L.15 Cellular differentiation Dr.Kawthar Khalaf

Learning Objectives

- Discuss how the generalized cells of a developing embryo or the stem cells of an adult organism become differentiated into specialized cells
- Distinguish between the categories of stem cells
- Explain the types of cell death

How does a complex organism such as a human develop from a single cell—a fertilized egg—into the vast array of cell types such as nerve cells, muscle cells, and epithelial cells that characterize the adult? Throughout development and adulthood, the process of cellular differentiation leads cells to assume their final morphology and physiology.

Differentiation: Is the process by which unspecialized cells become specialized to carry out distinct functions.

Stem cells and development

What are stem cells?

A **stem cell**: Is an unspecialized cell that can divide without limit as needed and can, under specific conditions, differentiate into specialized cells. Stem cells are divided into several categories according to their potential to differentiate.

One of the most important questions in biology is how all of the specialized, differentiated cell types in the body are formed from just a single cell.

The first embryonic cells that arise from the division of the zygote are described as **totipotent** because they have the possible to differentiate into any of the cells needed to enable an organism to grow and develop (figure 1).

The embryonic cells that develop from totipotent stem cells and are precursors to the fundamental tissue layers of the embryo are classified as pluripotent.

Pluripotent cells can give rise to all of the cell types that make up the body from any of the three germ layers , example : embryonic stem cells are considered pluripotent.

Multipotent cells can develop into more than one cell type, but are more limited than pluripotent cells; adult stem cells and cord blood stem cells are considered multipotent.

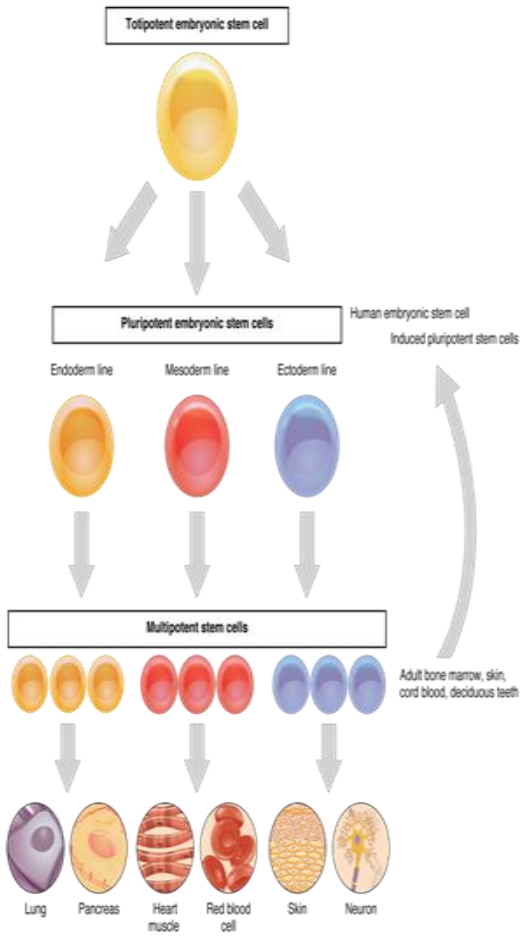
Oligopotent cells, are similar to the multipotent stem cells, but they become further restricted in their capacity to differentiate **,**an excellent example of this cell type is the hematopoietic stem cell (HSC).

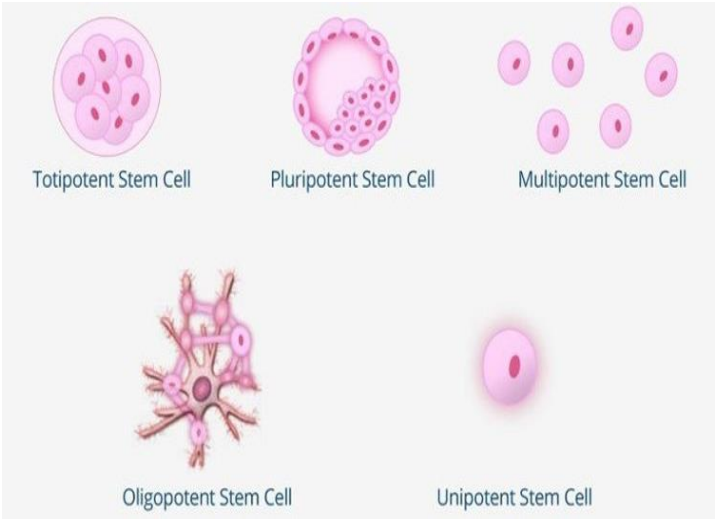
In contrast, a **unipotent stem cell**, is a fully specialized and can only reproduce to generate more of its own specific cell. An example of this stem cell type are muscle stem cells.

Stem cells are unique in that they can also continually divide and regenerate new stem cells instead of further specializing. There are different stem cells present at different stages of a human's life. They include the embryonic stem cells of the embryo, fetal stem cells of the fetus, and adult stem cells in the adult.

