Architectural Similarities Between the Structure of Adolfo Suárez Madrid-Barajas Airport and Actin Filaments with Binding Proteins

Bruna Karoline Tatematsu

BIO 219 / Cell Biology
Final Research Paper
3 May 2016
Rule to Build By:

The first rule to build by on the Living Architecture website states that both human and nature complex architectures can be assembled from simple repeating units (Morris and Staudinger, 2016).

What:

The structure of the Adolfo Suárez Madrid–Barajas Airport in Spain, and the arrangement of globular actin with its acting binding proteins in the cells maximize flexibility by assembly of simple repeating units to form complex structures (Morris and Staudinger, 2016). While repeating subunits allow flexibility in the structural shape of the airport and cells, forces of tension and compression provide structural and cell support.

How:

The core building of the Barajas Airport spans over a total area of 470,000 m² and reaches a maximum dock length of 1,142 m. The building is set up in a sequence of three parallel spaces separated by canyons—inner courtyards that receive natural light (Constructalia, 2015). The 200,000 m² of corrugated bamboo roof structure is connected above by a chain of roof lights and is supported by columns (Scholtus, 2007). “Each main column has four support points, two in the center and two on the sides, all of them leaning on metal supports embedded in concrete plinths, of a special design and mating the building structure support.” (Constructalia, 2015). “The supports points of the main column ends consist in Y-shaped columns… the top section branches off into two separate arms, each supporting a main beam.” (Constructalia, 2015). (Figure 6).
Actin filaments are thin, flexible fibers about 7 nm in diameter and they are composed of many actin monomers, a globular protein composed of about 375 amino acids (Plopper, 2013). Actin filaments are also called microfilaments and they are twisted double chain of identical actin subunits (Reece, Urry, Cain, Wasserman, Minorsky, and Jackson, 2013). From the three cytoskeletal elements—microtubules, actin filaments, and intermediate filaments—actin filaments are the most complex due to its structure; actin filaments can easily form both linear and branched networks (Plopper, 2013). Typically five to ten percent of all the protein in an animal cell is composed of actin, and because they are “common requirements, actin filaments are found in a wide variety of locations and in a myriad of configurations” (Plopper, 2013). Half of the actin is assembled of free-floating monomers in the cytoplasm—when an actin filament is needed, monomers polymerize into filament (figure 1) and then when it is no longer needed, the filament depolymerizes into free-floating monomers (figure 3) (Reece et al., 2013). Monomers have at least two different domains and the nucleotide phosphate that it binds to determines the shape. Each monomer has specific binding sites, which allows the actin monomers to interact with other actin monomers forming a filament. Actin monomers are oriented in the same direction, giving different polarity the end of each actin filaments —plus end and minus end; this polarity is important when assembling acting filaments (Cooper, 2000).

Profilin is the protein that regulates the creation of actin filaments. Actin filaments are typically grouped together by acting binding proteins. The binding proteins have domains that bind to actin crossing link different filaments (figure 2). The interaction between protein and actin filament is due to its shape, flexibility, and spacer sequences in the binding site (Cooper, 2000). The cross-linking proteins separate the actin into two groups, actin bundles and actin networks. Acting bundles proteins are small rigid proteins that make the filaments to align with one another (Diwan, 2007). There are two types of actin bundles that involve different actin-bundling proteins. In the first type all the filaments supports projections of the plasma membrane; these actin bundles contain spaced actin filaments with same polarity aligned in parallel with the plus ends close to the plasma membrane (Cooper, 2000). The second type of actin bundle is made of filaments that are “loosely spaced and capable of contraction” (Cooper, 2000). Large actin binding proteins hold actin network together, and their domains are at opposite ends of each subunit (Cooper, 2000).

Acting cross-linking proteins are organized into three groups, based on the way they bind to acting filaments. Proteins in group I are fascin and scrin, villin protein is in group II, and group III is composed of fimbrin, dystrophin, ABP 120—dimer, α-actinin—adimer, filamin—dimer, and spectrin—tetramer (Plopper, 2013). Proteins like α-actinin, villin and fimbrin binds actin filaments in parallel bundles, and protein like filamin organizes actin filaments into loose meshwork—used as scaffolding within the cell (Diwan, 2007). The actin-binding domains of most of these proteins are similar in structure; they are separated by spacer sequences that vary in
length and flexibility (Cooper, 2000). Actin filaments are responsible for changes in cell shape, cell support, and cell movement, and it is due to these different types of cross-linking proteins (Plopper, 2013). For cell support, the actin filaments form a meshwork within the cell cortex providing the support needed; for movement, motor proteins pull on actin filaments, and when the actin filaments are immobilized on the cell surface, the force makes the plasma membrane to move (Plopper, 2013).

Actin filaments are complex yet helpful tool to control the organization of the cytoskeleton (Diwan, 2007). Actin filaments are used in a variety of cell structures depending on the cell’s needs. In order to maintain cell shape, some cells have a cytoskeletal network—actin and other proteins—inside the plasma membrane (Diwan, 2007). Some other cell structures that involves actin are filopodia, they are processes that extend out of the cell and they are composed of bundles of actin filaments that are bound by fascin; and lamellipodia, that are thin projections that help in cell movement and they are made of associating and dissociating branched arrays of actin filaments (Diwan, 2007). Actin filaments are also the preferred choice for rapid filament assemble and disassembly in sub-regions of the cytosol because they are smaller and simpler than intermediate filaments or microtubules (Plopper, 2013).

