Medical Biology

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Adipose Tissue

Adipose tissue is a specialized connective tissue consisting of lipid-rich cells called adipocytes. As it comprises about 15-20 % of total body weight in men; slightly more in women, the main function of adipose tissue is to store energy in the form of fat (triglycerides).

Structure and Location

Adipose tissue is distributed within two compartments of the human body:

- Parietal or subcutaneous fat, which is embedded in the connective tissue under the skin
- Visceral fat, which surrounds the internal organs.

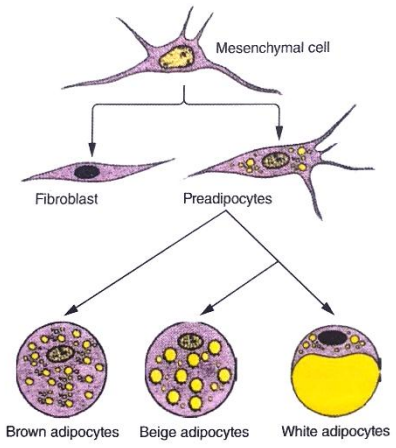
Like every other connective tissue, adipose tissue consists of *cells* and *extracellular matrix*. The cells are the most abundant structural elements of this tissue, predominating over the small amount of extracellular matrix. The main cells that compose adipose tissue are called *adipocytes*. Besides adipocytes, several other cell types are present; preadipocytes, fibroblasts, capillary endothelial cells, macrophages, mast cells and stem cells. These non-adipocyte cells collectively form the stromal vascular fraction, and their main function is to support and protect the adipose tissue.

The extracellular matrix is produced by both adipocytes and stromal cells. It consists of a fine network of reticular fibers (type III collagen), whose function is to hold the cells in place. Adipose tissue is richly supplied with blood vessels and unmyelinated nerve fibers. On histology slides, these structures are usually found within the meshwork that separates neighboring adipocytes.

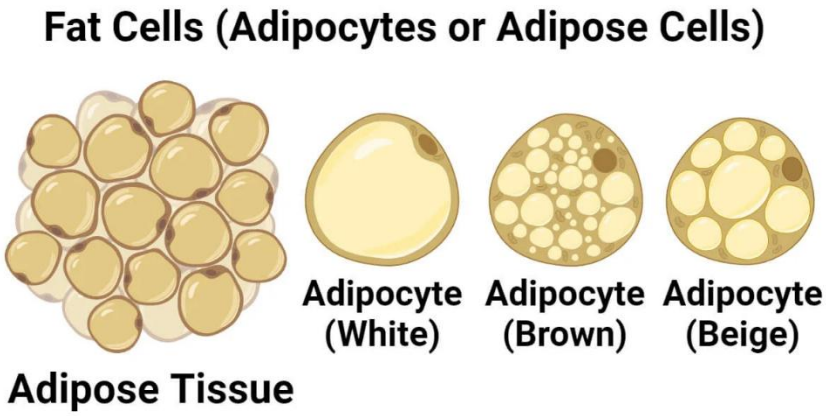
Adipocytes

Adipocytes (adipose cells, fat cells) are the building blocks of adipose tissue. There are three types of adipocytes that constitute two different types of adipose tissue:

- White adipocytes - main cells of the white adipose tissue
- Brown adipocytes - chief cells of the brown adipose tissue
- Beige adipocytes - a recently discovered type, found dispersed within white fat tissue



The origin of 3 types of adipocytes is from *undifferentiated mesenchymal cells* that give rise to *preadipocytes*. These cell types differ in their morphology and function.



White adipocytes are mainly present in white adipose tissue. Their shapes range from spherical (when isolated) to oval or polyhedral (as part of adipose tissue). The largest part of the cell is filled with a single (*unilocular*) lipid droplet that pushes and flattens the nucleus to the periphery of the cell. The cytoplasm forms a thin sheath around the droplet and contains a few mitochondria inside. The lipid droplets usually get lost during routine preparation of histological slides, which makes white adipose tissue appear as a delicate net of polygonal structures. These cells store fat.

In contrast to white adipocytes, *brown adipocytes* are smaller in size and have the lipids contained in multiple lipid droplets (*multilocular*). The droplets surround the centrally positioned nucleus. Brown adipocytes have plenty of mitochondria dispersed between the droplets which give these cells their brown appearance. The cytoplasm also contains Golgi apparatus, and only a small number of ribosomes and endoplasmic reticulum. These cells produce heat (thermogenic adipocytes). Same as in white adipocytes, the lipid droplets get lost in brown adipocytes as well during routine histological preparation. They are seen as a network of cells filled with numerous empty vacuoles.

Beige adipocytes are a distinct type of adipocyte with intermediate features between white and brown cells having *multilocular* morphology. They exist in white adipose tissue mainly in subcutaneous fat, but a small portion can also be found in visceral fat. Their differentiation occurs in response to cold.

Every adipocyte is surrounded by a thick basal lamina containing collagen IV as a major component (unlike other connective tissue cells). The strong external membrane of adipocytes is of key importance for resilience to mechanical stress and disruption.

White Adipose Tissue

The adipocytes in white adipose tissue are organized into lobules by connective tissue septa. The septa contain collagen fibers, nerve endings, blood and lymph capillaries. Extracellular matrix of white adipose tissue is made of reticular fibers and contains non-residential cells of adipose tissue (e.g. inflammatory cells).

