Stem Cells
science and ethics

Introduction

The aim of Stem Cells: science and ethics is to provide a clear and up to date overview of the science of stem cells and the legal and ethical considerations of the subject. It has been written by scientists, lawyers and ethicists to ensure that the information contained in it is accurate and up to date.

The booklet has been written for use by senior school students in Scotland, England, Wales and Northern Ireland. It has three chapters, each with case studies, activities and details of other resources that relate to the chapter subject. Also in the text you will find question boxes to initiate discussion and reflection and a summary of the key messages at the end of each chapter. The booklet links particularly well with attainment targets on the Higher/Advanced Higher and AS/A Level Biology and Religious Studies syllabi (Religious, Moral and Philosophical Studies in Scotland). These links are shown in the tables attached to these teaching notes. Suggested below are several ways in which the booklet could be used in the classroom. We hope that it will provide you with support in the teaching of the science and ethics of stem cells and its many connections throughout the field of biology. Enjoy!

Electronic copies of the booklet can be downloaded free from **www.bbsrc.ac.uk/engagement/schools/keystage5/stem-cells/**

Ways to use *Stem Cells: science and ethics* in the classroom

1. **To support the AS/A Level and Higher and Advanced Higher Biology Curricula by providing:**
   - *Up to date and relevant reading material for topics.*
   - *A basis for discussion of topics.*
   - *A media resource to introduce or reinforce a topic.*
   - *Extra examples.*
   - *Images.*
   - *Group or individual activities.*

   The AS and A Level specifications in Biology aim to encourage students to appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society. A further aim of the AS and A Level specifications in Biology is to encourage students to appreciate **How Science Works**. As part of this, candidates are required to:
   - *Consider applications and implications of science and appreciate their associated benefits and risks.*
   - *Consider ethical issues in the treatment of humans, other organisms and the environment.*
   - *Appreciate the ways in which society uses science to inform decision making.*

   The Higher and Advanced Higher Biology syllabi state that the courses should provide opportunities for pupils to acquire: positive attitudes such as being open-minded and being willing to recognise alternative points of view; having an interest in biology, in themselves and their environment; being aware that they can make decisions which affect the well-being of themselves, others, and the quality of their environment.

   We especially hope the booklet will provide a resource to help teachers and students achieve these aims.

2. **To support the AS/A Level Religious Studies and Higher/Advanced Higher Religious, Moral and Philosophical Studies curricula by providing:**
   - *Up to date and relevant reading material for medical ethics topics.*
   - *A basis for discussion of the use of human embryos.*
   - *Extra examples.*
   - *Images.*
   - *Group or individual activities.*

3. **As an extension or enrichment resource:**
   - *For students requiring additional reading material.*
   - *As supplementary reading material during time gaps in practical sessions or when other work has been completed.*

4. **As the basis for a school science event.**

5. **As a starting point for specific advanced qualifications with an interdisciplinary element such as Extended Project Qualifications or the Scottish Science Baccalaureate.**

6. **For cross-curricular work.**

   For developing cross curricular work in line with, for example the Curriculum for Excellence in Scotland or the Science Diploma in England and Wales.
   For example:
   - *Modern studies and biology (global, legal and ethical considerations of stem cell research).*
   - *Religious and moral education and biology (moral decisions regarding medical issues).*
   - *Art and biology (use of images to initiate art work, or artwork to initiate biological discussion).*
   - *Philosophy and biology (philosophical approach to the issues surrounding stem cell research).*

7. **As career material.**

   The interviews with scientists could be used as a basis for discussion about career paths for those that study biology.

Further reading

The web pages listed below contain further reading and resources on the subjects covered in the booklet. They can also be found listed at the end of each chapter.

