Lesson One

Cells, Organisms and the Variety of Life

Aims

By the end of this lesson you should be able to:

- understand the characteristics of living organisms
- describe, and state the functions of, the following cell structures: nucleus, cytoplasm, cell membrane, cell wall, chloroplasts, mitochondria, ribosomes and vacuole
- know the similarities and differences in the structure of animal and plant cells
- **explain the importance of cell differentiation in the development of specialised cells**
- **understand the advantages and disadvantages of using stem cells in medicine**
- describe the common features of, and give examples of: plants, animals, fungi, protoctists, bacteria and viruses
- understand the term 'pathogen' and know that pathogens may be fungi, bacteria, protoctists or viruses

Context

This lesson covers the whole of Section 1 'The nature and variety of living organisms' and elements (a) and (b) of Section 2 'Structures and functions in living organisms' of the Edexcel 2019 specification. Where aims are given in bold print (above), this indicates that they are only required for Paper 2 from June 2019 onwards.

Edexcel IGCSE Biology Chapter 1 pages 1–3, 11–13, and Chapter 2 pages 16–21.

Introduction

Biology is the science of life. What is life? How does it work? These are the questions Biology seeks to answer, and it is hard to imagine a more interesting set of questions to study!

Life is found in living objects called **organisms**: humans, cats, trees, flies, bacteria and so on. These organisms differ from each other, but they all share the following characteristics which together define what "life" is:

- they require **nutrition**: they need an input of energy and materials to make them work
- they **respire**: they release the energy that they need by the breakdown of large carbon-containing molecules
- they **excrete**: they get rid of the waste materials they make to the outside
- they **respond** to their surroundings: they change their growth and/or behaviour as their surroundings change
- they **move**: in some cases they move about from place to place, but even if they don't there is movement inside their bodies
- they **control their internal conditions**: they attempt to keep conditions inside constant even when the outside changes
- they **reproduce**: they make more organisms of the same sort to increase their numbers
- they **grow** and **develop**: they get bigger and mature over time

These characteristics describe what organisms *do*, and it is because they do all of them that we say organisms are alive.

But organisms also share a surprising common *structure*: they are all made up of one or more small boxes called **cells**. In this first lesson, and indeed in this first module, we shall be finding out about cells and seeing how what goes on in cells relates to the life of organisms as a whole.

Activity 1	Which of the above list of activities does a car do when it is running? Is a car alive? As with most activities, please write your answer in the box below and check with the suggested answer given at the end of the lesson.
	

Cells

Cells are too small to see with the naked eye, so they were only discovered in the seventeenth century following the invention of the **microscope**. Look at figure 1.4 on page 3 of *Edexcel IGCSE Biology* which shows how they appear down the microscope. The top picture shows some typical cells from an animal, and the bottom picture cells from a plant.

In the 1930s, the discovery of the **electron microscope** let us see cells under magnifications of up to 500,000X, rather than the mere 600X allowed by the normal light microscope. We could now see that cells contain many different small structures called **organelles**. Most of the ones you need to know about are labelled in figure 1.2 on page 2 of the textbook. Figure 1.3 shows part of a cell as seen down an electron microscope: notice how much bigger and more detailed the organelles appear.

The microscope has shown us the reason for many of the differences between plants and animals. Animal cells and plant cells are different, and this determines the differences between the whole organisms.

Activity 2	**Extension work**: If you are interested, you can find out about the discovery of cells by visiting www.ool.co.uk/0104bi on the very useful Sparknotes website.

Log on to Twig and look at the film titled: **What is a Cell?**

www.ool.co.uk/1041wd

Every living thing on our planet, from plants to animals, is made up of cells. Cells are the building blocks of life, but what are they and how do they work?

Animal Cells

The cells of animals, including our own, almost always possess a nucleus, cytoplasm, a cell membrane, mitochondria and ribosomes:

- The central **nucleus** has two main functions:

  (1) It *controls* the activities of the rest of the cell.

  (2) It stores the *information* needed to make new cells and, indeed, the whole organism.

- The rest of the cell is filled with a jelly-like **cytoplasm**. This is where most of the chemical reactions of life called **metabolism** go on.

- The cell is surrounded by an extremely thin, fragile layer called the **cell membrane** or **plasma membrane** made of lipid (fat) and protein. This membrane controls what enters and leaves the cell, so that the composition of the inside can be kept constant.

