16: PROKARYOTES (part 1)

We've got enough cell parts now to make a cell—but not a human cell. The only type of cell we can draw is a bacterium; but that fits in well with our study of the human body because humans are full of bacteria. For every one human cell in your body, there are ten bacterial cells. Estimates on the number of cells in a human body range from 15 trillion to 70 trillion. Many sources say about 37 trillion. Using the 37 trillion figure, that means you have 370 trillion bacterial cells inside of you, or on your skin. As long as the many species stay in balance, you remain healthy.

Bacteria are classified as ***prokaryotes.*** ("Karyo" means "nut or kernel," referring to the nucleus.) Prokaryotes ***do not have a true nucleus***. They have DNA, but they do not have a nuclear envelope around it. Another related group of organisms, the ***archaea***, are also classified as prokaryotes. Archaea used to be classified as bacteria. When scientists began examining bacterial DNA, they found that some types of bacteria had their DNA wound on little spools and some did not. The ones with the little spools were moved to a new group and given a new name: "archaea," meaning "old." You have both kinds of prokaryotes in your intestines. Some types of archaea produce methane gas, a partial explanation of where all that air and gas in your intestines comes from.

There are many types of bacteria. We will start by drawing something that represents what all bacteria have in common. It's labeled as a "basic" bacteria. This is a no-frills model, without any of the special features that many bacteria have. We will look at some of the special features after we see what they all have in common.

Bacteria are cells, and therefore must have a plasma membrane. However, unlike our cells, bacterial cells also have a cell wall outside of the membrane. The cell wall is made of a substance called ***peptidoglycan***. "Peptid" means "protein," and "glyc" means "sugar." It was mentioned in a previous lesson that sugars can be used as structural elements, not just as food. The cell wall is made of long strings of sugar molecules held together by protein cables. The cables that hang down are made of just four amino acids: alanine, glutamate, lysine and another alanine. We've already met glutamate and lysine.

Alanine has been called the most boring amino acid because it doesn't have a strong "personality." Its R group is the methyl group, CH_3. (Yes, the methyl group is showing up again already!) Although CH_3 is non-polar and therefore technically hydrophobic, it's small enough in comparison to the whole alanine molecule that it does not affect the amino's "personality" very much. Alanine does not act either hydrophobic or hydrophilic. It also does not carry an electrical charge It basically minds its own business and gets along well with everyone. Perhaps you know someone with alanine's personality? In some situations that's exactly what you want. Alanine shows up at some point in most proteins. About 8% of the amino acids in your body are alanine.

In this situation, alanine's job is to hang on to a sugar molecule or a glycine cable. The cables that run horizontally, parallel to the plasma membrane, are made of five gylcine amino acids. (Glycine is the smallest amino, with only an H as its R group.) There are also long molecules that act like molecular ropes, attaching the sugar layers from top to bottom and anchoring it to the plasma membrane. These long molecules have phosphate "hooks" at intervals. Phosphates, [PO_4's] are good at hanging onto sugar molecules, as we can see in DNA and RNA.

Bacterial cells have little enzyme robots that do jobs, just like our cells do. One particular enzyme attaches the glycine cables to the alanine cables. This enzyme can be prevented from doing its job by ***penicillin*** and other "cillin" antibiotics. The penicillin molecule interferes with the active site on the enzyme so it can't do its job. Without those cross-linking glycine cables, the bacteria's cell wall falls apart and the cell dies.

Bacteria do not have a true nucleus, but they do have DNA. Their DNA is circular, but the circle is so large that it folds and crumples into a lump. This central clump of DNA is called its ***genomic DNA***. A genome is a complete set of DNA— all the instructions the cell will ever need. We need to use the word "genomic" in order to distinguish this DNA from other DNA in the cell. Bacteria also have small circles of DNA called ***plasmids***. These are just bits of "bonus" information that might help the cell survive in certain situations. For example, resistance to antibiotics is often found as DNA code on plasmids. Bacteria can share this "bonus" information with other cells of it species by a process called ***conjugation***. In this process, a plasmid is transferred from one bacteria to another via a small tunnel that grows between the two cells. The donor cell makes a copy of the plasmid DNA and sends this strip through the tunnel to the recipient cell. The strip of DNA can then form a circle, and the recipient cell now has a new plasmid.

