DEVELOPMENTAL BIOLOGY LECTURE NOTES

Regeneration

If the tail of a house lizard is cut, the missing part develops again from the remaining part of the tail. In some cases, regeneration is so advanced that an entire multicellular body is reconstructed from a small fragment of tissue. Our body spontaneously loses cells from the surface of the skin and replaced by newly formed cells. This is due to regeneration.

Regeneration can be defined as the natural ability of living organisms to replace worn out parts, repair or renew damaged or lost parts of the body, or to reconstitute the whole body from a small fragment during the post embryonic life of an organism. Regeneration is thus also a developmental process that involves growth, morphogenesis and differentiation.

Types of Regeneration

Physiological Regeneration

There is a constant loss of many kinds of cells due to wear and tear caused by day-to-day activities. The replacement of these cells is known as physiological regeneration

Example:

Replacement of R.B.C's

The worn out R.B.C's are deposited in the spleen and new R.B.C's regularly produced from the bone marrow cells, since the life span of R.B.C's is only 120days.

Replacement of Epidermal Cells of the Skin

The cells from the outer layers of epidermis are regularly peeled off by wear and tear. These are constantly being replaced by new cells added by the malpighian layer of the skin.

Reparative Regeneration

This is the replacement of lost parts or repair of damaged body organs. In this type of regeneration, wound is repaired or closed by the expansion of the adjoining epidermis over the wound.

Example:

- Regeneration of limbs in salamanders
- Regeneration of lost tail in lizard
- Healing of wound
- Replacement of damaged cells.

Autotomy

In some animals like starfish, some part of the body is broken off on being threatened by a predator. This phenomenon of self-mutilation of the body is called autotomy

Example:

- Crabs break off their leg on approaching of the enemy

- Holothurians throw off their internal viscera
- Starfish breaks off an arm

Regenerative capacity in Animal Group

The capacity of regeneration varies in its extent in various animal groups. Regenerative capacity is very high among the protozoan, sponges and coelenterates.

Invertebrates

- In **sponges**, the entire body can be reconstructed from isolated body cells. The cells rearrange and reorganize to form bilayered sponge body wall.

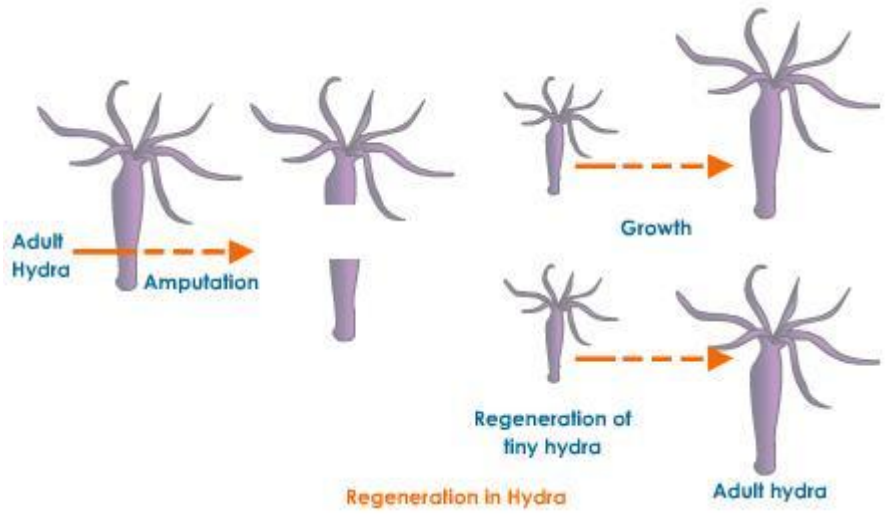
- Regeneration was first discovered in hydra by Tremble (1740). Even 1/1000th part of the body regenerate into new organisms.

- In hydra and planaria, small fragments of the body can give rise to a whole animal. When a hydra or a planaria is cut into many pieces, each individual part regenerates into a whole individual.

