NUCLEO-CYTOPLASMIC INTERACTIONS.

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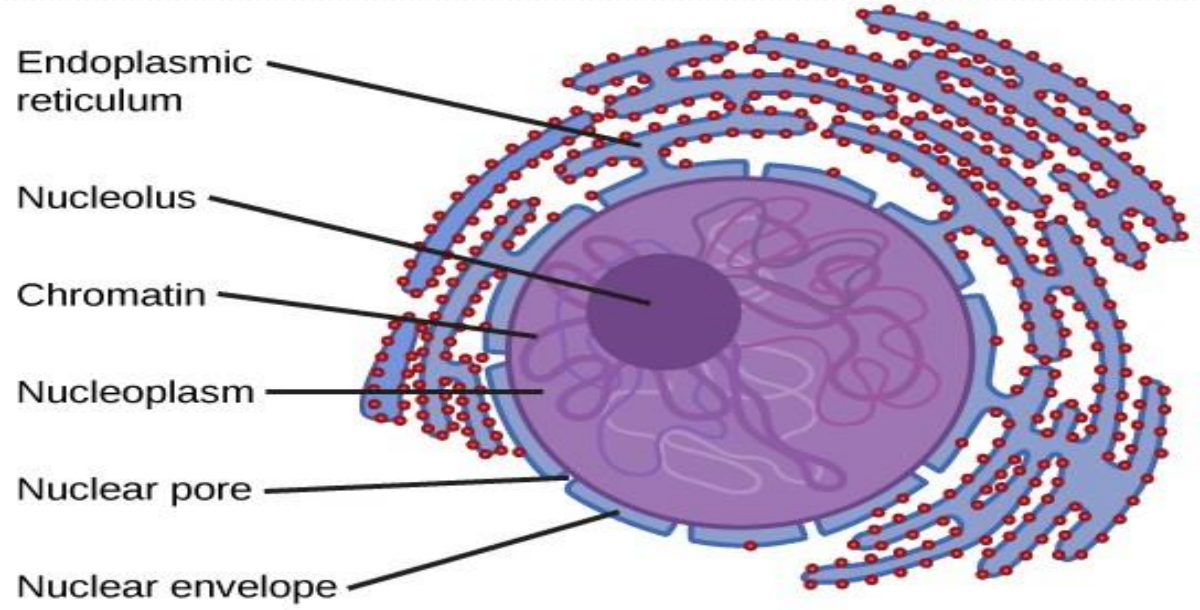
INTRODUCTION :

- Nucleus is the most important part of the cell situated in the cell cytoplasm. All the cellular activities are controlled by it. Nucleus is a directing and organizing unit without which the cell could not exist.
- It was discovered by **Robert Brown** in 1831 in the plant cells.



- The **nucleus** and **cytoplasm** are **interdependent** and one **can not survive** without the other.

- The **cytoplasm** provides most of the energy for the cell through oxidative phosphorylation and anaerobic glycolysis.

- The **cytoplasmic ribosome** contain most of the machinery for protein synthesis.

- The **nucleus** provides templates for specific synthesis(mRNA) and also supplies the other important RNA molecules(rRNA and tRNA).

- Thus, there exist a balanced dynamic relationship between nucleus and cytoplasm during **cleavage**, **gastrulation**, **histogenesis** and **cellular differentiation**.

- At the level of interaction between nuclear and cytoplasmic compartments, the cytoplasmic state has been shown to affect nuclear behaviour in cell functions.

- And different cytoplasmic or nuclear physiological state are implicated which are transmissible to their progeny.

- According to **Grant**(1978), the informational state of the cytoplasm or nucleus at any instant is an expression of spatial and temporal ordering of metabolic systems, that is the cells structural information.
- **Metabolic states are defined operationally by**

1) removal of nucleus or cytoplasm to see the effects of its absence on cell survival
2) transfer of nuclei from one cytoplasmic state to another to see nuclear behaviour changes in response to cytoplasmic signals and
3) fusion of cells in different states to form a hybrid.

- The discussion of nucleo-cytoplasmic interrelation therefore includes

i. the mechanisms by which the genes contained in the chromosomes exert their control on the metabolic processes of the cytoplasm and

ii. the mechanisms by which the cytoplasm influence gene activity.

Experiments showing interdependence and interactions .

1. **CONTROL OF NUCLEUS OVER CYTOPLASM** :

a) **Protozoa** : It was first noticed by **Balibini** in merotomy experiments in which protozoa were enucleated and studied. Such enucleated fragments are able to sustain most cellular activities. And they can form a cellulose membrane and carry on photosynthesis, react to stimuli and ingest food, activate cilia etc .

