Cell biology 1

Chapter outline

In this chapter you will:

- describe how the evolution of multicellular organisms allowed cell specialisation and cell replacement
- compare the complex cell structure of eukaryotes to that of prokaryotes
- outline how the structure of biological membranes makes them fluid and dynamic
- outline how membranes control the composition of cells by active and passive transport
- outline the unbroken chain of life from the first cells on Earth to all cells in organisms alive today
- describe how cell division is essential and controlled.

KEY TERMS AND DEFINITIONS

Cell cycle – the sequence of events that takes place from one cell division until the next; made up of interphase, mitosis and cytokinesis.

Endosymbiosis – theory that proposes that mitochondria and chloroplasts evolved from bacteria.

Eukaryotic – organism whose cell contains a membrane-bound nucleus.

Fluid mosaic model – the accepted model of the structure of a membrane that includes a phospholipid bilayer in which proteins are embedded or attached to the surface.

Prokaryotic – organism whose genetic material is not contained in a nucleus.

Exercise 1.1 – Trends in smoking

1 Use the information in Figure 1.1 to answer the following questions:

a State the percentage prevalence of smokers aged 20–24 in 1974.

b State the percentage prevalence of smokers aged 20–24 in 2012.

c Use the previous answers to calculate the percentage decrease of smoking prevalence in males aged 20–24 between 1974 and 2012.

d Outline the general trend that you observe in Figure 1.1 for the prevalence of smoking in males aged 20–24.

e What would be the difference in your answer to part d if the command term was 'describe' instead of 'outline'?

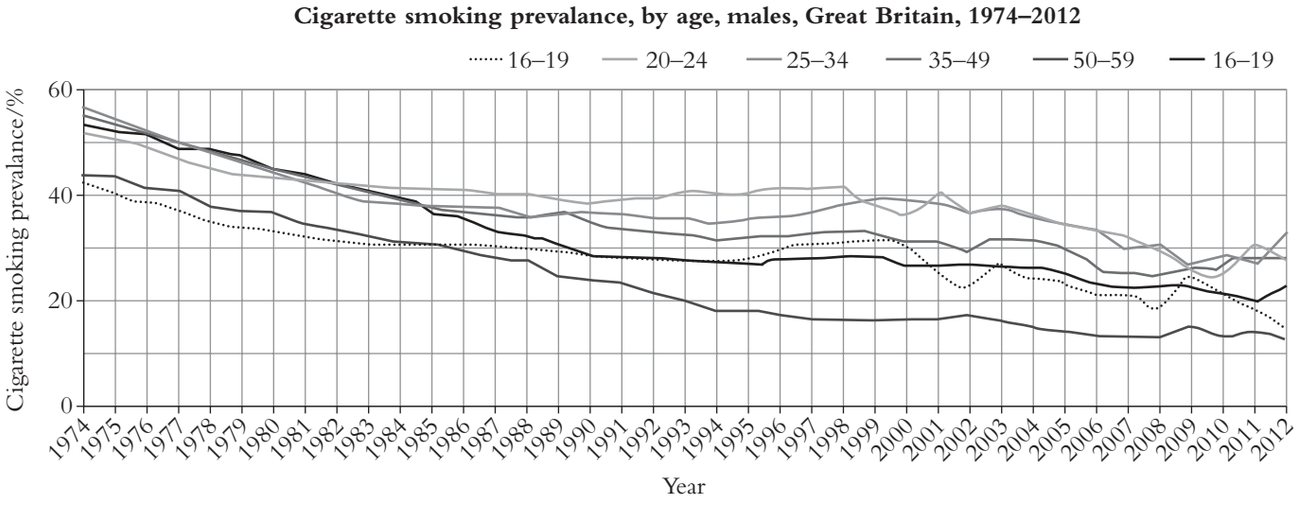

Figure 1.1 Trends in smoking in Great Britain.

