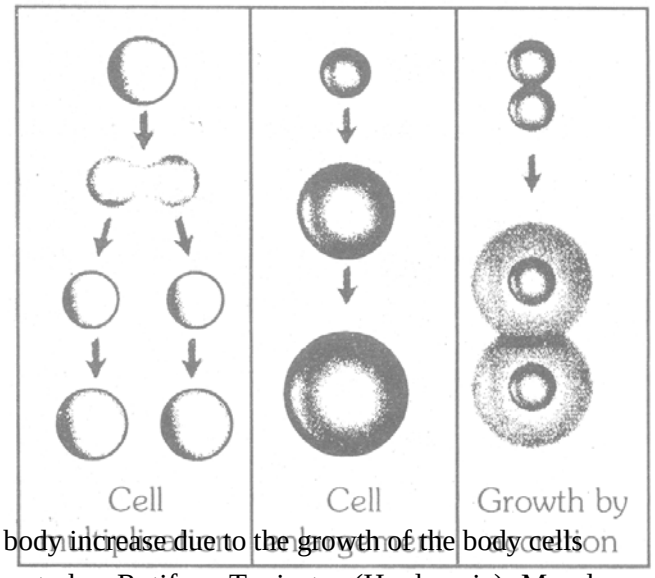
GROWTH, REPAIR & AGEING

- **Growth is an irreversible increase in the volume, weight, shape and size of the organisms due to the synthesis of protophasmic or apoplasmic substances (Matrix of bone marrow or fibres of the connective tissue).**
- In gernaral. Growth involves three process. These are (i) cell proliferation o rmultiplication. (ii) cell enlargement (iii) secretion of large amount of extracellular matrix.

  Note : Growth usually involves cell proliferation



Types of Growth

- There are three types of growth-

(1) **Auxetic growth -** In this type of growth volume of the body increase due to the growth of the body cells without an increase in the number of cells. E.g.→Nematodes, Rotifers, Tunicates (Herdmania), Muscle fibres, Neurons (Axon and dendrites)

(2) **Multiplicative growth -** Growth is mainly due to increase in number of cells. The increase in the number of cells takes place by somatic or mitotic cell division.

e.g.→ Embryonic growth.

(3) Accretionary growth-

Accretionary growth of animal is based on the activity of special cells. Cells do not increase in number and size but the size of tissue increases because of apoplasmic material (extra cellular material) secreted by some special cells, present in the tissue.

In post- empbryonic stage, majority of cells are differentiated and perform specific functions. Yet, some cells of the adults remain in the undifferentiated state and retain the ability to divide mitotically. These cells are called reserve cells. These cells supply new cells for replacing the differentiated cells. This replacement of cell by a new cell is also an accretionary growth because in increases neither size nor the number of cells.

Example:

(1) Secretion of extracellular matrix by chondrocytes, bone osteocytes and Erythropoiesis.

(2) Interstitial cells of Hydra and Archaeocytes of sponges are undirfferentiated cells.

Special point

- **Allometric growth :** Growth, in which different parts of the body grow at diffeing rates. It is also known as heterogonic growth.
- **Lens cells grow by multiplication :** cardiac and skeletal muscle cells grow by increase in volume, neurons grow by extension and growth of the axons and dendrites; cartilage and bone cells grow by secretion of exteracellular matrix.

Phases of Growth- Growth occurs in three phases-

(i) **Lag-phase –** Beginning of growth slow mainly cell division takes place. In this phase number of cells increase.

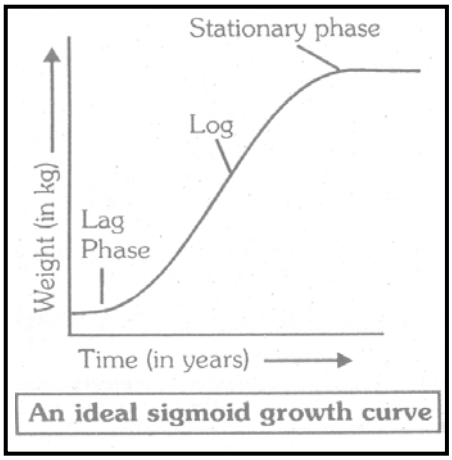
(ii) **Log-phase –** Period of rapid growth generally related to cell growth.

