Signaling Seen in Nuclear Pore Complexes and the Panama Canal

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Rule to build by:
To control transit through a corridor, signaling must occur.

What:
The nature built structure that upholds this principle are nuclear pore complexes that regulate access into the nucleus regulated by signaling. The manmade structure that upholds this principle is the Panama Canal that regulates flow of goods based on signaling such as exchange of currency.

How:
Nuclear pores are protein complexes embedded in the nuclear envelope that allow for the passage of proteins into and out of the nucleus (Alber et al., 2007). The nucleus is surrounded by the nuclear envelope, which separates the nucleoplasm containing genetic material from the cytoplasm. To be transported through a nuclear pore, a set of specific signals must be present on the transported proteins to initiate the passage through the nuclear pore and therefore into or out of the nucleus (Nelly, 2001). The first of these signals are two signal sequences built into the transported protein called the nuclear localization sequence (NLS) and the nuclear export sequence (NES). The NES is used for proteins specifically for proteins leaving the nucleus. The NLS is used as a signaling sequence only for proteins entering the nucleus (Rout, 2001). Both sequences allow for transport through the envelope because they act as ligands to the receptor proteins called importins and exportins which chaperon the protein being transported to the outer or inner rim of the nuclear pore in a process called docking (Alber et al., 2007). The protein being transported is released on the introduction of DTP to a G protein called Ran. Ran binds to the importins and the exportins to encourage the release of the protein into the nuclear pore. The Ran GTP & exportin/ importin complexes are then cycled back through the pore leaving the package on the other side of the nuclear envelope (Gorlich, 2016). The protein docking causes a conformation change in the nuclear pore complex allowing for the folded protein to pass through the pore (Beck et al., 2004). The diameter of the pore is 38 nanometers which matches the dimensions of the particles known to be transported though the pores (Alber et al., 2007). The import and export of the proteins would not occur successfully without the correct signaling to direct the mechanism through which proteins are transported through nuclear pores.

To be able to transport cargo through the nuclear envelope the nuclear pore complexes have adapted a specific set of conserved structures key to the regulation of transport through the pore.
The nuclear pore complexes are large, weighing approximately 50 KD and consisting of around 30 individual folded proteins (Alber et al., 2007).

The Panama Canal is a series of locks that allow quick passage of container ships carrying cargo between the Atlantic and Pacific oceans. To enter the Panama Canal the ships must use several forms of communication to make a successful journey. The first form of communication used is the payment for the right to use the canal that acts as a resource to the managers at the canal saying that it is ok to allow the ship to come through (Experience Panama, National Geographic). The second form is contact with the Panama Canal using radio to inform the workers at the canal to make a conformational change in the lock gates allowing the ships to pass through (see figure 1). While the ship is going through the canal a group of experienced pilots take control and communicate with the crew members onboard the passing ship and workers on the ground to direct the ship safely through the locks. Many of the ships in use today fill the canal to the extreme limits where a two hundred fifty ton ship will on have centimeters to spare on either side. Upon entering the canal there is one section where ships are side by side and must use radio communication to plan their interaction so that they do not collide (Experience Panama, National Geographic). Without the combination of constant communication and the resulting interactions the ship would not be successful in trying to pass through the canal.

**Why:**
A mechanism is a description of all the steps required to achieve a goal in the order in which they happen and a summary of all interactions between all the players involved. In the case of the nuclear pores they use a mechanism as described above to transport proteins into and out of the cell. The signaling mechanism is induced either by chemical bonding or physical contact that initiates responses. The pores have evolved over time using natural selection to only allow specific proteins with the correct signals in place to be transported as seen in figure 3 (Schwartz, 2016). The viability of the cell in which the pores are located and the viability of the organism in which the cell is located depend on the accuracy of this signaling mechanism (Bukata, 2013). If the nuclear pores where allowed to randomly select candidates for transport through the nuclear envelope they would likely disrupt the functioning state leading to cell death for a high percentage of cells. Through the use of specific signals the nuclear pores are able to “decide” if a package that is in its proximity has been predetermined to require transport by a higher organized signaling mechanism. While the mechanism itself is complex the use of signaling for the pores really comes down to a yes or no question. If the pore sees the required signaling molecules at the right times it will do as it is instructed by the signals making it a “dumb” organelle. This is an evolutionary advantage because the intent of the signaling sequences is not modulated by the pore allowing for the end goal of transport to occur as long as the command is in place. A prevalent example of this property applies to the regulation of protein production. The nuclear envelope not only protects the DNA from damage but also adds another layer of regulation by separating the regions where transcription and translation physically occur (Hoelz et al., 2011). By allowing for transport of only properly marked messenger RNA’s through nuclear pores to where translation occurs reduces chances of error that would be present if the translation machinery were located directly next to the DNA.
Signaling in the Panama Canal (seen in figure 2) is of the utmost importance to allow the smooth operation of the mechanism by which ships are transported from one ocean to the other. If the money signaling did not occur the process would halt from a lack of the signals. If the communication between ships and the canal were to cease any random ships could go through at any time, which would induce a chaotic and hazardous situation. Through advancements of technology the system of checks that are required to pass through the canal have evolved increasing the efficiency at which the mechanism can operate. In other words a higher order signaling mechanism has been selected to keep up with the high demand for passage and larger ships entering the canal (Experience Panama, National Geographic).

**Figures:**

![Figure 1](http://www.escapeartist.com/blog/us-spending-5-5b-to-keep-up-with-panama/)

**Figure 1.** One of many locks used in the Panama Canal. Notice the safe distance at which ships are located from each other and the lack of confusion shown in this image. The proper use of resources and signaling allows for the smooth operation and organization of all the elements involved in its use. Retrieved from [http://www.escapeartist.com/blog/us-spending-5-5b-to-keep-up-with-panama/](http://www.escapeartist.com/blog/us-spending-5-5b-to-keep-up-with-panama/) (Reeves, 2016)
**Figure 2.** A pilot on board radios the location of the ship while navigating the Panama Canal. The information provided by the radio communication allows for the successful journey through the canal. Retrieved from documentary Mega structures the Panama Canal by National Geographic at https://www.youtube.com/watch?v=_4F867o_U1w

**Figure 3.** The nuclear pore complexes use a specific set of signaling to allow transport through the nuclear envelope. Notice the pink and black arrows showing the required interaction between signalers and receptors. If the proper signals are not present the nuclear pores will not allow transport creating a regulatory system that encourages normal function in cells. (Figure retrieved from Biologie Online Lernen Nuclear Pore Transport (GTP-Proteine) http://www.karteikarte.com/card/1147244/nuclear-pore-transport-gtp-proteine-import-export.)
References


Images: