Cellular adaptations

LEC.6

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These reactions are induced by physiological or pathological stimuli; the aim is to escape cell injury.

The adaptive responses include:-

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

Atrophy:

This refers to a decrease in the size of the cell by loss of cell substance. When sufficient numbers of cells are involved, the entire organ or tissue decreases in size i.e. become atrophic.

Causes of atrophy include:

1. Decrease workload e.g. muscular atrophy due to immobilization as in fractured limb.
2. Denervation (loss of nerve supply) e.g. paralysis of a limb due to nerve injury or poliomyelitis.
3. Ischemia *e.g.* brain atrophy as an ageing phenomenon due to atherosclerosis.
4. Under nutrition, as in starvation and Kwashiorkor.
5. Loss of endocrine stimulation e.g. atrophy of the gonads in hypopituitarism and senile endometrial atrophy (decrease estrogen secretion from the ovary).

The aim of this adaptation (atrophy) is to bring into balance cell survival in the face of reduced blood supply, nutrition etc. the cells become smaller with diminished function and thus reduced metabolic needs and by doing so they escape injury. The reduction in size is due to reduction in the number of its structural components e.g. mitochondria, myofilaments, endoplasmic reticulum etc. Because of the above cell debris accumulate; some

resist digestion by intracellular enzymes and become enclosed by a membrane (residual bodies) e.g. lipofuscin granules. When the latter is present in sufficient amount it imparts a brown discoloration to the affected tissue (brown atrophy of the heart). If the cause is severe or persistent, the atrophic cell gets injured and eventually dies to be replaced by fibrosis.

Hypertrophy

This Refers to increase in the size of cells and as a consequence the size of the organ or tissue containing them (opposite to atrophy).

It is due to synthesis of more structural components within the cell (more enzymes, more mitochondria and more myofilaments etc.).

It can be physiological or pathological. Examples include

1. Uterus in pregnancy (physiological: hormonal).
2. Skeletal muscles in athletes (physiological: increased workload).
3. Left ventricle in systemic hypertension (pathological) increased workload; the ventricle has to contract against increased pressure in the aorta).

The excessive workload induces increase in cellular constituents i.e. more enzymes, more mitochondria (ATP production) and more myofilaments. The aim is to achieve equilibrium between the demand and the cell's functional capacity. If the burden persists the hypertrophy reaches a limit beyond which the enlarged muscle is no longer able to compensate for the increased work and cardiac failure ensues. At this point there is lysis and loss of myofibril's contractile elements.

Hyperplasia

This refers to an increase in the number of cells in an organ or tissue leading to an increase in its size. Hyperplasia and hypertrophy are closely related and often occur together (e.g. in estrogen induced enlargement of the uterus during pregnancy; there is both hyperplasia and hypertrophy of the myometrium). Not all adult cell types have the same capacity for hyperplasia. Those

capable of cell division (labile cells) can undergo profound hyperplastic growth e.g. those of the epidermis, mucosal surfaces, hepatocytes, fibroblasts and bone marrow cells. On the contrary, nerve cells and those of the heart (myocardial cells) and skeletal muscle fibers have no capacity for hyperplasia (permanent cells). Intermediate among the above two are those of bone, cartilage and smooth muscle cells. Hyperplasia is divided into physiological and pathological.

A. **Physiological hyperplasia** is either

1. Hormonal (e.g. proliferation of the breast glandular epithelium in females at puberty or during pregnancy).
2. Compensatory (e.g. after partial hepatectomy).

B. **Pathological hyperplasia** is mostly either due to

1. Excessive hormonal stimulation (e.g. endometrial hyperplasia) or
2. The effect of growth factors on target cells (as in wound healing).

Metaplasia

This refers to replacement of one mature cell type by another mature cell type. It may represent an adaptation of cells more sensitive to stress by other cells that are more resistant to the adverse environment.

Examples include:-

1. Squamous metaplasia of the laryngeal and bronchial respiratory epithelium due to habitual smoking.
2. Squamous metaplasia of the urothelium in the urinary bladder due to Bilharzia or vesical stone.
3. Columnar metaplasia of esophageal squamous epithelium as a result of prolonged reflux of acidic gastric juice into the esophagus.
4. In the mesenchymal cells e.g. Formation of bone in long-standing fibrosis of soft tissue as a result of injury.

Dysplasia

This refers to disturbed proliferation of cells associated with atypical cytological changes that involve cell size, shape, and organization.

It is not an adaptive process but considered here because of its close relation to hyperplasia. It is most commonly encountered in lining epithelia, mostly squamous e.g. that of the uterine cervix and metaplastic squamous epithelium of the respiratory passages (in habitual smokers). The increased proliferative activity produces greater amounts of DNA and thus the nuclei appear more hyperchromatic. Although there is an increase in mitotic activity, there are usually no abnormal mitoses. The latter is usually met with in cancerous states. Dysplastic changes are often found adjacent to foci of cancer indicating that it is a stage that precedes development of frank malignancy. However, dysplasia does not necessarily progress to cancer.

Degenerative changes

Calcification

This refers to abnormal deposition of calcium salts.

There are two forms of calcification:-

1. **Dystrophic calcification** refers to calcium deposition in nonviable or dying tissue that occurs despite normal serum calcium levels and the absence of any derangement of calcium metabolism.
2. **Metastatic calcification** signifies deposition of calcium in viable tissue, almost always a reflection of some derangement of calcium metabolism that leads to hypercalcemia.

Dystrophic calcification is noted in:

1. Areas of necrosis (whether coagulative, caseous, liquefactive or fat necrosis).
2. Advanced atherosclerosis
3. Damaged or aging heart valves.

Calcification is seen **grossly** as fine, white granules or clumps giving gritty feeling.

Microscopically (with H & E stains) it appears as basophilic (bluish), amorphous granules that may coalesce to form larger clumps. Sometimes calcium deposition occurs in a rounded lamellar

fashion at a nidus of necrotic cells. These structures are called **psammoma bodies.** This is seen in some tumors such as papillary carcinomas of the thyroid and ovary as well as in some meningioma.

Metastatic calcification is seen in cases of hypercalcemia of any cause. It principally affects blood vessels, kidneys, lungs and gastric mucosa.

Hyaline change

This refers to intra- or extra-cellular homogeneous, pinkish alteration in sections stained with H& E.

Examples of **intracellular hyaline change** include:-

1. Hyaline droplets within renal tubular epithelium in cases of proteinuria.
2. Russel bodies in plasma cells.
3. Viral inclusions (nuclear or cytoplasmic).
4. Alcoholic hyaline in liver cells (Mallory bodies).

Extracellular hyalinization may be encountered in:-

1. Collagen in old scar.
2. Hyalinization of arteriolar walls associated with hypertension and diabetes.
3. Amyloid deposition.