# Stem Cells and Cellular Differentiation

All multicellular organisms, including human beings, begin life as a single cell called a *zygote*— the fertilized egg—formed by the combination of a sperm cell and an egg cell.

The zygote undergoes a series of cell divisions to generate many cells.

As the cells of this early stage organism, now referred to as an *embryo*, continue to undergo cell division.

At this stage the daughter cells begin to show differences in their shapes, contents and functions, i.e. the cells transform or differentiate into ***specialized cells***. (Specialized cells from tissue and organs such as bone, heart , liver and skin.)

The process that produces specialized cells is called *cellular differentiation*.

**Cellular differentiation**: the process by which a cell becomes specialized to perform a specific task/function, i.e. the specialization of different cells for different functions.

Cellular differentiation is a result of the genetic information encoded in the cell's DNA, it is passed from the parent to the offspring in the eggs and sperm cells.

In animals, a cell that can differentiate into many different cell types is referred to as a ***stem cell***.

**stem cell**: an undifferentiated/immature, (unspecialized), cell that can divide to form specialized cells, (i.e. an unspecialized cell that may transform into a specialized cell ).

As the embryonic stem cells divide through the process of the cell cycle, i.e. mitosis and cytokinesis, each of the resulting daughter cells can develop into a different type of cell, depending on which parts of its DNA is 'switched on'; hence the embryonic stem cells will differentiate into a variety of cell types. (A possible reason: some of the chemical reactions controlling the genetic information are blocked.)0

(Note: a zygote is an embryonic stem cell because it is an embryo and also because it can differentiate into any type of cell.)

Stem cells start to clump together to form particular tissue layers, e.g. epithelial tissue, muscle tissue or nerve tissue.
These tissue stem cells can only differentiate into certain types of cells, e.g. only the epithelial tissue forming the base layer of skin can only differentiate into different types of skin cells, not nerve or blood cells.

<u>There are two types of stem cells</u>:

1. **Embryonic stem cell**: these come from an embryo in the earliest stage of cell division— less than a week old, i.e. these are the cells that multiply during fetal development. Embryonic stem cell are found in the blastocyst* stage of early development, the cells have not specialized at this stage. They have the potential to become any kind of cell.

2. **Tissue stem cells**: exist within specialized tissue and can only differentiate into certain types of cells, e.g. tissue stem cells found in bone marrow can differentiate into red blood cells, white blood cells, or platelets, (thus success of bone marrow transplants). (Tissue stem cells are often referred to as 'Adult Stem Cells'.

blastocyst*: at about five days after fertilization, an early embryo is called a blastocyst.

[Stem cells are also present in adult humans in bone marrow, skin, spinal cord and the brain. However, stem cells in adults are difficult to isolate and collect because they make up only one out of every 10 000 cells.]

Under laboratory conditions, embryonic stem cells are able to keep dividing for a year or even longer, without ever differentiating.

Embryonic stem cell are sometimes called '**source**' or '**starter**' cells, because they can become any of the ~ 300 different types of human body tissue.

The significance of harvesting embryonic stem cells, which can specialize into any type of cell, have the potential to re-grow, and replace any damaged or diseased cells, tissues, or organs so they can be placed inside the body.

Scientists obtain embryonic stem cells from eggs fertilized in vitro (outside the womb), sometimes from unused embryos from fertility clinics.

