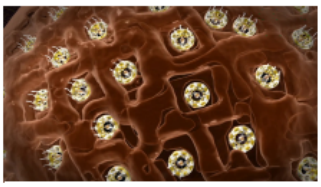


June 16, 2023 | Margaret Helder

Internal Beauty: the Nuclear Pore Complex

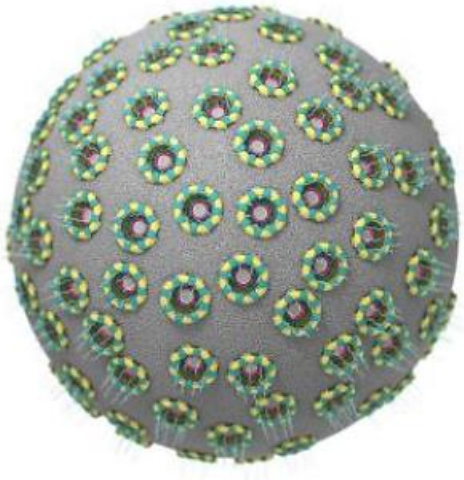
CELL BIOLOGY

Like a 3-D puzzle solved in 15 minutes, the nuclear envelope is a wonder to behold

This article by Margaret Helder, PhD, is edited here by J. Michael Fischer. The original is at https://crev.info/2023/06/internal-beauty-the-nuclear-pore-complex/

Imagine that you are a jigsaw puzzle fan. Imagine that you have been given a special challenge, a five-hundred-piece, three-dimensional puzzle made up of thirty different shapes. How long would it take you to solve that puzzle and reproduce the designated architecture? Years maybe?

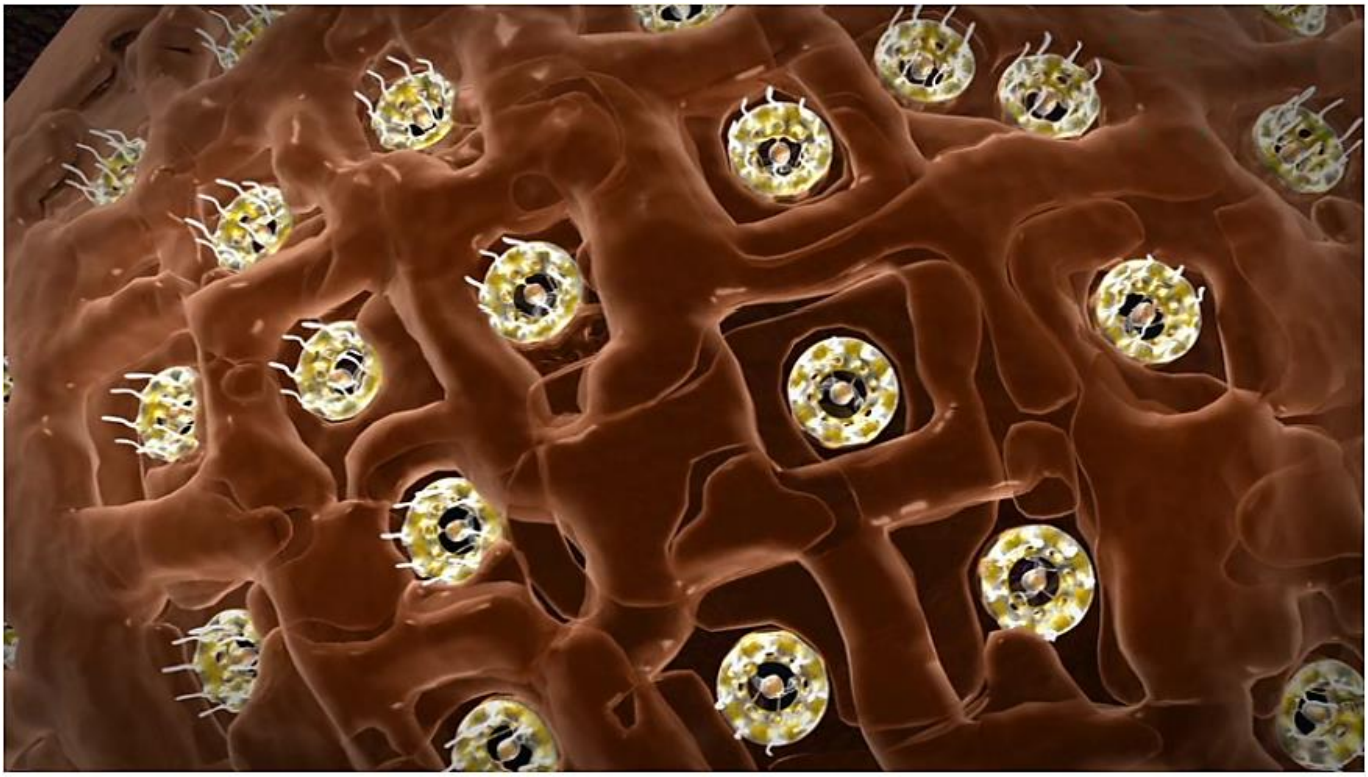
The cells in your body solve this challenge in 15 minutes maximum! How do they do it? Nobody knows, but the story is interesting. Every cell in your body comes equipped with a nucleus which contains the information necessary to direct the life activities of that cell. Any large molecules which need to enter or exit the nucleus, must pass through special gates or pores in the nuclear envelope. There are thousands of such pores in the nuclear envelope.



