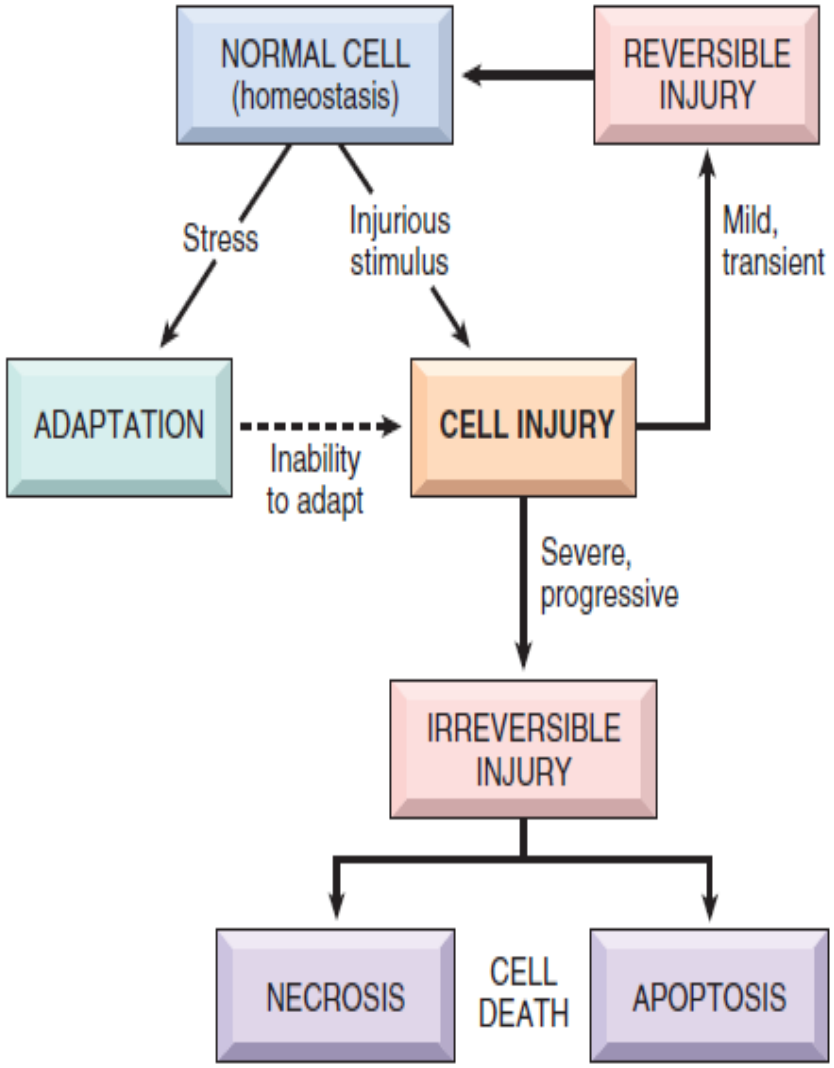
Cellular Responses

All diseases exert their effects on the smallest living unit of the body, namely, **the cell**.

Each cell in the body is designed to carry a specific function or functions. Cells normally maintain a steady state called **Homeostasis**.

Homeostasis is a mechanism that maintains a stable internal environment despite the changes present in the external environment.

The body maintains homeostasis by controlling temperature, pH, blood pressure, chemical reactions, electrolyte concentrations, water content.



Cellular response to persistent Stress

Definition of cellular adaptation: it refers to changes a cell makes in response to different types of stimuli or environmental changes. The adaptation may be **physiologic (normal)** or **pathologic (abnormal).** Cellular adaptations are reversible changes (The cell returns to its normal state when the stimuli are removed). However, the prolonged presence of stimuli can impact the function of cells and lead to cell injury.

