UNIT 1: CELL BIOLOGY  TOPIC E: STEM CELLS & DIFFERENTIATION

Essential Idea(s)
- Stem cells are capable of dividing and differentiating along different pathways.

IB Assessment Statements and Class Objectives:

1.1 U4 Multicellular organisms have properties that emerge due to the interaction of their cellular components.
   - Define and give examples of emergent properties.

1.1 U5 Specialized tissues can develop by cell differentiation in multicellular organisms.
   - Define tissue.
   - Outline the benefits of cell specialization in a multicellular organism.
   - Define differentiation.

1.1 U6 Differentiation involves the expressions of some genes and not others in a cell
   - Describe the relationship between cell differentiation and gene expression.

1.1 U7 The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses.
   - Define zygote and embryo.
   - List 2 key properties of stem cells that have made them on the active areas of research in biology and medicine today.
   - Explain why stem cells are most prevalent in the early embryonic development of a multicellular organism.
   - Contrast the characteristics of embryonic, umbilical cord and adult somatic stem cells.
   - Define totipotent, multipotent and pluripotent.

1.1 A3 Use of stem cells to treat Stargardt’s disease and one other named condition.
   - Outline the cause and symptoms of Stargardt’s disease.
   - Explain how stem cells are used in the treatment of Stargardt’s disease.
   - Outline the cause and symptoms of leukemia.
   - Explain how stem cells are used in the treatment of leukemia.

1.1 A4 Ethics of the therapeutic use of stem cells from specially created embryos, from the umbilical cord blood of a newborn baby and from an adult’s own tissues
   - List the source and mechanism of obtaining stem cells.
   - Discuss the benefits and drawbacks in using embryonic, cord blood and adult stem cells.

1.1 NOS2 Ethical implications of research- research involving stems cells in growing in importance and raises ethical issues.
   - Explain why biological research must take ethical issues into consideration.

3.5 U5 Clones are groups of genetically identical organisms, derived from a single original parent cell.
   - Contrast sexual and asexual reproduction.
   - Define clone and cloning.

3.5 U7 Animals can be cloned at the embryo stage by breaking up the embryo into more than one group of cells.
   - Describe the process of reproductive cloning via embryo splitting.
   - Outline example of cloning animal embryos via natural and artificial embryo splitting.

3.5 U8 Methods have been developed for cloning adult animals using differentiated cells.
   - Describe the process of reproductive cloning via somatic cell nuclear transfer.

3.5 A4 Production of cloned embryos produced by somatic-cell nuclear transfer
   - Outline the production of Dolly the sheep using somatic cell nuclear transfer.

3.5 U6: Many plant species and some animal species have natural methods of cloning.
   - Describe 1 example of a plant species and 1 example of an animal species with natural methods of cloning.
UNIT 1: CELL BIOLOGY
TOpic E: STEM CELLS & DIFFERENTIATION

Emergent Properties

Definition of Emergent Property:

*a property that appears when parts come together to make a whole*

Example of Emergent Property:

In multicellular organisms, different cells have different structures and perform different functions. Humans have ~220 different specialized cell types. Cells specialize through a process called **DIFFERENTIATION**. A tissue is formed when a group of differentiated cells work together to perform the same function.

How does differentiation happen? In humans, every single SOMATIC CELL has the exact same ~25,000 genes, but in any given cell, less than ½ of the genes are ever EXPRESSED. The other genes are there in the cell, but are not being used.

What triggers gene expression? This is a hot area of research in biology right now! Currently, we know gene expression can be activated by the position of the cell, hormones, cell-to-cell signals, and environmental signals.
UNIT 1: CELL BIOLOGY

PART A: Basics of Human Embryology

Websites:
- These two videos give an overview of the early stages of human development.
- Click on the cell in the lower left corner of the diagram by the number 1. This will show you a picture of a fertilized egg. After that, click the next button above each diagram to advance through human development. You'll only need to proceed through Carnegie Stage 6.
  - http://www.visembryo.com/baby/
- Read through the two pages to familiarize yourself with the different types, or potencies of stem cells.
  - http://www.explorestemcells.co.uk/TotipotentStemCells.html

Questions:
1. Sketch the following stages of human development:

<table>
<thead>
<tr>
<th>Zygote</th>
<th>Morula</th>
<th>Blastocyst</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="egg+sperm_fused" alt="Zygote" /></td>
<td><img src="8" alt="Morula" /></td>
<td><img src="cells" alt="Blastocyst" /></td>
</tr>
</tbody>
</table>

2. What is the ICM and where is it found?
   inner cell mass → make entire animal (outer cells make placenta)

3. Draw and label a cross section of an embryo, depicting the three embryonic tissue layers.

   ![Embryo Cross Section](ectoderm mesoderm endoderm)

