Teacher Tune-up

Quick Content Refresher for Busy Professionals

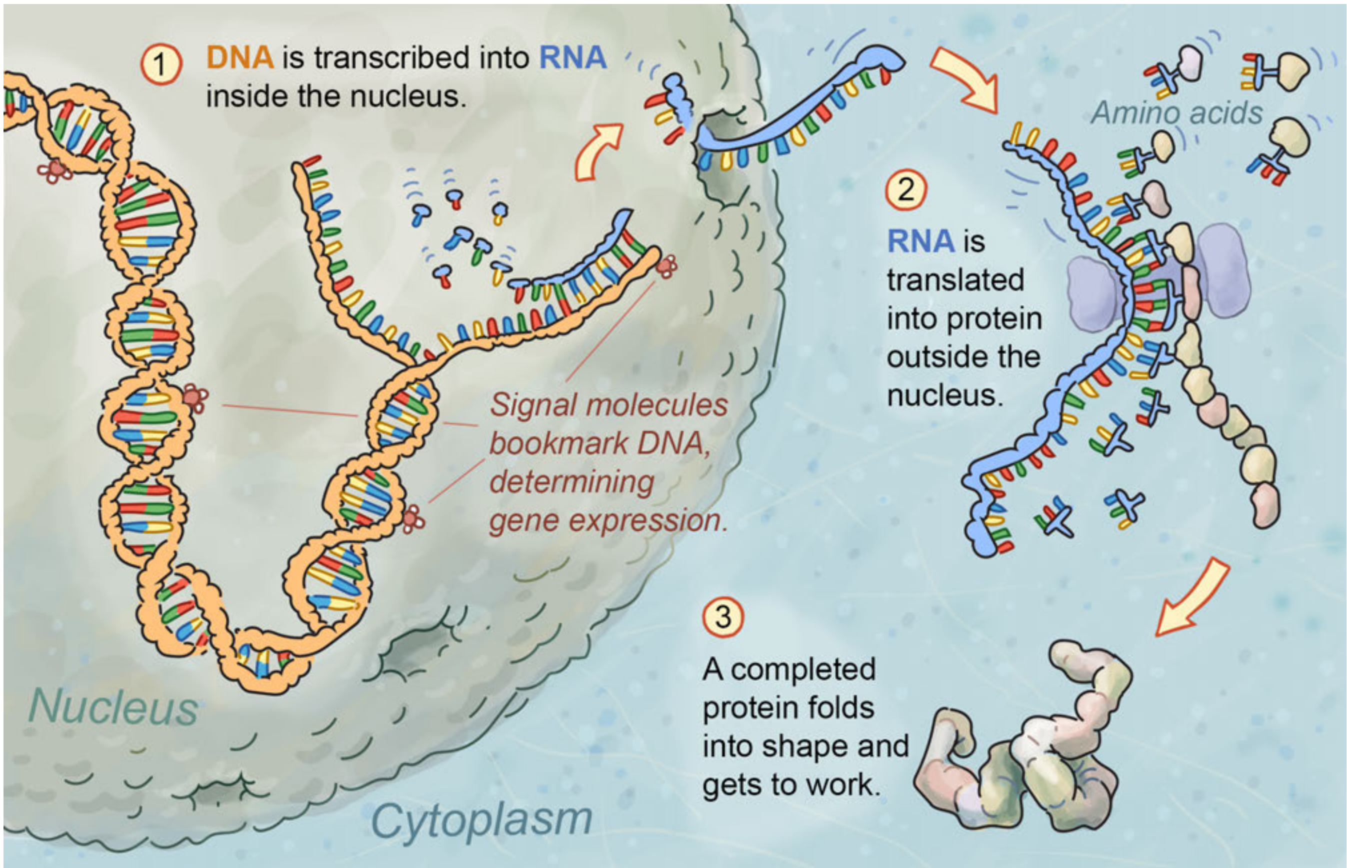
How do cells do the basic things they do?

