Structural similarities between grana in chloroplasts and the Galaxy SOHO Complex in Beijing, China

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Rule-to-Build-by:

By increasing surface area in a structure, access to natural light is gained.

What:

The biological structure of grana, or stacks of thylakoids in the chloroplasts follow this principle, as does the human – built Galaxy SOHO structure in Beijing.

How:

Chloroplasts are specialized organelles found in algae and plant cells. They contain chlorophyll, a light-absorbing pigment and are the site of photosynthesis. Chlorophyll is also responsible for the green appearance of plants, and chloroplasts are thus found in all the green parts of a plant. Photosynthesis is the series of reactions that convert CO2 from the atmosphere into organic molecules. The reactions involved in this process are driven by the capturing of light from the sun after which this light energy is converted into chemical energy. The leaves of a plant are the primary site of photosynthesis as much of the process of photosynthesis relies on the capturing of light energy from sunlight. The chlorophyll pigment is the molecule able to absorb the energy from photons of light. Once absorbed, electrons in chlorophyll can interact with the absorbed photons of light and will consequently be raised to a higher energy level. Chloroplasts are enclosed by an inner and outer membrane separating the extracellular space from the intermembrane space and the stroma, the material inside the cell. Within the chloroplast, there are stacks of flat disc-like membrane-enclosed units called thylakoids which provide a third membrane for chloroplasts which separates the stroma from the thylakoid space. Thylakoids have an important function in plant cells. First and foremost, they are the site of the major reactions necessary to capture energy for the plant by harvesting light energy (Alberts et al. 2010). The two photosystems necessary in oxygen-dependent photosynthesis for the conversion of light energy into electrochemical potential are found in thylakoids (Allen & Forsberg 2001). Both the light harvesting and the electron transport occur in the thylakoid membrane (Routaboul, fischer, & Browse 2000). Thylakoids tend to stack up together tightly into structures called grana. The stacking up of the thylakoids drastically increases the number of thylakoid membranes able to gain access to light from the sun and process it into chemical energy (Alberts et al., 2010). Mature and developed chloroplasts can contain up to 60 stacks of thylakoids in their stroma. The number of thylakoids that make up these grana stacks ranges from less than ten thylakoids in high light chloroplasts, or in plants that have extreme exposure to sunlight, to over a hundred thylakoids in plants that grow under extreme shade conditions (Staehelin, 2003).

The thylakoid membranes are essential in the harvesting of light in plant cells, and their stacking up in grana follows the above described rule-to-build-by. The light absorbing molecules are all organized into units in the thylakoid membrane (Smith, 1987). In order to drive the reaction that converts the light photons into chemical energy useful for the cell, thylakoid membranes must have access to sunlight. The more light photons they can capture, the more energy they can provide the cell with. This means that the more thylakoid membrane is exposed to sunlight, the more energy can be converted. Thylakoids are therefore stacked up tightly into grana to increase the amount of thylakoid membrane that has access to sunlight (Alberts et al., 2010).

The Galaxy SOHO project is a large complex of 330,000m^2 located in the center of Beijing. Its structure was designed by Iraqi architect Zaha Hadid and British architect Patrik Schumacher both of whom work under the Zaha Hadid Architects firm. It is comprised of four continuous organically-shaped units that although set apart, are connected and fused by stretched bridges. The overall shape is fluid and lacks corners or “abrupt transitions.” Unlike the thylakoids stacked up in grana, the different levels of the Galaxy SOHO have different functions. While the first three floors house public facilities such as retail and entertainment services, the higher levels house offices for innovative businesses. The public can take advantage of the magnificent view by visiting a bar, restaurant, or other dining facility on the top floor. To increase the surface area, each of the four units is built in a circular way, leaving the middle of the unit un-built. This type of structure gives the interior of the unit access to the sunlight that enters through the open space in the middle of the unit (Galaxy Soho, 2012).