2 Figure 1.2 shows a similar graph for the prevalence of both male and female smokers over time.

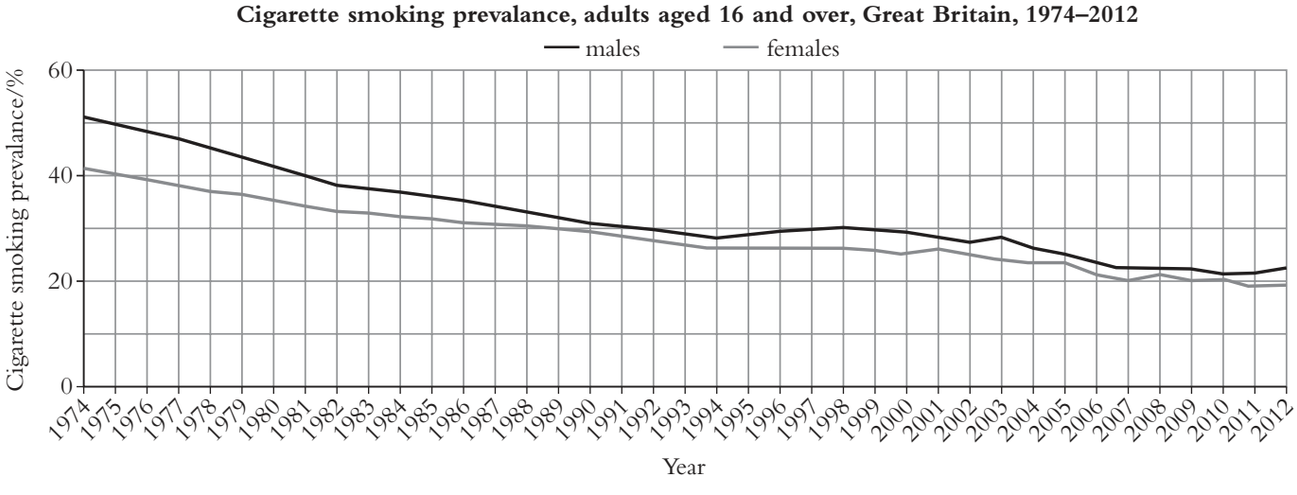

Figure 1.2 Trends in smoking prevalence for males and females over 16 in Great Britain.

a Compare the trend in smoking prevalence for males and females between 1974 and 2012.

b Explain why the prevalence of smoking has become similar in males and females.

3 You are responsible for the social media page of a company that promotes healthy living. Your editor has asked you write a tweet about why people should stop smoking. You only have 140 characters (not words) to use but must get your message across to the thousands of followers that will read it. Use your message to tell people why they should stop smoking cigarettes.

4 Read the following article about smoking before answering the questions that follow.

To vape, or not to vape?

Many people smoke electronic cigarettes (e-cigarettes) as these are deemed to be much safer than traditional tobacco-filled cigarettes. E-cigarettes are battery-operated devices that provide inhaled doses of a vaporised solution and liquid nicotine.

Manufacturers claim that the devices offer the following advantages:

- A safer alternative to tobacco cigarettes.
- Flavoured to taste better for customers.
- Help smokers to stop smoking and reduce the damaging effects of tar, nicotine and other carcinogenic ingredients.
- Fewer people, especially children, are now smoking tobacco cigarettes.

However, various authorities, such as the Food and Drug Administration (FDA) and the Centers for Disease Control and Prevention (CDC) have raised the following questions or statements.

- The products might not be safe to use.
- There are traces of nicotine and other toxic chemicals in the e-cigarettes.
- Use among children has doubled.
- The ingredients have not been sufficiently studied or regulated.
- The voltage of the device and the temperature of the vapour can affect level of emissions.
- New, probable carcinogens have been identified in vapour – propylene oxide and glycidol.

It is clear that manufacturers do not explicitly state that e-cigarettes are safer as they tend to imply this message. It is evidently successful as the industry is worth over three billion US dollars in America alone. Coupled with the recent decreasing trends in numbers of smokers, this can only be a good thing. Most e-cigarette companies are part of the same tobacco companies that they are trying to replace; is this unbiased enough for e-cigarette users to feel safe?

a Identify the evidence from this article that supports e-cigarettes as being safer than tobacco cigarettes.
b State the names of the authorities named in the article that offer a different viewpoint to the manufacturers.
c Glycidol is a potential carcinogen. Define *carcinogen*.
d Using the article above, discuss whether you think that students at your school should be allowed to smoke e-cigarettes.

5 The harvesting, production, and sale of tobacco is banned in Bhutan and the consumption of tobacco is largely prohibited in public places. The government of Bhutan has taken these steps as part of its drive for spiritual content and happiness (Gross National Happiness). Tobacco is recognised as being harmful to both spiritual and social health. Bhutan is the only country in the world with such wide-ranging

control over tobacco. However, the penalties for infringement of these laws has been criticised as being draconian and overly harsh.

