Redundancy in Collagen Fibers and Free Spirit Spheres

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Rule to Build By:

Complex human-built and nature-built architectural forms should be produced with redundancy in order to increase the strength of the structure.

What:

The nature-built structure that upholds this principle is the collagen fibers found in tendons, which increase in number after working out. The ropes holding up the Free Spirit Spheres are an example of a human-built structure that also upholds this rule to build by.

How:

Tendons are connective tissues that connect muscles to bones, which are made up of mostly collagen (Darrow, 2011). Under a light microscope, one can see that a normal tendon consists of dense, parallel, and slightly wavy collagen bundles (Khan, Cook, 2003). Collagen is a group of proteins found in many cellular structures. It acts as a structural system that increases the strength of the tendons (Locations and Functions of Collagen, 2012). Collagen molecules are long triple-stranded helices, with each strand made up of a collagen polypeptide chain. The collagen molecules are then assembled into ordered polymers, called collagen fibrils, which can then pack into thicker collagen fibers (Alberts, et al., 2010, p. 694). The way that collagen fibers are assembled provides an immense amount of tensile strength. However, if collagen fibrils do not assemble correctly, tendons have a significantly lower tensile strength (Alberts, et al., 2010, p. 695). In tendons, collagen is arranged in bundles of parallel fibers, giving the tendons a rope-like structure (Erickson, 2002). The greater the collagen content, the more tensile strength there is in a tendon.

There are several different varieties of collagen. Mammals have around twenty different collagen genes, each of which codes for the different types of collagen needed to compose different tissues. In total, collagens make up approximately 25% of the total mass of protein in mammals, which happens to be more than any other protein (Alberts, et al., 2010, p. 694). The different types of collagen are named using Roman numerals. The main collagens that are found in connective tissue are types I, II, and III. These are the main sources of tensile strength in connective tissues, including tendons (Erickson, 2002). Type I collagen is the most abundant collagen in the body. Gram for gram, type I collagen it is stronger than steel. Type I collagen is one of the most prevalent types of collagen in tendons, thereby strengthening the tendons immensely. Type II collagen forms a network of fibers. This network is filled with many individual collagen molecules, which individually may be weak, but with the redundancy of them are very strong. These collagen molecules, which are then arranged into collagen fibers, help to provide tensile strength to the tendon. Type III collagen is usually found in the same areas as type I collagen, helping provide the structural strength (Kelly, 2009). Working together, these three types of collagen provide the basic foundation for tendons, providing them with a strong structure.

When exercising, many athletes are concerned with building up their muscle content. However, it is also important to think about the impact of exercise on tendons. As was mentioned previously, tendons connect muscles to bones, so they are connected to the muscles. This means that every time a person moves a muscle, they are putting stress on the tendon. The tendons run parallel to the muscle fibers, which makes it so that the tendon component has a large impact on athletic movements (Brandon, 2009). When a person exercises, the tendon stimulates collagen synthesis. This, in turn, makes the tendon stronger, by providing a strengthening support system of collagen (Moerch, et al., 2012). When a tendon is stronger, due to an increased amount of collagen, it is more capable of allowing athletic movements without being harmed. This is clearly beneficial to the person, as it allows them to exercise more without fearing a torn tendon, which is a difficult part of the body to repair. The more collagen present in a tendon, the more strength that tendon will have.

Furthermore, a tendon will remain strongly connected, with incredible tensile strength, even if one of the pieces of collagen is broken. This is because there are so many collagen fibers in each tendon. Torn tendons are the result of several collagen fibers being torn, not just one. When this happens, it is a very traumatic experience for the body, and it is much harder to repair than other parts of the body. Tendons do not have a steady blood supply, so they do not have the chance to fully heal like other parts of the body (Darrow, 2011). That being said, it is evident why collagen must be created in redundancy in tendons, as it allows the tendon to function even with a broken strand of collagen. The function of tendons is important, as it allows a person to move by connecting the muscles to the bones.

The Free Spirit Spheres are a set of wooden and fiberglass nut-shaped structures that are suspended within the rainforest of Vancouver Island, Canada. The "sphere" is attached to a web of rope, which connects to strong trees within the forest. Each "sphere" has four main anchor points on the top as well as four main anchor points on the bottom. Three nearly vertical ropes are connected to each of the Free Spirit Spheres, which provide a great amount of support to keep the "sphere" suspended. Further support is provided by a web of ropes, which increases the strength to the Free Spirit Spheres. The way it is suspended is intended so that the sphere and rope web are able to function naturally within the environment. If a tree falls or another unexpected event occurs, some of the strands of the web will break. This leaves the "sphere" still suspended, held up by the other ropes and strands. This clearly provides the "sphere" with structural support and strength and allows it to remain suspended, even when part of the web is not functional (Chudleigh, 2012).

