Adipose Tissue: White & Brown Fat

by Catherine M. Haug, February, 2007; updated and moved to pdf on Cat's Kitchen, April 2021

Adipose (fat) tissue is a loose connective tissue composed mostly of adipocytes. Adipose tissue helps to store energy in the form of fat, cushion internal organs, and insulate the body. Adipocytes contain lipid droplets of stored triglycerides. These cells swell as they store fat and shrink when the fat is used for energy.

There are three types of adipose tissue: white, brown, and beige adipose (7), of which I discuss white and brown fat in this article.

This article Includes:

See also (this site):

1. Diet and Health Menu;
2. Notes on Insulin Resistance (IR);
3. Choline, Inositol, and Insulin Resistance;
4. Ketogenic Diet;
5. Cyclical Ketogenic Diet (CKD) and Metabolic Mitochondrial Therapy (MMT)

Adipose Tissue

White fat

This is the familiar form of fat that accumulates under the skin and around organs. Its purpose is to store fuel for future use. White fat cells (adipocytes) have a single vacuole which simply grows larger and larger as more fat is added, and have much fewer mitochondria than brown fat cells. (2a, 3a)

- **Visceral fat** is white fat that accumulates around the waistline and belly, and has been blamed for the obesity epidemic. It's accumulation is believed by many to be responsible for type-2 diabetes. (2b) But I believe both visceral fat and type-2 diabetes are a consequence of insulin resistance.
- **Subcutaneous fat** is white fat that accumulates under the skin, such as in the hips and buttocks. It is in the news lately because there is some evidence it protects against diabetes. That is, it improves cell sensitivity to insulin. (6)

Visceral and subcutaneous have different gene expressions, even tho they are both white fat. Mercola reports: "*when researchers added more subcutaneous fat subcutaneously, there was no major difference in health outcome. But when they placed subcutaneous fat in with visceral fat, in the abdominal cavity, all of a sudden there were surprising health benefits, such as weight loss and improved metabolic function.*" (6)

The liver converts excess dietary carbs, fats and proteins into triglycerides, then packages them into VLDL lipoproteins for transport in the blood. These VLDL particles arrive in the capillaries embedded in the adipose tissue, where they are taken up by the adipocytes. There, an enzyme called lipoprotein lipase (LPL) facilitates this uptake by hydrolyzing the individual fatty acids from the triglycerides.

Brown Fat

This fat is abundant in many newborn or hibernating mammals. It is called "brown" because it is rich with blood capillaries and mitochondria, giving it a rusty or brown color. (2a) Brown fat is related to muscle tissue. Researchers at Harvard University identified "a sort of master switch that promotes the production of brown fat. This molecular switch, known as PRDM16, regulates whether immature cells will turn into brown fat or into muscle cells." (from Mercola and Web MD)).

For more about brown fat, see **What is Special about Brow Fat**, below.

Function of adipose tissue

Adipose tissue performs complex metabolic and endocrine functions. Among the endocrine products produced by adipose tissue are:

- **TNF-α** (tumor necrosis factor alpha): a cytokine involved in systemic inflammation, whose primary function is to regulate the immune system; (5a, 2c)
- **IL-6** (interleukin 6): a pro-inflammatory cytokine that stimulates immune response to trauma such as burns; (5a, 2d)
- **Acylation-stimulating protein**: a protein that stimulates triglyceride synthesis; (5a, 5c)
- **Estrogen**, especially in breast tissue; (5b) and
- **Leptin**: a hormone that plays a key role in regulating energy intake and energy expenditure, including the regulation of appetite and metabolism. (5a, 2e)

What is special about Brown Fat?

Brown fat's purpose is to burn energy and generate heat in response to cold or excess calorie intake. (4) Brown fat is activated when the body is exposed to cold temperatures, boosting the metabolic rate to warm the body. Perhaps taking a daily cold shower could help one lose weight.

Unlike white fat cells, the brown fat cells contain several smaller vacuoles to contain the fat, and have a higher number of mitochondria than white fat adipocytes.

