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**Core Course IV**

**Developmental Biology**

**UNIT II**

**Syllabus:**

Cellular Differentiation – Cyto - differentiation – Chemo differentiation.

Stem cells- totipotency and pleuripotency

Embryonic stem cells and their applications.

Cleavage- Patterns of cleavage- radial, spiral and bilateral;

Types – Meroblastic, holoblastic and superficial, factors affecting cleavage

Blastulation – Types of blastula - Fate maps

Presumptive organ forming areas in Frog

Presumptive organ forming areas in Chick

Morphogenetic movements and Gastrulation in Frog

Morphogenetic movements and Gastrulation in Chick

**Cellular Differentiation**

**Synopsis:**

A. What is a cell ?

B. What is differentiation?

C. Definitions by different authors

D. Four types of differentiation

1. Morphological differentiation
2. Physiological differentiation
3. Chemo-differentiation
4. Cyto-differentiation

E. Processes involved during differentiation

1. Qualitatively different egg-cytoplasm

2. Blastomeres

3. Cleavage – nuclei

4. Influence of cytoplasm on Nucleus

5. mRNA synthesis

F. Factors causing differentiation

1. Induction

2.Competence

3. Determination

4. Tissue interaction

5. Cytoplasmic factors

6. Nuclear factors

a. Expression of genes:

4 steps in the expression of genes

1. Regulation of Replication

2. Replication of Transcription

a. Hamoglobins in Hmans

b. Puffs in chromosomes

3. Regulation of the Processing Level

4. Regulation of Translation

G. Dedifferentiation

H. Metaplasia

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**A. What is a cell?**

Cell is the structural and functional unit of an organism

**B. What is differentiation?**

The progressive specialization in structure and function of a cell or an organ is called **differentiation.**

**Spiegel Man (1948**) defined differentiation as “the production of unique enzymatic patterns”

**Balinsky (1970)** defined differentiation as “the production of unique protein patterns”

The process of formation of distinct adult cell types from a common progenitor cell type is called **differentiation**

**C. Four types of differentiation**

1. Morphological differentiation
2. Physiological differentiation
3. Chemo-differentiation

4. Cyto-differentiation

**1. Morphological differentiation**

- refers to the development of a definite shape and form for a structure

Ex: A nerve cell is provided with a long process called Axon

Ciliated cells are provided with cilia

Muscle cells are provided with myofibrils, etc.,

2**. Physiological differentiation**

- the early embryonic cells are more or less alike. As the development proceeds, the cells attain a special ability to do a particular function. This is called Physoilogical or functional differentiation

**Ex: Nerve cells are specialized to conduct impulses**

**3. Chemodifferentiation**

- chemodifferentiation or chemical differentiation consists of changes in the chemical composition of a cell or organ. It brings about morphological and physiological differentiation. Chemical changes are invisible. But they are under the direct control of genes

**4. Cyto differentiation**

- the process by which cells gradually specialize to undergo changes in shape and function is called cytodifferentiation

**D. Processes involved during differentiation**

The differentitation of a cell is brought about by the following events:

1**. Qualitatively different Egg-cytoplasm:**

i. The process of differentiation starts from the egg stage itself

i. The egg-cytoplasm has different areas but are qualitatively different

iii. Hence, the egg cytoplasm is not homogenous but heterogenous

**2. Blastomeres**

i. When the egg divides during cleavage, the different cytoplasmic materials are given to different blasomeres.

ii. Thus the cytoplasm of different blastomeres is qualitatively different

**3. Cleavage-nuclei**

1. During cleavage, the egg-nuclei divides into many daughter nuclei.

II. Each cleavage nucleus has the ability to develop into a complete embryo

III. This means that the cleavage nuclei are **totipotent and equipotent**

**E. Factors causing Differentiation**

Differentiation is brought about by a number of factors. They are

1**. Induction**

- The influence of one structure in the formation of another structure is called **induction**

- The structure exerting the influence is caloled inductor

- this kind of tissue –interaction brings about differentiation

- Ex: 1. The ectoderm develops into the neural tube under the influence of chordomesoderm

2. Somites develop into cartilages under the influence of notochord

3 The lens develop by the induction of optic vesicle

**2. Competence**

- It is the ability of a part of an early embryo to develop in a particular direction under a particular stimulus

- the ectoderm is competent to develop into the eural tube under the influence of chordomesoderm

- the endoderm and the mesoderm have no ability to develop into the neural tube

**3. Determination**

The process of restriction imposed upon a group of cells in an embryo for the cells to develop into a particular organ is called **determination**

Ex” During development, the cells or tissues acquire the capacity for self-determination

**4. Tissue Interactions**

During development the neighbouring tissues interact to produce differentiation

4.a. Ex: Interation between ectoderm and mesoderm

- the limb bud is formed of mesoderm and apical ecodermal ridge which are responsible for the development of a normal limb

- if the apical ectodermal ridge is removed from the limb –bud, the remaining mesenchyme cells cannot develop into normal limb

-if the apical ectodermal ridge is transplanted to an abnormal place above the mesoderm, the the ectodermal ridge induces the underlying mesoderm to develop in to a normal limb

-This experiment proves that limb-differentiation is brought about by the interaction between the ectoderm and the mesoderm

**5. Cytoplasmic factors**

The differentiation of early embryonic cells is mainly due to the influence of cytoplasm on the nucleus.