Cells are marvels of complexity, and different kinds of cells—from unicellular bacteria to multicellular plants and animals—have very different strategies for living. Broadly speaking, though, one can imagine all cells as tiny, organic, self-replicating robots that must all be able to do four basic things: they must (1) store and execute instructions, (2) get and use energy, (3) get and use materials, and (3) get rid of waste. What basic mechanisms do cells use to do these things?

Instructions

When scientists talk about instructions in the cell, they are generally referring to DNA. DNA is like a recipe book for making proteins, written in the form of a very long molecule containing sequences of four different chemical structures known as bases (adenine, thymine, cytosine, and guanine, or A, T, C, G for short). Each distinct protein recipe within a DNA molecule is called a gene.

The DNA in each cell is its permanent set of instructions, and must be kept unchanged (protected in the cell nucleus, for those cells that have one, as human cells do). So when a cell gets a signal that it's time to express a gene, it makes a temporary, shorter copy of the gene in the form of another molecule known as RNA. (RNA uses the same bases as DNA, except that it substitutes uracil for thymine.) RNA molecules are then decoded by other molecular machinery inside the cell.



The bases of DNA (and RNA) are the “letters” of the code, and the “words” are 3-base sequences called codons. There are $4^3 = 64$ such unique codons (because each of three slots in the codon can be filled by one of four bases). That’s more than enough codons to specify the 20 different amino acids the cell can string together, in various orders and lengths, to form protein “sentences” (with extra “stop” codons left over to act as periods at the end of the sentence). So a gene is just a sequence of codons that says how to combine animo acides into a protein. And proteins are the chemical workhorses of the cell, serving all kinds of functions throughout the body. That’s it in a nutshell—that’s how DNA knocks over the first molecular domino in the cascade of cause and effect that determines how organisms look and behave!

Different kinds of cells within a human express different genes, meaning that only certain genes are turned into RNA, and then proteins. Genes that aren’t expressed still exist in a cell, but if no RNA is made from them, then the proteins those genes encode won’t be formed. Being able to switch gene expression off and on differently in different cells allows a multicellular organism that grows from a single fertilized egg to generate and maintain a team of diverse specialists, with cells as different as a muscle cell, a skin cell, or a neuron in the brain.

Energy

Expressing different genes leads to different combinations of protein production, and many of these proteins are catalysts, driving selected chemical reactions in the cell. All of these chemical reactions (building up certain molecules and breaking others down) and the work of moving substances around, into, and out of the cell, require energy.

There are two main ways cells get energy. Some cells, such as plant cells, use photosynthesis: they harvest energy from sunlight to break and build molecules. Other cells, such as in animals or fungi, get all of their energy from food. Yeast cells, for example, absorb sugars from their environment. By breaking down these sugars using chemical reactions, a yeast cell obtains energy to employ in other reactions. Human cells do the exact same thing. This energy is used for all sorts of functions: building structures for growth, breaking down molecules, moving matter within the cell, communicating with other cells, and more. (For more on how energy is captured and transferred among different organisms, see L1t2, “Food Webs and Trophic Levels.”)

Materials

Cells obtain materials through their membrane. This membrane isn’t a firm, durable shell, or even a solid sheet of flexible skin such as we’re used to at the macroscopic scale. Rather, it is a layer made up of fatty material, a so-called fluid mosaic of lipid molecules. Picture a layer of ping pong balls forming an unbroken fluid mosaic over a pool of water, with an occasional soccer ball in the mix to represent a protein amongst the lipids, and you’ll have some notion of how the pieces in a cell membrane can slide around in relation to each other while maintaining a continuous barrier.

This lipid layer lets some materials, like water or oxygen, pass into the cell all by themselves in a process called diffusion. Molecules move from more concentrated areas to less concentrated areas, like perfume wafting through a room or a drop of food coloring diffusing evenly throughout a glass of water. If you place a plant cell under a microscope and add some pure water, you will likely see the cell get fatter, as water crosses into the cell through its membrane and fills up the space inside.

Other materials the cell needs pass through its membrane using special channels made of proteins, little portholes in the barrier that are specially designed to admit only certain atoms or molecules. These channels may be triggered by other molecules, which tell them when to open and close. For example, when a nerve cell gets activated, signals open channels in its membrane so that ions (electrically charged atoms) can rush through the membrane, creating an electrical charge that propogates along the length of the cell.

