The Spectrin Lattice and Suspension Bridge Design

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Rule to Build By: To construct self-supporting structures, balance forces of tension and compression.

What:

The spectrin lattice is a microscopic sub-cellular structure that is located just beneath the cell membrane to provide mechanical support (Wikipedia, 2010). The physical structure of the spectrin lattice appears very similar to the criss-cross pattern of the cables seen in suspension bridges. Suspension bridges are used to cross long expanses to provide a way of passage from one point to another for cars, trains, and people. Both of these structures are created to sustain high levels of mechanical strain whether it is the contracting force muscle cell or the weight of one thousand cars crossing over a river. The spectrin lattice and suspension bridge are extremely similar in structure and function but differ greatly in composition and scale.

How:

The spectrin lattice is a cytoskeletal structure made of spectrin protein that lines the inside surface of the cell membrane and connect actin filaments to the cell membrane (Wikipedia, 2010). It can come in a variety of shapes like hexagons and pentagons which prove to be architecturally stable. The two conformations are created by different numbers of spectrin filaments binding to the actin filaments (Wikipedia, 2010). To create both of the geometric shapes the spectrin proteins associate with short actin filaments and anchoring proteins to create a scaffolding structure that encompasses the underside of the entire cell membrane and is incredibly elastic (Bennet, 2004). The spectrin filaments are anchored to the cell membrane by a protein called ankyrin. The strong but flexible architecture that creates the spectrin lattice upholds the principle of balancing forces of tension and compression because it allows for the cell to undergo large amounts of mechanical stress without damaging or completely rupturing the membrane (Dhermy, 1991). The geometric nature of the lattice spreads and absorbs the forces of compression and tension by transferring the forces

from point to point (Bennet, 2004). There is a type of traumatic brain injury called diffuse axonal injury in which the spectrin lattice is compromised by the proteolytic enzyme calpain. The destruction of the spectrin lattice causes the cell membrane to bud off or “bleb” as seen in apoptosis, which ultimately kills the cell (Wikipedia, 2010). The spectrin lattice is needed to prevent the cell from being destroyed when mechanical force or pressure is exerted upon it by its surroundings. It is absolutely critical in the balance of tension and compression in cells.

Suspension bridges uphold the principle of balancing forces of tension and compression by creating a system that can withstand massive amounts of force and weight without being destroyed or structurally compromised (Wikipedia, 2010). A suspension bridge consists of a deck, which is the surface the cars or other vehicle travels on, towers (usually two) that support most of the bridges weight, and cables that evenly transfers the force from the deck to the towers. The force of compression pushes down on the suspension bridge's deck, but because it is a suspended surface the cables transfer the compression to the towers, which direct the compression down into the earth where they are entrenched several hundred feet (Wikipedia, 2010). The cables and anchoring points on either end of the bridge are the recipients of the force of tension between the deck and the towers and are extremely taught (Morrissey, 2010). The cables of the bridge represent the spectrin filaments that associate with the anchoring protein ankyrin, which represent the anchoring blocks of the bridge. The actin filaments represent the towers because they receive the compression force from the spectrin filaments when pressure is applied.

Why:

The reason why the spectrin lattice upholds the rule of balancing forces of tension and compression is because its geometric structure and flexible attributes give the cell membrane strength while also allowing for movement. The geometry of the hexagons and pentagons create a system that disperses force at the points of intersection and each side of the figure receives an equal amount of pressure when force is applied (Pascual, Castresana, & Saraste, 1997). In the repeating structure the hexagons and pentagons associate with each other and the force is dispersed around the entire cell to prevent membrane rupture in the region experiencing the most mechanical strain. The propagation of the forces helps to maintain the cell membranes integrity and shape. The evolutionary advantage that the spectrin lattice provides is the ability of cells to withstand mechanical forces without being damaged or destroyed (Pascual, Castresana, & Saraste, 1997). Spectrin can be found in many different cells, for example red blood cells, which help them maintain their round concave structure under high pressure and in crowded vessels and capillaries and also in nerve cells to which provides support to their long dendrites and axons (Pascual, Castresana, & Saraste, 1997). The spectrin lattice

allows for cells to maintain their integrity and continue functioning under different environmental conditions. This ability creates durable tissues, organs, and systems that can also withstand various environmental conditions (Pascual, Castresana, & Saraste, 1997).

The reason why suspension bridges uphold the rule of balancing forces of compression and elevation is found in its design. By transferring the downward compression of the load deck to the towers it creates a strong and stabile structure that can endure a lot of mechanical stress. The cables act as the mode of transport for the compression while also maintaining tension between the towers and the anchors in order to keep the towers erect (Morrissey, 2010). Suspension bridges are also able to move and flex in order to maintain its integrity in windy conditions. Construction of a suspension bridge does not require a lot of material, which makes it a relatively simple design (Morrissey, 2010). This reflects the simplicity of the repeating hexagonal shapes used to make the spectrin lattice.

