

What are pathogens?

Pathogens can be a variety of different things but the main characteristic they all have is they cause disease to their host (Balloux & van Dorp, 2017). Pathogens are so diverse and can have many different characteristics but they all affect every living organism. Pathogens can be found within any environment and can sustain living in them. The number one spot that contains most of the pathogens in the human body can be found in the gut. It makes you ask if they are in our gut then why aren't we constantly sick? This is because not all pathogens will cause harm and the given name for that is microbes. Some microbes have been found to be beneficial to those biomes within the gut.

There are five main types of pathogens which will be discussed further later on in this paper. The five different types of pathogens consist of bacteria, viruses, fungi, protists, and parasitic worms. These five types of pathogens can be categorized into obligate pathogens or facultative pathogens. Obligate pathogens need a living host for survival while facultative organisms are capable of surviving within multiple hosts (Balloux & van Dorp 2017). Obligate pathogens include every virus, some bacteria, some protozoans, and some parasites. Some of them can require multiple different hosts but usually with the vector or intermediate host being an arthropod or mollusk. Facultative pathogens can occasionally cause infection to the host but not always. They consist of some bacteria and fungi. We will be focusing on what attributes make up the five types of pathogens.

Bacteria

All bacteria consist of the same structure that can best be described as a pill capsule with hair and a tail (Fig 1). This

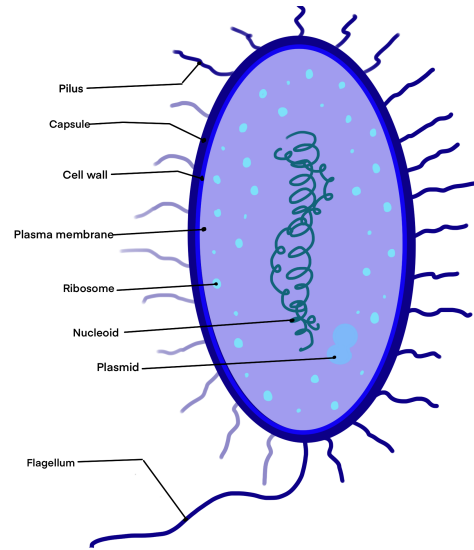
hair, which is called flagella, is what helps make the bacteria move throughout the body. The pill capsule portion consists of a cell wall that contains a single loop of DNA, cytoplasm, and ribosomes within. There is no nucleus that would automatically make them a prokaryote. The lack of a nucleus is made up for by the plasmid which is what stores the DNA as a nucleus would. Bacteria can be found in many different shapes forms like spheres, spirals, or even rods (Fig 2). The sphere-shaped bacteria is usually referred to as cocci, the rod-shaped bacteria is referred to as bacilli and the spiral-shaped bacteria is called spirochetes. All bacteria are single-celled organisms that are much larger than viruses. Bacteria are very unique due to their need for oxygen. The need for oxygen makes some bacteria aerobes and those that don't need oxygen are called anaerobes. Some bacteria can go with or without oxygen depending on the environment they are in which would make them facultative anaerobes bacteria. Oxygen determination helps scientists be able to differentiate the different types of bacterial species. Bacteria can be stained by scientists to determine if they are either gram-negative or gram-positive. Depending on the color of the bacteria after a gram stain is given, the color will allow the scientist to know if they are gram-positive (purple or blue coloring) or if they are gram-negative (pink coloring).

Gram-positive bacteria don't have an outer membrane like the gram-negative do. Instead of having an outer membrane, the gram-positive bacteria had a very thick peptidoglycan layer. The cell wall within these different types of bacteria can be either thicker or thinner. The thicker cell walls would mean the bacteria is most likely gram-positive and the thinner gram-wall would make the bacteria gram-negative. Bacteria can be found just about anywhere especially within the human body. There are even more bacteria cells in the body than

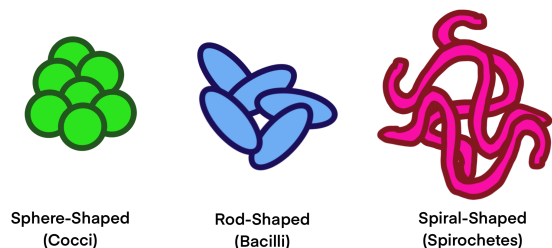
human cells. Some bacteria are more susceptible to living under certain environmental conditions that may be a bit extreme. The bacteria that are found in these extreme conditions are usually referred to as endospores which are very terrible pathogens that can cause anthrax. Bacteria enter their host through phagocytosis which is when they enter by being ingested (Alberts et al. 2002). Bacteria mainly induce a cell to be ingested by using their pili which helps with the interaction between the bacteria cell and their host cells. Pathogenic bacteria reproduce rapidly and release toxins that will make you sick through infections. Bacteria reproduce through a process called binary fission which is when the cell duplicates the DNA within and then divides itself into two different cells with the same copy of DNA. Different bacteria can cause different types of infections but the most commonly known are E.coli, UTIs, food poisoning, STIs, sinus, and ear infections.

