Course code: BIO205

Course Title: Introductory Molecular Biology

Content: Cell differentiation

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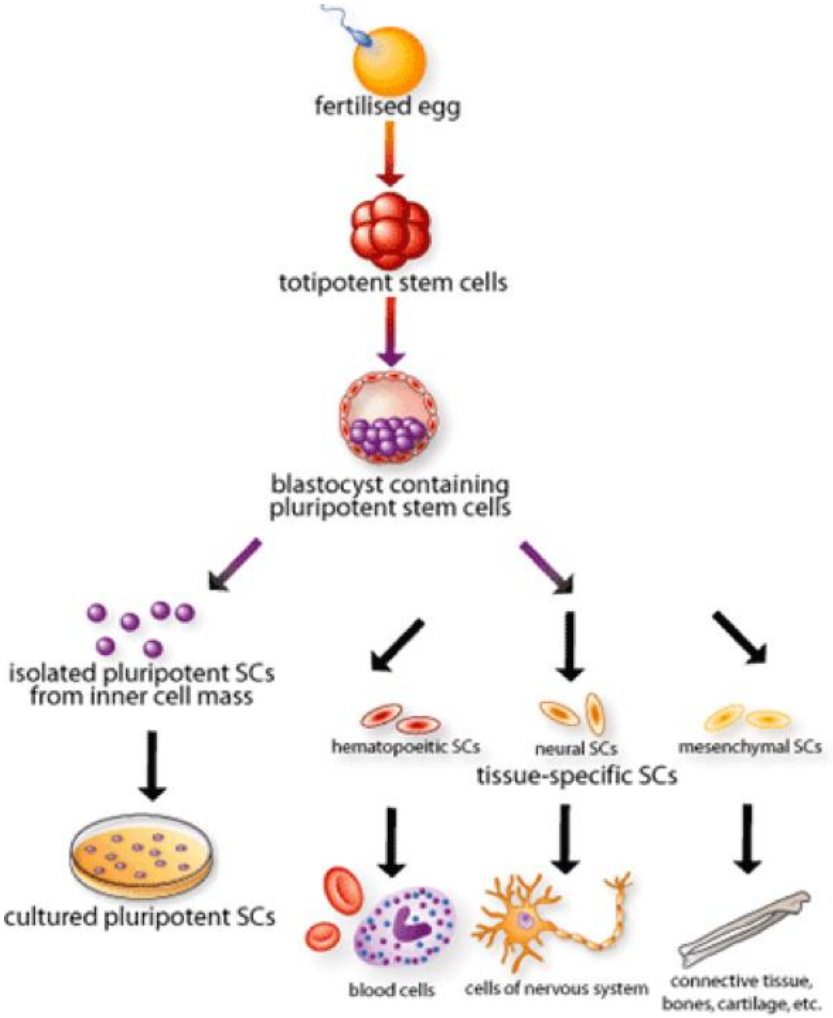
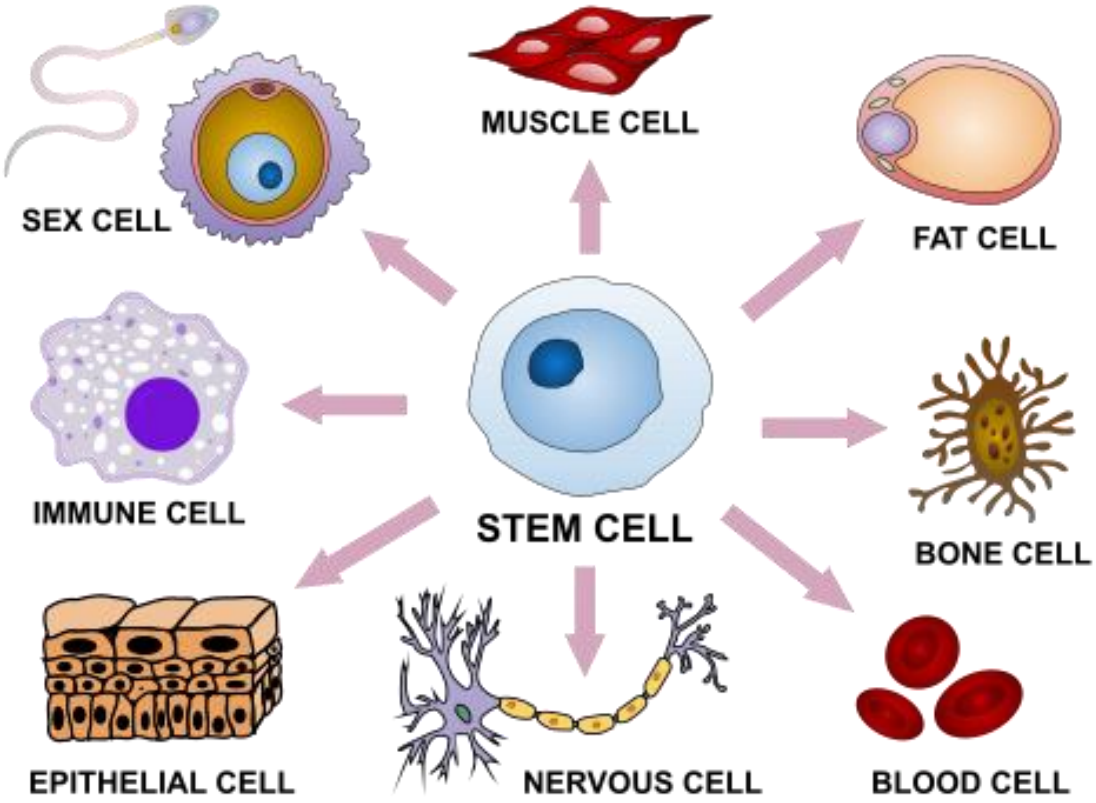
Cell differentiation