Science of stem cells

Web Address	Description
http://www.eurostemcell.org/films	The European Consortium for Stem Cell Research has made four films looking at different aspects of stem cell research. This website also provides information and activities on stem cell research in several languages.
http://stemcells.nih.gov	A website providing comprehensive information on basics of stem cells. It also provides enormous research resources covering scientific, social and ethical aspects of stem cell research.
http://www.explorestemcells.co.uk	A UK website about stem cells, highlighting some developments in stem cell research in the UK.
http://www.medicalnewstoday.com /sections/stem_cell/	Updates on stem cell research.
http://www.umich.edu/stemcell/	A series of online lessons provided by the University of Michigan about stem cell research.
[Reference/webpage no longer available – Feb 2016]	An online interactive game generated by the Centre of the Cell where the player has to decide how to repair the damaged cartilage of a patient called Ben.
[Reference/webpage no longer available – Feb 2016]	Interactive and visual introduction on the basics of stem cells.
[Reference/webpage no longer available – Feb 2016]	Video interviews about the stem cell scandal in South Korea.
www.bbsrc.ac.uk	Website for the Biotechnology and Biological Sciences Research Council.

Legal and global perspectives

Web Reference	Description
[Reference/webpage no longer available – Feb 2016]	An article (with various related links) from CNN featuring Barack Obama's view on stem cell research, providing an overall outlook of stem cell research in the USA in the coming few years.
[Reference/webpage no longer available – Feb 2016]	A fact sheet summarising laws governing stem cell research in the USA, EU and UK.
[Reference/webpage no longer available – Feb 2016]	Constantly updated news and guidance on recent UK policies on stem cell research and related ethical issues.
[Reference/webpage no longer available – Feb 2016]	Regularly updated information on world policies on stem cell research.
http://www.law.ed.ac.uk/ahrc	Website for SCRIPT, the University of Edinburgh law and technology research centre under the directorship of Professor Graeme Laurie.

Ethical issues

Web Reference	Description
[Reference/webpage no longer available – Feb 2016]	International forum for discussion of stem cells, also providing news about stem cell research.
http://www.topix.com/forum/tech/stem-cell-research	An open forum for discussions of stem cell research. Please note that as this is an open forum there can be some strongly polarised views represented.
http://www.beep.ac.uk	The Bioethics Education Project supports students in learning to discuss bioethical issues and teachers in planning lessons on them.
http://www.npr.org/templates/story/story.php?storyId=16493814	Radio interview on 'making embryonic stem cells without human embryos?'
http://www.wilsoncenter.org/index.cfm?topic_id=116811&fuseaction=topics.event_summary&event_id=161696	Video interviews regarding the controversy of stem cell research.

Further information

Stem cells: science and ethics was commissioned by the Biotechnology and Biological Sciences Research Council (BBSRC) from the Scottish Initiative for Biotechnology Education in collaboration with Edinethics Ltd and the Institute of Stem Cell Research, MRC Centre for Regenerative Medicine and the School of Law, all based at the University of Edinburgh. These notes and the accompanying curriculum links documents were produced for BBSRC in 2010.

The teachers' notes were written by Jan Barfoot and Cathy Southworth. Please contact us with any questions or feedback – we will be pleased to hear from you and are here to help!
Email: stemcellshelp@ed.ac.uk Telephone: 0131 650 7123

Curriculum Links - England

AQA AS/A Level Biology

Unit	AQA A Level Biology course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
BIOL2 The Variety of Living Organisms	**3.2.6 In complex multicellular organisms, cells are organised into tissues, tissues into organs and organs into systems.** Cell differentiation.	Chapter 1 p6 with reference to cell differentiation.
BIOL 5 Control in Cells and in Organisms	**3.5.7 Gene expression is controlled by a number of features.** Candidates should be able to: evaluate the use of stem cells in treating human disorders.	Most of Chapter 1 but especially: Chapter 1 p9 list of sources of human embryonic stem cells in the UK. Chapter 1 p13 summary comparison of embryonic stem cells and tissue stem cells and introduction to induced pluripotent stem cells. Chapter 1 research case studies on p8, p10, p12, p14 and p18. Chapter 1 p16-p17 with reference to proposed stem cell therapies. Chapter 1 p20 final comments relating to issues of hype and realistic expectations.