- However, these enucleated cells generally survive only a short time(within 5-10 minutes) and are incapable of growth and reproduction.

- As observed in ***Amoeba proteus*** that after the removal of cell nucleus, its movement has been slowed down and it can no longer digest foods.

- When a nucleus is transferred from one Amoeba to another of same species(homotransfer) activation of cytoplasm division and mass culture may occur.

- And when a nucleus of another species is implanted(hetero -transfer), the cytoplasm is activated but cell division occurs less readily(Loneh and Danielli,1960).
- These experiments have shown that the cytoplasm of a cell can not survive alone and that its activities are on same manner initiated and regulated by the nucleus.

b)Nucleo-cytoplasmic relationships in *Acetabularia* :

- J.Hammerling in 1934 demonstrated that the nucleus controls the functions of the cells and ultimately the characters of the individuals by conducting experiments on ***Acetabularia***, a unicellular marine alga.
- ***Acetabularia*** has a stem between 3 to 5 cm long and a cap 1cm in diameter.
- The nucleus is located in the basal or rhizoid end of the cell.

- In ***Acetabularia***, nucleus can be removed simply by cutting off rhizoid. And resulting enucleated cells are active in photosynthesis and can survive for many weeks.
- Each ***Acetabularia*** species has a particular cap morphology.
- If a nucleus from ***Acetabularia crenulata*** is implanted into an enucleated ***Acetabularia mediterranea*** from which the cap has also been removed, the resulting cell will eventually develop a cap of the ***A. crenulata*** type.(intermediate)