Figures:

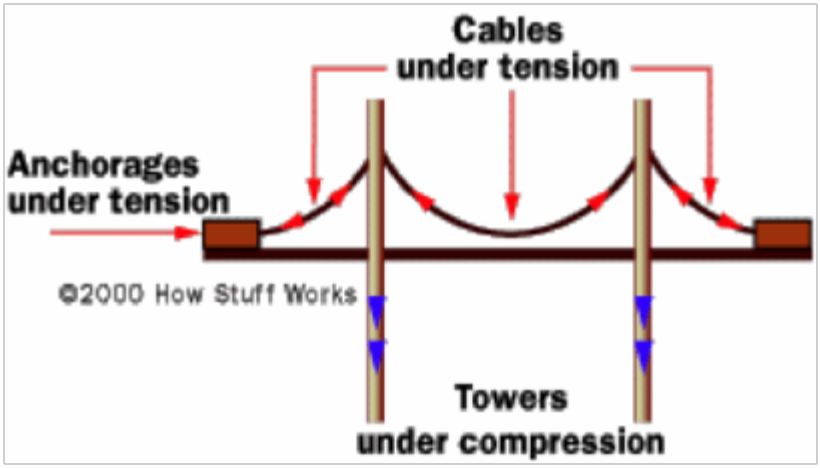

Figure 1: The diagram above shows the forces acting on suspension bridges and how its structure is adapted to withstand them. It is clear that the towers absorb compression and the anchors and cables absorb tension. (Morrissey, 2010).

Figure 2: The picture above shows the Golden Gate Bridge, as suspension bridge found in San Francisco, CA. The same structures are seen here as in Figure 1 with the towers, load deck, cables, and anchors (Niewiroski, 2007).

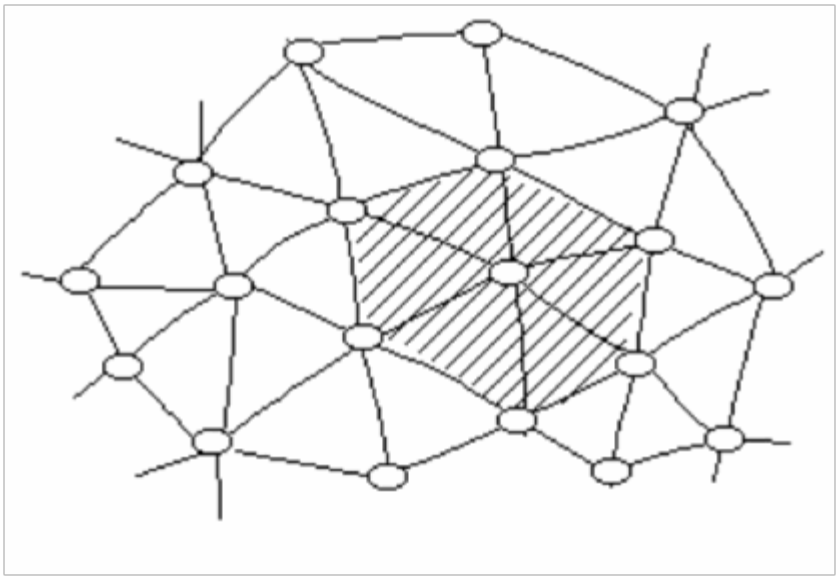

Figure 3: The spectrin molecules form a mesh-like pattern that is anchored to the membrane by ankyrin molecules (ellipses). The basic shape is hexagonal (shaded) (Cell Biology Wiki, 2009).

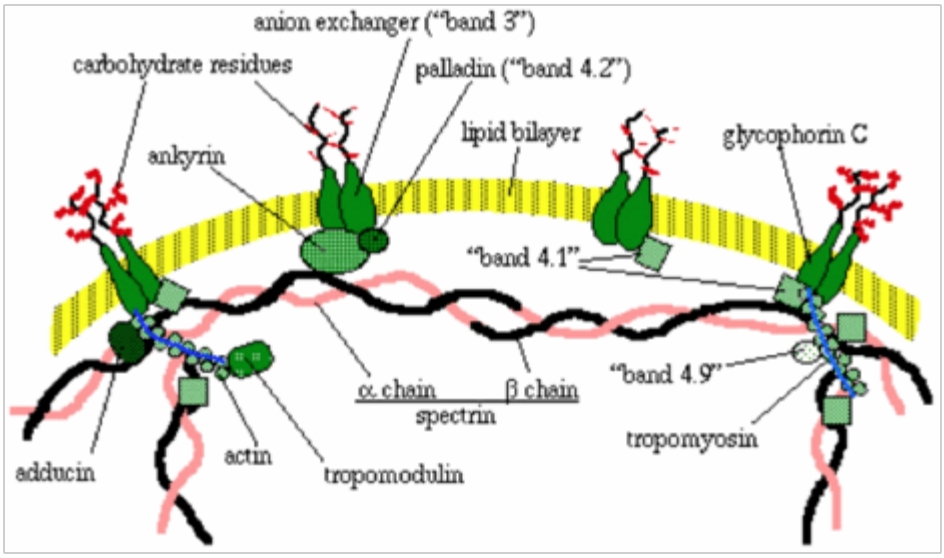

Figure 4: The picture above shows spectrin in the erythrocyte membrane cytoskeleton. It associates with the actin filament, which in turn binds to ankyrin to secure it to the cell membrane (Cell Biology Wiki, 2009).

References

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