Edexcel AS/A Level Biology

Unit	Edexcel AS/A Level Biology course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
AS Unit 2: Development, Plants and the Environment	**Topic 3: The voice of the genome** 11 Explain what is meant by the terms stem cell, pluripotency and totipotency and discuss the way society uses scientific knowledge to make decisions about the use of stem cells in medical therapies (e.g. regulatory authorities relating to human embryo research, ability of stem cells to develop into specialised tissues, potential sources of stem cells, who could benefit from the therapies, procedures to obtain stem cells and their risks). 13 Explain how cells become specialised through differential gene expression, producing active mRNA leading to synthesis of proteins, which in turn control cell processes or determine cell structure in animals and plants (details of transcription factors are not required at AS).	Chapter 1 p5 the terms pluripotent and totipotent are described in the context of human development. Chapter 1 p7 definition of stem cells. Chapter 1 p9 sources of stem cells. Chapter 1 research case studies on p8, p10, p12, p14 and p18. Chapter 1 p13 summary comparison of embryonic stem cells and tissue stem cells and introduction to induced pluripotent stem cells. Chapter 1 p16-p17 with reference to proposed stem cell therapies. Chapter 1 p20 final comments relating to issues of hype and realistic expectations. Chapter 2 p28 with reference to what the law in the UK says about stem cell research. Chapter 2 p30 with reference to the commercialisation of stem cell therapies. Chapter 1 p6 with reference to genetic control of differentiation. See also the description of how induced pluripotent stem cells are made on p13.

Curriculum Links - England continued

OCR AS/A Level Biology

Unit	OCR AS/A Level Biology course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
F211: Cells, Exchange and Transport (AS)	**1.1.3 Cell division** In multicellular organisms, stem cells are modified to produce many different types of specialised cell. Understanding how stem cells can be modified has huge potential in medicine. (g) Define the term stem cell. (h) Define the term differentiation. (i) Describe and explain... how cells of multicellular organisms are specialised for particular functions.	Chapter 1 p7 with reference to why scientists carry out research on stem cells. Chapter 1 p7 stem cell definition. Chapter 1 p6 with reference to cell differentiation. Chapter 1 p6 this concept is introduced under the section on genetic control of cell differentiation.
F215 Control, Genomes and Environment	**5.2.1 Cloning in plants and animals** Farmers and growers exploit "natural" vegetative propagation in the production of uniform crops. Artificial clones of plants and animals can now be produced. a) Outline the differences between reproductive and non-reproductive cloning. (e) Describe how artificial clones of animals can be produced. (f) Discuss the advantages and disadvantages of cloning animals.	Not directly described in the booklet but several supporting bits of information when addressing these topics concerning cell differentiation, definitions of totipotent and pluripotent cells and somatic cell nuclear transfer.

AQA AS/A level Science in Society

Unit	AQA AS/A Level Science in Society course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
Ethical Issues in Medicine	**3.1.5 Ethical issues in medicine** The context: • Stem cells, potential therapies using stem cells and ethical issues surrounding the use of embryonic stem cells. • Cloning of animal cells and its use to produce embryonic stem cells for therapies. Reproductive cloning. • The legal and moral responsibility of scientists in the context of experiments on human and other animals and in stem cell research.	Chapter 1 p7 definition of stem cells. Chapter 1 research case studies on p8, p10, p12, p14 and p18. Chapter 1 p9 list of sources of human embryonic stem cells in the UK. Chapter 1 p13 summary comparison of embryonic stem cells and tissue stem cells and introduction to induced pluripotent stem cells. Chapter 1 p16-p17 with reference to proposed stem cell therapies. Chapter 2 p28-p29 with reference to what the law in the UK says about stem cell research and how this compares with other countries. Chapter 2 p30 with reference to the commercialisation of stem cell therapies. Chapter 3 p35 with reference to the status of the early human embryo. Chapter 3 p42 with reference to ethics and the scientists. The following activities will allow students to explore different viewpoints regarding stem cell research and consider the implications of the research: Chapter 1 p19 role play activity based on a proposed

