

Similarities in architecture between the Eiffel Tower and actin filaments with their accompanying binding proteins

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Rule to Build By: An architectural principle shared by both nature and human architecture is that complex structures can be made from the assembly of simple repeating units.

What: Two structures that uphold this principle are the Eiffel Tower in Paris, and the arrangements of actin in conjunction with its actin binding proteins within cells.

How: The Eiffel Tower upholds this principle because it is a open lattice wrought iron tower. The Eiffel tower is 986 feet tall, and it is composed of 18,000 pieces of iron. These pieces of iron are formed into trusses, which are a rigid framework composed of short pieces and are made into a stable shape. In the case of the Eiffel tower, the trusses are triangles. The entire tower is composed of many interlocking trusses of various sizes that give the support necessary for the tower to stand upright and withstand wind. (PBS 2001).

Actin filaments are composed of many actin monomers. Five percent of all the protein in an animal cell is actin, with half of the actin already existing in filaments and the other half composed of free floating monomers in the cytoplasm. When the actin is required to create a filament, it is added together to create one. When the filament is no longer needed, the filament is broken down into free floating monomers again (Alberts 2010).

Actin monomers are globular proteins composed of only around 375 amino acids, and each monomer has a specific binding site at each end. The binding sites allow each actin monomer to bind to two other actin monomers, and form a chain. The binding sites are set up so that all of the actin monomers are orientated in the same direction, giving actin filaments polarity with a plus end and a minus end of the filament. Two proteins regulate the creation and dissimulation of actin filaments. Cofilin is responsible for actin filament dissimulation and profilin is responsible for actin filament creation (Cooper 2000).

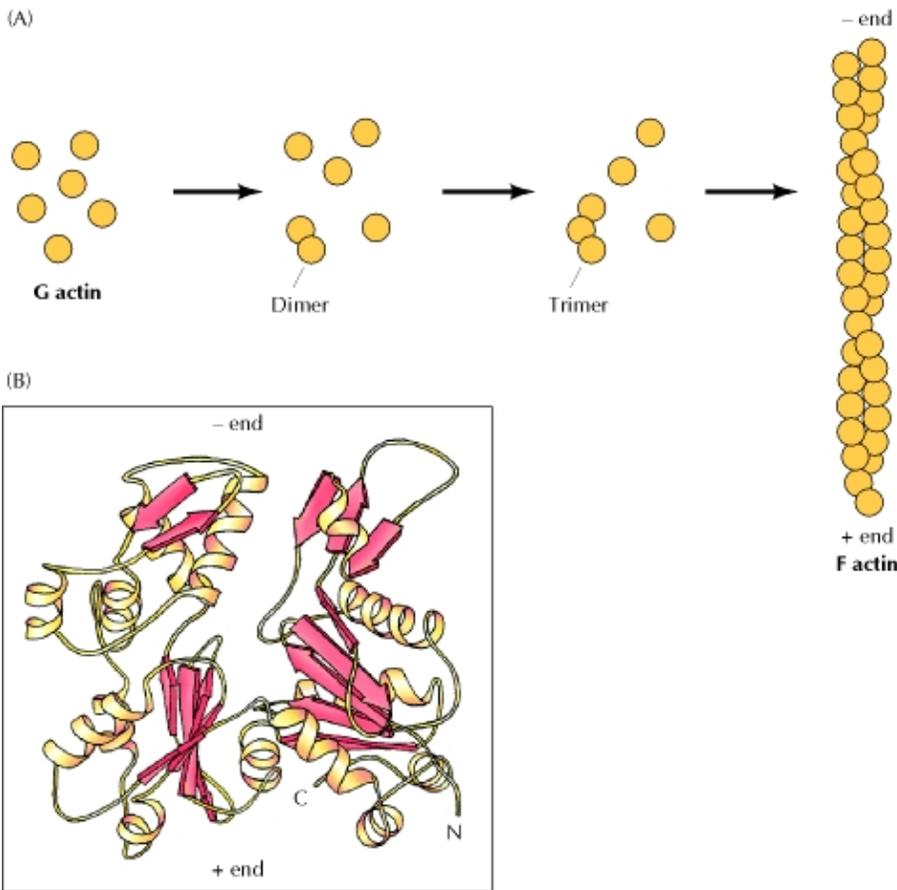


Figure 1 depicts the actin monomers joining together to create the actin filaments that will be used within the cell. The figure also depicts the tertiary structure of the actin monomers (Cooper 2000).

