Geodesic Domes and the Spectrin Lattice

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Cell Biology 219
Living Architecture
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4 December 2012

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Rule to Build Buy: In order to construct self-supporting structures, the force of stress placed on the structure must be balanced (Morris, Staudinger).

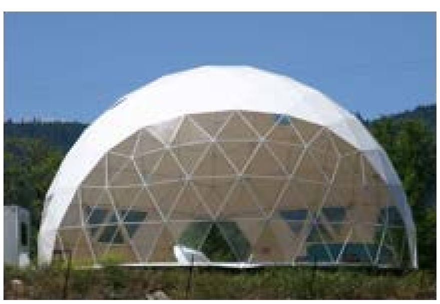
What: Geodesic domes are spherical structures based on a network of circles. A network of triangles formed by intersections of circles supports the structures (Weisstein, 2012). Similarly, the spectrin lattice located beneath the cell membrane provides mechanical strength for the cell by using triangles made by the intersection of spectrin molecules (Sigma Aldrich,2012).

How: Geodesic domes are designed with many intercrossing circles on the outermost face of the dome, that when intersected, make triangles on the surface. The intersections are known as chords, which are line segments that join two points of a curve. Triangles are often used in construction due to the amount of strength that triangles provide; the distribution of weight across the three points allows the structure to hold a lot of weight while still being stable. Geodesic domes therefore use many triangles to balance the gravitational forces that are exerted upon the sphere. By using the different geometrical shapes, especially the usage of triangles, the geodesic dome upholds the rule to build by due to the fact that these geometrical shapes distribute the stress (Wikipedia, 2012) (Weisstein, 2012).

A living cell is a network of working machinery that is surrounded by cytoplasm and is enclosed by a cellular membrane. The structure of the cell itself is formed by the interlinking proteins called spectrin, which polymerize the alpha and beta dimers in an antiparallel pattern to form long strands that are located beneath the plasma membrane of the cell. Spectrin is located beneath the cytoplasmic surface of vertebrate erythrocyte cells, also known as red blood cells. The erythrocyte skeletal membrane is formed of about 5-7 extended spectrin molecules that are linked to actin filaments, which are about 40 nm in length. The polymerized strands of spectrin form an interlocking network, which is known as the spectrin lattice. Spectrins are extended strands of flexible molecules that are approximately 200- 260 nm in length and about 3-6 nm across. The spectrin lattice is also known as the cellular skeleton, due to the fact that is upholds the shape of the cell. Each strand of spectrin contains an actin-binding domain at each end, which allows the strands to link actin filaments to the cellular membrane. This lattice of spectrin and actin encompasses the entire underside of the cell and is extremely elastic. The crossing pattern of the spectrin lattice forms many geometrical shapes, such as triangles, which provide the mechanical strength for the cell. These triangular shapes allow the forces acting upon the cell to be balanced, thus allowing the cell to keep its form and not burst under any form of pressure. Spectrin is also responsible for the organization of the organelles within the cell, the shape of the cell, the maintenance of the lipid asymmetry of the plasma membrane and the arrangement of transmembrane proteins. The spectrin-actin network is anchored to the plasma membrane of the cell by a protein called ankyrin. The ankyrin protein binds to the beta subunit of spectrin. The protein ankyrin is bound to the cytoplasmic domain of the anion exchanger (Sigma Aldrich, 2012). The destruction of the spectrin-actin network causes the cell membrane to bud off, which is seen in the process of apoptosis, which is also known as cell death. This network upholds the rule of balancing forces by distributing the amount of stress placed upon the cell by making triangles out of spectrin strands to distribute the amount of stress across the geometrical shapes instead of across the cell surface. This is important because it allows the cell to undergo mass amounts of mechanical stress without rupturing or damaging the cell. The different geometrical shapes, especially triangles, disperse the amount of stress that is placed upon the cell. The network is absolutely necessary for the survival of the cell because it prevents the cell from being destroyed by the amount of pressure that is exerted upon the cell. There are also many diseases that can occur when there are defects within the spectrin lattice. The most common disease that is directly related to a defect within the spectrin lattice is elliptocytosis, which is a blood disease where a large number of the patient’s red blood cells are not their normal biconcave shape, but instead are elliptical. In the most severe form of this disease, the patient can develop hemolytic anemia, which is the abnormal breakdown of red blood cells (Alberts et al., 2012) (Sigma Aldrich, 2012) (Biles, 2010) (Uniprot.com, 2012) (WebMD, 2012).