(iii) **Stationary phase –** Growth become stabilize.

Growth curve-

A graph drawn between weight and regular time interval is called growth curve.

Sigmoid Curve : In most of the multicellular animals, the growth rate differ in different time intervals. Sigmoid curve resembles with the letter 'S'. In the initial stage, the curve rises slowly, shows rapid growth rate in the middle which slows down later and converts into a parallel line which shows the cessation (end) of growth.



An ideal sigmoid growth curve

Growth of human body

❖ Growth period includes-

1. Pre-natal-

(i) Human embryo size is 150 m a the time of implantation.

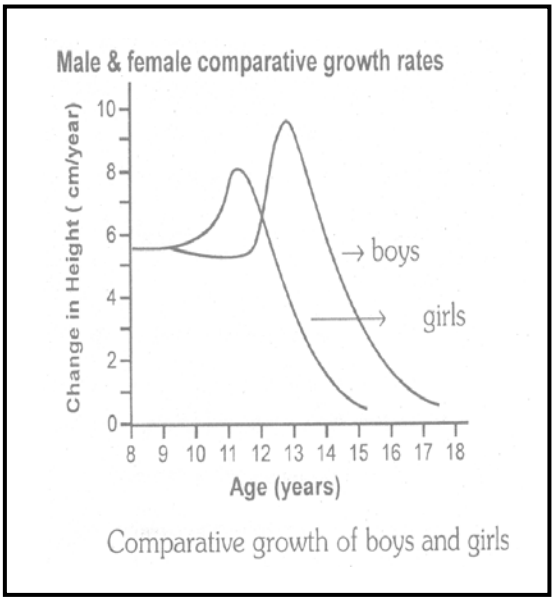
(ii) from about 4 month of implantation then embryo grow at the rate of 10 cm/month.

2. Post natal

(i) First year after birth growth occurs at the rate of 2 cm/month then declines steadily. It shoot at puberty stage and after puberty the physical growth of human body start declining. Size of the head before birth is 1/3 of whole body while at birth it is ¼ of the whole body. After this due to rapid growth in the size of body the head size in an adult is only 1/8 of whole body.

(ii) Adolescent – (8-18 years for female, 7-19 years for male) this is a rapid growth period of mental & physical development. Attainment of sexual maturity and development of external/accessory sexual traits.

(iii) Post adolescent – 19 to 22-23 yrs. Slowing down of growth finally stopping. It almost stops after 22-23 years.



Comparative growth of boys and girls

Note:-

1. Fibroblast growth factor (FGFs), Control cell proliferation (increase number) in the development of limbs in chick.
2. Studies reveal that cells must receive signal through growth factors or other proteins for division and survival. In the absence of required signal, internal death programme is activiated which finally result in the death of the cell or cell suicide. This is called apoptosis.
3. Growth rate or a growing tissue depends on the rates of both **cell proliferation** and **cell death.**

REGENERATION

❖ Regenaration can be defined as “rreplacemnt, repair, restroration or renewal of damaged or lost parts of the body or reconstitution of whole body from a small body fragment during the post embryonic life of an organism.”

Note:-

(1) The process of regeneration was first discovered by Abraham Trembley (1744) in Hydra

(2) The physiological environment of regeneration is entirely different from embryonic environment.

(3) In the process of regeneration, already well differentiated cells are dedifferentiated fist and then undergo redifferentiation.

Regeneration is of following type-

(1) Physiological regeneration-

❖ This type of regeneration is not seen externally.

Example:

In mammals formation of new R.B.C. in place of dead R.B.C.

Formation of new sperms in place of released sperm by ejaculation.

(2) Reparative regeneration-

❖ It is localized cell proliferation. It occur in all animals.