Mitochondria are energy factory organelles within our cells, responsible for energy production, in the form of ATP. It is believed they evolved from a single-cell organism (prokaryotes). They contain DNA material separate from that of the cell's nucleus, and have both an outer and inner membrane. These membranes are responsible for the electrochemical gradient that leads to ATP production, but can also be used to generate heat by recycling the protons generated by this gradient back into the mitochondria, without producing ATP, through the action of a protein called thermogenin. (2a, 2b)

What does this all have to do with obesity and weight gain? When brown fat is present, excess dietary fuels can be burned to produce heat, rather than stored as white fat. White fat is what accumulates under the skin, leading to obesity.

Brown Fat and Insulin Resistance

Some animals, like mice, have brown fat throughout their lives. Others, like sheep and humans seem to lose most of their brown fat by adulthood; however, their precursors (preadipocytes) remain in the body lodged in white fat depots.

Researchers at Joslin Diabetes Center and Children's Hospital Boston developed cell lines of precursor cells that give rise to brown fat in mice. Then, in 2005, they studied the effect of insulin on these preadipocytes to convert them to brown, rather than white, fat cells. This led to their discovery of a group of genes that govern the genesis of brown fat. Through genetic manipulation, they developed preadipocytes that could not form brown fat. This led to several discoveries, including:

- Insulin-resistant cells lacking in IRS-1 (Insulin Receptor Substrate-1) failed to develop into mature brown fat cells; restoring the IRS-1 mostly restored the ability to form brown fat cells.
- Elevated production of a protein called necdin inhibits the ability of preadipocytes to form brown fat cells.
- A transcription factor called CREB is essential for reducing necdin production. (3a)

This research is opening the doors for development of drugs to fight obesity. But to me, this research is a very important factor in the accumulated knowledge about insulin resistance (IR), which is behind the set of disorders collectively termed Syndrome-X or Metabolic Syndrome. Rather than fighting obesity by suppression mechanisms (drugs), wouldn't it be better to work on the underlying problem of insulin resistance?

Additional Brown Fat Articles

Here are a few articles on brown fat that I have yet to investigate: (links have been updated)

- Insulin resistance of glucose metabolism in isolated brown adipocytes of lactating rats. Evidence for a post-receptor defect in insulin action. (ncbi.nlm.nih.gov/pmc/articles/PMC1136913/) (old, original link was pubmedcentral.nih.gov/articlerender.fcgi?artid=1136913)
- Brown adipose tissue–specific insulin receptor knockout shows diabetic phenotype without insulin resistance (jci.org/articles/view/13103)
- Glucose utilization in vivo and insulin-sensitivity of rat brown adipose tissue in various physiological and pathological conditions. (ncbi.nlm.nih.gov/pmc/articles/PMC1153011/)

Also a few articles on other fat regulators like leptin:

- cat.inist.fr/?aModele=afficheN&cpsidt=13585923 < can't open this link
- Set Your Fat Thermometer at a Healthy Level: ezinearticles.com/?Set-Your-Fat-Thermostat-at-a-Healthy-Level&id=6942 (updated)

References / Sources:

I've updated these links, & did some reorganization. numbers in parenthesis are original ref #s.

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2. Wikipedia:
   a. (2) en.wikipedia.org/wiki/Brown_fat
   b. (3) en.wikipedia.org/wiki/Mitochondria
   c. (8) en.wikipedia.org/wiki/Tumor_necrosis_factor
   d. (9) en.wikipedia.org/wiki/Interleukin_6
   e. (12) en.wikipedia.org/wiki/Leptin
3. Science Daily:
   a. (4) ScienceDaily: 'Brown Fat' Cells Hold Clues For Possible Obesity ... (www.sciencedaily.com/releases/2005/06/050608060136.htm)
   b. (6) Regulator Of Fat Thermostat Found: sciencedaily.com/releases/1997/12/971225183203.htm
4. (5) Weight Loss Strategy: Drugs To Turn White Fat Into Brown: futurepundit.com/archives/002053.html (not secure)
5. Pub Med:
   a. (7) Role of adipose tissue in body-weight regulation: mechanisms regulating leptin production and energy balance: pubmed.ncbi.nlm.nih.gov/10997652/
   b. (11) The importance of local synthesis of estrogen within the breast: pubmed.ncbi.nlm.nih.gov/3504615/
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6. (13) Mercola: Good News About Big Bottoms: articles.mercola.com/sites/articles/archive/2008/05/22/good-news-about-big-bottoms.aspx
7. (14) The Purpose and Composition of Adipose Tissue: thoughtco.com/adipose-tissue-373191