Curriculum Links - England continued

AQA AS/A Level Religious Studies

Unit	AQA AS/A Level Religious Studies course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
Topic II Ways of Moral Decision-Making (Unit 4C)	**A. Medical research and medical developments** The use of embryos, human cells.	Chapter 1 p7 definition of stem cells. Chapter 1 research case studies on p8, p10, p12, p14 and p18. Chapter 1 p9 list of sources of human embryonic stem cells in the UK. Chapter 1 p13 summary comparison of embryonic stem cells and tissue stem cells and introduction to induced pluripotent stem cells. Chapter 1 p16-p17 with reference to proposed stem cell therapies. Chapter 2 p28-p29 with reference to what the law in the UK says about stem cell research and how this compares with other countries. Chapter 3 p35 with reference to the status of the early human embryo. The following activities will allow students to explore different viewpoints regarding stem cell research and consider the implications of the research: Chapter 1 p19 role play activity based on a proposed application for a clinical trial using stem cells. Chapter 3 p44 the ethical matrix activity gives students the opportunity to consider the ethical issues surrounding stem cells from differing perspectives.

Edexcel AS/A Level Religious Studies

Unit	Edexcel AS/A Level Religious Studies course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
AS Unit 2: Religious Studies - Investigations	**Area C: The study of ethics** **8. Medical ethics.**	Stem cell research would make an interesting investigation topic for students to examine from one or more ethical perspective.

OCR AS/A Level Religious Studies

Unit	OCR AS/A Level Religious Studies course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
G572 Religious Ethics	**Applied ethics** Genetic engineering. Candidates should be able to demonstrate knowledge and understanding of: • The ethical questions raised by... human embryo research.	Most of Chapter 3 but with specific reference to the status of the early human embryo on p35. The following activities will allow students to explore different viewpoints regarding stem cell research and consider the implications of the research: Chapter 1 p19 role play activity based on a proposed application for a clinical trial using stem cells. Chapter 3 p38 the task on this page (A stem cell story) using easily available films and discussion questions to explore both the science and the ethics of stem cells. Chapter 3 p44 the ethical matrix activity gives students the opportunity to consider the ethical issues surrounding stem cells from differing perspectives.

Curriculum Links - Northern Ireland

CCEA AS/A Level Biology

Unit	CCEA AS/A Level Biology course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
AS 1: Molecules and Cells	**1.8 Tissues and organs** 1.8.1 Appreciate the specialisation of cells in tissues and organs.	Chapter 1 p6 with reference to cell differentiation.
A2 1: Physiology and Ecosystems	**4.2 Immunity** 4.2.5 Understand the concept of transplant rejection.	Chapter 1 p11 with reference to immune rejections. See other comments on this topic on p10, p14 and p15.

CCEA AS/A Level Religious Studies

Unit	CCEA AS/A Level Religious Studies course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
AS 6: Religious Ethics: Foundations, Principals & Practice	**Theme: bio-ethics** Knowledge, understanding and critical evaluation of: • Sanctity of life, personhood. • Human infertility, new reproductive technologies.	Chapter 3 p35 with reference to the status of the early human embryo.

Curriculum Links - Scotland

SQA Higher Biology

Unit	SQA Higher Biology course specification	Relevant material in *Stem Cells: science and ethics* 3rd Edition
2: Cell Biology	**e) Cellular response in defence in animals and plants** ii. Cellular defence mechanisms in animals. Antibody production: The problem of tissue rejection and the use of suppressors in tissue transplantation.	Chapter 1 p11 with reference to immune rejections. See other comments on this topic on p10, p14 and p15.
3: Control & Regulation	**a) Control of growth and development** 2. Genetic control iii. The control of cell differentiation by switching particular genes on and off.	Chapter 1 p6 with reference to the genetic control of cell differentiation. See also the description of how induced pluripotent stem cells are made on p13.