Example : (1) Healing of wound and repair of body parts.

(2) Regeneration of mammalian liver or kidney, the cells divide but do not form an undifferentiated mass of cells or tissues; they produce cells similar to themselves and maintain their differentiated functions. This intermediate type of regeneration is called compensatory regeneration or reparative regeneration.

(3) Restorative regeneration-

❖ There is restoration or replacement of a lost body part or formation of a complete organism from a body fragment is also restorative regeneration.

❖ According to “Morgan” there are two types of regeneration-

(i) Morphallaxis (ii) Epimorphosis

(i) Morphallactic Regeneration/Morphallaxis - In some animals, when animal is being cut in to pices then each piece of animal regenerates form complete animal this is called morphallaxis. Ex. Amoeba, Hydra, Sponges and Planaria.

(ii) **Epimorphic regeneration/Epimorphosis -** When only the lost body part or damaged part regenerate the in is called epimorphosis.

Examples of epimorphosis:-

(1) Regeneration of lost limb in Salamander (amphibian)-

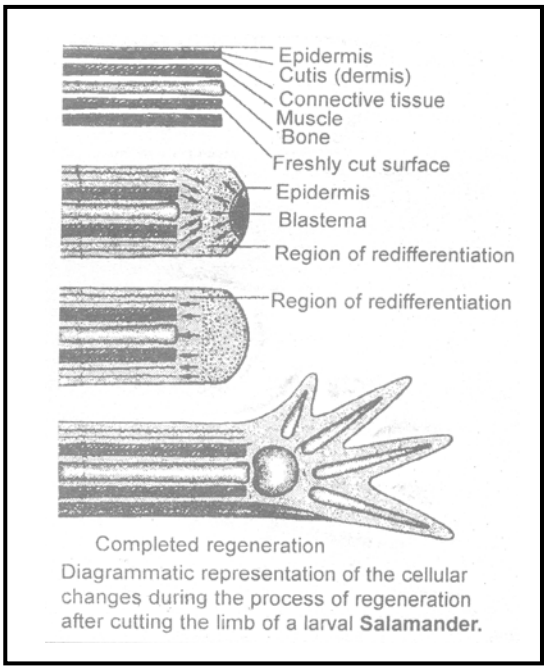
(2) Amputation of Newt’s tail-

(3) Regeneration of an appendage in an Arthropod and arms in starfish.

(4) Regeneration of tail in Lizards.

Mechanism of Regeneration in Salamander:

- Salamander (aphibian) involves dedifferentation of adult structures in order to form an undifferentiated mass of cells.
- These cells are highly proliferating. They accumulate under the epidermis that has already expanded from the margin of the wound and within next two days, bulge out to form a conical lump.
- This lump of dedifferentiated cells along with the epidermal covereing is called regeneration blastema or regeneration bud.
- These deddirentiated cells continue to proliferate and eventually redifferentiate to form the rudiment of limb, which eventually transforms into a new correctly patterned limb structure. This type of regeneration is naed as epimorphosis or epimorphic regeneration.



Diagrammatic representation of the cellular changes during the process of regeneration after cutting the limb of a larval **Salamander.**

Factor contolling Amphibian's limb Regeneration:

Amputation of newt's tail triggers a series of events. Mesenchymal cells by process of dedifferentiation form regeneration blastema or regeneration but.

- GGF (Glial growth factor) and FGF (Fibroblast growth factors) are small peptide growth factors with multiple biological and differentiation.
- IGF = Insulin like growth factors are necessary for growth and cartilage differentiation in tail blastema.

Note: Another neural agent is transferrin (an iron transport protein), that is necessary for mitosis in all dividing cells.

