

Chinese Handmade Shoe Soles and Tight Junctions

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Living Architecture Research Project Report

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Rule to Build By:

“The easiest way to connect two sheets is to seal them together.”

What:

Human build structure: Chinese traditional handmade shoe sole

Biological structure: Tight junctions seal adjacent epithelial cells together

How:

Epithelial cells arrange side-to-side to form epithelial tissues. This particular arrangement of cells usually coats other tissues that locate underneath. Epithelial cells can be exposed to air, like the skin cells, or to other organic substance such as those that form the lining of the gut (Alberts et. al, 2009). Because epithelial cells need to connect to each other side to side, so they need junctions to resist the tension when the whole tissue is stretched.

Tight junctions, in particular, are the “gates” and “fences” between the epithelial cells (Wegener, 2011). Tight junctions are discovered in 1963 (Felman et. al, 2005), and two models were built to help discovering its architecture. Tight junctions were hypothesized to contain several types of proteins that polymerize into strands, or, they were in fact another type of lipids (Tsukita & Furuse, 1999). The second model of tight junctions was proved to be correct when Shoichiro Tsukita and Mikio Furuse discovered two major component proteins in tight junctions through the use of freeze-fracture electron microscopy (Tsukita & Furuse, 1999). Proteins of the tight junctions seal adjacent epithelial cells beneath their apical surface; and, according to Tsukita and Furuse (1999), these tight junctions cluster at “discrete sites of apparent membrane fusion” or “kissing-points.”

Many more types of proteins and molecules are involved in forming the strands of the tight junctions, but components and formation of tight junctions have not yet been determined completely. Major proteins that polymerize the tight junctions are called claudins and occludins. They arrange in strands and seal the extracytoplasmic leaflet of lipid bilayer to that of opposing membranes (Alberts et. al, 2009). These two families of protein have similar “topologies” (Wegener, 2011), but they do not share similar amino acid sequences (Tsukita & Furuse, 1999). Freeze-fracture microscopy looked at the cytoplasmic (P-face) and extracytoplasmic (E-face) leaflet of plasma membranes. It was found out that proteins of the tight junctions arrange as “continuous, astomosing strands” in the P-face while forming “complementary grooves” in E-face (Tsukita & Furuse, 1999). Furthermore, according to Krause et. al (2008), the extracellular loops of the proteins determine the function of the tight junction strands as a whole. Scientists even looked at the genes of occludins and claudins, and they found out that one or two types of amino acids are dominant on the extracellular loops of both proteins. The peptide sequence of occludin is understood better than that of claudin, and according to Tsukita & Furuse (1999), more than 60% of the amino acids on the extracellular domain of occludin are glycine and tyrosine. Extracellular loops of occludin have similar lengths where as claudins contain a large and small loop. When the proteins polymerize into strands along the E-face of epithelial cells, extracellular loops would attract to one another. Extracellular loops of occludin only have affinities with that of complementary occludin, and large loops of claudin would bind to small loops of claudins of adjacent cell (Tsukita & Furuse, 1999).

Before the trend of industrial revolution entered China, most of the daily products were handmade. Shoes, in particular, are one of the most important necessities demanded. Shoes at that time were made of cottons and fabrics pads. The shoe sole is a challenging part for shoemakers because it determines the shoes’ comfortness (Sina.com, 2009). To make a

shoe sole, firstly, a shoemaker needs to sandwich some cottons between two identical thin fabric pads. Secondly, the shoemaker will use a thick wooden needle to seal the pads together with twines (Sina.com, 2009). Each shoe sole on average requires 800 sealing by hands. Sometimes, depending on different demands, shoemakers need to seal more than two fabric pads one on top of another. Because of the shoe soles are sealed tightly, each pair of homemade shoe can be worn for many years.

