Similarities Between Intermediate Filaments and a Rope Course

KarryAnne Belanger
Living Architecture Research Project Report
Bio219/Cell Biology
Wheaton College, Norton, Massachusetts, USA
December 4, 2012

Click here for Hela Cell Report

Rule to Build by:

The first rule to build by on the Living Architecture website is "To maximize flexibility of architectural form, assemble complex structure from simple repeating units."(Morris and Lane, 2012)

What:

The intermediate filament system is an example of a cellular structure that upholds this rule. To demonstrate this rule in a human built structure, we explore a rope course.

How:

Intermediate filaments extend through out the cytoplasm of the cell creating a complex system (Alberts, et al, 2010 Pg. 572). Due to their strength, it is believed that their primary purpose is to add structural support (Cooper, 2000). This strength allows the cell to survive stretching that can occur during movement and other applicable tensions. Intermediate filaments are one of three types of protein filaments that make up the cytoskeleton. All three of the protein filaments are similar in that they are composed of repeating proteins (Alberts, et al, 2010 Pg. 573). Intermediate filaments differ from microtubules and actin filaments in that they are not composed of a single type of protein, but consist of a variety of different proteins. There are four main groups of proteins constituting intermediate filaments that contain around fifty different proteins. These groups include keratins, vimentin, neurofilaments, and nuclear lamins. Each group of intermediate filament proteins is specialized for a select group of cells. (Cooper, 2000).

Intermediate filaments are formed from polymerization. The basic unit of an intermediate filament is the monomer (Childs, 2001). Monomers consist of an alpha helical segment with an amino terminus and a carboxyl terminus on opposite ends. The alpha helical regions of monomers consist of nearly identical amino acid sequences that enable them to pair together and form a final structure that is roughly the same length throughout (Alberts, et al, 2010 Pg. 574). The formation of a coiled dimer is the first step of the polymerization of an intermediate filament. A coiled dimer is formed when two monomers come together and coil around one another. Each monomer has the three previously mentioned parts and when the dimer is formed, the amino termini pair with themselves, as do the carboxyl termini forming the dimer with the amino groups on one side and the carboxyl groups on the opposite side (Childs, 2001). The next process of the polymerization of an intermediate filament is the formation of a tetramer, which is when two coiled dimers noncovalently bond together. At this point, the two amino termini of one dimer are paired with the two carboxyl termini of another dimer. The second to last step of polymerization is the process of two tetramers coming together, joining end to end. Finally, a total of eight tetramers are twisted together forming the intermediate filament. The final form of the intermediate filament leaves the amino and carboxyl termini of the filament accessible for various interactions (Alberts, et al, 2010 Pg. 574). Intermediate filaments thus need to be constructed from repeating units to function properly, confer structural support for the cell, and strength against stress.

Of the groups of intermediate filaments, keratin is the most important for tissues, including the epithelial tissue. Desmosomes act as intercellular junctions on the plasma membrane of cells, connecting keratin between cells. These intercellular junctions then provide support for the mechanical stress that many tissues endure. Without the support of these intercellular junctions, the tissues could shear. (Delva, et al, 2009) Desmosomes connect the keratin filaments of one cell to another through cadherin proteins and a plaque of other proteins. The plaque of proteins is found inside the cell and acts as a way to anchor the keratin filaments. These plaques span the plasma membrane and interact with cadherin proteins that are outside of the cells. The cadherin proteins of one cell interact with the cadherin proteins of another cell in the extracellular space between them. Through these interactions, cells of a tissue confer tensile strength. (Alberts, et al, 2010 Pg. 704) Therefore, it is not only important for an individual cell to be constructed of repeating units for the intermediate filaments so that it can have structural support and strength against stress. It is also important

for a system of cells like tissues to be constructed of the same intermediate filaments. These intermediate filaments provide structural support and strength for all of the individual cells but also for the tissue as a whole by strongly connecting the cells together so that they wont break apart under stress.

