Comparison of Plant Cell Wall to Buildings Engineered to Survive Earthquakes

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Living Architectrue Research Project Report

Bio 219/Cell Biology

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Rules to Build By:

"To construct self-supporting structures, balance forces of tension and compression" and "To achieve the best design, continuously tinker with the building plans. (Morris)"

What:

The interwoven proteins, polysaccharides and polymers of cell wall is an example of a cellular structure that fits these rules and earthquake engineering of buildings fit these rules.

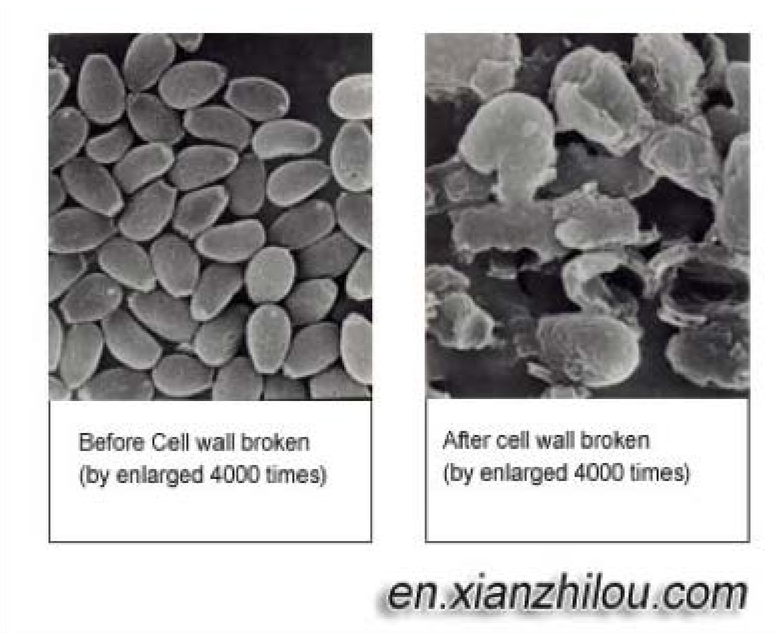

Figure 1: An example of what happens to a cell wall that is broken by forces of compression and stress. Shoddy construction of a cell wall will lead to death for the plant cell due to its membranes extreme fragility. Picture courtesy of "Why Shall Ganoderma Lucidum Spores' Cell Wall Be Broken?"

Figure 2 : An example of a building that has broken by the forces of an earthquake. Shoddy construction is often the cause of property damage in an earthquake. Most casualties of earthquakes are the result of building destruction. Picture courtesy of <http://www.telegraph.co.uk/news/picturegalleries/pictures-of-the-year/3813200/Pictures-of-the-year-natural-disasters.html?image=4>.

How:

There are several ways in which cell walls and earthquake engineered buildings fit these rules of architecture. The first is that cells and people and constantly changing their designs to fit the situation at hand. Cellouse microtubules in the cell wall are built along lines of stress that the cell has experienced. This makes every cell wall different, tailored to what that specific cell has experienced in its lifetime (Alberts 2009).

Cell walls are designed to withstand forces of tension and compression. The cellouse microtubules that orient in lines of stress interweave with other structural proteins (Alberts 2009). Some examples of proteins and polymers that help construct the cell wall are pectin which fill the space between the polysaccharides and proteins to provide resistance to compression (Osumi 2002). This gives the cell wall its tensile strength that it requires in order to be strong yet allow for growth. The orientation of the cellulose micro fibrils determines how the plant will grow. Plant cells tend to elongate perpendicular to the orientation of micro fibrils, which in turn form in lines of stress (Osumi 2002). The stress that a cell wall goes through in its life time will determine the final shape of the plant itself (Alberts 2009)f.

A cell wall constantly be under from pressure on two sides. Being part of a living organism means that that there is compression from the plant holding it's self together. At the same time turgor pressure will place pressure from inside the cell (Alberts 2009). If the cell wall is not constructed properly than the plant cell will rupture.

An important part of the cell wall is the middle lamella. The middle lamella is rich in pectin and without it plant cells could not connect with each other (Alberts 2009). Its ability to balance all of the tension that it receives is very important for one very important reason. When looking at human buildings that are cemented to each other, they receive huge damage during an earthquake. The middle lamella's ability to balance both compression and tension far exceeds anything of human design (Osumi 2002). The structure of the interwoven matrix of proteins, polysaccharides, and polymers that make up the cell wall is constructed a certain way (Alberts 2009). The bases of the structure are the cellulose microfibrils, which give the cell wall its general strength. Interwoven with the cellulose are several different proteins and polysaccharides. One example is pectin but cross-linking glycan is also woven into the mix. The pectin fills the space between the cellulose microfibril (Alberts 2009)s. Glycan also does this, filling this space gives additional resistance to compression and tension.

This structure is constantly tinkered with by the cell to achieve a configuration that best allows the cell to flourish. It must withstand compression on both sides of the cell.

Earthquake engineering also tries to follow these rules. Designs for withstanding the normal pressures of a structure as well as the tension provided by an earthquake are constantly being remodeled ("Earthquake Engineering."). Older buildings also are tinkered with to attempt to make them more earthquake secure ("Earthquake Engineering.").

