is a non-dividing state that a cell enters when the G_1 restriction point does not give the go-ahead for the rest of the cycle to continue.
14. Chromatin is a three-dimensional network of DNA and associated proteins that makes up a eukaryotic chromosome. In a non-dividing cell the chromatin exists as very long thin fibres that are not visible with the light microscope.
15. (a) This cell cycle is 20 hours long.
    (b) Interphase is the longest phase and during interphase the G_1 phase is the longest section (8 hours).
    (c) At point X in the cycle is the replication of DNA in the nucleus.
16. The cell cycle can be disrupted due to genetic predisposition or the action of mutagens.
17. Genetic predisposition means that the genome of the person contains specific genetic variations, often inherited from a parent that gives the person an increased likelihood of developing a particular disease or disorder.
18. A mutagen is a chemical or physical agent that causes a mutation changing DNA and the genetic information.
19. Proto-oncogenes are a group of normal cellular genes that have the potential to become oncogenes.
20. Proto-oncogenes code for proteins that stimulate cell growth and division, inhibit cell differentiation and stop cell death.
21. An oncogene is a gene that is part of the normal genome or a gene found in viruses that triggers cancerous characteristics.
22. Mutations can cause a proto-oncogene to become an oncogene.
23. When a proto-oncogene is mutated to become an oncogene there will be increased cell division, decreased cell differentiation and inhibited cell death. This means a mass of cells will be produced in a tissue or organ forming a tumour.
24. The uncontrolled cell division will form a mass of cells called a tumour (neoplasm).
25. A benign tumour is a mass of cells that will stay at the original site and have a slower growth rate than a malignant tumour. Whereas the cells of a malignant tumour detach and spread to other organs and tissues and have a faster growth rate with less differentiation than the cells in a benign tumour.
26. B
27. D

3 Binary Fission

1. Prokaryotes do not have membrane-bound organelles, e.g. nucleus and include the bacteria and archaea.
2. Eukaryotes have membrane bound organelles, e.g. nucleus and mitochondria and include plants, animals and fungi.
3. Prokaryotes, e.g. bacteria and eukaryotes, e.g. protozoans.
4. The genetic material in prokaryotes is in a circular DNA bacterial chromosome which is found in the nucleoid region of the bacterial cell. Bacteria also have plasmids which are small rings of DNA with a limited number of genes.
5. In bacteria binary fission starts with the replication process. The origin of replication is a specific part of the bacterial chromosome which replicates and one copy of the origin moves to the other end of the cell. The nuclear material replicates and the cell elongates. When replication of the nuclear material has finished the cell membrane grows inward to split the long cell into two identical daughter cells.
6. It is believed that mitosis evolved in some way from binary fission.
7. Variation arises by mutation. In organisms that rely on binary fission for reproduction, mutation is the main source of variation. Some unicells have other ways to introduce genetic variety, e.g. conjugation in bacteria.
8. Plasmids are a small ring of DNA that can give the bacteria additional capabilities, e.g. the plasmids of some bacteria give them resistance to antibiotics.
9. D

4 Rates of Binary Fission

1. Under favourable conditions some prokaryote species can reproduce within 15 to 20 minutes while other species or if there are unfavourable conditions a new generation is produced in a longer time frame, e.g. 24 hours.
2. Exponential growth is a J-shaped curve when the original number is increased by a consistent rate over a period of time.
3. *E. coli* is a Gram-negative, facultative anaerobic, rod shaped bacterium found in the lower intestine of many endotherms.
4. *E. coli* is often used in laboratory experiments as under favourable ideal conditions it can reproduce in 20 minutes producing many generations within a short time. This allows the investigation of many aspects of reproduction and evolutionary adaptations.
5. (a) If there are 2×10^{10} new cells each day and there is 1×10^7 mutation rate per gene then the number of bacteria with a mutation of that gene = $(2 \times 10^{10}) \times (1 \times 10^7) = 2000$ bacteria with a mutation in that gene.
    (b) If there are 4300 genes on the *E. coli* chromosome and each gene is mutated 2000 times, then the total number of mutations per human host is $4300 \times 2000 = 9$ million mutations per human host per day.
    (c) The rapid reproduction rate of *E. coli* by binary fission means that new generations are quickly produced, e.g. the population growth rate can be at an exponential rate for an extended time period. Even though the mutation rate for an *E. coli* gene is 1×10^7 per cell division the massive number of cells within the bacteria population and the fast reproduction rate means that there could be 9 million mutations per human host per day. This provides the genetic diversity for the bacteria to be able to survive new environmental selective pressures and rapidly evolve.
6. An endospore is a resistant cell with a thick coat produced by some bacterial cells to survive harsh environments.
7. The formation of endospores is vitally important for the survival of some species of bacteria. Endospores are formed when conditions become unfavourable and thus the bacteria can stay in a dormant state until favourable conditions return. This can be many years or even decades.
8. A

5 Mitosis and Cytokinesis

1. (a) Mitosis is a process during cell division in which the cell nucleus divides into two.
    (b) Since all organisms begin life as one cell, a fertilised egg mitosis is essential to become a multicellular organism. Genetic information is transferred to new cells as DNA and mitosis increases the number of cells. Even when the organism has ceased 'growing', mitosis is still needed. Older cells need replacement as they are damaged or worn out and some parts, even in adults, are continually growing, e.g. hair and fingernails in humans, and root tips and shoot tips in plants.
2. (a) Cytokinesis is the division of the cell's cytoplasm following the division of the nucleus.
    (b) Cytokinesis is important because it stabilises the internal concentration of materials in the two new cells, making sure each new cell has sufficient organelles for growth and carrying out the processes of living.