Different Animal Groups and their Regenerative Body Parts

Animal groups	Regenerated body part
(A) Invertebrates	
1. Sponge	Fragmented body parts
2. Flatworm (e.g. Planaria)	Fragmented body parts
3. Coelenterates (e.g. Hydra)	Fragmented body parts
4. Arthropoda (e.g. Insects, Spider, Crustaceans)	Limbs/Appendage
5. Annelida (e.g. Earthworm)	Body segments
6. Mollusca (e.g. Snails)	Parts of the head, foot, eye, eye stalk Arms
7. Echinodermata (e.g. Starfish, Sea cucumber)	
(B) Vertebrates	Skin, liver (only reparative)
1. Mammals (e.g. man)	Limbs, Tail
2. Amphibia (e.g. Salamander)	Tail
3. Reptilia (e.g. Lizards)	Beak
4. Aves (bird)	Fins
5. Pisces (e.g. Fishes)	

Example of Regeneration:

- In sponges for regeneration both pinacoderm and choanoderm are esseritial.
- Planaria have high degree of regeneration.
- Annelids- Polychaelta and oligochaeta have few power of regeneration. Hirudinia do not have power of regeneration.
- Crabs and spiders show autotomy (self mutilation) of legs.
- Salamander and axoltal larva can regenerate limbs, tail and external gills.
- Frog and toad can not but tadpole can regenerate amputated tail and hind limb

Special Point

- The regenerative faculty of hydra is so powerful that it can regenerate its decapitated head. It is virtually immortal and hence, it has named so after the mythological monster, Lerna, which had seven heads.
- Sea cucumber can regenerate respiratory organ (tree) and alimentary canal after ejecting them outside the body through the anus. (Evisceration)
- In ascidians, blood can give rise to a fully functional organism.
- Removal of the lens from the eye of a newt results in the regeneration of a new lens from the pigmented epithelium of the iris.
- Apoptosis: Cell suicide due to activation of internal death programme.

AGEING

- Ageing is a progressive deterioration in structure and function of Cell/ tissue/organs/organ system with age, due to which decline in the rate of metabolism, ability to repair and resist infections.
- An impairment of physiological function due to ageing, is called senescense.
- Gerontology (Sceince of ageing)- It is the branch of developmental biology that deals with the study of various aspects of ageing including remedial measures.
- Vladimir korenchevsky is the father of gerontology.

Effects of Ageing -

(A) Physiological changes in Ageing-

(i) Brain:- With age, the brain loses some cells (neurons). Propagation of nerve impulse reducing with the **advancing age.** The decline is about ten percent more in a man of 75 years as compared to of 50 years old person.

(ii) Sight :- Difficulty in foucssing close up may begin in the 40s.

(iii) Hearing :- It becomes more difficult to hear higher frequencies with age. Hearing declines more quickly in men as compared to women.

(iv) Lungs:- maximum breathing (vital) capacity may decline about 40 percent between the ages of 20 and it takes about 1.5 litres of oxygen in the same time.

(v) Heart :- It grows slightly larger with age. Maximal oxygen consumption during exercise declines in men by about 10% with each decade of adult life, and in women, by about 7.5%. However, cardiac output stays nearly the same as the heart pumps more efficiently.

(vi) Kidneys:- In old age the number of uriniferous tubules is reduced to half. As a result the output of urine also decreases.

(vii) Body fat :- The body does not lose fat with age. Women are more likely to store it in the lower body parts- hips and thighs and men in he abdominal area.

(viii) Muscles :- Without exercise, estimated muscle mass declines 22 percent for women and 23 percent for men between the age of 30 and 70. Exercise can prevent this loss.

(ix) Personality :- After about the age 30, Personality is stable. Sudden change in personality sometimes suggest disease processes.

(x) Digestive system: With the advancing age, the number of taste buds are reduced to about one third on the tongue. The secretion of digestive juices also decreases in old age. This results in indigestion, loss of appetite, dyspepsia, constipation and gas formation, etc.

(xi) Retention of water : Cells gradually lose their capacity to retain water therefore skin becomes dry and wrinkled in old persons.

(B) Cellular Changes:

The cellular changes associated with the phenomenon of ageing are mentioned below:

(i) E.R. : Due to ageing the amount of granular endoplasmic reticulum decreases in the cytoplasm of old cells.