One type of adult stem cell is the epithelial stem cell, which gives rise to the keratinocytes in the multiple layers of epithelial cells in the epidermis of skin. Adult bone marrow has three distinct types of stem cells:

1- **Hematopoietic stem cells**, which give rise to red blood cells, white blood cells, and platelets
2- **Endothelial stem cells**, which give rise to the endothelial cell types that line blood and lymph vessels.
3- **Mesenchymal stem cells**, which give rise to the different types of muscle cells, cartilage, bone, tendon, ligaments and even nerve cells





Cell death

There are two types:

1- **Apoptosis**
2- **Necrosis**

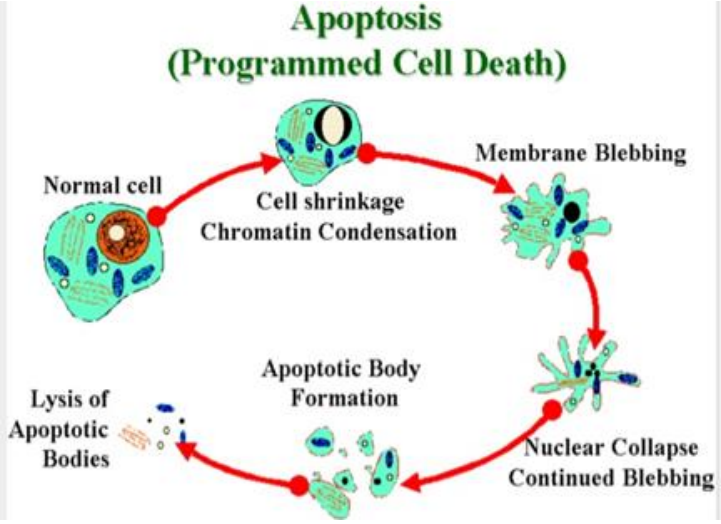
Apoptosis (programmed cell death):

Is genetically programmed cell death which leads to organized break down and elimination of the cells, is generally triggered by normal, healthy processes in the body. It happens at the end of G1 in cell cycle

It is a very orderly process during which the genome of the cell is broken down, the cell is fragmented into smaller pieces and the debris is phagocytes that clean up the cell fragments

Morphologically, apoptosis is characterized by

1- Shrinkage of nuclear and cell volumes: Small dark-stained (pyknotic) nuclei can sometimes be identified with light microscope.
2- Chromatin condensation and fragmentation of DNA by activation of endonuclease enzymes that are cleaved DNA between nucleosomes into small fragments.
3- Changes in the cell membrane by formation of small blebs known as apoptotic bodies.
4- Formation of phagocytic cells recognize apoptotic bodies and remove them by phagocytosis without inflammatory phenomena.

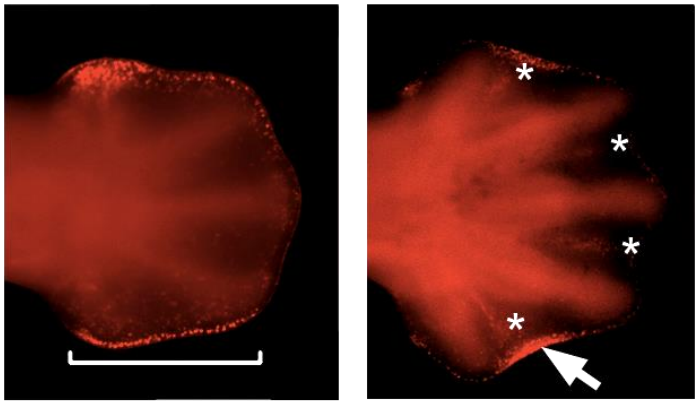


Why do cells undergo apoptosis?

1-Sculpting organs from overgrown tissue in the fetus (some cells need to be "deleted" during development – for instance, to shave an complicated structure like a hand out of a larger block of tissue.

2- Removes webbing between fingers in fetus.

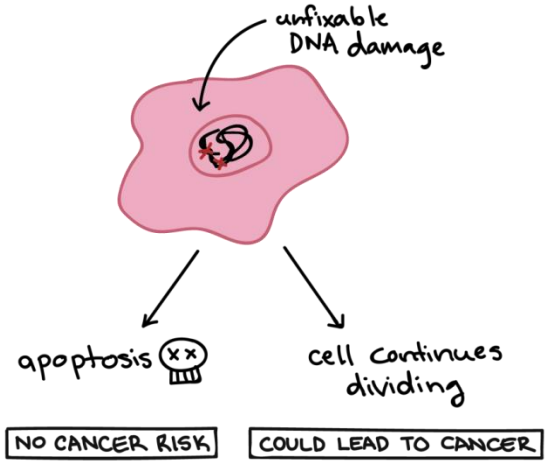
Red dots show cells undergoing apoptosis



Developing mouse paw, embryonic day 12.5

Developing mouse paw, embryonic day 13.5

3-Some cells are abnormal and could hurt the rest of the organism if they survive, such as cells with viral infections , DNA damage or cancer cell.



4-In human body, cells were produced every second by mitosis there is a similar number die by apoptosis. Cells in an adult organism may be eliminated to maintain balance – to make way for new cells or remove cells needed only for temporary tasks.

Necrosis:

Cells die accidentally due to external or internal factors:

1- Mechanical trauma (ex. a poisonous spider bite),

2-Lack of nutrients (ex. lack of blood supply may due to disrupt blood supply to associated tissue).

3- Thermal effects (extremely high or low temperature) can result in necrosis due to the disruption of cells.)

Necrosis begins with cell swelling, the chromatin gets digested, the plasma and organelle membranes are disrupted, the ER vacuolizes, the organelles break down completely and finally the cell lyses, discharging its intracellular content and stimulating an immune response (inflammation).