Not all bacteria are bad for you, most are actually good for your health. The most common healthy bacteria can be found within your gut. The healthy bacteria are usually called microbes that can be found within the microbiome of your gut or even on your skin. It is very important to have healthy bacteria within your gut in order to allow the absorption of nutrients or even break down the gut.

When treating a bacterial infection, the doctor will usually prescribe an antibiotic that will help with the infection. The antibiotic will destroy the bacteria's cell wall or the DNA within the cell. Some bacteria can become susceptible to antibiotics when they are overused. This is where they will no longer respond to the treatment, making them antibiotic-resistant bacteria.



(Figure 1: The common structure of a bacteria with the showing of a capsule, flagellum, and genetic material.)



(Figure 2: The different shapes of bacteria starting from left to right: Cocci, Bacilli, and Spirochetes.)

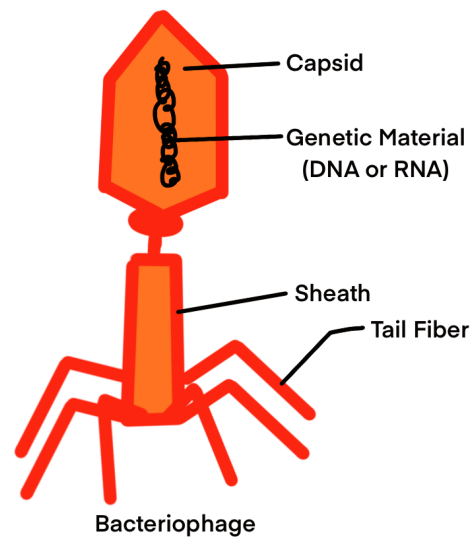
Viruses

Viruses are infectious pathogen that contains either DNA or RNA. They are not considered cellular organisms so they are neither prokaryotes nor eukaryotes. They are able to live with a host cell that can be either eukaryotic or prokaryotic. Some viruses are capable of infecting other bacteria cells, which would be classified as a bacteriophage. They surround their genetic material with a protein coat that protects the genetic material from any environmental

contents (Fig 3). Unlike bacteria, the genetic material can be either single-stranded or double-stranded. They are the smallest known pathogen to be found.

There are different viruses and the way they can be classified. They are typically classified based on whether or not they are single-stranded or double-stranded. The single-stranded is labeled as ss and the double-stranded is labeled as ds. They are also classified on whether or not they have DNA or RNA. RNA viruses are the most commonly found viruses that have infected humans. Viruses are also classified according to whether or not they have an envelope.

Viruses are particularly known for hijacking their host cellular mechanisms. This is the only way they are able to reproduce. They first start off by attaching to the cell's outer membrane, which they find by the use of proteins on their outer surface. Once attached to the cell membrane they are taken through the cellular membrane where they enter the cell's cytoplasm. They then release their genetic material into the cell like a shot releasing medicine. They release their genetic material by shedding their viral coat into smaller cellular vesicles. That genetic material then is duplicated or replicated, creating new viruses before being released out of the cell to then repeat the cycle (Cohen 2016). The now infected cell will start to produce more of the viral genetic material than its own products. This will eventually lead to the host cell being harmed or it will die altogether. Some viruses will remain dormant once in their host cell which isn't causing any harm at the moment, this stage is referred to as the lysogenic phase. Once the virus is starting to form new viruses, the phase is referred to as the lytic stage. Some common known viruses are COVID-19, HPV, and herpes. There are many more viruses but those are just a few common known viruses.



(Figure 3: The structure of a bacteriophage.)

Fungi

When you think of fungi, you might think of mushrooms, yeast, or even mold. Fungi can be found in just about any habitat or environment. A fungus is a eukaryotic organism. They can be either single-celled or multicellular organisms. Some are pathogenic to plants and even humans. They are most commonly found in soil or anything to do with plants but a small amount is known to cause diseases in animals.