(ii) Plasma membrane : The permeability of plasma membrane gradually decreases with the advancing age, probably due to accumulation of calcium in the cellular membranes.

(iii) Decline in cell volume: The formation of lipid vacuoles in cell reduces the cellular volume. It is called hypotrophy.

(iv) Nuclear pyknosis : With the advancing age, nucleus becomes shrunken and stains deeply, such nucleus is called pyknotic and the degenerative process is known as nuclear pyknosis. It is due to condernsation of the nuclear material.

(v) The rate of **DNA duplication decereases .** (Due to Mutation) & reduction in the size to telomere.

(vi) Reduction in the capacity of **cellular multiplication.**

(vii) **Lipofuscin** pigment granules accumulate and reduces the activity of cells.

(viii) Aldolase enzyme activity in liver cells is reduced.

THEORIES OF AGEING

Theories of ageing are divided into two groups-

(1) Programmed theories (2) Damage or error theories

(1) Programmed theories-

According to this theory ageing follows a biological time table. Programmed theories have three sub categories

(A) Endocrine theory

(B) Programmed Senescence theory

(C) Immunological theory

(A) Endocrine theory :-

- Hormone decline with age. Human growth hormone (GH) levels decrease in about half of all adults with the passage of time.
- The male hormone, testrosterone, may decline with age, though less frequently or significantly than estrogen in women.

- ❖ The hormone, melatonin released from the pineal gland, responds to light and seems to regulate various seasonal changes in the body. As it declines during ageing.

Note: Dehydroepiangrosterone (DHEA), produced in the adreanla glands, is a weak male hormone and a precursor to some other hormones, including testosterone and estrogen. DHEA is being studied for its possible effects of selected aspects of ageing, including immune system decline, and its potential to prevent certain chronic diseases, like cancer and multiple sclerosis.

(B) Programmed senescence theory :- Ageing is the result of the sequential switching on and off of certain genes. Studies on immune system reveal that B or T lymphocytes, having the receptor for self antigens, Undergo programmed cell death or apoptosis.

(C) Immunological theory:- Maintains that a programmed decline in immune system leads to an increased vulnerability to infectious diseases and thus causes ageing and death.

- ❖ According to immune theory, due to decline of thymus, immunity decreases resulting in more diseases damage and destruction of cells.

(2) Damage or error theories:-

Free radicals crosslinking, wear and tear, error catastrophe and somatic mutation as the causes f ageing.

(A) Living theory:-

- ❖ Ageing is the by product of metabolism; the greater an organism's rate of oxygen metabolism, the shorter its life span.

(B) Free radical theory:-

- ❖ It suggests that free oxygen radicals causes cells and organs to stop functioning.
- ❖ A free radical is a molecule with an unpaired, highly electron. An oxygen-free radical is a by- product of normal metabolism, produced as cells turn food and oxygen into energy.
- ❖ The free radical takes an electron from another molecule, which, in turn, becomes unstable and combines readily with other molecules.
- ❖ A chain reaction can ensue, resulting in a series of compounds, some of which are harmful. They damage proteins, membranes, and nucleic acids particularly DNA, including the DNA in mitochondria, the organelles within the cell that produce energy.
- ❖ Free radicals have been implicated not only ageing but also in degenerative disorders, including cancer, **artherosclerosis, cataracts,** and **neurodegeneration.**

(C) Crosslinking theory :- Highlights that an accumulation of crosslinked proteins damages cells and tissues, slowing down functional processes and results ageing. In a process called non-enzymatic glycosylation or glycation, glucose molecules attach themselves to proteins, setting in motion a chain of chemical reactions that ends in the proteins binding together or crosslinking, thus altering their biological and structural roles. The process is slow but increases with time Crosslinks, which have been termed advanced glycosylation end products (AGEs).

AGEs have been linked to stiffening connective tissue (collagen), hardened arteries, clouded eyes, loos of nerve function, and less efficient kidneys.