Artist's rendition of the nuclear pore complex dotting the surface of a cell's nucleus. (Image by Valerie Altounian/Science.)

Special molecular machines, by far the largest in the living cell, form special gateways called nuclear pore complexes. *Each consist of 500 protein molecules which come in 30 different shapes and sizes*.

When the cell is about to divide, it eliminates the nuclear envelope! The nucleus thus divides out in the open cell. However, as the process of division ends, the cell hurriedly forms a new nuclear envelope around each of the two daughter nuclei. How does the cell solve this puzzle in 15 minutes or less and why does it need such speed?



Nuclear envelope with NPCs (Illustra Media)

The nuclear envelope quickly forms around the nucleus to protect the genetic information inside. *At the same time, about 4000-5000 gaps in the envelope are filled with the nuclear pore complex machinery.*

The macromolecular machine which forms the nuclear pore complex consists of two doughnut-like structures stacked together, one facing the nuclear interior, and the other facing the cytoplasmic exterior cell material. Inside lie flexible tangled filaments. It is these filaments which control whether cargo gets past them into or out of the nucleus.

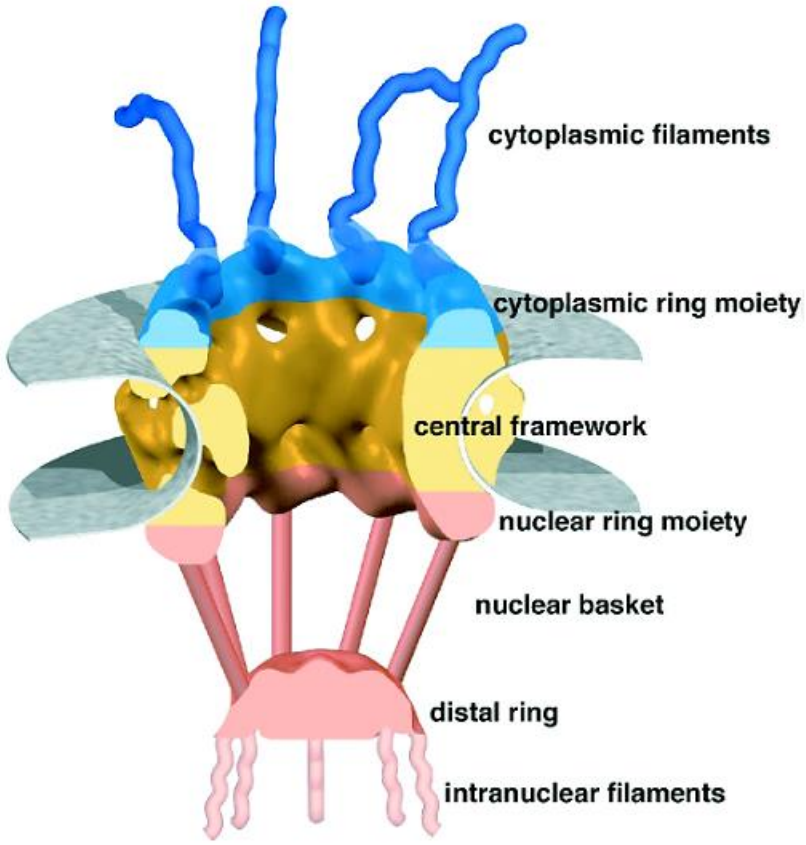


Illustration of a nuclear pore complex

Somehow, metabolic processes direct the 500 protein molecules in each NPC to assume exactly the correct architecture. They will need to be perfect so that large molecules can enter or exit the nucleus.

It is amazing to people who understand three-dimensional architectures that the cell manages to juggle 500 individual proteins (in 30 different shapes), precisely arranging them within minutes into a beautiful functional structure, the NPC. It is like building a house within minutes instead of weeks or months.

Inside the nucleus, proteins expedite the copying of information from DNA into RNA. Spliceosomes (more proteins) then chop out certain unneeded sections of the RNA molecule. We now have a strand of messenger RNA (mRNA) which will (once it has emerged into the cytoplasm) direct the manufacture of a specific protein needed by the cell. But the mRNA can’t get out of the nucleus (yet). Proteins must form a cap on the front end of the chain and a long tail of adenosine monophosphate (like adenosine triphosphate or ATP, only lacking two phosphate groups) attaches to the back end. The tail stabilizes the long chain of nucleotides. This complex is now called mRNP (ribonucleoprotein complex). Finally, a

transcription-export complex connects to the mRNP cargo. The filaments in the channel-proper of the NPC now recognize the cargo, and carry it across the nuclear envelope out into the cytoplasm.

The living cell is a masterpiece of precision and mind-boggling complexity. The nuclear envelope (a double membrane around the nucleus) is just a very small component of the cell. Nevertheless, this envelope performs an essential function: to protect the integrity of the genetic information in the nucleus and the information coming out of the nucleus into the surrounding cell material (cytoplasm). It is here in the cytoplasm that the information coming from the nucleus is turned into reality.

There is one extra frill, however. As the nucleus grows larger after cell division, more nuclear pores are needed. The fascinating thing is that in this case, the NPCs form by a different process which takes longer (about an hour to complete), but the composition and function of the new NPCs are the same as the ones that formed earlier.

One process used to form the NPC would be dramatic enough. However, the cell most unexpectedly manages to utilize two fundamentally different processes. To achieve the same structure by two routes when there are so many component pieces which could potentially be placed incorrectly, obviously makes the resulting architecture most improbable if only chance processes were involved.

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