Why:

Since most of the energy harvesting in plant cells occurs in the membranes of thylakoids, the tight stacking of thylakoids on one another into grana has great evolutionary benefits for the plant as an organism. The stacks of thylakoids and the flattened disc-like structure of these organelles provides increased membrane surface for energy harvesting reactions to occur in. The more membranes there are, the more light can be captured from the sun, and the more energy can be converted through photosynthesis and transported to parts of the cell and organism that need it. Photosynthesis is absolutely crucial to the survival of a plant as it is one of the major sources of energy. The converted energy provides the plant with the fuel to develop, grow, function and reproduce. Nearly all organic material in plants necessary for their survival is produced by the energy captured from photosynthesis (Alberts et al., 2010).

To illustrate the evolutionary benefits for the structuring of thylakoids into stacks of grana, researchers have found that the thylakoids in chloroplasts account for approximately fifty to sixty percent of the membrane surface area in high light plants that are exposed to extremely sunny conditions. In plants that grow under low light conditions, this percentage can be as high as seventy percent. The increased amount of thylakoid membrane surface in the latter plant type, demonstrates the need for these types of plants to have as much exposure to light energy as possible. The increased membrane surface area enables the plants in low light conditions to capture as much energy as possible (Staehelin, 2003).

The Galaxy SOHO complex was inspired by the grand scale of Beijing and traditional Chinese architecture in which open connected spaces are common. All levels are lit by skylights which provide even the lower levels of the units that are exposed to the inner courtyard with daylight and adequate shading. In addition to the pleasant light that the skylights provide for the interior of the building, it has also made the complex very environmentally friendly, earning the project a LEED Silver rating (Meinhold, 2012).

Figures:

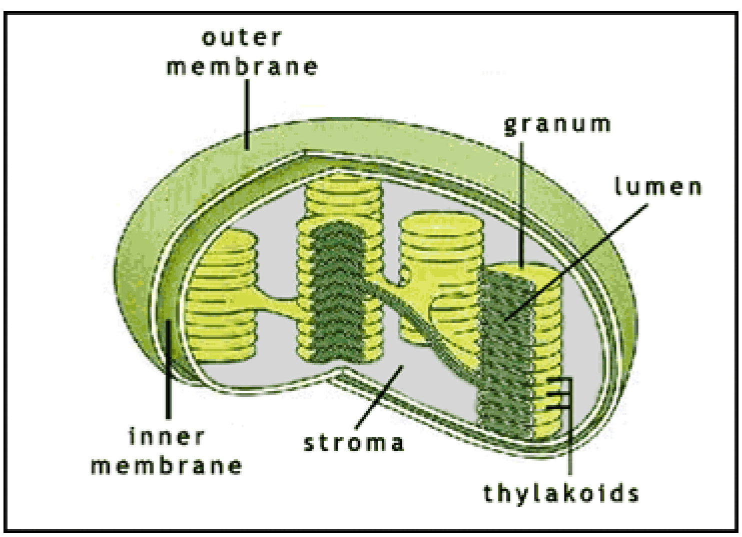

Figure 1: This is an artistic representation of a chloroplast. In the picture, the grana are shown composed of stacks of thylakoids increasing the thylakoid membrane available in the cell to process energy captured from sunlight

(Tutorvista, 2010).

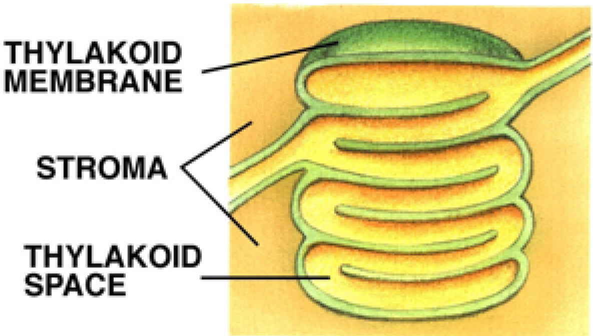

Figure 2: This image depicts the extent to which the thylakoid membrane is increased by the stacking up of several thylakoids into a granum. This structure aids the plant cell by increased exposure of the thylakoid membranes to sunlight for the capturing of light energy (Collins, 2002).

