Secondary Science 11 to 16

A Practical Guide

Gren Ireson, Mark Crowley,
Ruth Richards and John Twidle

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Introduction

Our approach to the learning and teaching of science is based loosely on a constructivist approach which both challenges and engages the learner. While we see science as being very much a *hands-on* activity we like to take this a stage further and make science a *minds-on* activity.

For teachers, our experience has shown that those new to teaching or those teaching outside their specialism have three key questions:

- Do I have the subject knowledge?
- How does the subject link to the National Curriculum?
- How can I make the topic engaging, fun and *minds on*?

This book, over twelve chapters, addresses these questions by:

- linking to the English, Irish, Scottish and Welsh curricula;
- linking to 'How Science Works';
- setting the scene with Key Stage 3 subject knowledge;
- developing Key Stage 4 subject knowledge;
- presenting fun, *minds-on* activities; and
- providing references and further reading.

The twelve chapters are structured around four sections which draw together key areas of science, biology, chemistry, physics and earth science, and it is hoped that this will make navigation easier for the reader.

Each chapter takes a standard approach, starting with questions to test your knowledge (the answers are addressed during the main text), explanatory text and practical work, and further reading. Where appropriate, *practical activities* and *engaging activities* are also suggested.

The authors recognize that this book is not a replacement for the vast number of texts available but, by drawing on their collective experience of both school and higher education, this book addresses areas that trainee and practising teachers have found difficult in the past. Having worked through this book and having involved yourself in the practical activities, it is expected that you will have developed sufficient confidence and competence to tackle areas not explored here.

Section 1 Beginnings and development of living things

This section has a biological focus which should help to develop your understanding of a number of biological processes. In this section, of two chapters, you will be introduced to the science of:

- cells – the building blocks of living organisms;
- reproduction – the continuation of life; and
- genetics – the variation and inheritance of characteristics.

This links to, and will help you deliver, the various national curricula for England, Ireland, Scotland and Wales as set out below.

By working through this section it is expected that you will be able to describe and explain:

- the various functions of animal and plant cells;
- the process of reproduction;
- the process of genetic inheritance; and
- the passing on of characteristics.

Please turn over to see how this section relates to your curriculum.

National Curriculum for England	Junior Certificate Science Syllabus	Environmental Studies – Society, Science and Technology	Science in the National Curriculum for Wales
KS3, 3.3 **a** life processes are supported by the organisation of cells into tissues, organs and body systems **b** the human reproductive cycle includes adolescence, fertilisation and foetal development **c** conception, growth, development, behaviour and health can be affected by diet, drugs and disease **d** all living things show variation, can be classified and are interdependent, interacting with each other and their environment **e** behaviour is influenced by internal and external factors and can be investigated and measured **KS4, 5** **b** variation within species can lead to evolutionary changes and similarities and differences between species can be measured and classified **c** the ways in which organisms function are related to the genes in their cells	**1B4** Reproductive system: male and female reproductive systems menstrual cycle fertilization and pregnancy contraception **1B5** Genetics: inheritable and non-inheritable characteristics chromosomes and genes **1C1** Living things: life processes and common characteristics of living organisms relationship between cells, tissues, organs and systems	Living things and the processes of life: Variety and characteristic features Developing an understanding of the characteristic features of the main groups of plants and animals, including humans and microorganisms The principles of genetics are also considered The processes of life Developing an understanding of growth and development and life cycles, including cells and cell processes The main organs of the human body and their functions are also considered	**KS3, 1** Life Processes and Cell Activity: **1** That animals and plants are made up of cells **2** The functions of the cell membrane, cytoplasm and nucleus in plant and animal cells **3** The functions of chloroplasts and cell walls in plant cells **4** Variation, Classification and Inheritance **KS4, 1** Life Processes and Cell Activity: **1** That cells have a nucleus, a cell membrane and cytoplasm **2** That the nucleus contains chromosomes that carry the genes 3 Variation, Inheritance and Evolution: **1** That sexual reproduction is a source of genetic variation, while asexual reproduction produces clones **2** That mutation, which may be beneficial or harmful, is a source of genetic variation and has a number of causes **3** How gender is determined in humans **4** The mechanism of monohybrid inheritance where there are dominant and recessive alleles **5** That some diseases are inherited **6** The basic principles of cloning, selective breeding and genetic engineering **7** The potential benefits and ethical dilemmas posed by advances in cloning and genetic engineering

1 Looking at life

Ruth Richards

This chapter covers:

- the characteristics of life
- cell structure
- practical techniques for making slides
- levels of organization
- diffusion and osmosis.