Using the information in the text above, and your own knowledge of the effects of smoking, evaluate whether Bhutan is right to enforce anti-tobacco laws.

Exercise 1.2 – Drawing and labelling cells

1 Look at the question and the answer provided below it (in the form of a diagram) before answering the following questions.

Draw a labelled diagram showing the ultrastructure of a *Paramecium* cell.

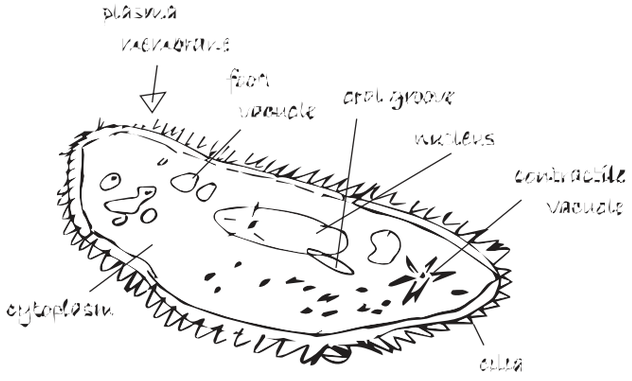

Figure 1.3 The ultrastructure of a *Paramecium* cell as drawn by a student.

a The student did **not** receive full marks for their drawing of the *Paramecium* cell. Suggest possible reasons why the student missed out on the full marks available.

b Identify the structure in Figure 1.3 that controls the water balance of the cell by contracting to expel its liquid contents.

c Look at the criteria in the table below. Some of these are guidance towards doing an excellent biological drawing. State the **four** criteria that are **not** relevant for an excellent biological drawing.

Straight label lines	Artistic quality	Clearly written labels
Rough lines used for outlines	Scale bar included where appropriate	Use of an arrowhead
Lines touch the intended structure	Excellent use of colour	Good use of the space allowed
No unnecessary shading	No unnecessary colouring	Clear lines drawn with pencil

Table 1.1

d Figure 1.4 shows a labelled drawing of a liver cell. Copy and annotate the drawing with the functions of each named structure.

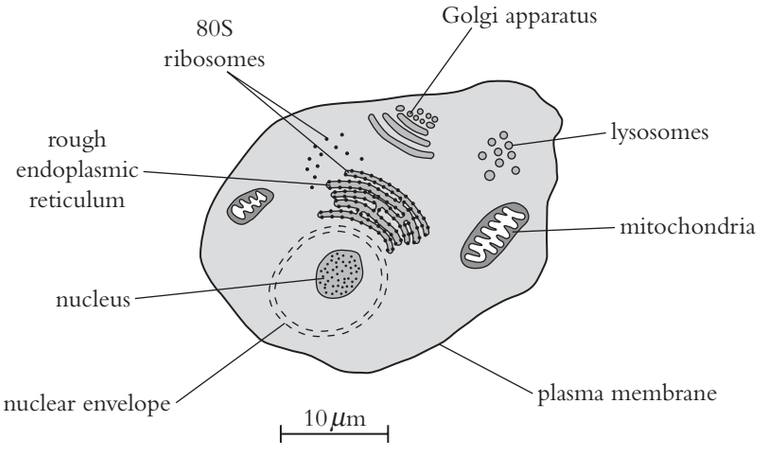

Figure 1.4 A labelled drawing of a liver cell.

e The liver cell is a eukaryotic cell. State **one** difference between an animal cell and a plant cell.

2 Figure 1.5 Shows a microscopic image of a mitochondrion.

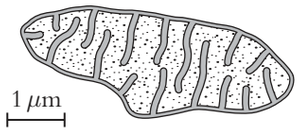

Figure 1.5 A microscopic image of a mitochondrion.

a State the size shown by the scale bar.
b Use a ruler to measure the length of the mitochondrion at its longest points.
c Use a ruler to measure the length of the scale bar.
d Use the formula provided to calculate the actual length of the mitochondrion. Convert all units to be the same and show your working.

$$\frac{\textbf{scale}}{\textbf{length of scale bar}} = \frac{\textbf{actual length}}{\textbf{measured length of mitochondrion}}$$

e State the formula used for calculating the magnification of the image.
f Calculate the magnification of the microscope used to capture the image in Figure 1.5.
g Outline the role of the mitochondrion in eukaryotic cells.