There are **five types** of cellular adaptation:

1. **Atrophy**
2. **Hypertrophy**
3. **Hyperplasia**
4. **Metaplasia**
5. **Dysplasia**

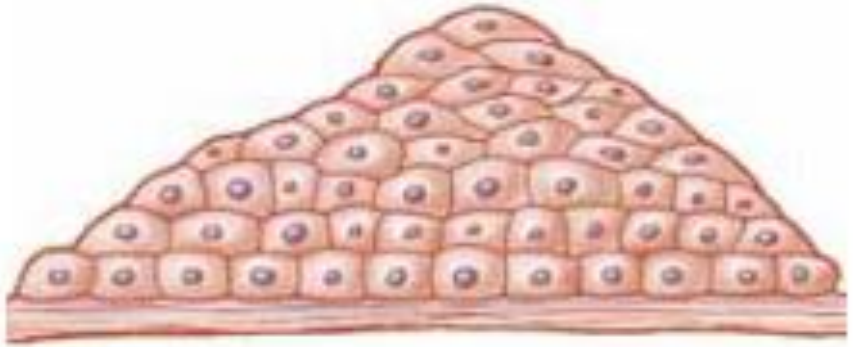
Cellular adaptation

Normal cells

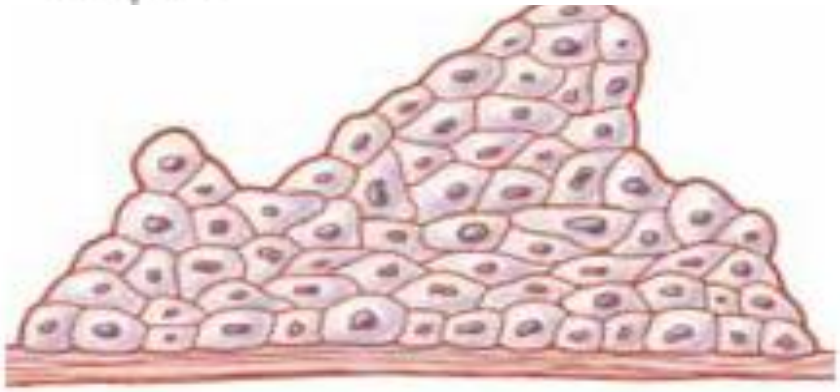
Atrophy

Hypertrophy

Hyperplasia



Metaplasia



Dysplasia

Atrophy

Atrophy: is a reduction in the **size** and **number** of cells resulting in a reduction in the **size** of an organ or tissue.

Atrophied cells reduce oxygen consumption and other cellular functions by decreasing the number and size of their organelles and other structures (e.g. fewer mitochondria and endoplasmic reticulum structures).

Cell size, particularly in muscle tissue, is related to **workload**. As the workload of a cell declines, oxygen consumption and protein synthesis decrease.

Aetiology of Atrophy

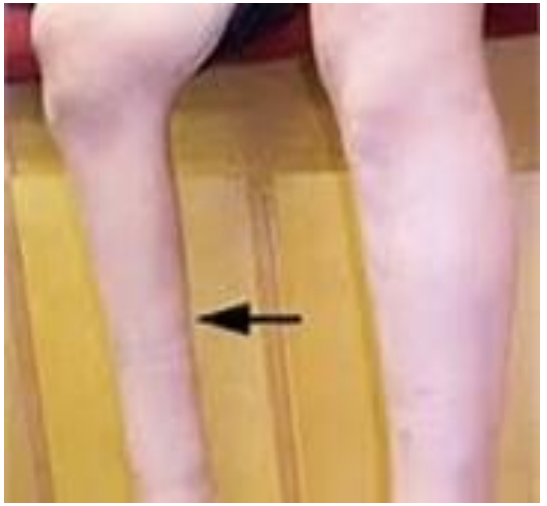
Aetiology of Atrophy can be physiological or pathological causes.

A. Physiological atrophy:-

1. During normal development some embryonic structures undergo atrophy. e.g. after puberty, the **thymus gland** slowly starts to decrease in size.
2. The reduction in the size of the uterus that occurs shortly after birth.
3. Loss of estrogen stimulation in women during menopause results in atrophic changes in the ovary.