Test your own knowledge

Before reading the material in this chapter test your current knowledge with the following questions:

1. How do we know something is alive?
2. What is a cell? What are the main components of an animal and a plant cell? Which components are shared by both plant and animal cells?
3. What is the function of each cell component?
4. How do substances get in and out of cells? Are there any rules for this?
5. What is the definition of a cell, an organelle, a tissue and an organism?

What is life?

Everything that is considered to be alive carries out the seven characteristics of life. These are known by the mnemonic MRS GREN (**M**ovement, **R**espiration, **S**ensitivity, **G**rowth, **R**eproduction, **E**xcretion and **N**utrition).

The following information can be used to construct a card sort for students to recap this topic from Key Stage 3:

- **Movement:** Organisms may move all or parts of their bodies towards or away from influences that are important to them. For example, a plant may move its leaves towards the sun.
- **Respiration:** The release of energy stored in food, such as glucose, to provide power for the cell to function. The energy currency of the cell is adenosine tri-phosphate, or ATP for short. Respiration takes place in the mitochondria of every cell.
- **Sensitivity:** Awareness of the organisms' surroundings. This may be complex, such as the passage of nerve impulses, or simpler, such as the growth of plant roots down into the soil.
- **Growth:** An increase in size, such as the division of one cell into two identical cells (mitosis).
- **Reproduction:** The formation of more individuals from one parent (asexually) or two parents (sexually).
- **Excretion:** Getting rid of the products of the chemical reactions that have taken place in the organism (metabolism). Metabolism occurs at a cellular level, and so excretion includes getting rid of water and carbon dioxide. (Not getting rid of solid waste!)
- **Nutrition:** Using a food source to release energy for cell function. This is either autotrophic, when plants make their own food by photosynthesis and then metabolise it, or heterotrophic, when ready-made food is taken into an organism.

The cell

What is a cell? A cell is a single unit that can function on its own and can divide to form other cells of the same type. It is a package that contains all the 'bits' needed to be alive. These component parts of cells are called organelles. The cell itself is the basic unit of life, and all multicellular organisms are derived originally from one cell. It should be noted that animal cells are generally smaller than plant cells and lack some of the cell contents of plant cells.

How science works

The cell was first discovered by Robert Hooke in 1665. He used a basic microscope to look at thin slices of cork (from a cork tree) and he saw boxes that reminded him of monks' rooms or cells. Hence the name – 'cell'.

A good way to get students to compare animal and plant cells is by using a Venn diagram. This helps assess prior learning and gives you the basis to discuss any misconceptions that the students may have.

Provide the students with a list of the cell components and ask them to categorize these as being present in animals only, plants only or in both animal and plant cells (a shared field in the centre). Students could be asked to extend this by underlining the components that cannot be seen by using an ordinary light microscope, such as the ones they may use in class.

The completed example is shown in Figure 1.1. The words underlined are those components that cannot be seen through a standard light microscope as used in schools.