- **Mitochondria** (singular: mitochondri*on*) are sausage-shaped organelles where most of the energy of the cell is released in a process called **respiration**. Think of them as the "power stations" of the cell, providing the energy which the cell needs to do all of its other processes.

- **Ribosomes** are very small structures, only visible under an electron microscope, where new protein molecules are assembled. They are the small, black (unlabelled) dots outside the nucleus in Figure 1.3.

Plant Cells

Plant cells are more complicated than animal cells. They possess all of the above four structures, plus three extras as well:

- A thick, tough, layer outside the cell membrane called the **cell wall**. It is made of the material **cellulose**. The cell wall helps the cell keep its shape, and stops it bursting when the cell is placed in water.

- Mature plant cells have a large central **vacuole**, surrounded by a membrane, and filled with a watery solution called **cell sap**. This acts as a store of soluble materials for the cell.

- Leaf cells also have green structures in the cytoplasm called **chloroplasts**, which absorb light energy to make the plant's food in a process called **photosynthesis**. Cells in non-green parts of the plant, such as the roots, lack these.

Plant cells differ from animal cells in having these extra three parts, and in being unable to change their shape because of their tough cell wall. This explains why:

- plants do not move about, whereas animals do

- plants do not need to feed on other organisms, whereas animals do

Get it right! The outer layer of an animal cell is called the "cell membrane", *not* the "cell wall". A plant cell has both, but the cell membrane is right inside the cell wall and is often invisible.

Log on to Twig and look at the film titled: **Types of Cell**

www.ool.co.uk/1042db

Skin cells, sperm cells and nerve cells are just some of the cell types that perform specific functions in our bodies. What are they and what do they do?

Measuring very small Objects

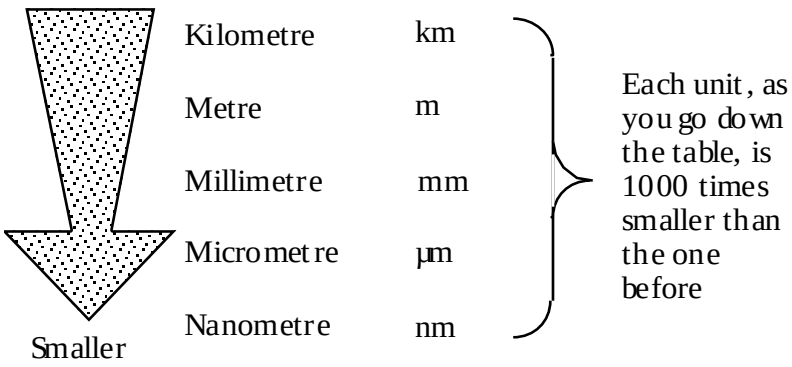
In your exam you will be expected to be familiar with the units used to measure very small objects, such as cells and organelles. You will already be used to those that we use to measure larger objects.

The units scientists use to measure length are all derived from the **metre**, which we abbreviate to **m**. You will already have encountered:

- the **kilometre**, or **km**. This is 1000m.
- the **millimetre**, or **mm**. This is $\frac{1}{1000}$ m.
- the **centimetre**, or **cm**. This is $\frac{1}{100}$ m, or 10mm.

However, you may not yet have encountered two units which we use for measuring tiny sizes and distances. These are:

- the **micrometre**, or **micron** written **µm**. This is $\frac{1}{1000}$ mm. You could not see anything this small with the human eye, you would need a light microscope.
- even smaller, there is the **nanometre**, written **nm**. This is $\frac{1}{1000}$ µm, and is used for measuring things only visible under an electron microscope. The cell membrane is only about 7.5 nm across, which is very thin indeed!



Activity 3	**A** 1. How many millimetres are there in 6 centimetres? 2. How many micrometres are there in 2 millimetres? 3. Convert 25μm into mm. **B** Study figure 1.2 on page 2 of *Edexcel IGCSE Biology*. Notice the "scale line" which indicates the size of 10μm on the pictures. (a) Use the scale lines to estimate the diameter of (i) a typical animal cell (ii) a nucleus (iii) a chloroplast (iv) a mitochondrion in micrometres. (b) Now express your answers to part (a) in millimetres.
	