Actin filaments are twisted chains of identical actin monomers, and are thinner and more flexible than microtubules. They rarely occur alone in the cell, but are grouped together by actin binding proteins (Alberts 2010). They are organized into two groups, actin bundles and actin networks which are controlled by actin binding proteins. All actin binding proteins have at least two domains that bind to actin, allowing them to cross link different filaments. The protein's interaction with actin is determined by its shape, as well as by its spacer sequences in the binding site. Actin bundling proteins are small rigid proteins that cause the actin filaments to align close to each other. The actin binding domains in most of the actin binding proteins are similar, but the spacer sequences vary in length. These variances are part of the reason that different proteins have different effects on actin (Cooper 2000).

Actin binding proteins have many varied effects on actin filaments depending on what structure the cell needs. If the structures the cell needs have to be able to stand upright, actin bundling protein is used to provide the necessary support. Cross-linking proteins cause actin to form a meshwork within the cell cortex to provide support. Other actin binding proteins include side binding protein, severing proteins and capping proteins (Alberts 2010).

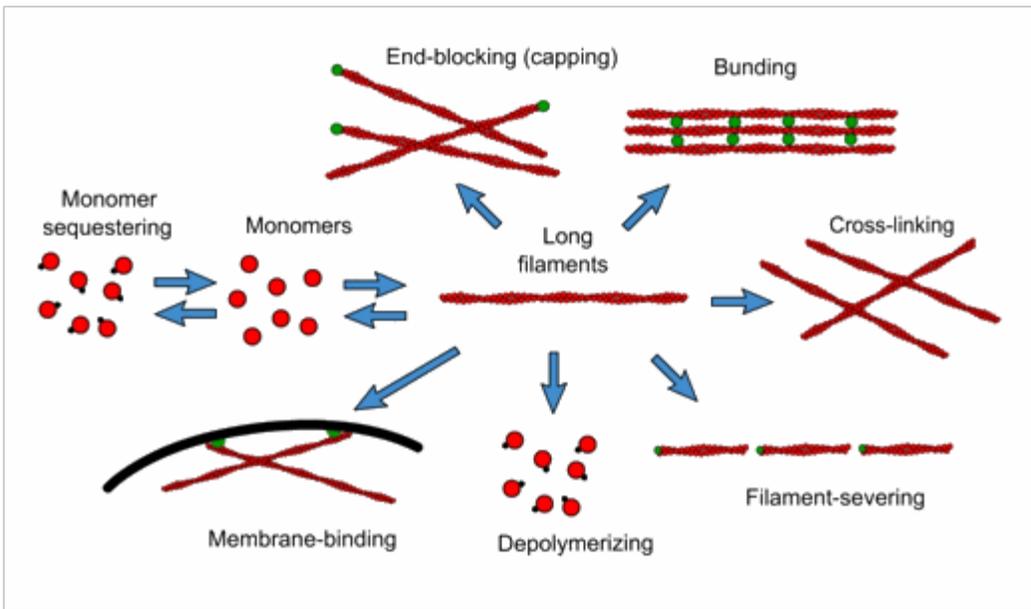


Figure 2 depicts the assortment of actin binding proteins that can cause actin to create many different structures and shapes within the cell using only actin monomers to start with (Hunan 2012).

There are many types of actin binding protein that can cause cross-linking of actin filaments. Proteins such as α -actinin, villin and fimbrin cause actin filaments to associate in closely packed parallel bundles. Filamin causes actin filaments to associate in a loose meshwork that can be used as scaffolding within the cell. Even within one category of actin binding proteins there are many complex structures that can be made from the actin filaments (Diwan 2007).

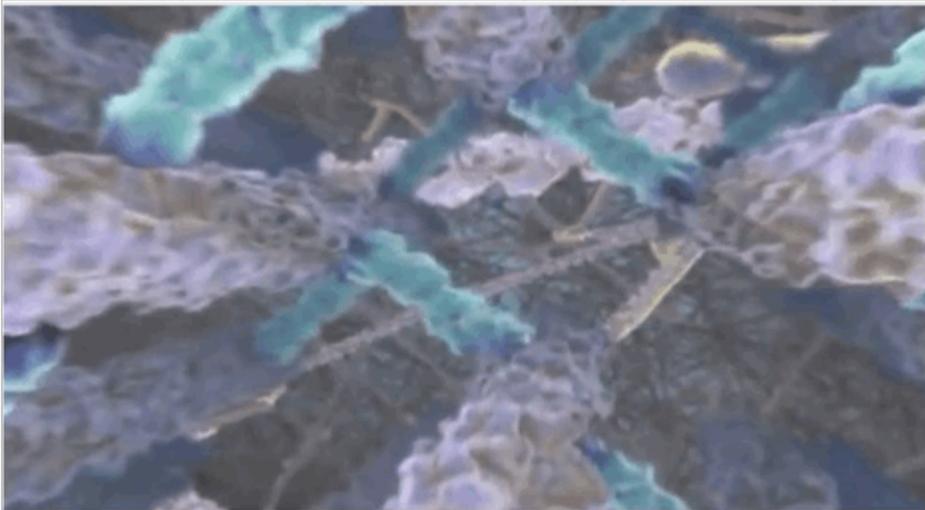


Figure 3 depicts the many actin binding proteins responsible for cross linking actin filaments within the cell as well as the large number of filaments and proteins responsible (Inner Life of a Cell 2007).