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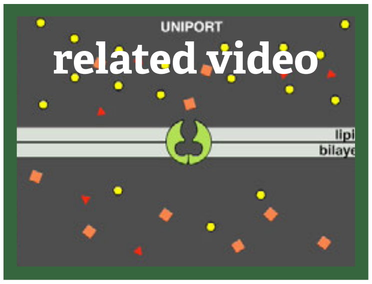
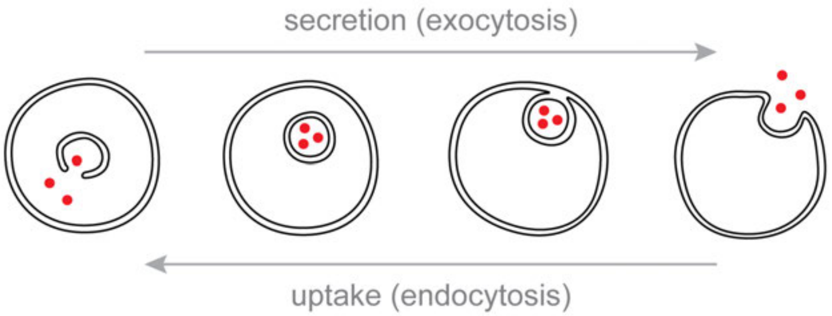
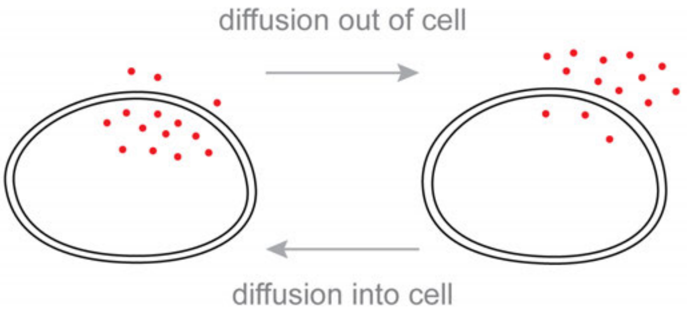


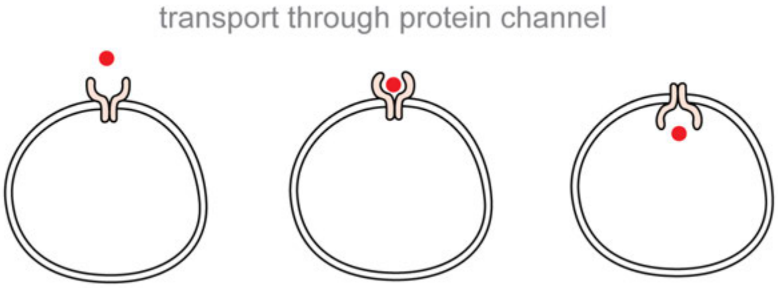
Waste

As cells take in and process materials, waste inevitably builds up. Cells deal with waste multiple ways. First, they are very efficient recyclers, breaking down old molecules that they don't need any more and using the scavenged atoms to build new molecules. Cells can also enclose waste in vesicles—small compartments made of the same type of lipid layer as the cell membrane. Most cells degrade their waste inside these special vesicles and then either reuse the materials or dispose of the small molecules that result through the membrane using protein channels. But in some types of cells, vesicles containing waste merge with the cell membrane from within, open up to the outside, and disgorge their contents. This process is called secretion, or exocytosis. More commonly, cells use secretion not for waste removal, but to move newly made useful materials that function outside of the cell to the cell exterior. (The opposite process—bringing material into the cell using vesicles, is uptake, or endocytosis.)

Some waste can even cross the membrane on its own. For example, when cells produce carbon dioxide from respiration, the molecules will diffuse across the membrane out of the cell. All cells, from the tiny yeast to the diverse cells of humans, produce waste as part of living, and all cells have methods for removing this waste so that the cell can still function.







(For more on how materials move through cell membranes, see L7t1, "How do substances pass through the cell membrane on their own?" and L7t2, "How does the cell move large materials through the membrane?")