Cells, Tissues, Organs and Systems

A large organism like a human being contains millions of cells. These are not just jumbled together, but are arranged in **several levels of organisation**:

- A group of similar cells which are specialized to perform a particular function is called a **tissue**. A good example is the cells in one of your muscles, which are all specialized to contract and move the body.

- A group of different tissues joined and working in co-operation is called an **organ**. For example, several sorts of tissue (muscle, valve tissue etc.) combine together to form the human heart.

- When groups of organs work together to perform a particular function they form a **system**. So, for example,

the heart plus the blood and blood vessels forms the circulatory system, which is one of the systems in a human being.

Activity 4	Study the diagram on page 13 of the textbook which labels many of the major organs in the human body. Pages 12 -13 list some of the major systems in the human body, which we shall study in the second and third modules of the course.
	

Here is a summary of the levels of organisation found in organisms in general:

organelles → cells → tissues → organs → systems → organism

Get it right!

- An "organ" is usually (but not always) a visible lump which can be cut out of the organism, like the heart or the brain.
- A "tissue" is a collection of similar cells. Organs are usually made up of several different sorts of tissue combined together.
- "Systems" are collections of organs which cooperate to perform some major life process, like excretion or digestion.

Cell differentiation and stem cells (June 2019 onwards)

When new cells are produced during cell division (see Lesson 17) they have a general round shape as shown on the left of Figure 1.2 on page 2. These cells then change in appearance

and function to produce the specialised cells found in tissues. These changes are called (cell) **differentiation**, and the specialised cells are said to be **differentiated** cells. These differentiated, specialised cells are usually unable to divide.

Cells in an animal which are undifferentiated and still able to divide are called **stem cells**. Stem cells can give rise to a range of different tissues by cell division followed by cell differentiation. Many of the cells in an animal **embryo** (see Lesson 14) are stem cells: they can divide and differentiate to produce all of the tissues and organs in the adult animal.

Using stem cells

Because differentiated cells are often unable to divide, it means that an adult animal is often unable to repair damage to its tissues and organs. Brain and heart cells, for example, cannot divide, so damage to the brain or heart is permanent.

The surgical implantation of stem cells from "spare" human embryos offers a way of repairing these organs and tissues. The transplanted stem cells divide, and them differentiate to produce new brain or heart cells like those around them.

"Spare" human embryos are often produced during fertility treatment to help women have babies. However, many people regard these embryos as potential human beings, and therefore think it is wrong to use them in this way to help other people.

Work is ongoing to produce stem cells from adult differentiated cells. These could them be used to repair patients without destroying any embryos in the process.

The Variety of Living Organisms (all students)

There are upwards of 10 million different types or **species** of organism alive on our planet today. Biologists divide them up into five major types or **kingdoms**, which differ in:

- the nature of their cells, and
- their form of nutrition (feeding).

Grouping organisms like this is called **classification**, and the study of grouping is called **taxonomy**.

We will look very briefly at each of the five groups now, but they will all be studied in more detail later in the course.

Animals

Animals are **multicellular**, i.e. composed of many cells. Their cells lack cell walls which allows them to change shape and move around, and they are the only group to be often controlled by a nervous system.

Animals get their nutrients by feeding on other organisms and they often store energy in the form of a chemical called glycogen.

Animals are divided into two subgroups: the **vertebrates** which have backbones (fish, amphibians, reptiles, birds and mammals), and the **invertebrates** which do not. A housefly (an insect), a mosquito (another insect) and a human being (a mammal) are all animals. See figure 2.2 on page 17 of the textbook.

Plants

Plants are also **multicellular**. Their cells, as we have seen, are surrounded with a tough cell wall made of cellulose, which means that they do not move around.

Plants are the only group not to feed on other organisms. Their cells contain chloroplasts, using which make their food from simple substances using light energy by photosynthesis. They often store their energy as starch or sucrose (sugar), rather than as glycogen.

Like animals, plants are divided into several subgroups. The most important is the **flowering plants** which (obviously!) have flowers. Non-flowering plants include the ferns and mosses. Maize and other cereals, and peas and beans (see figure 2.1 on page 16 of the textbook) are all flowering plants.

Fungi

Fungi are rather like curious hybrids between plants and animals.