Why:

Tight junctions have various functions, and it does more than just connecting adjacent epithelial cells. Through paracellular sealing, tight junctions prevent leakage of solutes “from apical to the basolateral compartment or vice versa (Wegener, 2011).” For absorptive cells in the gut, such function is essential because leakages of solutes would destroy the pumping activities of absorptive cells. In addition, without a fence like tight junction, a balance of medium would be destroyed because extracellular medium would leak to both sides of the cell (Alberts et. al, 2009). Tight junctions also prevent key membrane proteins in the apical area from moving to basolateral region. For example, if tight junction is not present in the gut lining, transfer of glucose from the gut lumen to the extracellular fluid would be impossible because glucose must be transferred through specific types of transporters in different regions of a gut epithelial cell (Alberts et. al, 2009). Na^+ -driven glucose symports, which should always be at the apical surface, might diffuse down to basolateral surface, glucose uniports and Na^+ - K^+ pumps, which should be at the basolateral surface, might diffuse to the apical surface. Such change of transporters might also vary the electrogradient of Na^+ and glucose across the gut epithelial cells’ membrane. Therefore, tight junctions might also help generate electrochemical gradient across epithelial cells’ membrane (Wegener, 2011).

Monomers of the tight junction strands also contribute in the cell signaling pathways. For example, occludin has a coiled-coil domain at its C-terminus region, and amino acids at this region interact are found to interact with different regulatory subunits such as: c-Yes, PI 3-kinase and connexin 26 (Felman et. al, 2005). Since connexin 26 is a monomer that forms gap junction, the tight junction and the gap junction are found to have “similar proximity (Felman et. al, 2005).”

Shoe sole sealing does more than just connecting two fabric sole pads together. Through sealing cottons between the pads, sweat from feet can be absorbed. If the shoemaker seals lavender and other herbs along with the cottons, the shoe sole would also help relax feet. In fact, the shoe sole pads need to be sealed in certain patterns, and it is these patterns that enable the shoe to be able to have air circulation within the shoes (Jiaxing Daily, 2009).

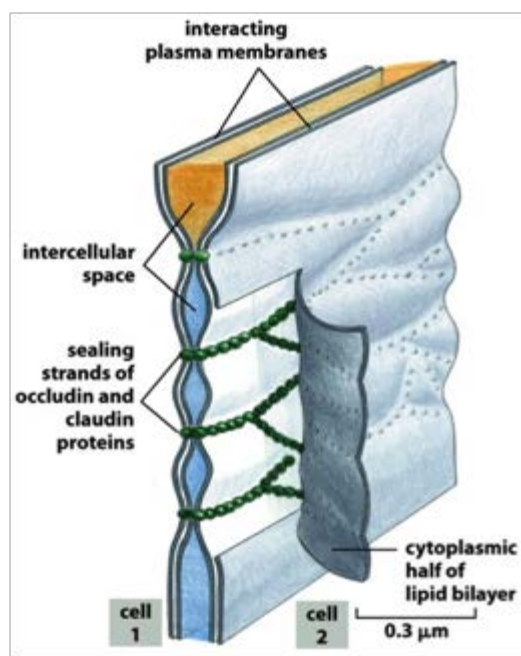


Figure 1 Strands of tight junctions seal the extracytoplasmic (E-face) leaflet of adjacent epithelial cells’ plasma membranes. Occludin and claudin are the two major proteins forming the tight junctions. Tight junctions help preventing solutes from the intercellular space between cell 1

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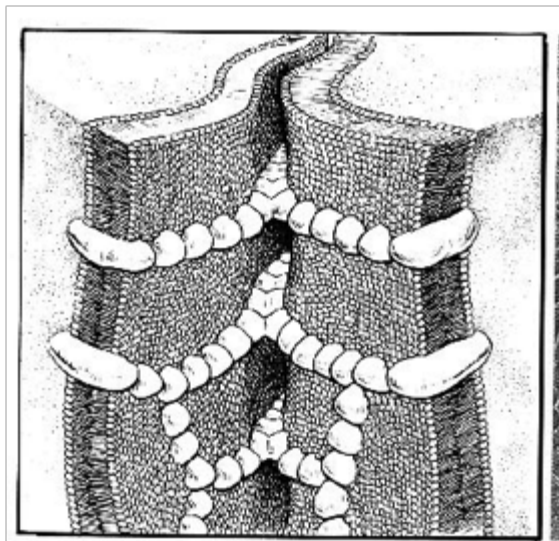