Why:

The building of cell walls by a plant cell is a process that is unique to each cell and is a design that is tinkered with. Due to the cell walls flexibility in building, the plant cell has many options. For example if the plant cell needs to have a rigid and waterproof wall than lignin, a polysaccharide, can be produced (Alberts 2009). The lignin can be deposited into the wall, which in turn will make it more waterproof (Alberts 2009). The wall will also be unique to the cell's life experiences due to its strength coming from the long fibers that originate in lines of stress (Alberts 2009).

A plant cell wall also must balance forces of compression and tension in order to provide its cell with protection. Proteins, polysaccharides, and many different polymers are woven to together to create the final structure (Alberts 2009). The cell wall is a complex interwoven structure that resists compression and tension as well as determines how the plant will elongate in the long run (Alberts 2009). The interweaving of proteins along stress lines also allows it to undergo a great deal of compression without being damaged. Even if under extreme stress the cell wall will withstand the pressure, it has to; a plant's plasma membrane is in contrast delicate and easily ruptured. Without a strong tensile cell wall the cell will rupture under the lightest pressure.

One of the biggest pressures that a cell wall will face is turgor pressure. This constant water pressure will press the plant's membrane directly against the cell wall. If the cell wall cannot withstand compression it would rupture and kill the cell.

In human earthquake engineering, many designs have been tried over the age of human civilization. Earlier civilizations discovered their own ways to balance compression from the earth with the normal compression and tension of a building holding it's self together, much like how a plant cell must deal with compression from outside forces and inside turgor pressure ("Earthquake Engineering."). An example of early human earthquake engineering that shows this is the city of Pasargadae in ancient Persia ("Earthquake Engineering."). This city used the idea of base isolation, but ideas on how to protect buildings from internal and external forces has advanced since the time of the ancient Persians ("Earthquake Engineering."). There are now several more advanced base isolation ideas used to help buildings survive earthquakes. They are significantly more advanced than the simply Persian idea, yet are clearly from tinkering with the original simple design.

The example of earthquake engineering that most reflects a cell wall however is called reinforced concrete structures. These reinforced structures have steel reinforcement bars placed into potential lines of stress to help relieve compression and reinforce brittle structures. They fill the same purpose as the cellulose micro fibrils in cell walls ("Earthquake Engineering.").

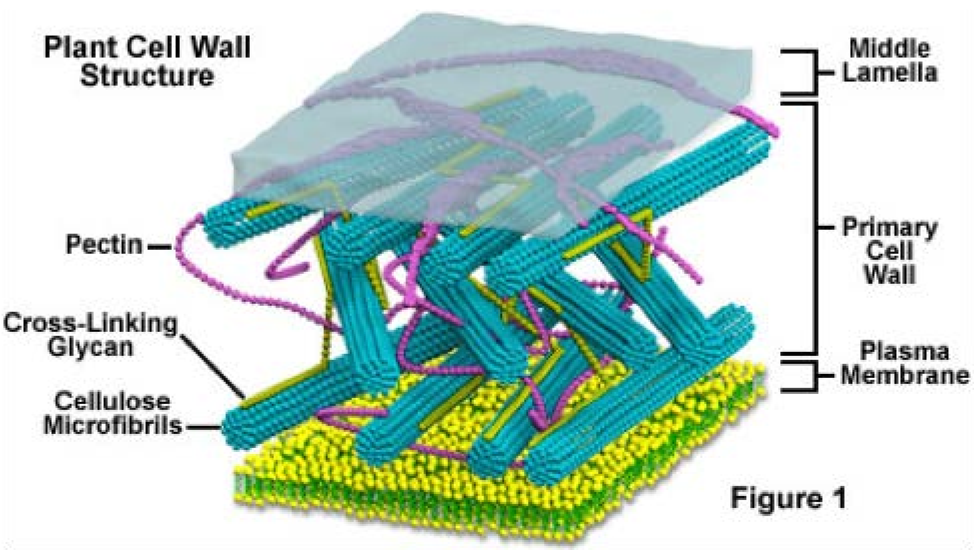

Figure 3: The cell wall of a plant cell is made up of cellulose micro fibril, pectin, and cross-linking glycan. The micro fibrils are interwoven with other structural proteins to form a structure that resists compression and tension. This allows the plant cell to withstand extreme stress to its cell wall. Picture courtesy of "Molecular Expressions Cell Biology: Plant Cell Structure - Cell Wall." Molecular Expressions Cell Biology: Plant Cell Structure - Cell Wall. N.p., n.d. Web. 01 Dec. 2012. <http://micro.magnet.fsu.edu/cells/plants/cellwall.html>.

Figure 4: Seismic testing on a full-scale 3D building. There are many visual similarities between the structures of a cell wall. The way that steel is interwoven into the building's structure resembles the way that micro fibrils are interwoven with structural proteins to create a structure that can with stand compression as well as tension. Picture courtesy of "News & Events." - JRC. N.p., n.d. Web. 04 Dec. 2012. <http://ec.europa.eu/dgs/jrc/index.cfm?id=1410>.

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