Some fungi are **unicellular** or one-celled (e.g. yeast), but most consist of long threads called **hyphae** forming a network called a **mycelium** (see figure 2.7 on page 18 of the textbook). Each hypha has several nuclei, rather than the one-cell-one-

nucleus pattern found in the other groups. Their cells have cell walls like plants, but they are made of a different material called **chitin** (which, bizarrely, is also found in insect skeletons!).

Fungi do not move about but, unlike plants, they do not make their own food by photosynthesis. They grow on their food source, penetrating it with their hyphae. These send enzymes out into their food (= **extracellular secretion**) and digest it externally before absorbing it, a pattern is called **saprophytic nutrition**. They can store energy as glycogen, like animals.

Moulds like *Mucor* (figure 2.6), toadstools (figure 2.5) and yeasts (figure 2.3) are all fungi.

Activity 5	**Extension**: Fungi are weird organisms. You can find out more about them than you will probably want to know (!) at www.ool.co.uk/0111bi. You may make notes below.
	

Protoctists

Protoctists is the name given to one-celled plants and animals. One-celled animals are called **protozoa**; one-celled plants are called **algae**. *Amoeba* (figure 2.8(a)), which lives in ponds, and *Plasmodium* (figure 2.8 c) a parasite living in human blood, are protozoa. *Chlorella* (figure 2.8(b)) is a fresh water alga.

Bacteria

Bacteria are single-celled organisms whose cells are much smaller and simpler than those of the first four groups. Each bacterium is only about $1/10^{th}$ as long (so having only about $1/1000^{th}$ of the volume) of a normal human cell (see figure 2.9 on page 19 of the textbook). It also has different features to normal cells:

- No proper nucleus, but a single, circular chromosome plus smaller circular **plasmids** made of the genetic material DNA (see later)

- No other proper organelles (no mitochondria, for example)

- A cell wall outside the cell membrane. In this respect it is similar to plants, protoctists and fungi, but the wall is made of mucopolysaccharide (a sugar-protein mixture) instead of cellulose or chitin

- A **capsule** or slime layer outside the cell wall

- Sometimes one or more **flagella**, which beat to move the cell along

A few bacteria can make their own food by photosynthesis like plants, but most depend on other life for their food supply. Many grow on dead material, rotting it down, like fungi. These are called **decomposers**. The ones that cause disease – **pathogenic bacteria** – feed on the bodies of other organisms while they are still alive.

Lactobacillus bulgaricus, a rod shaped decomposer bacterium used in making yoghurt (see figure 2.11 page 20) and *Pneumococcus*, a spherical pathogenic bacterium that causes pneumonia (see figure 2.12), are examples of bacteria.

Viruses

Viruses, which cause diseases in humans such as the common cold and AIDS, are much smaller than any of the types of organism described above. They are not made of cells, so they are <u>not</u> "living organisms". They do, however, often behave as if they are alive.

A diagram of a typical virus "particle" is given in figure 2.13 on page 21 of the textbook. It is much smaller than a bacterium, and can only be seen under an electron microscope. It consists simply of a short section of DNA (<u>or</u> a similar chemical called RNA) containing its genes, surrounded by a protein coat. Sometimes there is also an envelope outside this, derived from its host cell.

A virus can only live inside another living host cell, so it is sometimes called an **intracellular parasite** ("intra" means

"within"; "parasite" means it lives and feeds on/in another organism while it is still alive). When outside a cell it does nothing at all – no respiration, feeding, growth or any other activities of life. When it invades a host cell it "hijacks" the cell's chemistry and diverts it into the construction of new virus particles. Once these are completed the cell lyses (splits) and dies, releasing many new viruses to repeat the process. The new viruses often surround themselves with envelopes made from the host cell membrane as a way of fooling new host cells that they are not aliens but one of the body's own cells. Viruses always cause damage, by destroying host cells as they reproduce.

Although very simple, it is clear that viruses are not the original form of life. Biologists wonder if they may be "escaped genes" that have wandered off from other cells to pursue an independent life of their own!

Different viruses can invade the cells of all the five types of organism. They include:

- The tobacco mosaic virus (see figures 2.14 and 2.15 on page 21) which attack the leaves of tobacco plants, stopping them forming chloroplasts
- The influenza virus, that causes influenza (flu) in humans
- The Human Immunodeficiency Virus (HIV), that causes AIDS in humans.

Activity 6

Extension work

Viruses are also strange and fascinating organisms! You can find out more about them, and their discovery, online at www.ool.co.uk/0113bi.

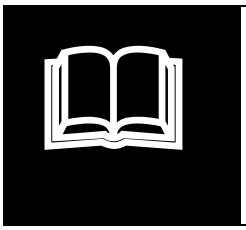
Pathogens

"**Pathogen**" is the biological term for what is commonly called a "germ". It means *a disease-causing microorganism.*

Pathogens may belong to any of the following main groups:

- Viruses: e.g. the influenza virus and HIV
- Bacteria: e.g. *Pneumococcus*
- Fungi: e.g. the fungus causing athlete's foot
- Protoctists: e.g. *Plasmodium*

However, not all members of these groups are pathogens. Many are harmless, and some are useful to us.



Now is the time to read through chapter 1 pages 1–3, 11–13 and chapter 2 pages 16–21 of *Edexcel IGCSE Biology*. They cover the same topics as this lesson, so will add to your understanding of the material.

Keywords

Organism
Respire
Respond
Grow
Cell
Nucleus
Cytoplasm
Cell wall
Vacuole
Nanometre
Organ
Differentiation
Embryo
Species
Classification
Animal
Protoctist
Viruses
Unicellular
Saprophytic
Nutrition
Excrete
Reproduce
Develop
Organelle
Cell membrane
Mitochondrion
Chloroplast
Micrometre
Tissue
System
Stem cell
Kingdom
Plant
Fungi
Bacteria
Multicellular
Parasitic
Pathogen

Summary

Lesson One: Cells, Organisms and the Variety of Life

CHARACTERISTIC OF LIFE

CELLS
------ animal cells
------ plant cells

LEVELS OF ORGANIZATION

CELL DIFFERENTIATION AND STEM CELLS

KINGDOMS
------ animals
------ plants
------ fungi
------ protoctists
------ bacteria

VIRUSES

PATHOGENS

What you need to know

- The meanings of the words printed in **bold** in this lesson
- The characteristics of living organisms
- The parts of cells and their functions
- The differences between animal and plant cells
- The levels of organisation of organisms
- That differentiated cells can often not divide, but stem cells can divide
- Cell structure, nutrition, and examples of: animals, plants, fungi, protoctists, bacteria
- The structure and properties of viruses, and that viruses are not living organisms
- Meaning and examples of the term “pathogen”

What you might be asked to do

- Describe the structures and functions of the parts of cells.
- Identify the cells of animals, plants, fungi, protoctists, bacteria, and virus particles.
- Describe/Compare the similarities and differences between plants and animals in terms of their cell structure and nutrition.
- Use the various units of length given in this lesson correctly.
- Calculate the dimensions of cells and organelles from given scale lines.
- Explain the use of stem cells in medicine and why it is controversial
- Discuss whether or not viruses are "alive"
- Use, and spell, correctly the words printed in **bold** in this lesson.

Self-Assessment Test: Lesson One

Question 1

Different types of cells contain different structures.

(a) Complete the table below to show the structures contained in the different cells:

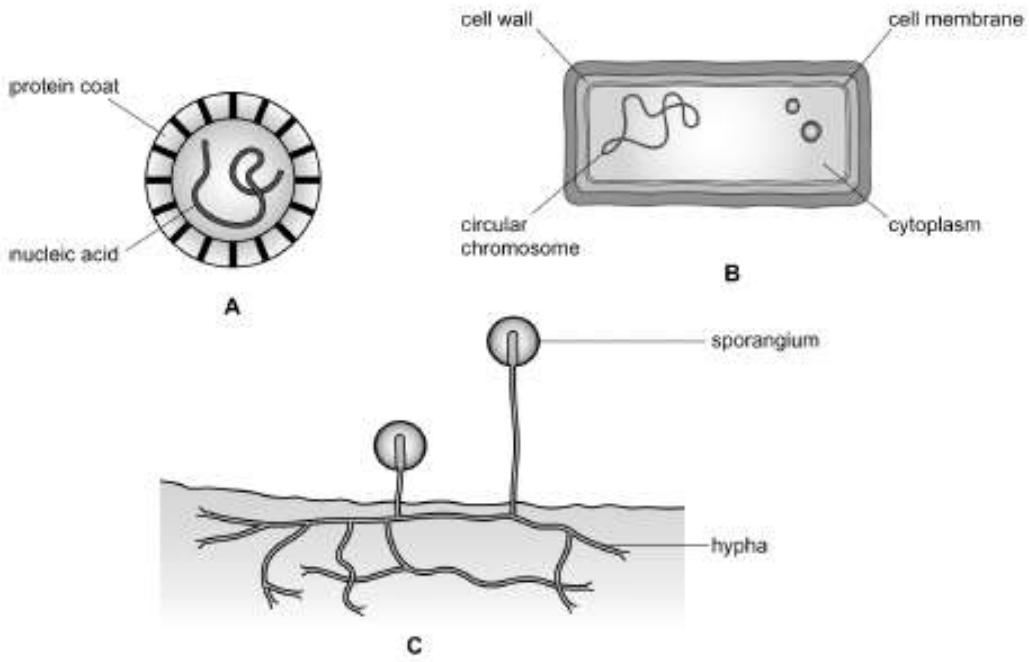
cell	structure			
	nucleus	cytoplasm	cell wall	chloroplast
neurone (an animal cell)		✓		
Pneumococcus (a bacterial cell)			✓	✘
yeast (a fungal cell)	✓			

(b) Which of these structures would you find in <u>both</u> a plant <u>and</u> an animal cell?

(c) Which of these structures contains the information for creating a new cell?

Question 2

The diagrams show three different forms of life, not drawn to the same scale.



(a) Which group does each organism belong to?

(b) Which is the smallest?

(c) For each of these statements, write the letter of the form (or forms) of life it applies to:

(i) It is an organism made up of only a single cell

(ii) It feeds by the secretion of extracellular enzymes onto food

(iii) It contains many nuclei

(iv) It is only able to reproduce inside another living cell

Question 3

(a) Convert 5.5mm into μm.

(b) Convert 3500μm into mm.

(c) A cell on a photograph taken down a microscope measures 15mm across. If the magnification of the microscope is 500×, what is the actual diameter of the cell in (i) mm (ii) μm?

Question 4 (June 2019 onwards)

Explain why:

(a) the body can usually not repair damage to the heart caused by a heart attack;

(b) stem cells might be used to repair this damage;

(c) many people think it is wrong to use stem cells in this way.

Suggested Answers to Activities

Activity 1

A car <u>does</u>: require nutrition (petrol), respire (break the petrol down to release energy), excrete (gases from the exhaust pipe), control their internal conditions (keep their engine temperature constant), and move. Some more advanced models also respond to their surroundings (adjust their braking to the road conditions). However, they do not grow, develop or reproduce (!), so it is best to say they are not alive.

Activity 3

A (i) $6 \times 10 = 60$mm

(ii) $2 \times 1000 = 2000$μm

(iii) $25 \div 1000 = 0.025$mm

B All answers are approximate:

(a) (i) 30μm

(ii) 3μm

(iii) 2μm

(iv) 1μm

(b) (i) 0.03mm

(ii) 0.003mm

(iii) 0.002mm

(iv) 0.001mm

Suggested Answers to Self-Assessment Test: Lesson One

Question 1

(a) Neurone: only nucleus and cytoplasm
Pneumococcus: only cytoplasm and cell wall
Yeast: only nucleus, cytoplasm, cell wall

(b) Nucleus and cytoplasm only

(c) Nucleus

Question 2

(a) A: viruses

B: bacteria

C: fungi

(b) A (the virus)

(c) (i) B (ii) C (and possibly B) (iii) C (iv) A

Question 3

(a) $5.5 \times 1000 = 5500\mu m$

(b) $3500 \div 1000 = 3.5mm$

(c) (i) $15 \div 500 = 0.03mm$

(ii) $0.03 \times 1000 = 30\mu m$

Question 4

(a) Heart muscle is made of differentiated cells. Differentiated cells can often not divide to replace lost cells.

(b) Stem cells are undifferentiated. If transplanted into the damaged heart they can divide, and the cells formed can differentiate to form new heart cells.

(c) Stem cells are currently usually obtained from “”spare” embryos. Many people think these are potential human beings, so it is wrong to use them in this way.