edexcel

INTERNATIONAL GCSE

Biology (2017)

TOPIC GUIDE:

Cell structure and stem cells

Pearson Edexcel International GCSE in Science

Pearson

Introduction to the teaching of cell structure and stem cells

Specification

In the 2011 Edexcel International GCSE specification, the section covering cell biology is set out in the following way:

Students will be assessed on their ability to:

> *2.2 describe cell structures, including the nucleus, cytoplasm, cell membrane, cell wall, chloroplast and vacuole*
>
> *2.3 describe the functions of the nucleus, cytoplasm, cell membrane, cell wall, chloroplast and vacuole*
>
> *2.4 compare the structures of plant and animal cells.*

In the revised 2017 Edexcel International GCSE specification, this section is set out in the following way:

Students should:

2.2 describe cell structures, including the nucleus, cytoplasm, cell membrane, cell wall, mitochondria, chloroplasts, ribosomes and vacuole

2.3 describe the functions of the nucleus, cytoplasm, cell membrane, cell wall, mitochondria, chloroplasts, ribosomes and vacuole

2.4 know the similarities and differences in the structure of plant and animal cells

2.5B explain the importance of cell differentiation in the development of specialised cells

2.6B understand the advantages and disadvantages of using stem cells in medicine

Summary of the changes

- Students now need to be able to recognise and explain the functions of mitochondria and ribosomes.
- Students now need to understand the importance of cell differentiation in the development of specialised cells.
- Students now need to understand the advantages and disadvantages of using stem cells in medicine.
- Points 2.5 and 2.6 are specific to Biology International GCSE and not the Science (Double Award) specification – hence being in bold type and with a specification reference ending with a ‘B’.

Mitochondria and ribosome structure and function

Students are now expected to be able to recognise mitochondria and ribosomes in cells and give basic descriptions of their functions.