Cell differentiation is a biological process wherein cells develop from one cell type to another with specialised functions.

- The fundamental differentiation of a cell takes place when a sperm cell fertilizes an egg and the hence formed zygote arrives at a specific size.
- The zygote transforms various forms of cells requiring differentiated cells to undertake specialized roles.
- In human development, a fertilized egg undergoes differentiation into other types of specialized cells present in the body such as muscle, neurons.
- Undifferentiated cells are known as **stem cells**. These stem cells are located in the embryos and in adults.


fertilised egg
totipotent stem cells
blastocyst containing
pluripotent stem cells
isolated pluripotent SCs
from inner cell mass
cultured pluripotent SCs
hematopoeitic SCs
neural SCs
mesenchymal SCs
tissue-specific SCs
blood cells
cells of nervous system
connective tissue,
bones, cartilage, etc.



Factors influencing cell differentiation

Cell differentiation is primarily influenced by:

i. **Gene structure**

- Gene structure is the prime factor for cell differentiation.
- Every viable gene possesses crucial instructions which decide the cell type and physical traits of the host.
- Any mistake here will influence the cell differentiation process and host-development.

ii. **Environmental conditions**

- Temperature, oxygen supply, availability of certain nutrients and many other environmental factors have an impact on the working of hormones because of the different proteins dedicated to transforming information and stimulation of hormones.

- Any impact on these molecules will affect the cell differentiation and development process.
- In Siamese cats, cells that develop at cooler temperatures produce dark hair colour. Hence, coat coloring is determined by their genetics and the temperature of their surroundings.

iii. **Cytoplasmic content**

- Cytoplasmic contents make cells more likely to specialize for certain functions.
- For instance, cells that use a lot of energy need more mitochondria and vacuoles.

iv. **Types of cell division**

- The kind of cell division also affects cell differentiation.
- For instance, **mitosis** produces identical nucleus/DNA whereas **cytokinesis** does not.

v. **Activities of neighbouring cells**

- Substances produced by one cell can diffuse across cell membrane.
- This may affect coding and expression of genetic information, hence cell function.

There are few instances leading to cell differentiation:

- Regular turnover of cells (blood cells in mature entities)
- Immature entity growing into an adult
- Damaged tissues undergoing repair when special cells are to be substituted
- Influence of cytoplasm
- Interaction between cells
- Hormones

Differentiated animal and plant cells tend to preserve all the genes necessary for programming the differentiation and development of a complex entity. Differentiated cells, in addition, possess a variety of proteins. Hence, cell differentiation can be ascribed to the pattern of gene expression which is to say that in each differentiating cell type, different genes are differently expressed.