Regeneration in Hydra

- Some **annelids** like earthworms are able to regenerate some segments removed from the anterior and posterior ends of the body.

- Some **molluscs** can regenerate only the eyes and heads while squids can also regenerate their arms.



Regeneration in Hydra

- Many **arthropods** (e.g., spiders, crustaceans, insect larvae, etc) can regenerate limbs only. Regeneration is faster in the young than in the adults. Regenerated part may not always be similar to the part lost. This type of regeneration is called heteromorphosis.

- **Echinoderms** (like starfish, brittle star, sea lilly) exhibit autotomy. They can regenerate arms and parts of te body.

Vertebrates

- **Fishes:** Lamprey can regenerate its lost tail. Some fishes have the ability to regenerate parts of its fins.

- **Amphibians**: The regeneration power is well marked in urodel amphibians like salamanders, newts and their axolotl larvae. They can regenerate limbs, tail, external gills, jaws, parts of eye like lens and retina. Tail and limb regeneration is found in the larval stages of frogs and toads.

- **Reptiles:** Lizards exhibit autotomy. When threatened, the lizard detaches its tail near the base to confuse its predator and later regenerates a new tail. The new tail differs from the old one in its shape, absence of vertebrae and the kind of scales covering it.

- **Birds:** Regeneration is restricted to parts of the beak.

- **Mammals:** Regeneration is restricted to tissues only. External parts are not regenerated. Skin and skeletal tissues possess great power of regeneration. The liver has the maximum capacity of regeneration. If one kidney is damaged or removed, the other enlarges to compensate the lost kidney. This is called as compensatory hypertrophy.

Regeneration is an usual form of asexual reproduction in several lower groups of animals.

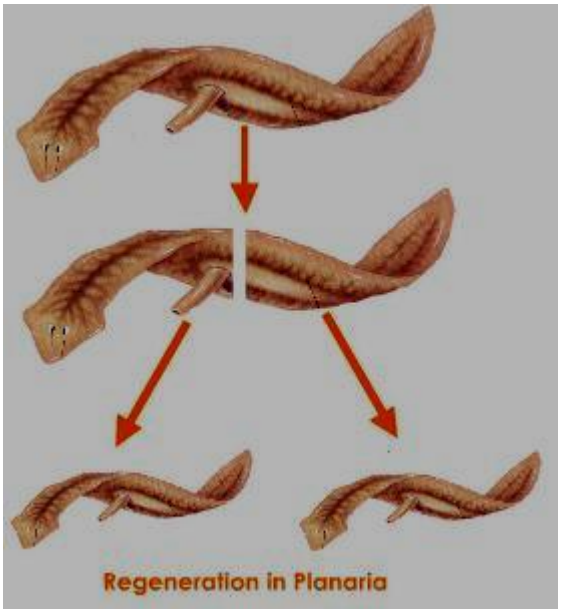
Types of Regeneration based on Cellular Mechanism

Based on cellular mechanisms regeneration can be of two types:

1) Morphallaxis

In this type, regeneration occurs mainly by the remodelling of existing tissues and the re-establishment of boundaries, thus involving very little new growth. As a result, the regenerated individual is much smaller initially. It subsequently increases its size and becomes normal after feeding. This type of regeneration is known as **morphallaxis or morphallactic regeneration**.

Example: Regeneration of hydra from a small fragment of its body.



2) Epimorphosis

In this type, regeneration involves dedifferentiation of adult structures in order to form an undifferentiated mass of cells. They are highly proliferating and accumulate under the epidermis, which has already expanded. Within two days, bulge transforms into a conical hump. This lump of dedifferentiated cells along with the epidermal covering is called regeneration bud or regeneration blastema. The dedifferential cells continue to proliferate and finally redifferentiate to form a rudiment of the limb. The rudiment eventually transforms into a limb. This type of regeneration is known **as epimorphosis or epimorphic regeneration**.