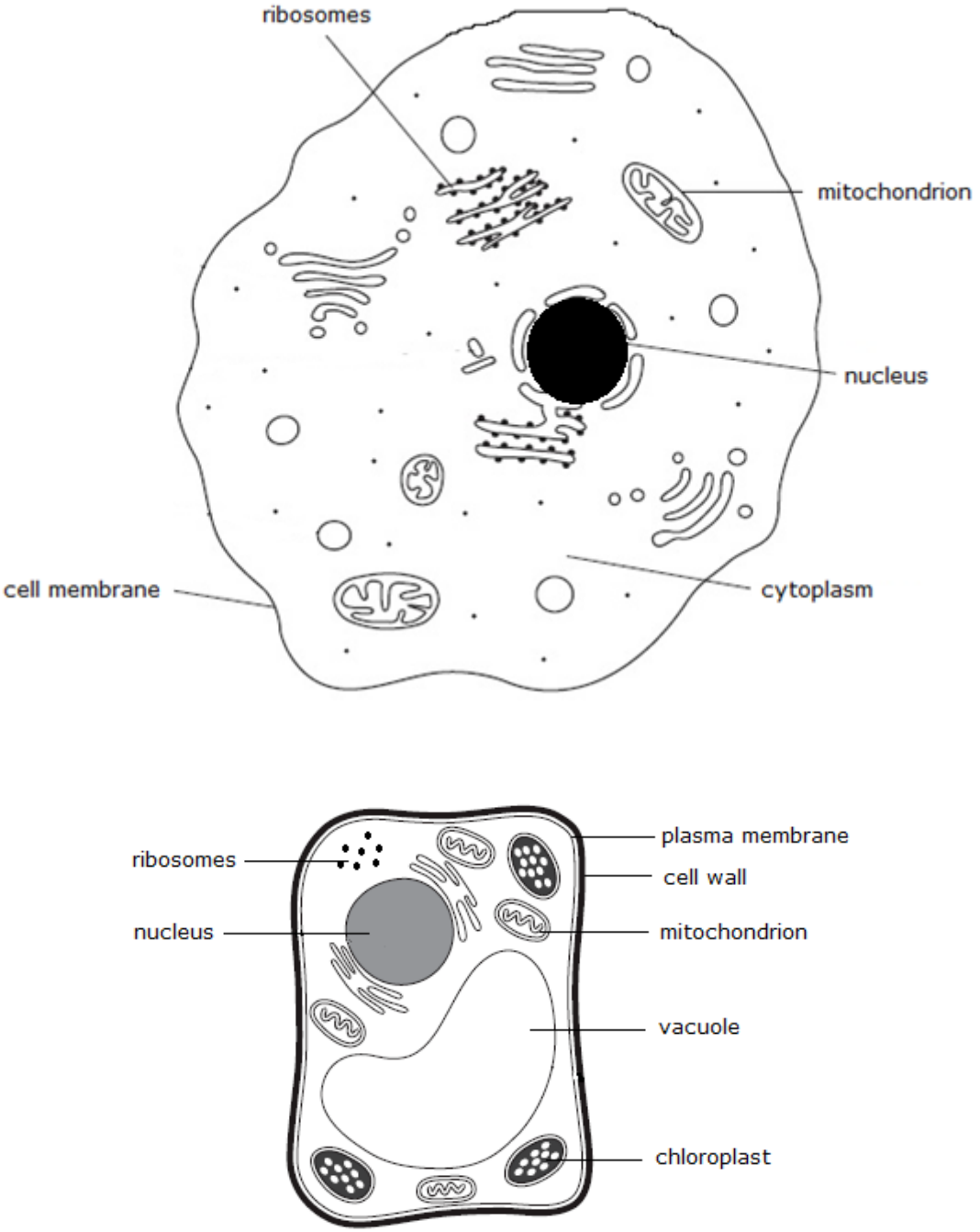

Figure 1. Structure of a generalised animal and plant cell

(a) Mitochondria

Students should appreciate the following features of mitochondria:

- their function is to carry out aerobic respiration and produce ATP
- they are found in eukaryotic cells (plant, animal, fungal and protoctist cells) but not in prokaryotic cells (bacteria)
- they have a characteristic, recognisable structure (see *Figure 2*).

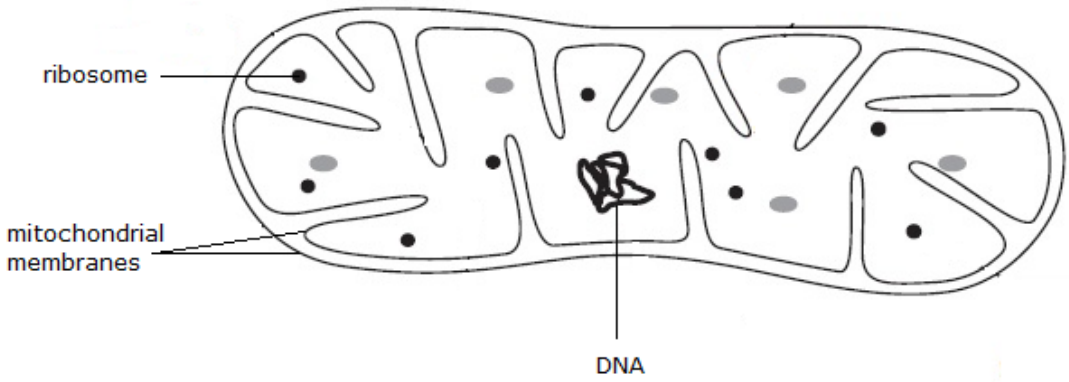

Figure 2. Structure of a mitochondrion

When studying mitochondria, the following aspects may be useful discussion points:

- cells that have many mitochondria have a high energy demand. Good examples are cells involved in active transport such as gut epithelium cells and proximal convoluted tubule cells, and active muscle cells. Students could be given diagrams of different cell types and could then consider the significance of the different mitochondrial numbers – this also helps students practice the sort of application questions that may feature in examination questions.
- an appreciation of the distinction between prokaryotic and eukaryotic is now included in the 2017 specification (statements 1.2 and 1.3). The absence of mitochondria (and other organelles) in prokaryotic cells should be discussed.

For extension work, students could consider the presence of DNA and ribosomes in mitochondria and their possible evolution from independent bacteria via endosymbiosis.

Students could also be encouraged to explore the fact that all mitochondria are inherited from the mother (egg cell) and none are from the father (sperm), and that maternal ancestry can be traced by sequencing the DNA. These topics are synoptic and encompass aspects of the variety of life and reproduction and inheritance sections of the specification.