<u>Stem Cell Research</u>

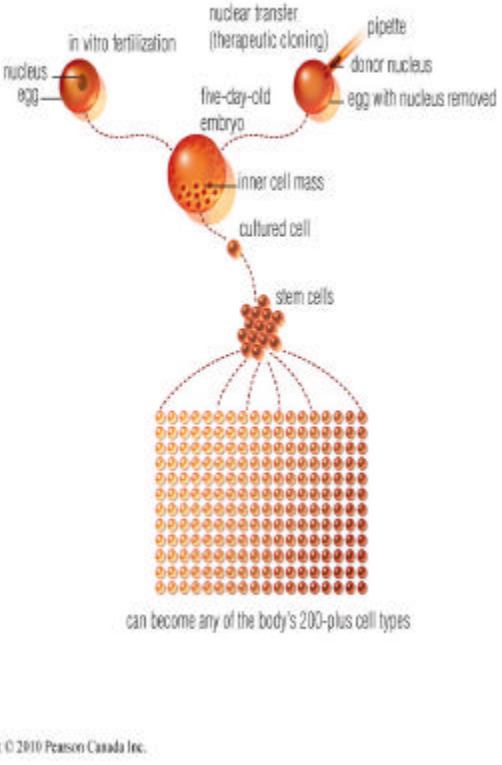




**Figure 1.41** Most stem cells used for research are taken from embryos created by in vitro fertilization. The process occurs when the egg is fertilized under laboratory conditions. Scientists are also working on getting cells from embryos produced by therapeutic cloning, in which the nucleus of a skin cell, for example, is inserted into an egg whose nucleus has been removed. Either way, after five days scientists transfer the embryo's inner cell mass — with its 40 or so stem cells — to a lab dish where the cells can reproduce. After many months, the original stem cells have grown into millions of healthy cells without beginning to differentiate into specialized cells.

Using stem cells to produce tissue for transplantation may also result in complications, the body can reject tissues grown from donated stem cells.
The problem of tissue rejection may be overcome by a process called cloning. Cloning produces cells that are genetically identical to the cells of the recipient, and thus are not rejected by the recipient's immune system.

Therapeutic cloning: the production of cloned embryos for the purpose of obtaining stem cells.

Reproductive cloning: the production of fully formed cloned organisms.

Cord Blood Cell Banking

The blood found in the umbilical cord is a rich source of stem cells.

These are not embryonic stem cell, they are similar to tissue stem cells because they can only differentiate into various kinds of blood cells, and not any type of cell.

They have the potential to develop into any kinds of blood cells.
This collected blood can thus be "banked" for possible future use by the child or its siblings.

## Tissue Stem Cell Transplantation

The blood found in the umbilical cord, being a rich source of stem blood cells is used together with bone marrow stem cells to treat diseases such as leukemia— cancer of the bone marrow.

Bone marrow is a tissue that creates cells that are involved in the body's defence against pathogens.

In a bone marrow transplant, diseased white blood cells are removed and existing bone marrow cells must be killed.

A donor supplies new healthy bone marrow cells that are injected into the patient's bloodstream.
The transplanted cells are taken up in the bone marrow and begin to produce healthy, cancer-free, new blood cells.

## Regeneration and Tissue Engineering

Regeneration refers to the ability of a tissue to repair itself.
(note: not all cells can regenerate: nerve, brain)

Regeneration allows some animals to replace damaged or diseased body parts.
Some animals, e.g. starfish, salamanders, some specie of gecko, and flatworms can regenerate lost limbs and large portions of the body.

(Humans are capable of regenerating liver tissue and fingertips.)

**Tissue Engineering**: field of research to discover ways to regenerate human body tissues and parts that do not normally regenerate.

## Assignment

1. a. The single cell in which all multicellular organism start as a single cell is called a(n) _____.

   b. A cell that can differentiate into many different cell types in an animal is called a ___ ___ .

   c. The term that describes the ability of a mammal's tissues to repair themselves is _____.

   d. The infection-fighting cells found in blood are _____ _____ _____.

2. a. What is the difference between embryonic stem cells and tissue stem cells?

   b. Briefly describe how tissue stem cells can be used to cure a disease.

3. a. What does the term 'regeneration' mean?

   b. Can humans regenerate? Explain.

4. Where do all of the different cells in our bodies come from? (Use terms such as: stem cell, specialized tissue, differentiate, organ, adult.)

5. Analyze why bone marrow transplants are sometimes effective in treating people who have cancer that affects blood cells.

6. Predict why stem cells might be useful in helping a spinal cord injury heal in the future. (Recall: Nerve cells do not naturally regenerate completely.)

7. Explain what is meant by the term "cellular differentiation".

8. a. What is a stem cell?
   b. How may stem cells be used to help humans?

9. a. If skin cells contain all of the genetic information to be nerve cells, why don't skin cells act like nerve cells?
   b. How are stem cells unlike skin cells and nerve cells?

10. Describe the process of a bone marrow transplant to treat leukemia.