Figure 2 Occludin and claudins polymerize into strands to form tight junctions. Affinities
The strands of protein seal the two lipid layers together through the strong affinity of proteins. <http://rickharris.squarespace.com/c7/>

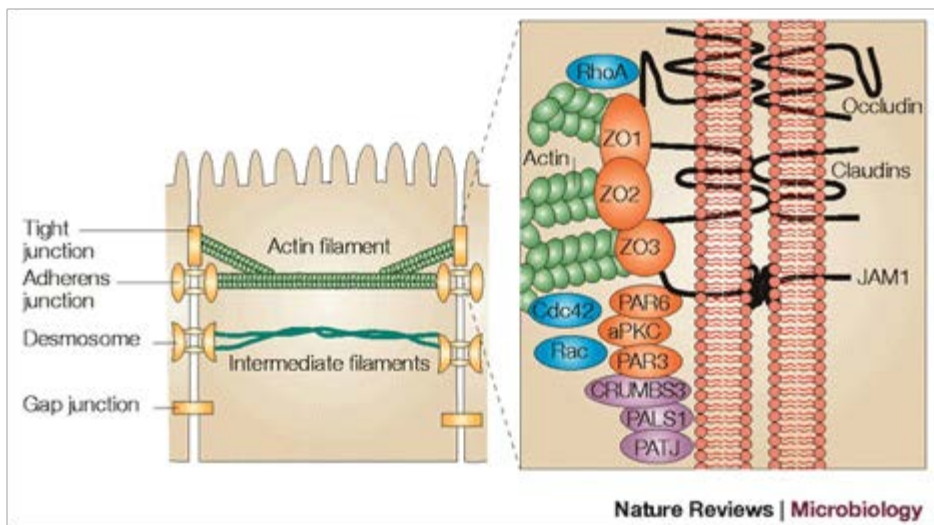


Figure 3 Attractions between extracellular loops of occludins and claudins bring strands of adjacent cells together. Here, occludins (shown as the 1st black line on the right) of from one cell only interact with occludins of adjacent cell. Claudins (shown as the 2nd black line on the right) and JAM1 (shown as the 3rd black line on the right) also interact in this way. In addition, tight junctions also interact with actin filament and it can be concluded that the tight junctions also contribute in the epithelial cells' movement. http://www.nature.com/nrmicro/journal/v3/n5/fig_tab/nrmicro1150_F2.html



Figure 4 A close-up photograph of a shoemaker sealing shoe sole pads. Cottons and other fabrics are sandwiched between shoe pads, and sealing the pads starts from sealing the edges. Thick needles and twines are used to seal up the pads.

<http://zhupingan163.blog.163.com/blog/static/135191724201051534539862/>



Figure 5 A typical pair of tradition handmade shoe from China. The shoe sole has 5 sole pads sealed together and is very light. The sole absorbs sweats and is very light when walking on it. <http://www.aibama.com/product/2601.html>

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Images:

Figure 1:

Alberts, B. Bray, D. Hopkin, K. Johnson, A. Lewis, J. Raff, M. Roberts, K. & Walter, P. (2009). *Essential Cell Biology* Third Edition. Garland Science, Taylor & Francis Crop, LLC

Figure 2:

Harris. R and McMillan. D (2012). **3. Gap Junctions**. [ONLINE] Available at: <http://rickharris.squarespace.com/c7/>. [Last Accessed 3 December 2012].

Figure 3

Aktories. K & Barbieri. J.T, (2005). Bacterial cytotoxins: targeting eukaryotic switches. *Nature Reviews Microbiology*. (3), pp.397-410

Figure 4

163.com, (June 2010), Photography Competition Collection: Chinese Farmers [Blog Post]. Retrieved from: <http://zhupingan163.blog.163.com/blog/static/135191724201051534539862/>

Figure 5

Aibamama.com, (December 2012), Chinese handmade shoe sale. Retrieved from: <http://www.aibama.com/product/2601.html>