How Adipose Tissue and the Beijing National Aquatics Center use simple repeating units to form complex structures

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Rule to Build By:

Rule One on the Living *Architecture* website states: To maximize flexibility of architectural form, assemble complex structures from simple repeating units.

What:

In living organisms, Adipose tissue upholds this rule-to-build-by. The Beijing National Aquatics Center or "Water Cube" is a human built structure that follows the first rule as well.

How:

Adipose tissue is a type of connective tissue that is specialized in storing fat in the form of triglycerides. Mammals have two different types of adipose tissue: white adipose and brown adipose. The concentration and distribution of each type varies from species to species. For the most part however, white adipose tissue accounts for the greater part the adipose tissue in an organism. White adipose serves three major functions: heat insulation, mechanical cushion, and as an energy source (Albright, 1998). Brown adipose tissue's major function is to produce heat by consuming energy. Therefore, brown adipose tissue is often found in animals adapted to living in cold environments and in animals that go into hibernation. In humans, brown adipose tissue is present in infants to help them stay warm(Cannon, 2004). White adipose tissue is found below the skin in the subcutaneous layer and surrounding certain organs like the kidneys. Adipose tissue is comprised of many cells called adipoctytes which are held together loosely by collagen fibers (Albright, 1998). Each adipocyte holds a droplet of triglyceride that takes up the majority of the space inside the cell, pushing the nucleus and other organelles to the plasma membrane. In fact, each adipocyte can devote 80% of its total area to triglyceride storage. As a result, adipocytes when packed into tissue, take on the three dimensional shape of a 14-sided tetrakiadecahedra. The tetrakiadecahedra provides for the most volume inside the cell while allowing the least surface area between the cells(Roberts, 2004). 90-99% of white adipose tissue mass is attributed to the triglycerides stored in the adipocytes. In white adipose tissue, each adipocyte is connected to a least one capillary. This is important because the blood flow helps drive metabolism, as a result, adipose tissue if very dynamic. In periods of energy excess or exertion fatty acids are transported from the white adipose tissue to the other tissues that are in need. Conversely, energy can be stored in the adipose tissue in the form of fatty acids. Therefore, these fatty acids are constantly being imported and exported from the adipose tissue. The adipose tissue needs to be connected to capillaries to form its function. However, obesity can be linked to heart problems such as high blood pressure. People who are obese have a high amount of adipocytes in there adipose tissue, and they have a harder time pumping blood through their increased adipose tissue. Brown adipose tissue though similar to white adipose tissue holds many smaller vacuoles containing triglyerides as well as many mitochondria. It is these mitochondria that give brown adipose its brown color. Adipose tissue may contain other cells such as fibroblasts, leukocytes, macrophages and pre-adipocytes, these additions to the

tissue augment its structural stability. However, 60-85% of adipose tissue is still composed of adipocytes(Albright, 1998). Adipoctyes can reproduce and make more adipocytes when the need for fat storage increases. Once the new adipocyte is made it stays in the tissue permanently. This is why when people lose a lot of weight they still often have loose and baggy skin; because the adipocytes still remain in the tissue they are just smaller now without their triglyceride droplet. Adipose tissue serves many functions in the body and is just as complex as any other tissue; nevertheless, the majority of this tissue is composed of simple repeating adipocytes.

The Beijing National Aquatics Center or the "Water cube" was designed to mimic a Weaire-Phelan structure. Denis Weaire and Robert Phelan discovered the Weaire-Phelan structure, as the most efficient structure to divide the most space while having the least amount of surface area between cells. The Weaire-Phelan structure uses two shapes to fulfill this princple, the 14-sided tetrakaidecahedra and the 12-sided dodecahedra. The Water cube in Beijing adapts the Weaire-Phelan principle and showcases it on a macro scale. The cube covers almost 8 acres, yet does not use a single concrete support or structural cable. Instead, the natatorium is composed of a network of slender pipes that are shaped into tetrakaidecahebras and dodecahedras (Roberts, 2004). These pipes are then connected to load bearing nodes throughout the structure, which makes the whole thing very stable. A form of Teflon called ETFE, which gives the building its foam bubble-like appearance, covers the whole building. This unique building was built by copying the Weaire-Phelan strucure, using simple repeating units just on a scale that has never been seen in human architecture before (Popular Science, 2006).