Bacteria must have ***ribosomes***. They've got enzymes, such as that enzyme that attaches the glycine cables, and enzymes (as well as all other protein gadgets) are made by ribosomes. They also have a ***cytoskeleton***, though it is not exactly the same as the cytoskeleton of an animal cell. Textbooks used to say that bacteria did not have a cytoskeleton, but this has been corrected as more research has revealed that they do indeed have their own bacterial version of a cytoskeleton. Some bacteria have gas-filled ***vacuoles*** that help them float or move. The watery fluid that fills the cell is called ***cytosol***. Cytosol is made of water, minerals, salts, sugars and enzymes. Sometimes there are particles such as oil droplets or mineral crystals floating around in the cytosol. These particles are called ***inclusions***. The word ***cytoplasm*** can be easily confused with the word cytosol. The cytoplasm is the cytosol plus the organelles floating in it, such as the ribosomes. In a human cell, the cytoplasm is basically everything outside of the nucleus.

The word ***morphology*** means “shape.” Or, more correctly, “study of shape,” because “-ology” means “study of.” Fortunately, bacterial shapes are easy to draw.

- The ***cocci*** *(cock-eye, or cocks-eye)* are little spheres.
- ***Diplococci*** are two spheres stuck together.
- The ***bacilli*** *(ba-sill-eye)* look like little rods or sticks, though some are stubby and rounded on the ends.
- ***Vibrio*** are C-shaped. (The most well-known vibrio is ***cholera***, an intestinal disease that often strikes after natural disasters like earthquakes, as drinking water is contaminated.)
- ***Streptococcus*** looks like a long chain. The illness we call strep throat is caused by one species of streptococcus, but there are many other species, too.
- ***Staphylococcus*** looks like a bunch of grapes. There are many species of staphylococci, but the one that gets most of the public’s attention is *Staphylocuccus aureus*, the one that causes “staph” infections on the skin. (S. aureus is part of our natural bacterial population and does not cause harm as long as it is kept in check by other species of bacteria.)
- The ***spirilli*** *(spir-ill-eye)* are spiral-shaped and often have a flagella at each end of their bodies. They can look squiggly as they move, but their bodies are not actually flexible. Spirilli are less common that the cocci and bacilli, but can be found in watery places like sewers.
- Unlike the spirilli, the ***spirochetes*** *(spi-ro-keets)* are flexible and can really bend around as they move. This is mainly due to their inner flagellum. They can spiral their way right through soft tissue (such as the connective tissue in our joints). The most famous spiriochete is the one that causes Lyme Disease.

Some bacteria have ***fimbriae*** *(fim-bree-eye)*. These hair-like structures help the bacteria to hold on to surfaces, including our cells. Some bacteria have additional hair-like things called ***pili*** *(pie-lie)*. These have several functions. They help the bacteria stick to surfaces. They can help the bacteria by acting like grappling hooks. The bacteria can toss out a few pili and the ends will stick to the surface out in front of the bacteria; then it retracts the pili so that its cell body is moved forward. It then repeats the process, throwing the pili out again and then pulling its body to close the gap. A special pilus can also be used for conjugation. This type is often called a conjugation pilus or a sex pilus. The pilus is extended in order to grab a passing bacteria. The trapped bacteria is then “reeled in” until it is almost touching. The pilus then acts as a transfer tube, allowing the plasmid DNA to be passed from donor to recipient, as we discussed on the previous page.

NOTE: Scientists are not in agreement as to whether fimbriae and pili are the same thing. Some insist that they are different and give good reasons for thinking so. Other scientists don’t see any difference and use the words interchangeably. This is good to know as you read books and websites on this topic. Be aware that the word “pili” might be used to describe what we have defined as fimbriae.

Bacteria are not part of human anatomy, but they are part of our physiology. Bacteria form a vital portion of our internal ecosystem and they affect our digestion and nutrition, our immune responses, and sometimes even our mental health. In the past, doctors and medical researchers did not realize the importance of bacteria in our bodies. Now they are beginning to understand how critically important it is, and some researchers have begun to catalog the ***human microbiome***, a list of all the microorganisms (including fungi, protozoans and viruses, too) normally found in and on humans. Medical care of the 21st century will increasingly be focused on maintaining a healthy microbiome.