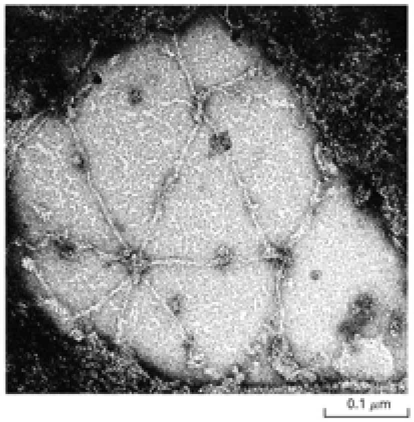
Why: Geodesic domes uphold the rule of balancing stress due to the design of the dome itself. The interconnecting circles form many small triangles on the face of the sphere, allowing the amount of stress placed on the sphere to be absorbed by the different points of the triangles. The construction of geodesic domes begins with a network of pipes that form an icosahedron, a shape consisting of 20 identical triangular faces, allowing the structure to endure mechanical stress. The triangles used to build geodesic domes also allow the structure to be stable under the mass amounts of gravitational force placed upon the dome (Weisstein, 2012) (Wikipedia, 2012).

The spectrin lattice upholds the rule of balancing stress due to the geometric structure that the network gives the cell, while still allowing the cell to be flexible. The geometry of the triangles made by the lattice disperses the amount of stress that is placed on the cell by its surroundings, across the cell. Since the stress is not localized, the cell does not rupture from immense amounts of stress. This lattice network is a large evolutionary advantage due to the amount of flexibility that it gives the cell, while still maintaining the integrity of the cellular membrane. Spectrin is found in many different eukaryotic cell types, including cardiac muscle cells and red blood cells. Cardiac muscle cells are cells within the body that are often under a lot of pressure, which means having a spectrin lattice network is extremely important to the lives of these cells. The spectrin lattice provides mechanical strength to the cardiac muscle cells to counteract the constant stress exerted on them from blood pressure. The spectrin network is essential for blood cells to withstand the constant amount of stress that is placed upon them while in the capillaries and veins. The flexibility that is given to red blood cells by the spectrin lattice is also very important because of the function of red blood cells themselves. The red blood cells are often rushed through the capillaries and veins, and when there are blockages, the red blood cells have to move around them in order to maintain their job of bringing oxygen to different tissues throughout the body. The spectrin network is essential to the living of cells because it allows eukaryotic cells to live in many different environments throughout the body. If the spectrin lattice was not located within the cell, directly under the cell membrane, the cells would go through the process called apoptosis, therefore dying (Alberts et al., 2012) (Sigma Aldrich, 2012) (Biles, 2010).

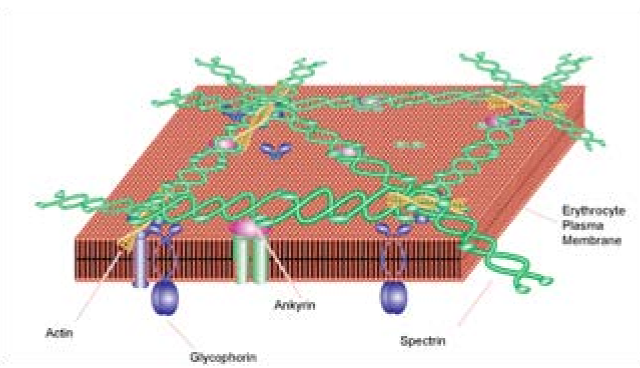


A geodesic dome that has left some of the internetwork of triangles exposed, showing the amount of geometrical shapes that are used in order to counteract the amount of gravitational stress placed upon the dome (Alibaba.com, 2012).

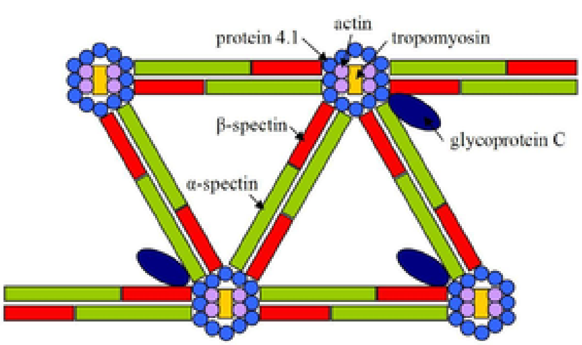
Spaceship Earth, located at Epcot Walt Disney World, is an extreme example of the amount of triangles used in geodesic domes. This dome contains hundreds of triangles across its surface (Wikipedia, 2012).



Human erythrocyte showing the triangles formed by the spectrin network underneath the cell membrane. The circles at each intersection of the spectrin stands are the actin connecting pieces (BioWeb, 2012).



The phospholipid bilayer shown in red with the spectrin lattice shown in light green. The spectrin lattice is shown forming triangles with actin connections at each end. The protein ankyrin is shown, which connected the spectrin lattice to the bilayer of the cell (Sigma Aldrich, 2012).



Interconnecting dimers of spectrin shown in red and green with circles of blue actin shown connecting the strands. The alpha and beta dimers of spectrin align in an every other format, forming long strands of spectrin that holds the cell together (Wikipedia, 2012).

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