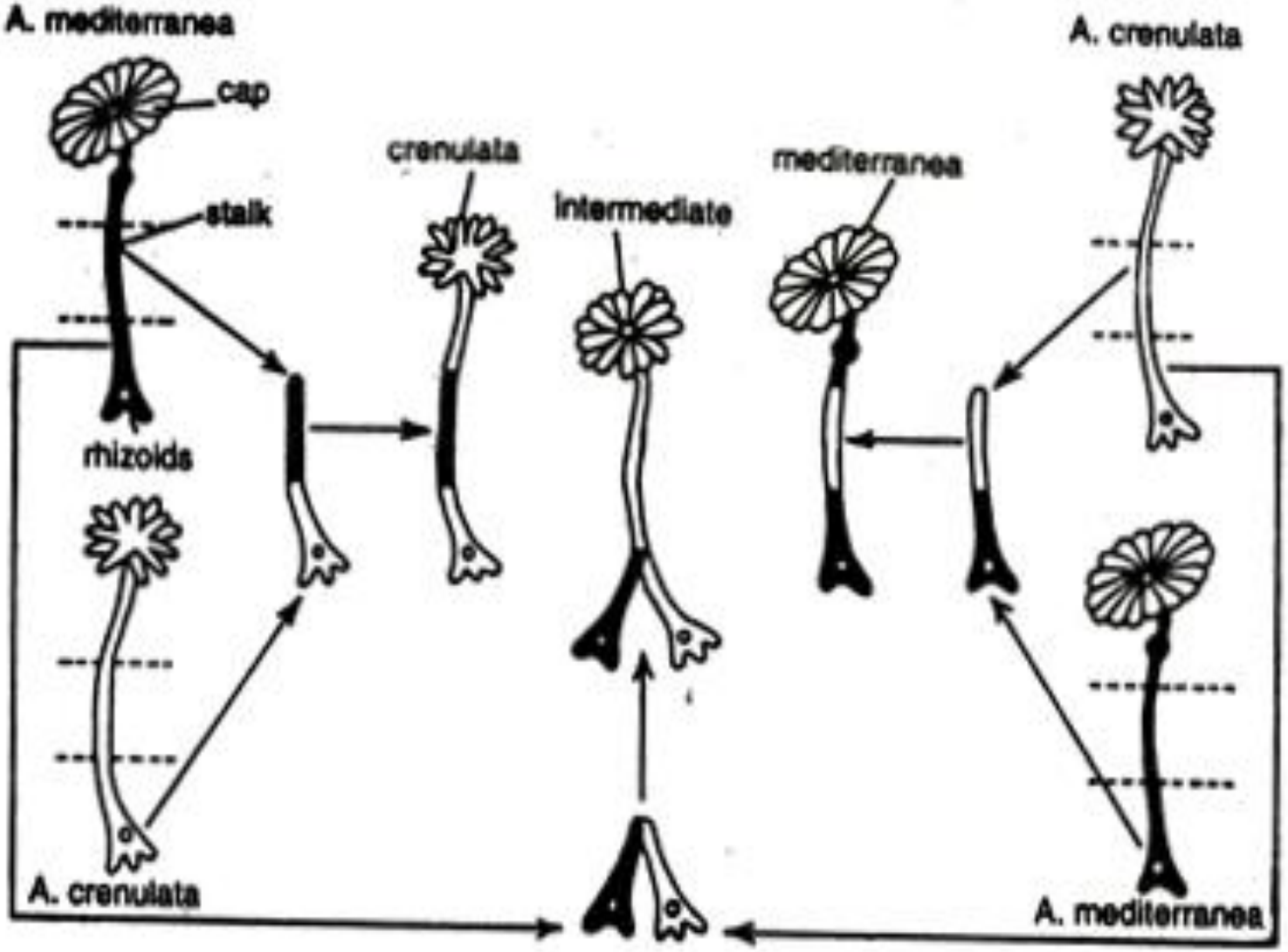
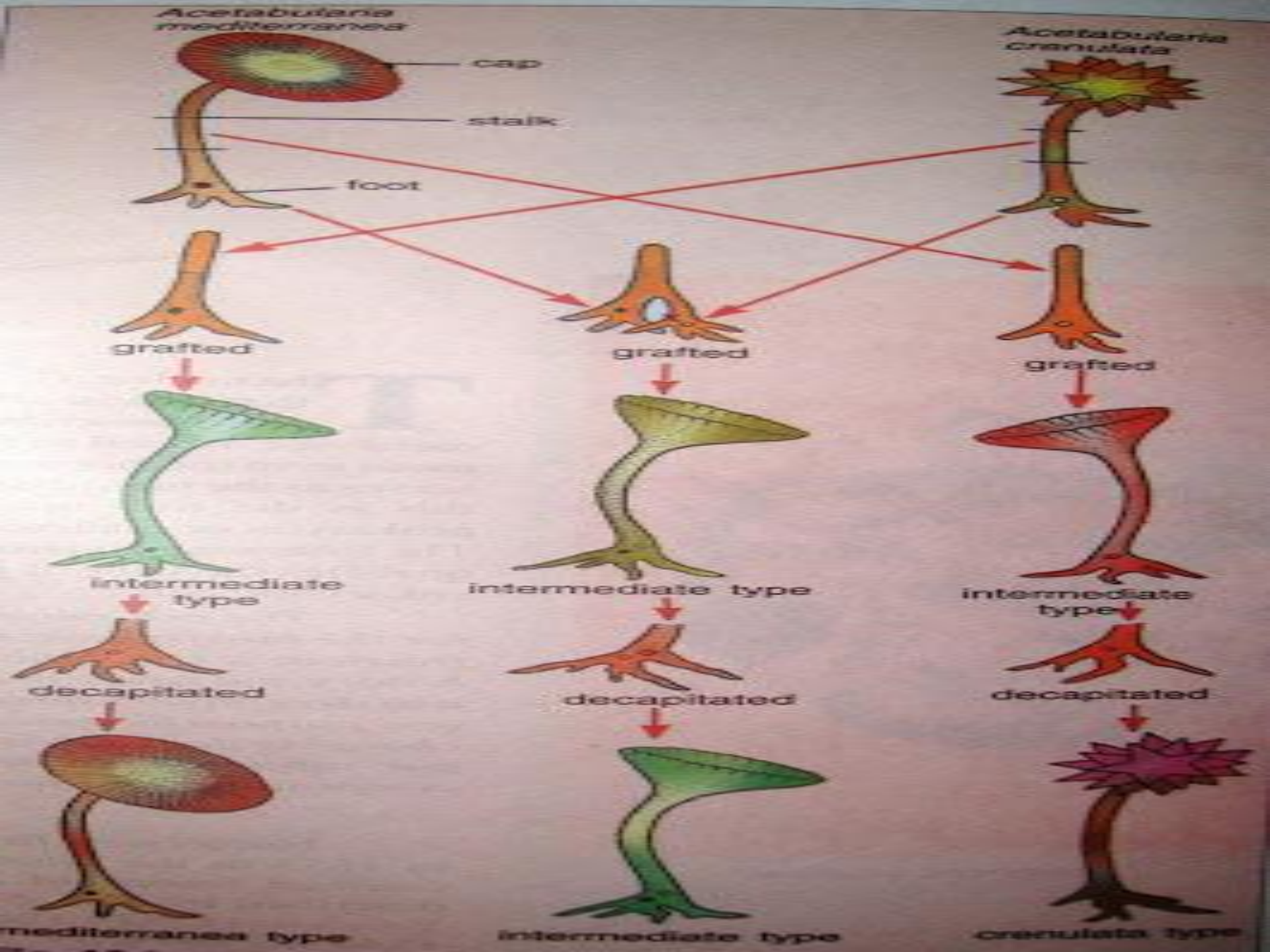


Fig. 9.8: Hammerling's experiment in Acetabularia showing relative roles of nucleus and cytoplasm.