Example: Limb regeneration in amphibians.

3)Heteromorphosis or heteromorphic regeneration

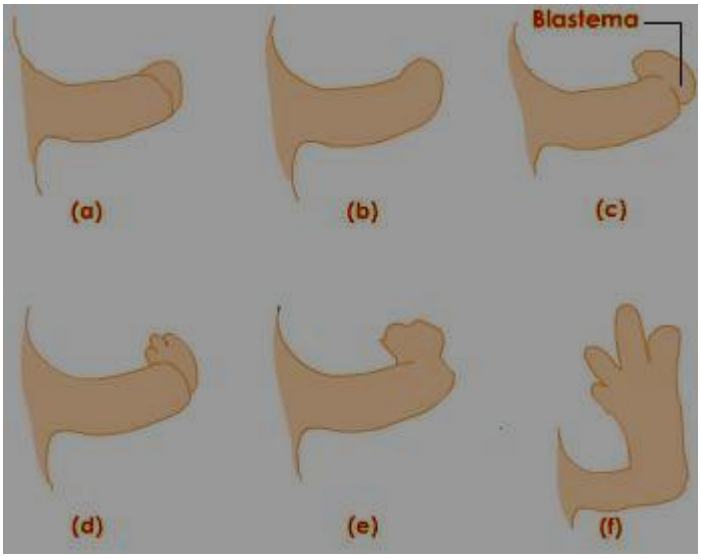
When a different organ develops from the one that has been removed, the phenomenon is called heteromorphosis. Eg. In shrimp Palinurus, eye is regenerated, If it is removed from the eye stalk. But if the eye is removed along with optic ganglion, instead of eye an antenna like organ is regenerated. This type of regeneration is exhibited by lower animals.

4) Super regeneration

The development of superfluous number of organs or parts of the body (eg. Heads, tail limbs) as a result of regeneration is known as super regeneration. When a deep incision is made on the head end of a planaria or earthworm, additional heads will develop. Incisions in the middle part cause the development of both heads and tails.

5) Wolffian regeneration

It is a special kind of regeneration found in urodles and anurans. In Newt, Triturus, if the lens of the eye is removed, a new lens is formed from uninjured iris. The original lens is developed from epidermal ectoderm but the regenerating lens, formed from iris is neurectodermal in origin. Thus regeneration of a part of an organ from a tissue other than its original embryonic tissue is called Wolffians regeration, named after the discover Wolf(1935).



Mechanism of Regeneration

Regeneration is a complex process which basically involves histological and physiological events.

Regeneration of a Limb of a Newt

The mechanism of regeneration in salamander involves the following stages-

- Wound healing: The epidermal cells from the edges of the wound migrate and spread over the exposed surface. This is known as wound healing.
- Blastema formation: A few days later, undifferentiated cells accumulate inside the epidermis, resulting in a bulge. This is known as **regeneration bud or blastema**.
- Redifferentiation and morphogenesis: The blastema develops rudiments of the lost organ, like the digits which grow into new digits.
- Growth: The regenerated limb increases and attains the size of a normal limb.

In planarians and in Hydra, there are undifferentiated cells called **neoblasts** which multiply and then migrate from the deeper parts of the body to the cut surface.

Growth Factors

Wound healing is due to accelerated mitosis. This is mediated by proteins called growth factors which act locally.

EGF

Epidermal growth factor stimulates the epithelium to undergo mitosis. EGF is also produced in the salivary glands, which is why an animal's licking heals a wound.

FGF

Fibroblast growth factor stimulates the endothelial cells of the blood vessels to divide and heal the injured blood vessels.

Platelet

Derived growth factor which stimulates the mitosis of fibroblasts at the site of injury to fill in the damaged areas under the blood clot.

Polarity in Regeneration

The body segments of Hydra or planarians exhibit distinct polarity during regeneration. Their anterior end always regenerates into head and posterior into the tail