Why:

Collagen fibers make up tendons. These fibers are made up of several individual collagen molecules, providing an extremely large amount of support for the tendons. Each collagen molecule individually provides tensile strength to the tendon, but the complex network of the collagen fibers provides the real tensile strength for the tendon. Collagen fibers are created in redundancy in order to make the tendon incredibly strong so that it can successfully serve its purpose, connecting the muscles to the bones. When exercising, people build up the collagen in their tendons. With more collagen comes more support, and therefore strength. This makes the tendon even stronger, allowing a person to put more stress on the tendon without causing further complications, such as tears. Tendons are important to allow the correct athletic movements, as they are the connection between the muscles and the bones. If a tendon is disconnected or hurt, it does not act properly, and thus impedes a person's athletic movement.

Another thing that obstructs athletic movement are tears in the tendon. Tears in the tendons are caused by several collagen fibers being torn. They are difficult to repair because the blood flow to the tendons is very minimal. If one collagen fiber is torn, it is simply replaced, causing no harm to the tendon. This, therefore, does not harm the person or impede their ability to move, as their tendons will continue to function properly. It is because collagen fibers are created in redundancy that one torn collagen fiber does not harm an individual. There are several other collagen molecules and fibers that are providing the same function to the tendon. Clearly, redundancy in collagen fibers in tendons is beneficial to humans because it provides structural support and allows for the function of tendons, even if one collagen molecule or a collagen fiber is damaged.

Similarly to the redundancy of collagen fibers in tendons, the redundancy of the ropes holding up the Free Spirit Spheres help to provide structure to the "spheres." The "spheres" are suspended in a way such that they are able to survive in the environment in which they are placed. In a situation where a tree collapses or something else comes in contact with the ropes, they are designed so that some of the ropes can break and the "sphere" will remain suspended, using the support of the other ropes. This allows the Free Spirit Spheres to function properly, even when some of their support system has been damaged.

Figures:

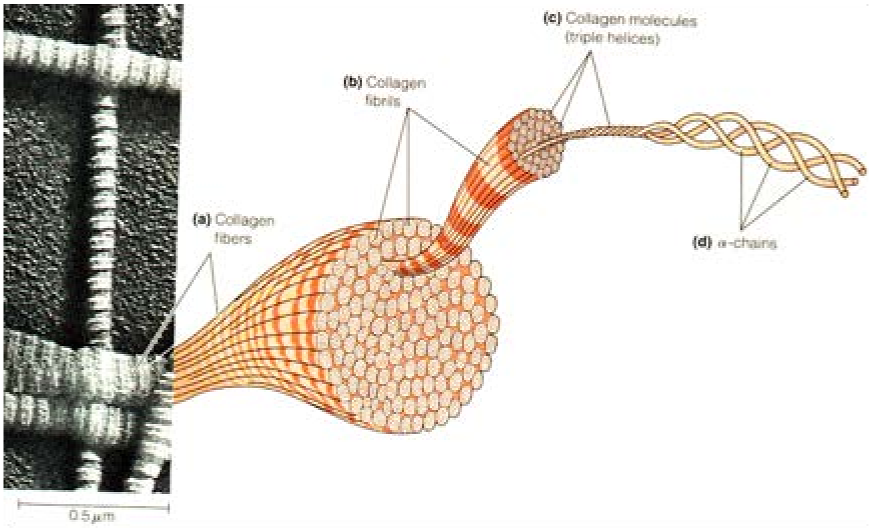

Figure 1. An electron micrograph of collagen (shown on the left) and a cartoon of the collagen structure (shown on the right). Note the very orderly appearance of the collagen fibers in the electron micrograph. Also note the complex structure of the collagen, as shown in the cartoon image (Collagen Fibers, 1999).

Figure 2. An image of a tendon under a microscope, showing the collagen fibers that make up the connective tissue. Note the orderly appearance of the tissue as well as how compacted the collagen fibers are, providing the tendon with immense strength (Tendon, 2009).

Figure 3. Free Spirit Sphere hanging in the rainforest in Vancouver Island, Canada. Note the number of tether points as well as the ropes connecting the “sphere” to other parts of the rainforest in order to suspend it, providing the Free Spirit Sphere with strength (Nellemann, 2009).

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