SQA Higher Biotechnology

Unit	SQA Higher Biotechnology course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
2: Cell Biology	**e) Cellular response in defence in animals and plants** ii. Cellular defence mechanisms in animals. Antibody production: The problem of tissue rejection and the use of suppressors in tissue transplantation.	Chapter 1 p11 with reference to immune rejection. See other comments on this topic on p10, p14 and p15.
3: Biotechnology	**a) Biotechnological processing** 6. New breeding techniques: ii. Embryo cloning. iii. Somatic cell cloning. **b) Biotechnological applications** 2. Clinical and forensic medical applications iv. Stem cell culture.	Chapter 3 p39 the ethical considerations of using somatic cell nuclear replacement to produce stem cells are explored. Chapter 1 p11 with reference to the UK Stem Cell Bank, stem cell culture and the information box on using stem cells for drug discovery and toxicity testing.

SQA Higher Human Biology

Unit	SQA Higher Human Biology course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
1: Cell Function & Inheritance	**e) Cellular response in defence** ii. Production of antibodies and the role of blood cells. Learning Activity: Discuss the problems of tissue rejection and use of suppressors in transplantation	Chapter 1 p11 with reference to immune rejections. See other comments on this topic on p10, p14 and p15.
2: The Continuation of Life	**a) Reproduction** 2. Genetic control ii. Intervention in fertility. The control of cell differentiation by switching particular genes on and off. **b) Development** i. Intrauterine development.	Chapter 1 p6 with reference to the genetic control of differentiation. Chapter 1 p9 with reference to *in-vitro* fertilisation. Chapter 1 p5 with reference to human development and the task on visualising embryo development on p6.

Curriculum Links - Scotland continued

SQA Advanced Higher Biology

Unit	SQA Advanced Higher Biology course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
1: Cell and Molecular Biology	**a) Structure, function and growth of prokaryotic and eukaryotic cells** iii Differentiation of cells into tissues and organs. iv Cell and tissue culture -the ability of stem cells to differentiate, unlike specialised cells. Mammalian cell culture.	Chapter 1 p5 with reference to human development. Chapter 1 p6 with reference to cell differentiation. See also the description of how induced pluripotent stem cells are made on p13. Chapter 1 p6-p7 with reference cell differentiation and the definition of stem cells and p8-p14 with the descriptions of embryonic, tissue and induced pluripotent stem cells. Chapter 1 p9 with reference to the formation of stem cell lines.
Optional Unit:	**a) Exercise and the cardiovascular system** ii Pathology of cardiovascular disease **b) Exercise and metabolism** iv Diabetes mellitus.	Chapter 1 -p17 contains an example of how stem cells could be used to treat heart disease. Chapter 1 -p17 contains an example of how stem cells could be used to treat Diabetes mellitus.

SQA Higher Religious, Moral and Philosophical Studies

Unit	SQA Higher Religious, Moral and Philosophical Studies Course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
2: Morality in the Modern World	**4 Medical ethics** 1 Use of human embryos. **Knowledge and understanding**— Definition of the beginning of life, uses of embryos (stem cell research, genetic selection, IVF), UK Law, HFEA guidelines. **Analysis**— Religious and secular viewpoints on the issues. **Evaluation** — Comment on the strengths and weaknesses of viewpoints on the different uses of embryos; religious and moral implications for the individual and society.	Numerous places throughout the booklet but particularly: Chapter 1 p9 list of sources of human embryonic stem cells in the UK. Chapter 1 p13 summary comparison of embryonic stem cells and tissue stem cells and introduction to induced pluripotent stem cells. Chapter 1 research case studies on p8, p10, p12, p14 and p18. Chapter 1 p16-p17 with reference to proposed stem cell therapies. Chapter 2 p28 with reference to what the law says in the UK about the use of stem cells. Chapter 3 p35 with reference to the status of the early human embryo. The following activities will allow students to explore different viewpoints regarding stem cell research and consider the implications of the research: Chapter 1 p19 role play activity based on a proposed application for a clinical trial using stem cells. Chapter 3 p38 the task on this page (A stem cell story) using easily available films and discussion questions to explore both the science and the ethics of stem cells. Chapter 3 p44 the ethical matrix activity gives students the opportunity to consider the ethical issues surrounding stem cells from differing perspectives.