4. What organs develop from each of the following embryonic tissues?
   a. Ectoderm nervous system, skin (brain)
   b. Mesoderm muscle (kidneys, heart)
   c. Endoderm gut (lung, liver, intestine)

5. Explain these terms and describe when (and where) in human development they occur?
   a. Totipotent develop into any cell
   b. Pluripotent can specialize, but are limited
   c. Multipotent most limited, can become a couple types

Stop! Show your teacher your work before you continue to the next section!
PART B: Stem Cells and Differentiation:

Websites:
- This website uses animations to introduce stem cell biology and the differences between embryonic and somatic (adult) stem cells.
  - http://learn.genetics.utah.edu/content/stemcells/scintro/
- This 15-minute film provides an engaging, accessible and visually stunning introduction to the world of stem cell research.
  - http://www.eurostemcell.org/films#story
- View the animations to learn about differentiation and types of somatic stem cell niches.
  - http://learn.genetics.utah.edu/content/stemcells/sctypes/

Questions:

6. What is cell differentiation? How many differentiated cell types exist in the adult human body?

   specialization ➯ 200

7. What are the two essential characteristics of stem cells?

   not differentiated - can become anything capable of dividing + renewing a lot

8. How are somatic (adult) stem cells different from embryonic stem cells?

   differentiated a little, can only become certain types

9. Where are somatic stem cells found in the body?

   everywhere but sex: brain, blood, muscle, skin, teeth, heart, gut, liver

Stop! Show your teacher your work before you continue to the next section!

PART C: Medical and Research Applications of Stem Cells

Websites:
- Watch the first seven minutes to learn how specialized cells develop from stem cells.
  - http://www.eurostemcell.org/films#cell fate
- Read about use of somatic stem therapy to cure leukemia.
  - http://learn.genetics.utah.edu/content/stemcells/sctoday/
- These animations and text explain how stem cells can be used to cure disease.
    - http://learn.genetics.utah.edu/content/stemcells/scfuture/
- Watch the video and read the summary article describing Stargardt disease.
  - https://www.youtube.com/watch?v=0XCKvQ0Pxfo
    - http://www.blindness.org/stargardt-disease
- Read the abstract providing an overview of how stem cells have been used to treat Stargardt disease.
UNIT 1: CELL BIOLOGY

TOPIC E: STEM CELLS & DIFFERENTIATION

Questions:

10. What is regenerative medicine?
   
   uses stem cells to repair damaged tissues that can't heal themselves

11. Describe an example of how stem cells can be used in regenerative medicine.
   
   stem cells could grow new healthy tissue to replace damaged tissues

12. What are hematopoietic stem cells? What cell types are derived from hematopoietic stem cells?
   
   produce blood + immune cells

13. What is leukemia? How can hematopoietic stem cells be used in the treatment of leukemia?
   
   • cancer of white blood cells
   • cancerous stem cells are killed, new stem cells are used to build new white blood cells

14. The umbilical cord contains hematopoietic stem cells. Are these cells totipotent, pluripotent or multipotent?
   
   multipotent

15. Why might understanding stem cells improve our understanding and treatment of cancer?
   
   • cancer cells grow rapidly → could be uncontrolled stem cells
   • understanding stem cells = understanding cancer

16. What is the cause of Stargardt disease?
   
   death of photoreceptor cells in central portion of retina (macula)

17. How have stem cells been used to treat Stargardt disease?
   
   stem cells were transplanted on eyes; replaced cell death on retina

Stop! Show your teacher your work before you continue to the next section!
Cloning

Definition:

1. **genetically identical cells produced asexually**
2. **genetically identical individual from a single cell**
3. **replicas of a macromolecule**

- Reproductive cloning generates an animal that has the **same DNA** as another currently or previously existing animal.
  - Natural reproductive cloning occurs in **sexual** reproduction, when the embryo splits in two to produce identical **twins**.
  - Natural reproductive cloning of organisms also occurs when organisms reproduce without having sex (**asexual reproduction**).
    - Single cell organisms (Bacteria, amoeba)
    - Anemones and hydra
    - Stick bugs
    - Some lizards, snakes and frogs
    - Some plants
- Methods of Cloning
  - **Embryo splitting**
    - Artificially splitting a single embryo at a very early stage of development.
    - Because this is done at an early stage and there are usually less than eight cells you can only make a few clones.
  - **Somatic Cells Nuclear Transfer**
    - Genetic material (nucleus from embryonic, fetal, or adult cell) is removed and placed into an unfertilized egg, whose nucleus has been removed.
    - Has the potential to create the clone of an adult organism as well as many clones at once.
    - Can potentially be used to create stem cells for therapeutic applications.

**Somatic Cell Nuclear Transfer**