Exercise 1.3 – Membrane structure and transport

1 Copy and complete the paragraph to show your understanding of how models of membrane structure lead to our current knowledge of membranes. All of the answers are included in the word grid below.

three	microscopy	bilayer	falsification
1925	mosaic	evidence	integral
tension	scientists	Danielli	

Many _____ have been involved in refining our understanding of membrane structure. This happens as they use _____ to support, and reject, theories as new data is gathered by developments in technology and _____. The lipid bilayer was first proposed by Gorter and Grendel (_____) but it was Davson and _____ (1935) that developed this theory to show a model of a phospholipid _____ between two layers of globular protein. The Davson-Danielli model attempted to explain the phenomenon of surface _____. The Davson-Danielli model was usurped in 1972 when Singer and Nicholson developed their 'fluid _____' model. This model described _____ proteins throughout the membrane and is the basis for the model that you use today in your biology lessons. Freeze-etching was used to provide a _____-dimensional view of the surface and detail of the membrane's structures and contributed to the _____ of the Davson-Danielli model.

2 Using the information in question 1, describe how falsification of theories allows scientists to develop new theories as they gather new evidence.

3 You may think of cholesterol as a bad thing, due to its association with heart disease and fatty foods. However, your membranes require cholesterol to function properly.
Which of the following statements about cholesterol is true?
A Cholesterol makes the membrane less flexible to give support.
B Cholesterol enables the membrane to remove hydrogen ions from saturated phospholipids.
C Cholesterol enables the membrane to maintain fluidity, even when there is a change in temperature.

4 Define the following words.
a Hypertonic.
b Hypotonic.
c Isotonic.

5 Carlos carries out an investigation to measure the change in mass of potato cylinders before and after being immersed in solutions of different sucrose concentrations. He records his results as below.

Test	Sucrose concentration (%)	Average percentage change in mass
A	0.0	2.5
B	10.0	−6.1
C	30.0	−17.5
D	50.0	−25.1
E	70.0	−25.5

Table 1.2

a State the sucrose concentrations that were hypertonic.
b State the sucrose concentration that was hypotonic.
c On graph paper, draw a line graph that shows how the sucrose concentration affected the average percentage change in the mass of the potato.
d Using the graph from part c, estimate the sucrose concentration that you would expect to be isotonic.
e Explain why the potato mass changed as it did for the range of sucrose concentrations.

Exercise 1.4 – Ultrastructure of cells

1 Eukaryotic and prokaryotic cells have a number of differences and similarities between them.

a Copy and complete the table below to show whether the description of the ultrastructure is from a eukaryotic cell or a prokaryotic cell.

Structure	Description	Eukaryotic or prokaryotic?
Nucleus	Present, surrounded by nuclear envelope	
Mitochondria	Never present	
Chloroplasts	Never present	
Endoplasmic reticulum	Usually present	
Ribosomes	80S	
Chromosomes	Long strands of DNA, associated with histones	
Cell wall	Always present	

Table 1.3

b Using all of the structures in the first column of the table in part a, outline the structure of a typical eukaryotic cell.

c Mitochondria can be found in the cytoplasm of most eukaryotic cells and their primary function is to produce adenosine triphosphate (ATP) by extracting energy from nutrients. This ATP is crucial to a range of cellular functions and is critical to our survival. The process of extracting energy is aerobic respiration and requires oxygen.

i State the singular term for mitochondria.

ii Explain why the production of ATP is important for the survival of our cells.

d State the main function of the eukaryotic organelles listed below.

i Plasma membrane.

ii Cytoplasm.

iii Centrioles.

iv Mitochondria.

v Chloroplast.

vi Vacuole.

vii 80S ribosomes.

viii Nucleus.

ix Rough endoplasmic reticulum.

x Golgi apparatus.

xi Lysosomes.

xii Cell wall.

e Of the organelles above, which ones would typically be found in plant cells but **not** in animal cells?

Exercise 1.5 – Cell division

1 Interphase is the longest phase of the cell cycle and is made of three main stages: G1, S and G2.

a State the terms that are represented by 'G' and 'S' during interphase.

b Determine the stage of interphase that produces the proteins required for DNA synthesis.

c State what happens to the amount of DNA in the S-phase of interphase?

d State which part of interphase is when mitochondria are replicated?