Students may find this article about three-parented babies and mitochondrial disease of interest in discussion:

https://www.newscientist.com/article/2107219-exclusive-worlds-first-baby-born-with-new-3-parent-technique/

(b) Ribosomes

Students should appreciate the following features of ribosomes:

- they are very small organelles found in the cytoplasm of all organisms (a consideration of the different sizes of ribosomes in eukaryotes and prokaryotes is beyond International GCSE)
- their function is the synthesis of proteins from amino acids (translation).

When studying ribosomes, the following aspects are useful discussion points:

- cells that produce large quantities of protein, such as pancreatic cells (which make enzymes or insulin) have many ribosomes (and mitochondria for energy release)
- ribosomes play an important role in the process of translation (specification section **3.18B**).

Cell differentiation and stem cells

Students are now expected to understand the concept of cell differentiation, the nature of stem cells and potential uses of stem cells.

(a) Cell differentiation and the types of stem cell

Students should consider:

- the general term 'stem cell' refers to undifferentiated cells that can divide and produce specialised cells. Stem cells are able to divide to make more stem cells and produce cells of different types.
- the term 'cell differentiation' refers to the process by which cells become different, specialised cell types.

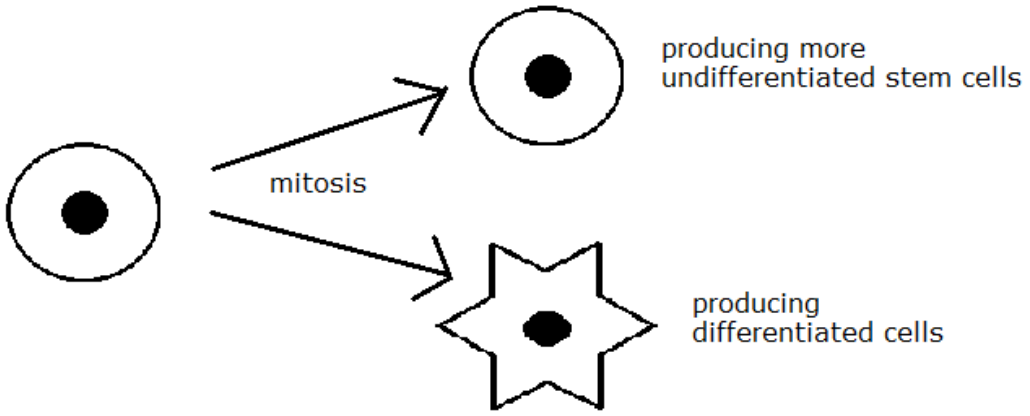

Figure 3. Stem cells can divide and produce both more stem cells and differentiated cells of different types.

After fertilisation, a zygote undergoes mitosis to produce an embryo. The cell number of the embryo doubles with each division (see *Figure 4*). Cells from an early embryo are considered to be early embryonic stem cells and are able to divide and produce any type of cell.

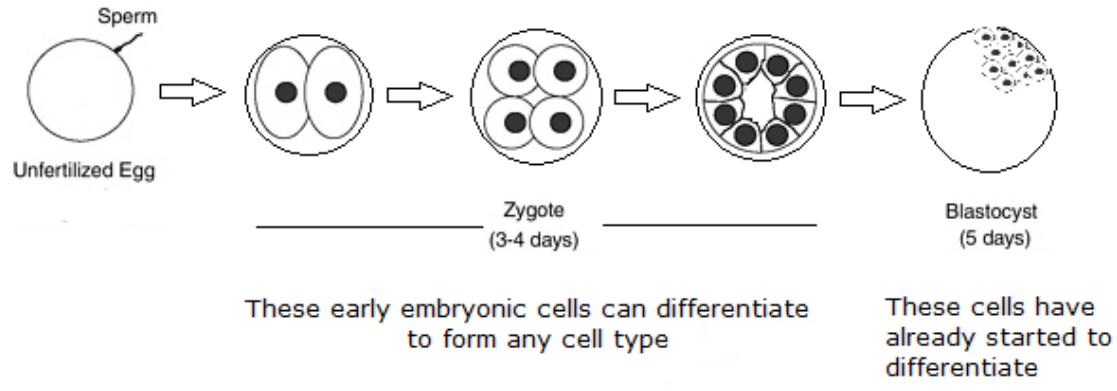

Figure 4. Diagram showing early mammalian embryonic development

Note the students are not expected to recall stages of embryonic development.