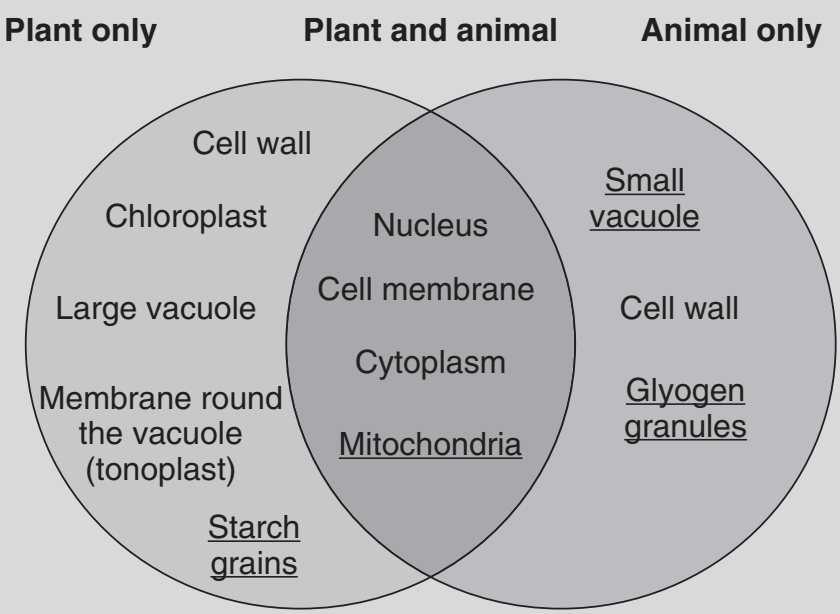

Figure 1.1 Venn diagram comparing plant and animal cells

The cell: card sort

The list of cell components, their description and function can be organized as a card sort. This can be seen in the card sort exercise shown in Figure 1.2, which can be easily differentiated by the removal of the more complex components. Simply cut these out in advance of the lesson.

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(Continued)

Cell component	Description	Function
Nucleus	Largest cell organelle. Contains strands of DNA. Appears patchy and dark coloured when a stain is added.	Regulates cell activities. Stores information which it passes on by cell division (mitosis and meiosis).
Cell membrane	Exterior layer of the cell. Composed of protein and oil (lipid).	Keeps all cell contents together. Is selectively permeable as it regulates what enters and leaves the cell.
Cell wall	Made of strong cellulose. Permeable to water and other substances.	Gives shape and support to the plant cell. Resists water movement into the cell when the cell is turgid.
Cytoplasm	Jelly-like substance (consistency of raw egg white). Composed mainly of water.	Supports the organelles. Store of water and/or pigments.
Chloroplast	Large green-coloured organelles.	To carry out photosynthesis. This uses trapped light energy to combine carbon dioxide and water to form glucose and oxygen. The glucose stores energy in its bonds.
Vacuoles	Large permanent vacuoles are found in the centre of plant cells. Small non-permanent vacuoles are found scattered throughout the cytoplasm in animal cells.	Storage of materials such as food or pigments and water control. Transport of substances around the cell and secretion of substances outside the cell (e.g. mucus or hormones).
Starch grain	Grains found inside plant cells. Small glucose molecules are converted into starch so that they can be stored.	Storage of food until needed. Glucose cannot be stored as it moves by diffusion and is therefore not kept in one place.
Glycogen granules and fat droplets	Granules or droplets found within the cytoplasm of animal cells.	Storage of food until needed.
Mitochondria	Organelles (about 5 nm) found in the cytoplasm.	Carries out aerobic respiration in cells.
Ribosomes	Tiny organelles (20 nm) found in the cytoplasm.	Make proteins by assembling amino acids in chains.

Figure 1.2 Card sort activity: the cell

Common misconceptions include students using the terms 'cell wall' and 'cell membrane' interchangeably and thinking that mitochondria can be seen with a light microscope. It should be noted that the cell membrane and tonoplast are difficult to see in many plant cells. The position of these can be highlighted during a practical by using the purple epidermis layers between the fleshy leaves in red onions. The position of the cytoplasm can be located because the cell contents are suspended within it.

Levels of organization: card sort

Cells can be added together to make increasingly complex organisms and parts of organisms. This can be seen in the card sort exercise in Figure 1.3.

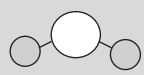
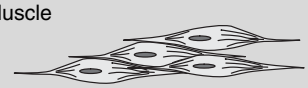
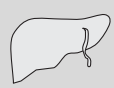
Level of organization	Description	Example
Atom	Fundamental unit of matter	Hydrogen 
Molecule	At least two atoms held together by chemical bonds	Water 
Organelle	Small units in cells that do one particular job	Mitochondrion 
Cell	The basic unit of life that can function independently	Sperm cell 
Tissue	Collection of similar cells that perform the same job	Muscle 
Organ	Collection of tissues that perform a specific or several functions	Liver 
Organ system	Collection of organs that work together to carry out a specific task	Digestive system 
Organism	A group of organ systems making up an individual	Mouse 

Figure 1.3 Card sort activity: levels of organization