Actin filaments in their final constructions are used in a variety of cell structures and processes depending on what the cell needs. Filopodia are processes extending out from the cell are composed of bundles of actin filaments bound by fascin, which causes them to be very close together and be stiff. Lamellipodia are thin projections on mobile cells that aid in cell movement, and are made out of constantly growing and dissociation branched arrays of actin filaments. Grouped actin filaments are also very important in the formation of the contractile ring in cytokinesis (Diwan 2007).

Why: The Eiffel tower upholds this principle of architecture because of its design. All of the iron pieces are arranged into triangle trusses of various sizes; larger ones towards the bottom and smaller triangles on the top. The trusses of iron are attached together creating four larger bases to serve as the legs of the tower, and then the smaller trusses were used in creating the top. The Eiffel tower is able to stand 986 feet tall and to withstand the force of wind as the construction

of the trusses do not allow the wind to grip any surface of the tower while providing sufficient structural support (PBS 2001).



Figure 4 depicts the many trusses composing the framework of the Eiffel tower and how the repeating nature of these simple structures can create the complex tower (EiffelTowerParis 2009).

Actin filaments and their actin binding protein uphold this principle as well. Actin monomers are very simple units of construction that can be easily added together to create longer actin chains. By themselves, actin filaments are not particularly useful to their cell because they cannot provide the necessary support to create the more complex structures in the cell that are needed. Actin binding proteins are necessary for actin to be able to be arranged in complex structure beneficial to the cell (Alberts 2010).

By constructing cell structures out of actin filaments, the cell can produce what it efficiently and strong. One such example is the actin cortex that underlay's a cells plasma membrane. Spectrin is a tetramer actin binding protein that has an actin binding domain on each end. The binding domains bind to short and stable actin filaments that create the meshwork all around the cells plasma membrane that provides support to the cell and is one of the reasons why the cell can either keep or change its shape (Cooper 2000).

Another example of the range of function of actin filaments are microvilli. Microvilli are thin protrusions from the cells plasma membrane that increase the surface area for absorption. Each Microvilli are composed tightly packed bundles of twenty to thirty actin filaments that are compressed together by the actin binding proteins villin and fimbrin. The bundles of actin filaments are bound to spectrin rich areas of the actin cortex in the cytoplasm, and these bindings help to support the microvilli and allows them to remain upright (Cooper 2000).

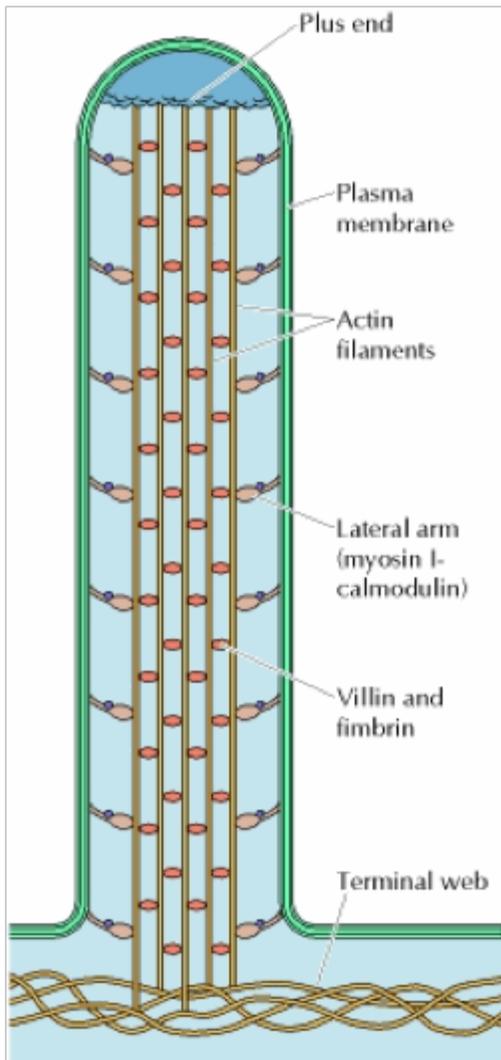


Figure 5 depicts the association of actin filaments with their respective actin binding proteins in the structure of a microvilli and its interaction with the actin cortex within the cell to provide support and allow the microvilli to remain upright (Cooper 2000).

These are only two of the many structures that actin filaments can create in cells. Alone, actin monomers and filaments are only the building blocks to create more structurally complex creations and with the help of their actin binding proteins then can create exactly what the cell will need (Alberts 2010).

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