After several mitotic divisions, the cells of an early mammalian embryo undergo their first differentiation. This means that the cells have begun to follow separate paths to eventually form different cell types. The first differentiation in an early embryo splits the cells into those cells that will eventually form the fetus and those that will form placenta, umbilical cord and amniotic sac. These cells are still stem cells but have a reduced number of types of cell that they can produce.

As cells divide and continue to follow different pathways, they change more and more and eventually differentiate into their final cell type. This is usually irreversible and it is very difficult for cells to 'undifferentiate'. Many tissues contain adult stem cells – these are stem cells that can still divide and produce more cells, but of a limited number of cell types. For example, bone marrow contains adult stem cells that can produce several different blood cells such as red blood cells, phagocytes, platelets and lymphocytes but no other cell types (see *Figure 5*). Students would not be expected to recall this example, but it may be useful to illustrate your teaching.

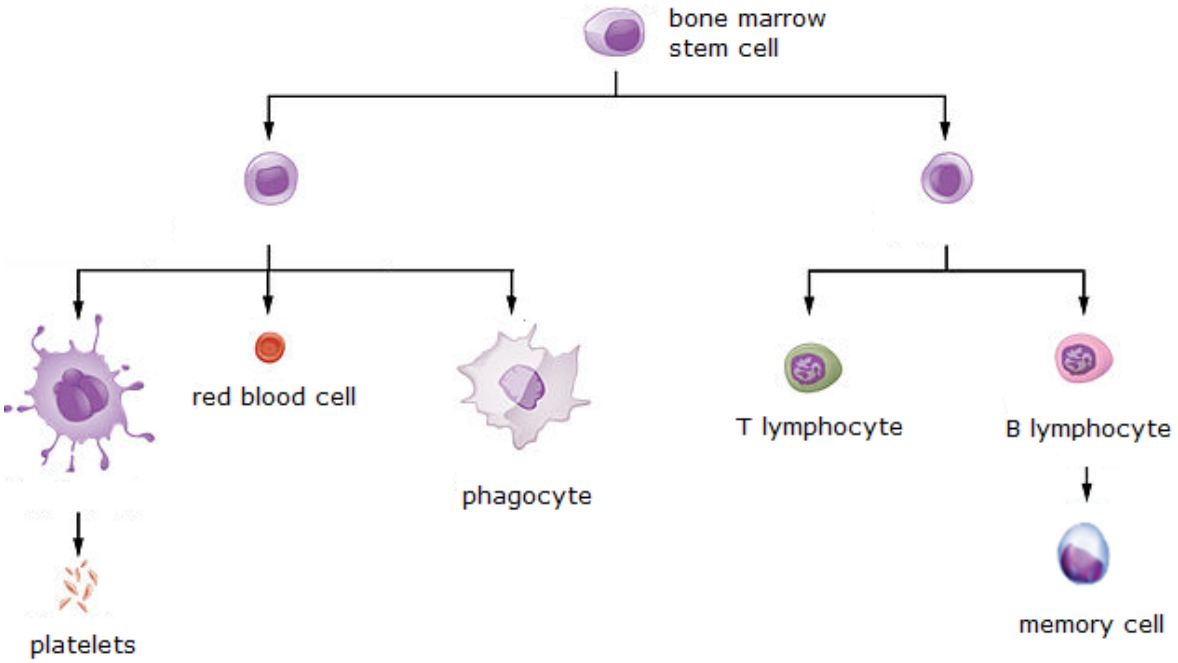

Figure 5. Cell differentiation of bone marrow cells to produce different blood cells

Plants also contain stem cells but unlike mammals, differentiated plant cells often have the ability to 'undifferentiate' and produce stem cells from which they can then make any tissue type. This feature is used when carrying out micropropagation.

Differentiated cells have specialised functions and so have particular features and adaptations. These are illustrated by cells such as egg cells, sperm cells, root hair cells, palisade cells, neurones and guard cells.

Suggested activities and teaching tips

- Students could investigate the adaptations of different types of cells. This could be carried out by using microscopes for cells such as palisade cells and plant epidermis cells, or by presenting them with a range of cell diagrams (for example sperm, egg, motor neurone, xylem vessels, guard cells).

- There are videos available on the internet showing the early development of mouse embryos and all the different stages of cleavage.

- A kinaesthetic approach, which may be suitable for students who find the topic more challenging, is to draw a fate map for different cells during development on the floor. Groups of students follow the paths taken and then make decisions to reach a final fate. Students cannot move backwards: this shows that cells cannot 'undifferentiate'. Dice can be used to select random cell directions.