Aetiology of Atrophy

B. Pathologic atrophy includes:



1) Disuse atrophy, e.g. atrophy of skeletal muscles of extremities that have been encased in plaster casts.

2) Neuropathic atrophy (denervation atrophy), e.g. atrophy of skeletal muscles of paralyzed limbs due to loss of their nerve supply.

3) Malnutrition and Ischemic atrophy (decrease blood supply), cells decrease their size and energy requirements as a means of survival. e.g. progressive brain atrophy due to ischemia.

4) Loss Endocrine stimulation e.g. Hypopituitarism may lead to atrophy of thyroid and adrenal glands.

Hypertrophy

Hypertrophy is an **increase** in the **size of cells**, resulting in an increase in the size of the organ.

It results from an increased workload imposed on an organ or body part and is commonly seen in **cardiac** and **skeletal** muscle tissue, which cannot adapt to an increase in workload through mitotic division and formation of more cells.

Aetiology of Hypertrophy can be physiological or pathological:

1- Physiological hypertrophy

i) hypertrophy of skeletal muscles of bodybuilders due to increased workload.

ii) Enlargement of the uterus during pregnancy due to estrogen stimulated smooth muscle hypertrophy and smooth muscle hyperplasia.

Pathological hypertrophy

i) Cardiac muscles (myocardial) hypertrophy in patient with hypertension or cardiac valve diseases.

ii) The thickening of the urinary bladder from long-continued obstruction of urinary outflow.

iii) Compensatory hypertrophy occurs in paired organs such as lung and kidney if one of them is removed.

Hyperplasia

Hyperplasia is an **increase in the number of cells** in an organ or tissue, usually resulting in increased volume of the organ or tissue.

It occurs in tissues with cells that are capable of mitotic division, such as the **epidermis, intestinal epithelium, and glandular tissue**.

Aetiology of Hyperplasia could be Physiological or Pathological

Physiological hyperplasia: which include:

A) Hormonal hyperplasia:

1. The proliferation of the glandular epithelium of the female breast at puberty and during pregnancy.

2. The physiologic hyperplasia that occurs in the pregnant uterus due to estrogen stimulation.

B) Compensatory hyperplasia: The regeneration of the liver that occurs after partial hepatectomy (e.g. partial removal of the liver) is an example of compensatory hyperplasia.

Pathological hyperplasia

Hormone-induced hyperplasia:

i) Excessive estrogen production can cause **endometrial hyperplasia** and abnormal menstrual bleeding.

ii) Actions of androgens cause **benign prostatic hyperplasia** which is a common disorder of men older than 50 years of age.

Metaplasia

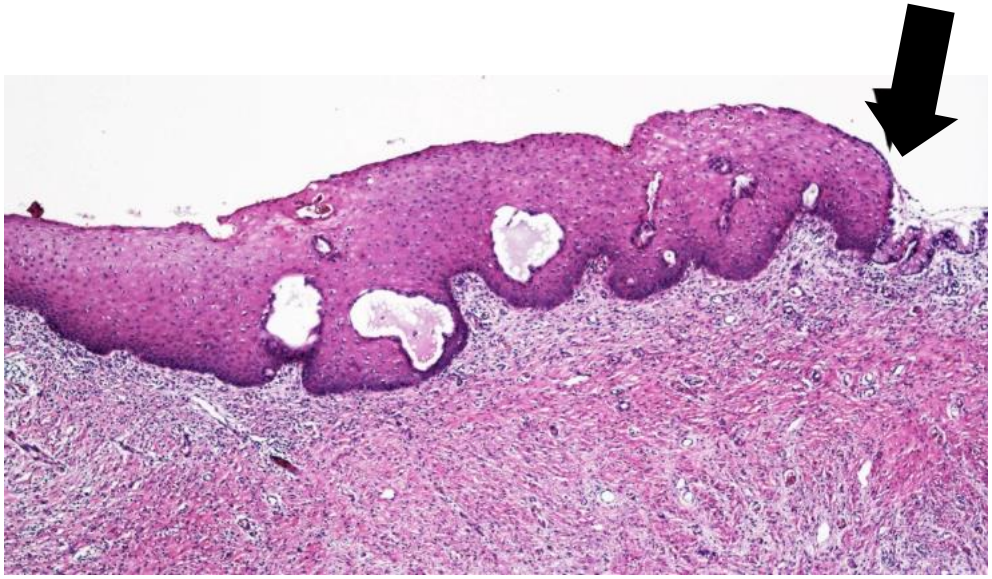
Metaplasia is a cellular adaptation in which **one adult cell type (epithelial or mesenchymal) is replaced by another adult cell type** better able to withstand the adverse environment.