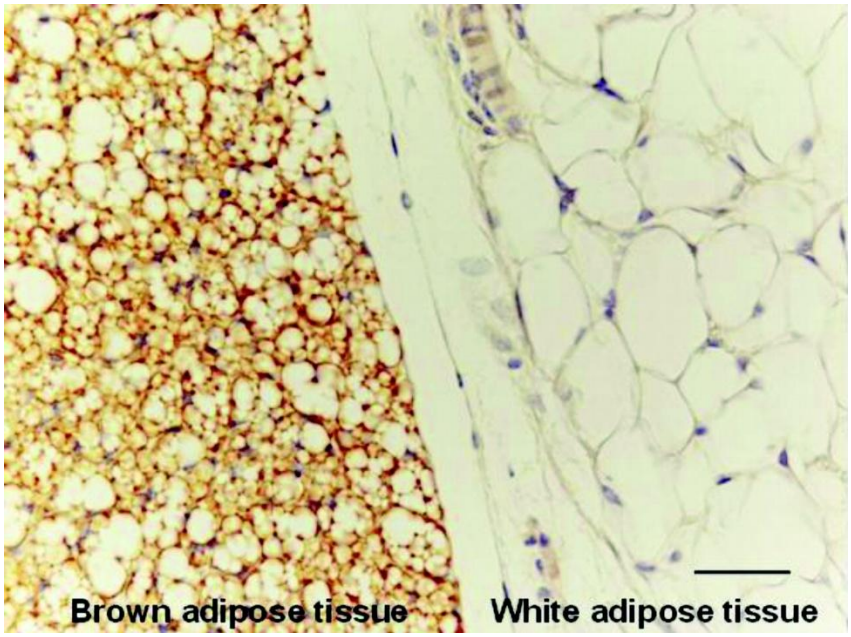
On a histology slide, the adipocytes appear empty with a thin rim of cytoplasm close to the basal lamina. This is described as **"signet ring"** appearance of the unilocular tissue.

White adipose tissue is the predominant type in adult humans. The greatest portion of this tissue is located in the skin (subcutaneous fat). The thickness of this layer depends mainly on localization and gender. For example, women have more unilocular adipose tissue in the thigh and breast regions. In comparison, men have more abdominal fat. White adipose tissue can be found in other parts of the human body.

Brown Adipose Tissue

In contrast to white adipocytes, brown adipocytes have the appearance of a sponge due to the multiple droplets in the cytoplasm. Groups of adipocytes are divided into lobules by connective septa, which contain a substantial amount of blood vessels and unmyelinated nerve fibers. The extracellular matrix between individual cells within the lobules is sparse.

Brown adipose tissue is usually located in the body of the newborns, and it makes about 5% of their body mass. Newborns have much less subcutaneous fat than adults, which is why they are predisposed for hypothermia. To prevent lethal hypothermia, newborns have a large amount of brown adipose tissue, which has a great capacity for thermogenesis. With age, the amount of brown adipose tissue decreases, but it remains widely distributed throughout the body until puberty. Finally, in adults, brown fat disappears from most sites. It remains in some regions only, such as around kidney, adrenal glands, aorta and mediastinum.



Function

- The most important role of white adipocytes is energy storage. They store fat in the form of triglycerides inside their cytoplasmic lipid droplets, which help to maintain free fatty acid levels in the blood.
- For a long time, adipose tissue has been considered only as a passive fuel reservoir. Now, it is also considered to be an endocrine organ which secretes several bioactive substances (hormones, growth factors, cytokines). The most important adipose tissue hormones include leptin (satiety factor) and adiponectin. These bio factors circulate through the human body and carry information to hypothalamus in brain and other target tissue such as liver, pancreas and muscle. These factors are of key importance in the pathophysiology of many metabolic disorders (e.g. type 2 diabetes mellitus).
- Different localizations of the adipose tissue have different roles in the human body. For example:

✓ Abdominal fat has a different metabolic profile than the rest of the fat in the body, and it has the biggest influence in inducing insulin resistance.

✓ Parietal fat has an important role in thermoregulation.

✓ Visceral fat provides cushion-like support for internal organs, protecting them from mechanical injuries.

- During reduced caloric intake, the amount of parietal adipose tissue decreases, while the visceral fat remains undiminished.
- In contrast to white, brown adipose tissue transforms chemical energy into heat. That way it prevents obesity, other metabolic disorders, and hypothermia.

Medical Application

1. Unilocular adipocytes can generate benign tumors called lipomas that are relatively common, while malignant adipose tumors called liposarcomas are uncommon.

2. In most obese individuals, adipocytes produce an excess amount of leptin, but target cells are not responsive due to insufficient or defective receptors.

3. Excessive adipose tissue accumulation, or obesity, occurs when nutritional intake exceeds energy expenditure, an increasingly common condition in modern, sedentary lifestyles. Although adipocytes can differentiate from mesenchymal stem cells throughout life, adult-onset obesity mainly involves increasing the size of existing adipocytes (hypertrophy). Childhood obesity, in contrast, often involves increases in both adipocyte size and numbers due to the differentiation of more preadipocytes from mesenchymal cells (hyperplasia). Weight loss after dietary changes is due to reductions in adipocyte volume, but not their overall number.