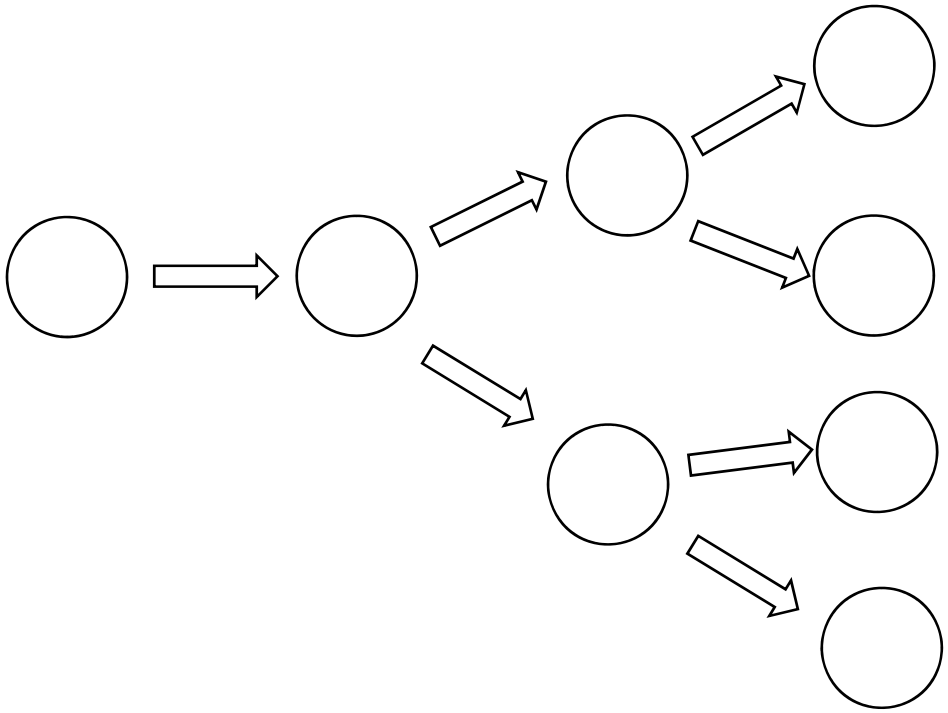

Figure 6. Diagram that can be drawn on floor.
Students follow the arrows forward but cannot go backwards.

- The concept of cell differentiation should be revisited when considering animal cloning and plant micropropagation. Cauliflower florets can be cloned by micropropagation using sterile nutrient agar, for example: http://www.saps.org.uk/secondary/teaching-resources/706-micropropagation-cloning-cauliflowers

- ESL candidates may need additional help with some of the names of different cell types encountered, for example, palisade cells and spongy mesophyll cells.

(b) Uses of stem cells

- Students are now expected to understand the advantages and disadvantages of using stem cells in medicine. No specific uses of stem cells are expected to be known but it is expected that students will be able to interpret data about stem cell uses and be aware of the general advantages and disadvantages of stem cells.

- Stem cells are cells that can divide and produce other cell types. They have the potential to be used to replace human tissues in patients that have lost those tissues. Potential therapies could include:
    - making nerve cells to repair broken spinal cords or damaged brain tissue
    - making heart cells to replace heart tissue damaged due to coronary heart disease
    - making new bone marrow cells to cure blood abnormalities
    - making cartilage tissue to repair worn joints
    - making new retinal cells to cure blindness
    - making pancreas cells that make insulin to cure diabetes

- There are three main sources of stem cell that could potentially be used as medical treatments. They all have different advantages and disadvantages. The three main sources are:
    (i) Embryonic stem cells (ES Cells)
    (ii) Adult / tissue stem cells
    (iii) Induced pluripotent stem cells (IPS cells)

  Note that only the first two of these – embryonic stem cells and adult stem cells – are likely to feature on examination questions.

(i) Embryonic stem (ES) cells

- These cells are extracted from very early embryos and are grown in laboratory incubators.
- Growth factor chemicals may be added to make the cells differentiate into the cell type that is required.
- The cells can be produced from spare human embryos that are produced for fertility treatment (IVF).
- The cells have the potential to turn into any type of cell.
- ES cells can also be produced by cloning (specification reference **5.19B**). An adult cell nucleus from a patient can be placed into an enucleated egg cell and mitosis started. The embryo that results from this can be used to harvest stem cells. The cells will have the same DNA as the patient in which they will be used.

Advantages

- ✓ ES cells can make any cell type.
- ✓ There are many spare embryos from IVF that would otherwise be allowed to perish. Using them for stem cells would mean that they have been used to improve other human lives.
- ✓ If cloned ES-cells are produced, they will have identical genes to the patient and so will not be rejected.

Disadvantages

- × Using ES cells raises ethical issues about 'killing' potential human lives.
- × If spare embryos from IVF are used, they will not be genetically identical to a patient and so could be rejected by the patient's immune system.
- × Human embryos are difficult to grow in culture and very fragile. This makes cloning inefficient.
- × To obtain human eggs and embryos, women need to donate eggs; there may be too few potential donors. (Recently, the use of enucleated animal eggs has been proposed to avoid this problem.)
- × It is difficult to make ES cells differentiate into the correct cell types. If they do not differentiate properly, they may form tumours and cancers in the body.

(ii) Adult / Tissue stem cells

- Adult stem cells are extracted from body tissues and grown in laboratory cultures.
- These cells are found in the bodies of children and adults.
- The cells can only differentiate into a limited number of different cell types. For example, bone marrow stem cells can only form blood cells.

Advantages

- ✓ These cells are easier to control as they are already partly differentiated. They are less likely to cause tumours.
- ✓ There are fewer ethical issues than when using ES cells as no embryos are killed.
- ✓ There are no concerns regarding a shortage of embryos or need for donors.
- ✓ If a patient's own cells are used, they will be genetically identical and not rejected by the patient.

Disadvantages

- × Not all cell types can be produced from adult stem cells. Nerve cells are very difficult to produce from adult stem cells making it difficult to create therapies for spinal cord and brain repair.
- × Adult stem cells can be difficult to extract.
- × Cells can age so adult stem cells taken from older people may not last long.

(iii) Induced pluripotent stem cells (IPS cells)

NB This section is included for completeness, but is unlikely to be assessed.

- Skin cells are grown in culture and reprogrammed into IPS cells by adding genes. Growth factors are added to make the IPS cells differentiate into different cell types.
- IPS cells have recently been developed by researchers.
- They are made by taking skin cells from a patient and genetically modifying them by adding genes to 'turn back the clock' and reprogram them. The IPS cells are grown in laboratory culture and then made to differentiate into the required cell types by adding chemical growth factors.

Advantages

- ✓ There are few ethical issues as embryos are not used.
- ✓ Many different cell types can be made.
- ✓ There are no concerns regarding a shortage of embryos or need for donors.
- ✓ If cloned ES-cells are produced, they will have identical genes to the patient and so will not be rejected.

Disadvantages

- × The success rate for producing them is low and they are still very much experimental.
- × By genetically modifying them they could form tumours and cancers.

Teaching tips

- The specification does not require students to know the exact differences between the different types of stem cell. However, as each type has different advantages and disadvantages, if students are familiar with both embryonic and adult stem cells, it will help their understanding.

- It is unlikely that there will be AO1 questions asking students, for example, to name a type of stem cell specifically; but they could be referred to in a comprehension or data analysis question that asks candidates to suggest reasons for using them (as part of an AO2 question).

- Students could produce a leaflet, booklet or newspaper article explaining what stem cells are, their potential uses and the issues raised by their use. The amount of guidance given to students can be altered depending on how challenging students find the topic.

- A good starting point is the websites of the Association of the British Pharmaceutical Industry: https://www.abpischools.org.uk/topic/stem-cells/1/1 and the Canadian Stem Cell Foundation: http://stemcellfoundation.ca/en

- ESL students and students who find the topic challenging may benefit from producing a glossary of terms.

- There are plenty of opportunities for extension work. Students could carry out a media survey to evaluate the latest research into stem cells – different topics could be given to different groups and then the groups could report their findings back to the class. Some care should be exercised with this as there are, unfortunately, many unregulated 'clinics' around the world offering cures by using stem cells which have no scientific validity.

- This topic can be revisited when studying the following parts of the Specification: **5.17B**, **5.18B**, **5.19B**, **5.20B**.

A note for teachers

Note that this Guide is intended to support teachers of International GCSE Biology and provides subject coverage beyond the demands of the specification.