Metaplasia usually occurs in response to **chronic irritation and inflammation**

Mechanisms of metaplasia: These changes are thought to involve the **reprogramming of undifferentiated stem cells** that are present in the tissue undergoing the metaplastic changes.

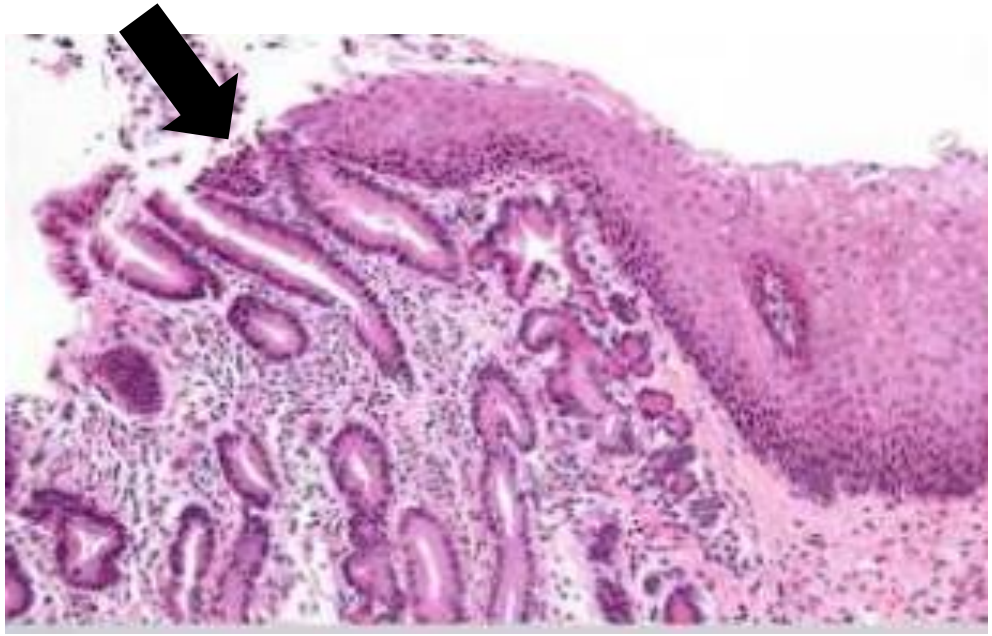
Metaplasia from columnar to squamous

1. Epithelial metaplasia from columnar to squamous, as occurs in the **respiratory tract** of the cigarette smoker, the normal **ciliated columnar epithelial** cells of the trachea and bronchi are often replaced by **stratified squamous epithelial cells.**



Metaplasia from Squamous to columnar

2. Epithelial metaplasia from squamous to columnar as in **Barrett's esophagus**, in which the esophageal **squamous epithelium** is replaced by **columnar cells** under the influence of refluxed gastric acid. Cancers may arise in these areas.



Dysplasia

Dysplasia is characterized by deranged cell growth of a specific tissue that results in cells that vary in size, shape, and organization.

Minor degrees of dysplasia are associated with chronic irritation or inflammation.

It is a precursor of cancer, it has been documented that cancer of the uterine cervix develops in a series of incremental epithelial changes ranging from severe dysplasia to invasive cancer.

However, dysplasia is an adaptive process and as such does not necessarily lead to cancer. In many cases, the dysplastic cells revert to their former structure and function.