2 Cyclins control the progression of cells through the cell cycle and were a serendipitous discovery by Tim Hunt. Cells can only enter the next stage of the cell cycle when each cyclin reaches a specific level. The cyclins bind to CDKs (cyclin-dependent kinases) and activate them. This, in turn, activates other proteins in the cell by attaching phosphate groups and they are then able to carry out their tasks.

a Tim Hunt was awarded the Nobel Prize in 2001 for his discovery of cyclins. His discovery was one of serendipity and Dr Hunt has often spoken about this in his public speaking engagements. Define *serendipity*.

b Look at the graph in Figure 1.6.

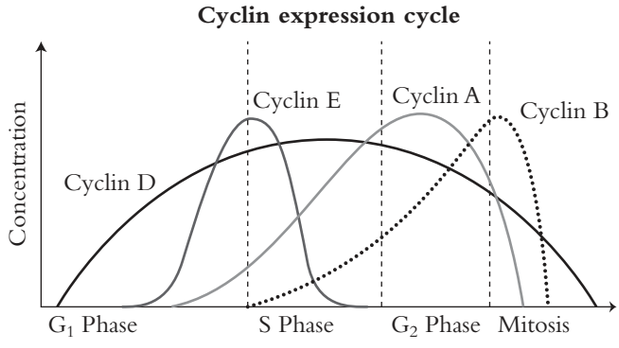

Figure 1.6 A simple cyclin graph.

i Identify the cyclin that is required throughout the cell cycle.
ii State which cyclin activates the G2 phase when it reaches its threshold level.
iii Using Figure 1.6, describe how cyclins are important in the regulation of the cell cycle.

3 The stages of mitosis are outlined below. List them in the correct order:

anaphase, telophase, metaphase, prophase, cytokinesis

4 Klaus is observing cells under a microscope that are undergoing mitosis. He identifies six cells that that have chromosomes lined up on the equator of their cell. Klaus also observes three cells that have visible chromosomes due to the disintegration of the nuclear membrane. There are five cells that have separated sister chromatids. The other 31 cells do not show any signs of mitosis.

a State the formula required to calculate the mitotic index of this particular population of cells.
b Calculate the mitotic index for these cells.
c State the stage of mitosis are the five cells with separated sister chromatids?
d Klaus finds the following text in his notes: *a package of histones with DNA wrapped around them*. State the name of the structure that his notes must be describing.

Exercise 1.6 – Endosymbiotic theory

1 Read the following conversation between two students and answer the questions that follow.

Paul: **Hi.**

Riya: Hi, how are you?

Paul: **Good, thanks. I'm revising endosymbiotic theory after Mr Hull mentioned it in class yesterday. He said that certain parts of eukaryotic cells were once independent prokaryotic cells.**

Riya: Yes, I think he mentioned mitochondria.

Paul: **Well, I don't understand. How did mitochondria become part of eukaryotic cells if they didn't exist?**

Riya: Basically, some cells engulfed the mitochondria and were then able to make useful energy. It is really clever and allowed these cells to develop into cells capable of respiration, not to mention photosynthesis as well.

Paul: **Wow! Did someone see all of this happen under a microscope?**

Riya: Microscopes were nowhere near invented when all of this happened! We just happen to know that the cell that was able to perform respiration was an ancestor of the mitochondria… and scientists worked it out from there.

Paul: **Thanks, Riya. Now I understand how eukaryotes evolved through the incorporation of free-living organelles into larger prokaryotic cells and organelles.**

a State the parts of eukaryotic cells that were once suggested to be prokaryotic cells.
b State the role of the mitochondria in cells today.
c Outline why there was no evidence at the time that endosymbiosis happened.
d Which organelle, not mentioned in the conversation, is the site for photosynthesis?
e State an example of a prokaryotic cell.

Exam-style questions

1 **The movement of molecules across a partially permeable membrane is not affected by which factor? [1]**
A Concentration gradient of the particles diffusing
B Surface area of the membrane
C A selective membrane
D Temperature

2 **The correct movement of water molecules in osmosis is: [1]**
A From high solute concentration to low solute concentration
B From low water concentration to high water concentration
C From low solute concentration to high solute concentration
D Between solutes of equal concentration

3 **Observe the following statements about cell theory.**
I Living organisms are composed of cells.
II Cells are the smallest units of life.
III Cells come from pre-existing cells.

Which combination of statements about cell theory is true from the statements above? [1]
A I and III only
B I and II only
C I, II and III
D None of the above