Similar to a cell containing repeating units of intermediate filaments and the desmosomes that connect the cells within a tissue with intermediate filaments, a rope course is made up of several repeating units in order to provide maximal structural support and strength to external stresses. Different ropes are made from various materials. Many strands of the material are twisted together, forming a large structure of these simple repeating units just as intermediate filaments are formed. Using repeated strands to form rope provides strength in each of the individual ropes. (Wikipedia rope, 2012) By using a system of rope that has been strengthened through repeating units, the rope course is able to provide enough support to preserve its structure. In addition though, these ropes are able to withstand external stresses when applied and keep the system together as a whole. A rope course also has poles and hooks that connect the rope of one part of the rope course to others in another part. This is very similar to the desmosome of a cell, and this is how the rope course provides strength and support for the individual parts and the system as a whole.

Why:

The evolutionary benefit of intermediate filaments resides in their ability to impart a bit of resilience in every cell to the variety of stresses they undergo in normal activity. For example, nerve cell axons undergo a lot of mechanical stress because of how long and thin they are. Intermediate filaments are extremely important for the survival of nerve cells because of their ability to provide structural support for the cell. (Alberts, et al, 2010 Pg. 574) As stated previously, intermediate filaments can be formed from any of 50 proteins and form into four main classes. Due to the evolutionary advantage of resilience that intermediate filaments offer, cells have changed their intermediate filaments from the original form for their specific needs. These cells all face varying amounts and types of stress and therefore need specialized support systems. It is known that different tissues need specific keratins and that there are many different genes for intermediate filaments. It would make sense that all of the intermediate filaments known had an evolutionary advantage of resilience to stress for the different cell types they reside in, and that is why they have been maintained throughout history. In addition some intermediate filaments are able to sense mechanical strength and signal remodeling of the cell that will provide support against the stress (Lane, 2000). Due to their importance in cells intermediate filaments play a pivotal role in many diseases that affect skin, hair, myopathy, neurodegenerative disorders, and protein interaction diseases (Omary, 2004). Some specific diseases that involve intermediate filaments are Hutchinson-Gilford progeria, Alexander disease, and Emery-Dreifuss muscular dystrophy. In all of these diseases the support system for the individual cells, that is their intermediate filaments have under gone mutations. These mutations lead to the cell being too weak to endure mechanical stress and if they do the cell can be ripped apart in the process (Lane, 2000). As exemplified by these diseases it is clear that properly formed intermediate filaments and non-mutated genes that encode for them are essential for the survival of a cell. Without intermediate filaments the individual cell does not have he structural support and strength it needs. Also without intermediate filaments the cells that make up tissues would not have the strength or support to stick together, and the tissue would begin to break down. The ability of intermediate filaments to provide structural support and strength that is so essential to the survival of a cell goes back to the basic idea that they are constructed from simple repeating units.

Similarly to cells, rope courses undergo a lot of stress as well. Rope courses must first provide structural support for the various objects that it holds together on a regular basis and must provide strength against any external stresses that threaten its structure as a whole. Individual threads would not be able to support the whole system against external stresses such as people, nor would an individual rope be capable of this task. Multiple ropes of repeating units of thread are required to provide strength against the external stresses the rope course endures and provide structural support.

Figures:

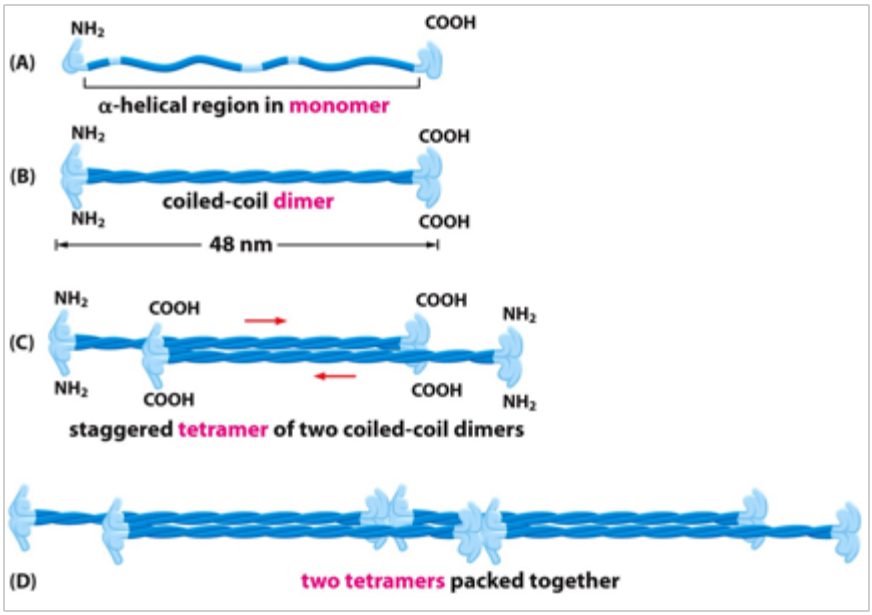

Figure 1: A depiction of the first four steps of polymerization of a intermediate filament. Note the locations of the amino and carboxyl termini and how when a dimer is formed they pair together, but when a tetramer is formed opposites are paired together. (Alberts, et al, 2010)

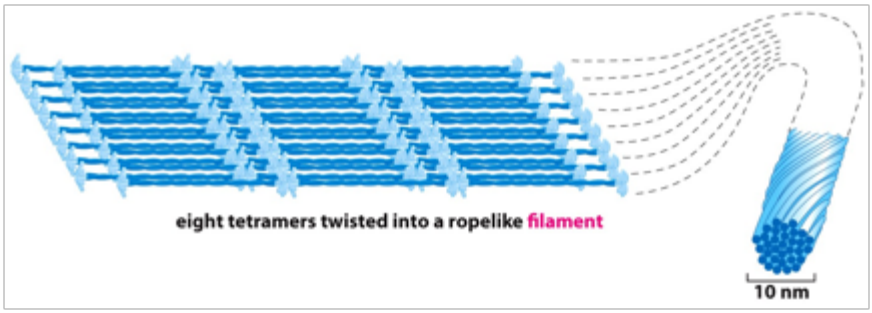

Figure 2: The final step of the polymerization of an intermediate filament. Eight tetramers are lined up together and twisted together to form the final structural form. (Alberts, et al, 2010)

Figure 3: A rope course currently in use. Note the way in which the ropes support various structures such as steps and beams and how they connect to the poles. (Ropes course, 2012)

References:

Morris, R. & Lane, E. Living Architecture. Wheaton College Biology Department. 2012. Accessed online at <http://acunix.wheatonma.edu/rmorris/la/> on 3 December 2012.

Cooper Gm. The Cell: A molecular Approach. 2nd edition. Sunderland (MA); Sinauer Associates; 200. Intermediate Filaments. Accessed online at <http://www.ncbi.nlm.nih.gov/books/NBK9834/> on 3 December 2012.

Childs, Gwen V. "Intermediate Filaments." *Intermediate Filaments*. N.p., n.d. Web. 04 Dec. 2012. <http://www.cytochemistry.net/cell-biology/intermediate_filaments.htm>.

"Rope." *Wikipedia*. Wikimedia Foundation, 27 Nov. 2012. Web. 03 Dec. 2012. <http://en.wikipedia.org/wiki/Rope>.

Delva, Emmanuella. Dana K. Tucker, and Andrew P. Kowalczyk. "The Desmosome." *Cold Spring Harbor Perspective in Biology*. N.p., 2009. Web. 3 Dec. 2012. <http://cshperspectives.cshlp.org/content/1/2/a002543.full>.

Omary, M. Bishr, Pierre A. Coulombe, and W.H. Irwin McLean. "Intermediate Filament Proteins and Their Associated Diseases." *New England Journal of Medicine* 351.20 (2004): 2087-100. *The New England Journal of Medicine*. Web. 3 Dec. 2012. <http://www.nejm.org/doi/full/10.1056/NEJMra040319>.

"Ropes Course." *In Squaw Valley, Lake Tahoe. Teambuilding Activities.* N.p., 2012. Web. 04 Dec. 2012. <http://www.squawadventure.com/ropes-course>.

Alberts, Bruce, et al. *Essential Cell Biology*. New York: Garland Science, 2009. Print.