Cellular Adaptation

Dr. Md. Sadequel Islam Talukder
M.B.B.S; M. Phil. (Pathology), MACP(USA)
Assistant Professor of Pathology
Dinajpur Medical College
Dinajpur, Bangladesh

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Cellular Adaptation

Cellular adaptation is a state that lies intermediate between the normal, unstressed cell and the injured, over-stressed cells.

Cells must constantly adapt, even under normal conditions, to changes in their environment. In somewhat more excessive physiologic stress or some pathologic stimuli bring about a number of physiologic and morphologic changes in which a new but altered steady state is achieved, preserving the viability of the cells is called cellular adaptation.

Types of Cellular Adaptation:

1. **Physiologic Adaptation –** Usually represents responses of the cells to normal stimulation by hormones or endogenous chemical substances, e.g. enlargement of breast and induction of lactation by pregnancy.
2. **Pathologic Adaptation -** may share the same underlying mechanism, but they provide the cells with ability to survive in their environment and perhaps escape injury.

General Mechanism of Cellular adaptation

1. Up- or down-regulation of specific cellular receptors involved in metabolism of certain components, e.g. in the regulation of cell surface receptors involved in the uptake and degradation of low-density lipoproteins (LDL).
2. Induction of new protein synthesis by the target cells, e.g. heat-shock response.
3. Production of one type a family of proteins to another or markedly overproducing one protein e.g. cells producing various types of collagens and ECM proteins in chronic inflammation and fibrosis.

Adaptation involves all steps of cellular metabolism of proteins – receptor binding, signal transduction, transcription or regulation of protein packaging and release.

Morphological Types of Cellular Adaptation

There are numerous types of cellular adaptation but 4 are common:

1) Hyperplasia
2) Hypertrophy
3) Atrophy
4) Metaplasia

Hyperplasia

Hyperplasia is one type of cellular adaptation in which there is an increase in number of cells in an organ or tissue, which may then have increased volume.

Hyperplasia takes place if the cellular population is capable of synthesising DNA, thus permitting mitotic division.

Types of Hyperplasia

1. Physiologic Hyperplasia
   - Hormonal Hyperplasia
   - Compensatory Hyperplasia

2. Pathologic Hyperplasia

Hormonal Physiologic Hyperplasia

It occurs due to hormonal stimulation in response to physiologic demands, e.g.

proliferation of glandular epithelium of the female breast at puberty and during pregnancy, and hyperplasia of pregnant uterus.

Compensatory Physiologic Hyperplasia

It occurs when a part of an organ is removed, e.g. hyperplasia that occurs when a portion of liver is removed.

Pathologic Hyperplasia
Most forms of pathologic hyperplasia are instances of excessive hormonal stimulation or are effects of growth factors on target cells, e.g. hyperplasia of endometrium, hyperplasia of prostate, hyperplasia of connective tissue cells in wound healing, skin warts.

Hypertrophy
Hypertrophy is an adaptive response in which there is increase in size of cells resulting from synthesis of more structural components in response to increased functional demand or by specific hormonal stimulation.

Types of hypertrophy

- Physiologic hypertrophy
- Pathologic hypertrophy

Example:
Physiologic hypertrophy
- Hypertrophy of myometrium during pregnancy stimulated by oestrogen
- Hypertrophy of skeletal muscle of muscle builders induced by workload.

Pathologic hypertrophy
- Hypertrophy of cardiac muscle induced by increased workload in hypertension or chronic haemodynamic overload.

Atrophy
Atrophy is an adaptive response in which there is shrinkage in the size of the cells by loss of cell substances. When a sufficient number of cells are involved, the entire tissue or organ diminishes in size or become atrophic.

Causes of Atrophy
- Decreased work load
- Loss of innervations
- Diminished blood supply
- Inadequate nutrition
- Loss of endocrine stimulation
- Aging

Examples of Atrophy
- When a limb is immobilised in plaster cast or when muscle become paralysed from loss of innervations, as in poliomyelitis, atrophy of the muscle ensue.
- In late adult life, the brain undergoes progressive atrophy, presumably as atherosclerosis narrows its blood supply and the sex glands shrink with depletion of endocrine stimulation.

Types of Atrophy
- **Physiologic atrophy -** loss of endocrine stimulation following menopause.
- **Pathologic atrophy -** Loss of nerve.

Mechanism of atrophy
Atrophy represents a reduction in structural components of cells. The cell contains fewer mitochondria and microfilaments and lesser amount of endoplasmic reticulum. There is finely regulated balance between protein synthesis and degradation in normal cells. Either decreased synthesis or increased catabolism or both may cause atrophy.

Slight increase of degradation over a long period of time may result in atrophy. Intracellular non-lysosomal proteinases play a role in such protein degradation. Atrophy also accompanied by marked increases in number of autophagic vacuoles within the cells that contain fragments of cell components (e.g. mitochondria, endoplasmic reticulum), which are destined for destruction, into which the lysosome discharge their hydrolytic contents. The cellular components are then digested.

Metaplasia
Metaplasia is an adaptive response in which one adult cell type (epithelial or mesenchymal) is replaced by another cell type. It represents an adaptive substitution of cells more sensitive to stress by cell types better able to withstand the adverse environment.

Examples of Metaplasia

Epithelial Metaplasia

1) Columnar to Squamous Metaplasia:

- Occurs in respiratory tract in response to irritation. In habitual cigarette smoker, the normal columnar ciliated epithelial cells of the trachea and bronchi are often replaced focally or widely by stratified squamous epithelial cells.
- Stone in the excretory duct of the salivary glands, pancreas or bile ducts may cause replacement of normal columnar epithelium by non-functioning stratified squamous epithelial cells.
- Deficiency of vitamin A induces squamous metaplasia in the respiratory epithelium.
- Squamous metaplasia of endocervical epithelium in response to chronic inflammation**.**

In all instances, the more rugged stratified squamous epithelium is able to survive under circumstances in which more fragile specialised epithelium most likely would have succumbed.

The influences that predispose to such metaplasia, if present, may induce cancer transformation in metaplastic epithelium. Thus common form of cancer in respiratory tract is composed of squamous cells.

2) **Squamous to columnar cell metaplasia:**

- **Barrett's oesophagus**, in which the squamous oesophageal epithelium is replaced by gastric columnar cells. The resulting cancers that may arise are glandular (adeno) carcinoma.

Mesenchymal Metaplasia

Fibrous connective tissue cells may become transformed to osteoblasts or chondroblasts to produce bone or cartilage where it is normally not encountered. This occurs particularly in foci of injury but occasionally with no cause.

Pathogenesis of Metaplasia

Metaplasia is thought to arise from genetic reprogramming of stem cells that are known to exist in most epithelium or of undifferentiated mesenchymal cells, present in connective tissue. Chemical, vitamins or growth factors most likely play a role in such metaplasia.

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