Note - Diabetes, in fact, is sometimes considered an accelerated model f ageing. Not only do its complications mimic the physiologic changes that can accompany old age, but also its victims have shorter-than-average life expectancies. As a result, much research on crosslinking has focused on its relationship to diabetes, as well as ageing.

(D) Wear and tear theory:-

- Cells and tissue have vital parts that wear out to bring up ageing. In the normal wear and tear of cellular life, DNA undergoes continual damage.
- Attacked by oxygen radicals, ultraviolet light, and other toxic agents, it suffers damage in form of deletions, or destroyed sections and mutations or changes in the sequence of DNA bases that make up the genetic code, DNA is damaged throughout life.
- Bilogists theories that DNA damage leads to malfunctioning of genes, proteins, cells and deterioration of tissues and organs.

  Note: humns repair DNA, more quickly and efficiently than mice or other animals with shorter life spans.

(E) Thory of errors catastrophe :- Damage to mechanisms that synthesise proteins, results in faulty proteins,

which accumulate to a level that causes catastrophic damage to cells, tissues and organs.

(F) Somatic mutation theory :- Genetic mutations occur and accumulate with increasing age, causing cells to deteriorate and malfunction.

Death-

It is the biological phenomenon due to irreversible breakdown in body functions. Death usually occurs due to lack of oxygen supply to tissue.

Causes of Death:

(i) Death can occur due to the weaking of tissue & vital organs by irreversible physiological & metabolic disorder.

(ii) A gradual incapacitation of the immune system of the body taken place with age resulting in death.

- Death recycles the material in the environment so it is essential in the life cycle of organism of important regulatory process of life.
- **Clinical death** is characterized by stoppage of vital functions like pulse, heart beat, and breathing, absence of light reaction on pupil, permanent dilation of pupil etc. most body organs remain alive for some time after clinical death. They can be used for transplantation e.g. eyes, kidney, heart.
- **Biological death** occurs when brain and other body parts begin of degenerate due to nonavailability of nutrients and oxygen.
- **Death in nature** occur due to ageing, predation, accident or disease.
- Ageing is absent in amoeba, bacteria and in some other animals which multiply by binary fission. They are nearly immortal. There death occure due to predation and in adverse conditions.

Special Points:

(1) Degrowth:- Decrease in mass of living matter or protoplasm due to destruction of constituent protein of protoplasm is called degrowth.

(2) Maximum life Span:- Maximum age reached by any member of a species or maximum number of

year survived by any member of a species is called maximum life span.

Life span of some selected animals

Name of animals	Maximum life span (Years)	Name of animals	Maximum life span (Years)
Ant Queen	15	Squirrel	16
Toad	36	Guinea-pig	7.5
Bullfrog	30	House Mouse	3.5
Mud Puppy	23	House Rat	4.6
Giant Salamander	55	Indian Elephant	70
Cobra	28	Horse	62
Turtle	123	Hippopotamus	49
Alligator	68	Find Back Whale	80
Crow	15	Dog	20
Giant Tortoise	152	Cat	28
Humming Bird	8	Lion	30
Parrot	140	Tiger	25
Swan	102	Pig	27
Great horned Owl	68	Chimpanzee	45
Eagle	55	Rhesus Monkey	29
Corcodile	60	Cow	15
		Carp	47

The maximum life span of human has been estimated to be about 121 year. This rests on the fact that a man in Japan. Shirechiyo Izumi, reached the age 120 years 237 days in 1986. He died after developing pneumonia.

(3) Average life span :- Average age reached by members of population or average number of years or age reached by members of a population (56 yrs in India, 78 yrs in U.S.A.)

(4) Life expectancy :- The number of years an individual can expect to live in a population is called life expectancy. It is based on average life span.

Note : Maximum life span is the characteristic of species and life expectancy is the characeteristic of populations.

❖ Life span of laboratory mouse is 4.5 years.

Butter fly - 1 to 2 week.

Moth - Few days