- Further, if two nucleate cells of different species are grafted together, a hybrid having a cap of intermediate morphology is formed.
- This results clearly demonstrates that the shape of the cap is determined by nucleus.
- Although , dependent on the nucleus, cytoplasm has some degree of functional autonomy like storage of information inactive form which later can helps in cap formation.


Acetabularia mediterranea
cap
stalk
foot
Acetabularia crenulata
grafted
grafted
grafted
intermediate type
intermediate type
intermediate type
decapitated
decapitated
decapitated
mediterranea type
intermediate type
crenulata type

C) Nucleo-cytoplasmic relationships in Sea urchin :

- An unfertilized Sea urchin egg, enucleated by being cut or centrifuged, may be stimulated to divide without fertilization by slight immersion in hypertonic solutions.
- In the total absence of a nucleus, it undergo division to form a multicellular and haploid embryonic form which later on regenerates and one with the nucleus forms into haploid and embryonic form.

- Apparently, division of cytoplasm done in limited time, can continue without the presence of a nucleus, but a nucleus is necessary for continued and normal functioning and differentiation of the cytoplasm of a cell.

d) Nucleo-cytoplasmic relationship in Amphibian eggs :

- Amphibian eggs are most useful for the study of mechanism of cell differentiation.
- During oogenesis, there is a high rate of RNA synthesis i.e. tRNA, rRNA, mRNA and it ceases during maturation and reinitiated after cleavage and gastrulation.
- Nuclear transplantation into amphibian eggs have been used to demonstrate that the amount of genetic information remains unchanged during all differentiation.

- Fiscbery and Gurdon(1968), transplanted the nucleus of a differentiated intestinal cell of tadpole of ***Xenopus laevis*** into an enucleated egg and found the normal adult frog developed from the combination of the egg cytoplasm and the transplanted nucleus.
- He concentrated upon the larval intestinal epithelium cells of the tadpole. Because of their large size, it is relatively easy to obtain undamaged nuclei from these cells.
- In *Xenopus*, the egg chromosomes can not be removed mechanically and instead are destroyed by irradiation.

Cyto-plasmic control of gene expression:

- The nuclear transplantation technique has also been used to examine the mechanisms by which genes are activated and expressed during cell differentiation.
- Nuclei from blastula , gastrula, neurula or even intestinal epithelium or brain undergo considerable changes when implanted into the egg's cytoplasm and results depends upon the time at which the nuclear implantation was made.

- For example if brain nuclei are injected into the growing oocyte ,they enlarge and RNA synthesis is activated within them.
- If the transfer is made between condensed chromosomes there is no change in the implanted nucleus.
- If the transplant is made at a later period i.e during cleavage, the nucleus enlarges and starts to synthesize DNA.
- Thus , these experiments demonstrate that the implanted nucleus responds according to the state of the cytoplasm.

- Somatic cell hybridization experiments show that the patterns of nucleic acid synthesis and gene expression by a nucleus can be modified by substances present in the cell cytoplasm.

- Red blood cell nuclei can be reactivated by cell fusion through the use of inactivated **Sendai virus**(a member of the para-influenza viruses) and other agents that affect membrane structure, such as polyethylene glycol and isolecithin.

- Through these techniques a nucleus can be placed in a different cytoplasmic environment.

- The initial product of the fusion of two different cells is a **heterokaryon**(a single cell containing a nuclei of two types).
- Eventually, both nuclei enter mitosis synchronously, form a single metaphase plate, divide and produce a hybrid cell line known as synkaryon.
- The cells of a hybrid cell line have a single nucleus containing chromosome from both paternal nuclei.
- In 1965, H.Harris found that chick erythrocyte nuclei are reactivated when fused to Hela cella(an undifferentiated cell line derived from the uterine carcinoma cells of a woman named Henrietta Lacks.

- Chick erythrocytes are terminally differentiated cells that have a highly condensed nucleus and are destined to die. But when fused to Hela cells the chick erythrocyte nucleus increases 20 times in volume, disperses its chromatin, resumes RNA synthesis, develops a nucleolus and eventually replicates its DNA.

CONCLUSION :

- The above experiments clearly show that the synthesis of macromolecules in a nucleus is controlled by the cytoplasmic environment.
- Only the cell cytoplasm is required to reactivate the chick erythrocyte nucleus .
- Although nucleus play an important role in a cell, the cytoplasm is the energy provider to a cell .Thus, both nucleus and cytoplasm are interdependent to each other and one can not survive without the other.

THANK YOU.