There are several different types of fungi and they can be divided according to their life cycles. Structure, and the type of spores they produce. Their spores are what is known as their reproductive cells. They can best be described as plant seeds, where they can be carried off into the wind to find new establishments to settle down and reproduce.

Multicellular filamentous moulds consist of hyphae which are very fine threads. They divide and grow creating branching chains that then form a network known as mycelium. From the tips of the hyphae, the digestive enzymes are released

which is what helps break down organic matter that is in the soil. This broken-down organic matter is helpful for fungi to use as food.

Macroscopic filamentous fungi are known for producing mycelium below the soil or in the ground. They make bodies unlike moulds and are best known for being mushrooms. The body is made up of connected hyphae that are tightly packed together and then divide in order to make up the different parts of the body. The body holds the spores which can then be released into the air, or hitch a ride on a nearby insect to go to a different environment where they may grow and repeat the process. When you look underneath a toadstool or mushroom you will see these fibrous-looking hairs underneath the head of the mushroom/toadstool. These fibrous-looking hairs are referred to as gills which are covered in their reproductive spores.

Yeasts are single-celled organisms that are similar to the size of a red blood cell. They reproduce a little differently from other fungi because they use a form of reproduction called budding. This is when a formation on the daughter cell is produced and once grown, they will eventually fall off. Yeast is a very commonly known fungus that most bakers know of.

Some commonly known pathogenic fungi are capable of penetrating their host cells by their hyphae. Once they are capable of penetrating the host cell, they are able to release spores into the host which will then start a parasitic growth. This will cause either an infection or in some cases, can kill the host cell. Most pathogenic fungi can reproduce asexually or sexually. Their cell wall is composed of chitin which can be found in insects or crustaceans.

Fungi no longer have that big of an effect on humans because animals have evolved over time to have a consistent response to fungal infections (Köhler 2015).

They are more likely to occur in immunocompromised individuals or those that have uncontrollable HIV infections. Fungal infections can be very hard to get rid of. Fungi can be ingested and if chosen wrongly they can lead to infection. Many known fungal infections include eating something moldy or athlete's foot. Some fungi produce spores that can be breathed in through the air. They usually start in the lungs or can even be present on top of the skin.

Protists

Protists are eukaryotic, unicellular organisms. They are neither an animal, plants, nor fungi. Protists can either be a filament or in colonies. They can either be motile or nonmotile. When motile they can use flagella, cilia, or pseudopodia. They can absorb nutrients from either photosynthesis, ingestion, or absorption. Protists can be classified under the algae category and some are even found under the fungal category within the kingdom system. Most protists have a locomotory organelle that can be viewed under a light microscope.

Protists reproduce from a process called asexual binary fission, similar to bacteria. Multiple fission is another form of reproduction. This process is when the nucleus divides to produce daughter nuclei. This process occurs repeatedly and can be used through forms of budding.

Protists are most commonly caused by the ingestion of infected food or contaminated water by feces which then enter the system of both people and animals. Once the protozoa are within the intestines, they then attach to the lining. This attachment makes it very difficult for nutrients to be absorbed. Some protozoa can be acquired through mosquito bites and the most commonly known infection is malaria. Protozoa are known for bursting from within

the cell and destroying the cells in the process (Ferreira 2002).

Parasites

There are three main types of parasites that can be found in humans. The first is protozoa which are one-celled organisms that can be free-living or parasitic. They can be transported to another host through ingestion of fecal matter or even through an arthropod vector in which they are in a bite of the mosquito or fly. They can either be motile or non-motile and their mode of transportation is how scientists are able to classify these different types of protozoa. Helminths are larger than protozoans and are multicellular. They are similar to protozoans in which then can be free-living or parasitic. Once they mature into their adult form, helminths are not able to reproduce within humans. There are three known helminths that are capable of being parasitic to humans and they contain flatworms, thorny-headed worms, and roundworms. Ectoparasites are very similar to mosquitos in that they suck blood from their host. The most common know ectoparasites are lice and mites. Protozoa and helminths are not always pathogenic but they can still cause small illnesses or severe diseases within humans.

Parasites are known as the most common in tropical climates. They can be ingested like protozoa can but are more like worms in the body. You usually ingest the eggs of the worms which then hatch and procreate. Most people have been infected by these parasitic worms, with the estimated total being about 50% of the human population (Ho 2019). Some parasitic worms can be dormant for a period of time and not cause infection till a while after ingesting.

Citations:

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