Mechanism of cell differentiation

- Multicellular organisms begin as undifferentiated masses of cells.
- Variation in gene activity and DNA expression determine the differentiation cells and ultimately, their specialization.
- Only specific parts of the DNA containing transcription factors which are are key to the cell differentiation process are activated.
- The activated parts determine the structure and function of a cell.
- Transcription factors are key to the cell differentiation process.
- The chemicals and hormones involved determine the course of action revolving around the DNA, deciding the transcription.
- The body and cells in the proximity decide the factors found in cells right from the fetal developmental stage to death. Both the DNA constituted in a cell and the location of expression of DNA is pivotal.
- The transcription factor has a direct influence on the proteins transcribing the DNA transforming it gradually to operating proteins and other cells. But, cells signal each other when they start to compress together indicating the action can no longer proceed.

Examples of Cell Differentiation

Examples in Plants

Although there is an involvement from various hormones, plants too emerge from one cell. Comparing the eggs in animals to seeds in plants, seeds harbours and nourishes its zygote just like the egg in animal cells. Cell division causes the zygote to divide, turning into an embryo. In the event of seed getting dispersed, stages of further development are ceased.

The embryo then forms into meristems, a specialized stem cell segment which differentiates outwards where one grows away and one towards the surface.

Root cap is formed in roots girdling meristems, which sheds when roots emerge through the soil, constantly replaced by meristems. Meristems are different on the surface creating both outward and inward cells. While the inward cells undergo similar differentiation as that seen in the root producing more vascular tissues, cells on the outside differentiate to leaves and stems. This can be compared to various organs in animals, where initial cells are not the same.

Examples in Animals

Process of fertilization in animals produces zygote which is totipotent (Totipotent cells are those cells that can be differentiated into any other cell type). All the complex tissues found in advanced animals arise from the zygote. In entities, cell differentiation commences early on.

Errors in cell differentiation

Abnormalities in cell differentiation can be categorized into three classes – anaplasia, dysplasia, and metaplasia.

Anaplasia

Anaplasia is the loss of apparent differentiation which can take place in advanced stages of cancer. Early stages of cancer appear to mimic the tissue from which they originated and are organized by their differentiation pattern. With development further, variants of more irregular features are generated along with expanding malignancy. Ultimately, a highly anaplastic growth takes place where the cancerous cells have no association visibly to the parent tissue.

Dysplasia

Dysplasia is the cell arrangement typically emerging from distress in their regular growth pattern. While few are precursor lesions to cancer, some others are innocuous and relapse immediately. For instance CIN (cervical intraepithelial neoplasia).

Metaplasia

In metaplasia one cell type is converted into another. Typically, it occurs when chronic damage to the tissue is succeeded by extensive regeneration. For instance, squamous metaplasia of the bronchi.

Stem Cell

Stem cells are specialized cells that can undergo self-renewal and differentiate into mature somatic cells in vitro and in vivo. They are found in embryos typically referred to as embryonic stem cells which can either be pluripotent or totipotent. Adult cells too are stem cells and are multipotent.

Types of stem cells

i. **Totipotent cells**

- Totipotent cells are found in early embryonic development.
- They can become any kind of cells in the body.
- They can differentiate to any embryonic or extraembryonic cell.
- Totipotent cells are stem cells which can differentiate into every cell type in the body.
- They can produce all adult cell types.
- Totipotent cells can enter germ line and they possess proven ability to self-replicate.
- Totipotency represents the cell with the greatest differentiation potential.
- Examples are **zygotes** or **spores**.
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ii. **Pluripotent cells**

- Pluripotent cells are the stem cells which can be differentiated into most, but not all the cell types.
- They are less versatile.
- In human, pluripotent cells are found in the **blastocysts**.

iii. **Multipotent cells**

- Multipotent cells are formed late in embryo development.
- They are the stem cells found in adults.
- They can differentiate into specific types of cells.
- Examples are the **skin** stem cells, adipose tissue, cardiac cells, bone marrow.

Summarily, adult cells are **multipotent**, while embryonic stem cells can either be **pluripotent** or **totipotent**.

Is cell differentiation reversible?

The undifferentiated adult stem cells lead to the formation of specialized cells which can be differentiated. Such adult stem cells are found in large numbers in humans in their bone marrow, brain and skin.

Latest studies suggest that adult skin cells can be caused to reverse the process of differentiation and infer the many features of embryonic cells. Such results are known as iPS or induced pluripotent stem cells, which is the area of future interest in this stream.