Why:

Adipose Tissue has many functions in the body. White adipose tissue provides heat insulation, helping to regulate temperature in the body. White adipose tissue also provides mechanical cushioning, wrapping around many vital organs such as the kidneys. When the body is jostled this tissue protects the organs from damage. Adipose tissue also provides a place for energy to be stored, in the form of triglycerides in the adipocytes (Albright, 1998). Brown adipose tissue helps heat the body and is important to mammals that live in cold environments and to infants (Cannon, 2004). After looking at these examples it is evident that adipose tissue has a myriad of functions. To perform all these functions the tissue must be able to take on many different three-dimensional shapes, each suited for its specific function. Since adipose tissue is composed primarily of adipocytes it is able to achieve this flexability. The adipocytes come together loosely bound by collagen fibers and are able to do things such as span an entire human body providing insulation. Or pack in between certain joints and provide cushion against mechanical force. Adipose tissue is a great example of how flexibility of architectural form can be achieved by using simple repeating units. Like stated before adipose tissue is composed of primarily adipocytes. These adipocytes can pack together in many ways and are not bound to a certain three dimensional structure between one another. As a result they are able to form these complex tissues with many varying and important functions.

For the water cube the rule to build by was stumbled upon in a backwards fashion. Architects wanted to build something unique and non-conventional. What they built was unique and non- conventional in terms of human architecture,

however, this kind of design had been going on in organisms for hundreds of thousands of years. By using simple repeating units, the uniqueness of the build was achieved relatively easily. Additionally and somewhat overlooked, a structurally sound building was created. The Water cube has no support beams or cables yet it is standing and is actually well made to handle the seismic activity common in Beijing. By imitating designs used to build three-dimensional structures in organisms, builders where able to design a build that was not only structurally stable, but also, in terms of human built structures unique.

Figures:

Figure 1: This is an image of the outside of the Beijing National Aquatics center. As can be seen this building is composed of many different cells linked together, giving the building a look similar to bubble in a foam

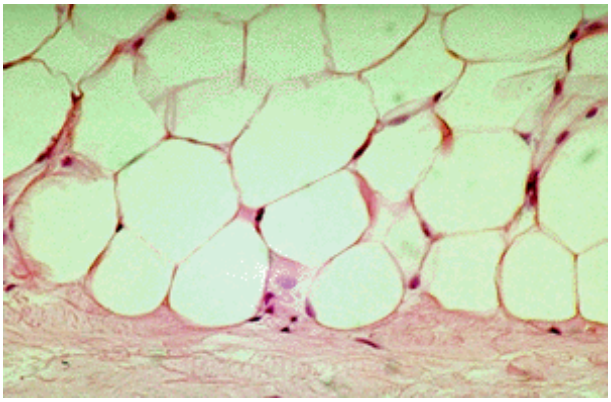

Figure 2: This is an image of white adipose tissue (WAT) in the subcutaneous layer of the skin. This tissue is composed of adipoctyes, which show up almost all white because of the fat droplet inside them. The cells plasma membrane can be seen as the pink line and the nucleus are the purple dots.

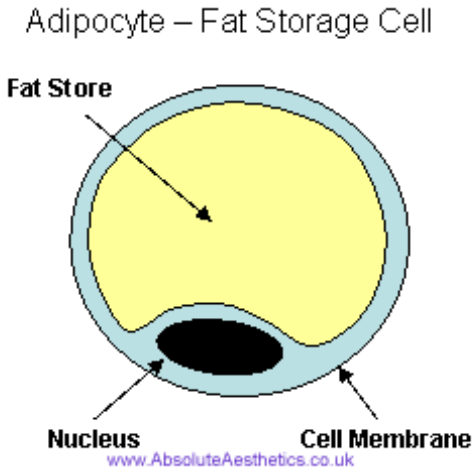

Figure 3: This is a simple interpretation of what a single white adipocyte looks like. This cell has a large vacuole that stores fatty acids. The size of the vacuole pushes all the other organelles towards the cell membrane.


Figure 4: This is a closer look at the cells that make up the water cube. In this image you can see the steel pipes that make the structure, as well as, that ETFE that is stretched over them.

References

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