**Ex: 1. Amhibian oocytes**

In frogs, the nuclei of brain cells synthesize RNA. When the brain nucleus is transplanted to mature oocytes, RNA synthesis in the brain nucleus is stopped. But DNA synthesis is initiated. It clearly shows that cytoplasmic factors influence the nucleus to undergo differentiation

E**x: 2 Heterokaryon**

Heterokaryon is hybrid cell formed by the fusion of two types of cells. Chicken erythrocyte with a He La cell (He La = a human carcinoma cell derived from the uterus of a patent named Henrietta Lacks).

When it is fused with He La cell, it resusmes RNA synthesis and DNA replication. This clearly explains that the synthesis of macromolecules in a nucleus is controlled by the cytoplasmic environment

**6. Nuclear factors**

* Differentiated cell contains the full set of genes required for normal development.
* The genome remains constant throughout cell-differentiation.
* During differentiation different cells synthesize different varieties of proteins.
* The proteins are synthesized under the direct control of genes (DNA)If cell synthesizes a particular protein that means the cell differentiates in a particular direction.
* Thus differentiation is brought about by variable rates of gene expression or differential gene expression

There are four main steps in the expression of genes. They are

1. **Regulation of Replication**
2. **Regulation of Transcription**
3. **Regulation of the Processing level and**
4. **Regulation of Translation**

Differentiation is brought about by the regulation and modification of one or more of these steps

**DNA Replication DNA Transcription HnRNA Processing**

**mRNA Translation Protein**

A. **Regulation of Replication**

* Replication is the duplication of DNA.
* Replication is a process by which DNA duplicates itself to produce another copy of itself
* Differential gene expression is achieved by gene amplification
* **Gene amplification:** Certain genes are selectively duplicated to produce millions of copies of these genes. This is called gene amplification

B. **Regulation of Transcription**

* Synthesis of mRNA by DNA is called Transcription
* The regulation of the expression of gen is mainly done at transcription

**Ex**: Hybridization experiments shows that production of specialized proteins is due to differential gene transcription

* The genes active in one cell may be inactive in other types of cells. Different sets of genes are active in different types of cells (Davidson, 1976)
* Among the active genes certain sets of genes are common for all cell types. These are called **house-keeping genes**. Which are required for the survival of cells. They do the same function in all types of cells. These include genes coding for membrane –proteins, glycolytic enzymes, ribosomal proteins, mitochondrial proteins and so on
* The remaining sets of active genes are different in the different cell types. These genes are called **luxury genes**.

I. **Haemoglobins in Humans**

The haemoglobin in adult humans is composed of four polypeptide chains. Two chains are similar and are called alpha chains; the other two chains are similar and are called bet **chains. Each type of chain s is produced by a separate gene**

**II. Puffs in chromosomes**

In Dipteran flies, the cells of salivary glands, malphighian tubules, rectum, midgut, etc., contain a special kind of chromosome called **Polytene chromosome** i.e., many stranded chromosome. These chromosomes contain a series of enlargements called **puffs or Balbiani** **rings.** The puffs are the places of chromosomes that are involved in mRNA transcription

It shows that the different pattern reflects a difference in protein synthesis in the various tissues

**III. Regulation of the processing Level**

Some of the RNA synthesized in the nucleus are destroyed without leaving the nucleus. All the genes in a cell are transcribed into RNA at all times

**Iv. Regulation of Tanslation**

Translation is the assembling of amino acids into proteins.

Ex: In sea urchin egg, fertilization is followed by a tremendous increase in protein synthesis; but in the unfertilized egg, there is no protein synthesis.

The mRNA remains masked or inactivated y a protein.

During fertilization the masking proteins is destroyed by a proteolytic enzyme poured into the egg by the spermatozoa.

As a result the mRNA is unmasked or activated and hence protein synthesis begins. Thus it is a very good evidence to show regulation at the translation level

**F. Dedifferentiation**

The reversal of differentiation is called **dedifferentiation**. During dedifferentiation, the differentiated cells lose their specialized structures and attain the property of embryonic cells.

Dedifferentiation is a common phenomenon in regeneration and in the development of cancer. During dedifferentiation the following changes occur:

i. The intercellular structures are destroyed

The normal arrangement of cells in the tissue is altered

The specific organ is like myofibrils, cilia,etc., disappear

Protein synthesis decreases

The cells develop the property of embryonic cells

**G. Metaplasia**

When a differentiated cell undergoes dedifferentiation and the redifferentiation into another differentiated cell, it is called **metaplasia**

During metaplasia the cell undergoes mitosis. When the lens of an anuran amphibian is removed, the iris undergoes dedifferentiation. **The dedifferentiated iris is redifferentiated into a lens. This is a case of metaplasia**

**H.Transdifferentiation**

It is process where one type of cell may give rise to another differentiated type of cell directly without any intervening mitosis.

Ex: In Hydar during regeneration, endoderm cells are transformed into ectoderm cells by **transdifferentiation.**

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