**Why:**

The Adolfo Suárez Madrid–Barajas Airport is assembled from simple repeating units—200,000 m² of bamboo strips in different sizes that forms the roof and columns with different shapes to support a main beam (figure 5) (Scholtus, 2007). The corrugated roof has its structure connected above with metals (Constructalia, 2015). The metal gives tension to the suspended roof while the support pillars are compressed. The repeating use of bamboo strips, metal, and columns in different sizes, all combined together form the unique corrugated roof. The repeated use of simple units also balances force and compression, and gives structural flexibility to the airport by allowing easy structural expansion if needed.

Actin monomers are like the metal, bamboo, and columns from Barajas Airport—these were simple materials of construction that once added together formed a roof. Actin monomers are also simple units of construction that once added together create complex structures—in this case, actin monomers form actin filaments (figure 1). The actin binding proteins are responsible for binding actin filaments together, giving it the necessary shape and support needed to form the complex structures in the cell (Plopper, 2013).

Microvilli can be associated with the columns of Barajas Airport because both main functions are to support. Microvilli are composed of packed bundles—twenty to thirty actin filaments compressed by the actin binding proteins villin and fimbrin (Cooper, 2000). These bundles contain closely spaced actin filaments aligned in parallel supporting the projections of
the plasma membrane, and increasing the surface area of the plasma membrane for absorption
and secretion functions (Albert, Bray, Hopkin, Johnson, Lewis, Raff, Roberts, and Walter, 2010).
The bundles of actin filaments are bound to spectrin for better support and rigid of the microvilli.
Spectrin is an actin binding protein that provides structural basis for cortical cytoskeleton in
erythrocytes—tetramer of two polypeptides chains (Diwan, 2007). Spectrin has acting binding
domain in both ends; these binding domains associate with short and stable actin filaments to
create the meshwork around the cell plasma membrane, giving support to the cell (Cooper,
2000).

Like in the Barajas Airport, the repeated use of simple units provides flexibility to actin,
and help balances force and compression. Elasticity, tension, and compression are other
advantages for actin because it can easily change shape. The tension is generated by a variety of
molecules that activate the actin polymerization or that physically link it to adhesion sites
bounded together (Duband 2013). Stress fibers and adhesion junctions function as tension cables
that control the shape of the cell by contracting circumferential belt in epithelial cells; this allows
the cell to pull on a substrate (Lodish 2000). The tension generated by the repeated units of actin
filaments in a cell can facilitate the connection between extracellular matrix proteins and the
actin cytoskeleton (Cooper, 2000). Another advantage for cells in using simple repeating units to
balance tension and compression is that filaments can effectively be assembled wherever and
anywhere they are needed. In case a cell suffers some kind of aggression, acting bundle from
both sides of the cut will retract keeping the cell stable; this process will be local causing little or
no change in others actin bundles and it is due to actin tension and elasticity (figure 4).
(Heidemann, Kaech, Buxbaum, and Matus, 1999)

Actin monomers, filaments, and actin binding proteins are the essential materials to
create complex structures. The repeating use of these materials can lead actin filaments to create
many complex structures in cells; and independently of the structure, the process will be the
same— monomers will assemble into acting filaments, and acting binding proteins will bind the
actin filaments together. This process of using simple repeating units will form different
structures (figure 1) that will aid the cell in different ways, such as support, movement, and cell
shape (Albert et al., 2010). The structural flexibility achieved by actin thru simple repeating units
allows actin to have an effective assembly of subunits, to be any size and shape, and allow
tension and compression to be supported in any part of the cell when needed (Morris-lecture,
2016).
**Figure 1:** Acting binding proteins uses actin monomers to create many different structures and shapes. The structures and functions of cytoskeleton are basically controlled by its binding proteins. Actin is show in red and the acting binding protein is shown in green. (Figure and legend information from Alberts et al., 2010)
Figure 2: Cross-linking proteins bundling acting filaments within the cell. Networks of actin filaments are stabilized by a variety of actin binding proteins. These acting filaments are responsible for stability and integrity of cell structure. (Diwan, 2007; figure from *Inner Life of a Cell* by Harvard Multimedia Biovisions, 2014)

Figure 3: Actin filament being depolymerized. Actin filaments are dynamic structures that are constantly polymerizing and depolymerizing depending on the cell needs—when an actin filament is needed, monomers polymerize into filament and when no longer needed, the filament depolymerizes into free-floating monomers. (Reece et al., 2013; figure from *Inner Life of a Cell* by Harvard Multimedia Biovisions, 2014)
Figure 4: Tension and elasticity of actin bundle in the cell. In part A at 0:00 shows Heidemann applying the needle to a cell; the small cut made in the middle of an actin bundle is shown at 0:07. After a couple minutes, the actin bundle retracts from both sides of the cut. Part B shows that cell remain stable after the cut. (Figure and legend information from Heidemann et al., 1999)
Figure 5: Unique design of Adolfo Suárez Madrid–Barajas Airport external area formed by columns and corrugated bamboo roof. The design of the building is composed of simple repeating units combined together—bamboo strips in different sizes and columns with equal shapes—to get the needed tension and support to form the roof. (Constructalia, 2015, figure from En.wikiarquitectura 2015)

Figure 6: Column supporting the roof of Adolfo Suárez Madrid–Barajas Airport. The main column is gray and has four support points leaning on metal supports. The columns that are Y-shaped support a main beam. (Constructalia, 2015; figure from En.wikiarquitectura, 2015)
References:


