

14.1: Adaptation

This section discusses cellular effects yet cell and chemical effects cannot be conveniently separated because cells are constructed of a variety of chemicals of diverse types. Specific intracellular chemical changes may occur as changes in the cell and may affect either its appearance or function. The actual mechanisms leading to cell damage are usually biochemical in nature.

Adaptation Explained

To maintain homeostasis, cells and tissues:

- "Cope" with new demands placed on them by constantly adapting to changes in the tissue environment.
- Are usually capable of an amazing degree of cellular adaptability.
- Adapt in a way that may be beneficial in nature (physiological) or detrimental (pathological).

Examples of **physiological adaptation** are:

- An increase in skeletal muscle cells in athletes due to exercise and increased metabolic demand.
- The increase in number and size of epithelial cells in breasts of women resulting from endocrine stimulation during pregnancy.

When these cells or tissues are damaged, the body attempts to adapt and repair or limit the harmful effects. Often the adaptive changes result in cells or organs that cannot function normally. This imperfect adaptation is a pathological change.

Examples of **pathological adaptations** are:

- Cellular changes in people who smoke cigarettes: The ciliated columnar epithelium changes to non-ciliated squamous epithelium in the trachea and bronchi of cigarette smokers. The replacement of squamous epithelium can better withstand the irritation of the cigarette smoke. However, the loss of cilia and mucous secretions of columnar epithelium diminish the tracheobronchial defense mechanisms.
- Replacement of normal liver cells by fibrotic cells in chronic alcoholics (known as cirrhosis of the liver): A severely cirrhotic liver is incapable of normal metabolism, maintenance of nutrition, and detoxification of xenobiotics.

If the change is minor, cellular adaptation may result and the cells return to normal. When damage is very severe, the result may be cell death or permanent functional incapacitation.

Cellular adaptation to toxic agents includes three basic types:

1. Increase in cell activity.
2. Decrease in cell activity.
3. Alteration in cell morphology (structure and appearance) or cell function.

Specific Types of Cellular Adaptations

Atrophy

Atrophy is a **decrease in the size of cells**. If a sufficient number of cells are involved, the tissue or organ may also decrease in size. When cells atrophy, they have:

- Reduced oxygen needs.
- Reduced protein synthesis.
- Decreased number and size of the organelles.

The most common causes of atrophy are reduced use of the cells, lack of hormonal or nerve stimulation, decrease in nutrition, reduced blood flow to the tissue, and natural aging.

- An example of atrophy is the decrease in the size of muscles and muscle cells in persons whose legs are paralyzed, in a cast, or infrequently used as when a patient is on bedrest.

Hypertrophy

Hypertrophy is an **increase in the size of individual cells**. This frequently results in an increase in the size of a tissue or organ. When cells hypertrophy, components of the cell increase in numbers with increased functional capacity to meeting increased cell

needs. Hypertrophy generally occurs in situations where the organ or tissue cannot adapt to an increased demand by formation of more cells. This is commonly seen in cardiac and skeletal muscle cells, which do not divide to form more cells. Common causes for hypertrophy are increased work or stress placed on an organ or hormonal stimulation.

- An example of hypertrophy is the compensatory increase in the size of cells in one kidney after the other kidney has been removed or is in a diseased state.

Hyperplasia

Hyperplasia is an **increase in the number of cells in a tissue**. This generally results in an enlargement of tissue mass and organ size. It occurs *only* in tissues capable of mitosis such as the epithelium of skin, intestine, and glands. Some cells do not divide and thus cannot undergo hyperplasia, for example, nerve and muscle cells. Hyperplasia is often a compensatory measure to meet an increase in body demands. Hyperplasia is a frequent response to toxic agents and damage to tissues such as wounds or trauma. In wound healing, hyperplasia of connective tissue (for example, fibroblasts and blood vessels) contributes to the wound repair. In many cases, when the toxic stress is removed, the tissue returns to normal. Hyperplasia may result from hormonal stimulation, for example, breast and uterine enlargement due to increased estrogen production during pregnancy.

Metaplasia

Metaplasia is the **conversion** from one type of mature cell to another type of mature cell. It is a cellular replacement process. A metaplastic response often occurs with chronic irritation and inflammation. This results in a tissue more resistant to the external stress since the replacement cells are capable of survival under circumstances in which the original cell type could not survive. However, the cellular changes usually result in a loss of function, which was performed by the original cells that were lost and replaced.

Examples of metaplasia are:

- The common condition in which a person suffers from chronic reflux of acid from the stomach into the esophagus (Gastroesophageal Reflux Disease). The normal esophageal cells (squamous epithelium) are sensitive to the refluxed acid and die. They are replaced with the columnar cells of the stomach that are resistant to the stomach's acidity. This pathological condition is known as "Barrett's Esophagus."
- The change in the cells of the trachea and bronchi of chronic cigarette smokers from ciliated columnar epithelium to non-ciliated stratified squamous epithelium. The sites of metaplasia frequently are also sites for neoplastic transformations. The replacement cells lack the defense mechanism performed by the cilia in moving particles up and out of the trachea.
- With cirrhosis of the liver, which is a common condition of chronic alcoholics, the normal functional hepatic cells are replaced by nonfunctional fibrous tissue.

Dysplasia

Dysplasia is a condition of **abnormal cell changes or deranged cell growth** in which the cells are structurally changed in size, shape, and appearance from the original cell type. Cellular organelles also become abnormal. A common feature of dysplastic cells is that the nuclei are larger than normal and the dysplastic cells have a mitotic rate higher than the predecessor normal cells. Causes of dysplasia include chronic irritation and infection. In many cases, the dysplasia can be reversed if the stress is removed and normal cells return. In other cases, dysplasia may be permanent or represent a precancerous change.

- An example of dysplasia is the atypical cervical cells that precede cervical cancer. Routine examination of cervical cells is a routine screening test for dysplasia and possible early stage cervical cancer (Papanicolaou test).
- Cancer occurs at the site of Barrett's syndrome and in the bronchi of chronic smokers (bronchogenic squamous cell carcinoma).

Anaplasia

Anaplasia refers to **cells that are undifferentiated**. They have irregular nuclei and cell structure with numerous mitotic figures. Anaplasia is frequently associated with malignancies and serves as one criterion for grading the aggressiveness of a cancer. For example, an anaplastic carcinoma is one in which the cell appearance has changed from the highly differentiated cell of origin to a cell type lacking the normal characteristics of the original cell. In general, anaplastic cells have lost the normal cellular controls, which regulate division and differentiation.

Neoplasia

Neoplasia is a **new growth of tissue** and is commonly referred to as a tumor. There are two types of neoplasia: benign and malignant. Malignant neoplasia are cancers. Since cancer is such an important and complex medical problem, a [separate section](#) is devoted to cancer.

Interactions

Interactions between two or more toxic agents can produce damage by chemical-chemical interactions, chemical-receptor interactions, or by modification, by a first agent, of the cell and tissue response to a second agent. Interactions may occur by simultaneous exposure and if exposure to the two agents is separated in time.

Chemical-chemical interactions have been mostly studied in the toxicology of air pollutants, where it was shown that the untoward effect of certain oxidants may be enhanced in the presence of other aerosols.

Interactions at the *receptor site* have been found in isolated perfused lung experiments. Oxygen tolerance may be an example, when pre-exposure to one concentration of oxygen mitigates later exposure to 100% oxygen by modifying cellular and enzymatic composition of the lung.

Damage of the alveolar zone by the antioxidant butylated hydroxytoluene (BHT) in mice can be greatly enhanced by *subsequent exposure* to oxygen concentration which, otherwise, would have little if any demonstrable effect.

The *synergistic interaction* between BHT and oxygen in mice results in interstitial pulmonary fibrosis. Acute or chronic lung disease may then be caused not only by one agent, but also in many instances by the interaction of several agents.

Knowledge Check

1) An increase in skeletal muscle cells in athletes due to exercise and increased metabolic demand is an example of:

- a) Pathological adaptation
- b) Physiological adaptation

Answer

Physiological adaptation - **This is the correct answer.**

The increase in skeletal muscle cells in athletes due to exercise and increased metabolic demand is an example of physiological adaptation since the increased muscle is beneficial rather than harmful.

2) A cellular response in which there is an increase in the number of cells in a tissue is known as:

- a) Atrophy
- b) Hypertrophy
- c) Hyperplasia
- d) Metaplasia

Answer

Hyperplasia - **This is the correct answer.**

Hyperplasia is an increase in the number of cells in a tissue.

3) A condition of abnormal cell changes or deranged cell growth in which the cells are structurally changed in size, shape, and appearance from the original cell type is

known as:

- a) Dysplasia
- b) Anaplasia
- c) Neoplasia

Answer

Dysplasia - **This is the correct answer.**

Dysplasia is a condition of abnormal cell changes or deranged cell growth in which the cells are structurally changed in size, shape, and appearance from the original cell type.

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