Curriculum Links - Scotland continued

SQA Advanced Higher Religious, Moral and Philosophical Studies

Unit	SQA Advanced Higher Religious, Moral and Philosophical Studies course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
3: Medical Ethics	**Beginning of life: the treatment and rights of embryos** Outcome 1 Embryonic stem cell research: legal and medical. Outcome 2 Embryonic stem cell research: religious and ethical viewpoints.	Numerous aspects of the booklet but particularly: Chapter 1 p9 list of sources of human embryonic stem cells in the UK. Chapter 1 p13 summary comparison of embryonic stem cells and tissue stem cells and introduction to induced pluripotent stem cells. Chapter 1 research case studies on p8, p10, p12, p14 and p18. Chapter 1 p16-p17 with reference to proposed stem cell therapies. Chapter 2 p28 with reference to what the law says in the UK about the use of stem cells. Chapter 2 p30 with reference to international considerations of stem cell research. Chapter 3 p35 with reference to the status of the early human embryo. The following activities will allow students to explore different viewpoints regarding stem cell research and consider the implications of the research: Chapter 1 p19 role play activity based on a proposed application for a clinical trial using stem cells. Chapter 2 p30 discussion and polling activity on the European law relating to patents. Chapter 3 p38 the task on this page (A stem cell story) using easily available films and discussion questions to explore both the science and the ethics of stem cells. Chapter 3 p44 the ethical matrix activity gives students the opportunity to consider the ethical issues surrounding stem cells from differing perspectives.

Curriculum Links - Wales

WJEC AS/A Level Biology

Unit	WJEC AS/A Level Biology course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
BY5 Environment, Genetics and Evolution	**5.2 Sexual reproduction in human** **5.6 Applications of reproduction and genetics** (e) Issues surrounding the use of stem cells for replacing damaged tissues and organs; IVF for aiding poor fertility.	Chapter 1 p5 with reference to human development. Chapter 1 p7 definition of stem cells. Chapter 1 research case studies on p8, p10, p12, p14 and p18. Chapter 1 p9 list of sources of human embryonic stem cells in the UK. Chapter 1 p9 inset box on *in-vitro* fertilisation. Chapter 1 p11 with reference to the issue of immune rejection. Chapter 1 p13 summary comparison of embryonic stem cells and tissue stem cells and introduction to induced pluripotent stem cells. Chapter 1 p16-p17 with reference to proposed stem cell therapies. Chapter 2 p28-p29 with reference to what the law in the UK says about stem cell research and how this compares with other countries. Chapter 3 p35 with reference to the status of the early human embryo.

WJEC AS/A Level Religious Studies

Unit	WJEC AS/A Level Religious Studies course specification	Relevant material in 'Stem Cells: science and ethics' 3rd Edition
RS3 ETH: Studies in Religion and Ethics (A2)	**4. Medical and genetic ethics** Issues raised by genetic manipulations including cloning and stem cell research.	The entire booklet is relevant but the following elements may be a useful starting point for background reading: Chapter 1 p7 definition of stem cells. Chapter 1 research case studies on p8, p10, p12, p14 and p18. Chapter 1 p9 list of sources of human embryonic stem cells in the UK. Chapter 1 p13 summary comparison of embryonic stem cells and tissue stem cells and introduction to induced pluripotent stem cells. Chapter 1 p16-p17 with reference to proposed stem cell therapies. Chapter 2 p28-p29 with reference to what the law in the UK says about stem cell research and how this compares with other countries. Chapter 2 p30 with reference to international considerations of stem cell research. Chapter 3 p35 with reference to the status of the early human embryo. The following activities will allow students to explore different viewpoints regarding stem cell research and consider the implications of the research: Chapter 1 p19 role play activity based on a proposed application for a clinical trial using stem cells. Chapter 3 p38 the task on this page (A stem cell story) using easily available films and discussion questions to explore both the science and the ethics of stem cells. Chapter 3 p44 the ethical matrix activity gives students the