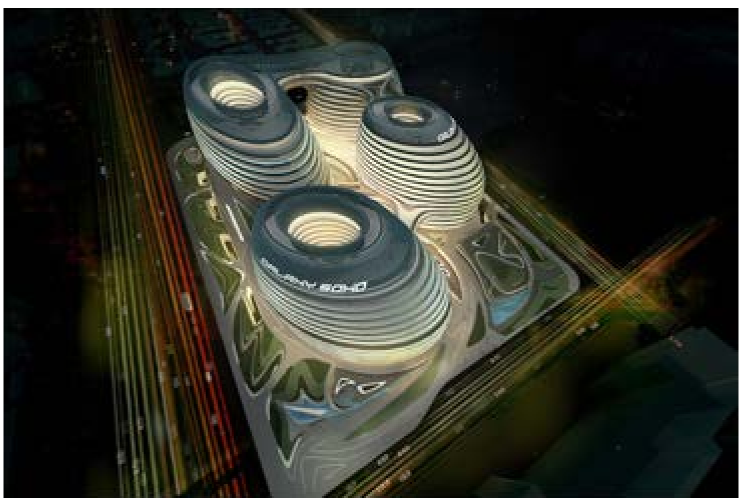

Figure 3: In this image, the units of the Galaxy SOHO are shown with the skylights providing daylight to the interior of the four building units. This type of structure increases the surface area of the complex, allowing increased exposure of the interior of the building to sunlight (DeZeen, 2012).

Figure 4: In this image the daylight provided by the skylights in the interior of the Galaxy SOHO is nicely demonstrated. Since the interior of the complex is also on the 'surface' of the building, it is exposed to daylight (Architecture Daily, 2012).

References

Alberts, Bray, Hopkin, Johnson, Lewis, Raff, Roberts, & Walter (2010). Essential Cell Biology. 3rd edition. New York: Garland Science.

Allen, J. F., & Forsberg, J. (2001). Molecular Recognition in Thylakoid Structure and Function. *TRENDS in Plant Science 6*(7).

Architecture Daily. Galaxy Soho/ Zaha Hadid Architects, by Hufton + Crow. (16 November 2012). Architecture daily. Retrieved from: http://www.archdaily.com/294549/galaxy-soho-zaha-hadid-architects-by-hufton-crow/

Collin (2002). Photosynthesis. Collin County Community College. Accessed online at: http://iws.collin.edu/biopage/faculty/mcculloch/1406/outlines/chapter%2010/chap10.htm

Dezeen. Galaxy Soho by Zaha Hadid Architects. 29 October 2012. DeZeen Magazine. Retrieved from http://www.dezeen.com/2012/10/29/galaxy-soho-by-zaha-hadid-architects/

Galaxy Soho/Zaha Hadid Architects. (2012). *"Galaxy Soho / Zaha Hadid Architects" 29 Oct 2012. ArchDaily*. Accessed online at: *<http://www.archdaily.com/287571>*

Meinhold, B. (2012). "Zaha Hadad's Light-Filled LEED Silver Galaxy SOHO Opens in Beijing" 14 Nov 2012. Retrieved from: http://inhabitat.com/zaha-hadids-light-filled-leed-silver-galaxy-soho-opens-in-beijing/

Routaboul, J., Fischer, S. F., & Browse, J. (2000) Trienoic Fatty Acids are Required to Maintain chloroplast Function at Low Temperatures. *Plant Physiology 124*(4): 1697-1705.

Smith. H. (1987). The Molecular Biology of Plant Cells: Botanical Monographs. CA: University of California Press.

Staehelin, L. A. (2003). Chloroplast Structure: From Chlorophyll Granules to Supra-Molecular Architecture of Thylakoid Membranes. *Photosynthesis Research* 76: 185-196.

Tutorvista (2010). Chloroplasts. Tutorvista. Accessed online at: http://www.tutorvista.com/biology/chloroplasts