**Common Bacterial Pathogens:**

**Staphylococcus aureus, Streptococcus and Bacillus**

**Overview of Bacterial, Human, Plant and Fungi Cells: Eukaryotic vs. Prokaryotic**

Bacterial cells have very unique features that set them apart from other cells, such as human cells. Bacteria are prokaryotic, meaning they lack a nucleus and membrane-bound organelles that are typically found in human, plant and fungi cells. Eukaryotic cells, which contain a nucleus and membrane-bound organelles, can be single-celled and multi-celled. Eukaryotic and Prokaryotic cells vary greatly not only in their structures, but also in the shape of their deoxyribose nucleic acid (DNA). Bacterial cells have circular DNA, while human, plant and fungi cells have linear DNA. While the genetic material, DNA, is kept in the nucleus in eukaryotic cells, it is kept in a structure called the nucleoid in prokaryotic cells. This nucleoid handles all of the genetic material and is not membrane-bound, which gives it a very irregular and non-consistent shape. DNA is known as the blueprint of the cell, it contains the genetic material for every cell and relays information so that the cell can fully function.

**Bacterial Cell Shapes**

Bacterial cells differ greatly in their shapes, because of this they have to be placed into different categories based on their shape. Morphology refers the study of forms and is a term that means the appearance of the any certain bacterium as it appears through a microscope. There are three main shapes that bacteria exist as and while each of these has their own sub-variations, only the three main shapes will be discussed in this chapter. These shapes include: coccus, bacillus and spiral. Coccus bacteria tend to have a more round or oval shape appearance. Bacillus have a rod like shape and the spiracle bacteria have, as you guessed, a spiral (twisted) shape. In this section, common bacterial pathogens will be discussed and you will see how these different pathogens exist in all of these different shapes.

**Gram-positive vs. Gram-negative Bacteria**

Before we can discuss some common pathogens, we need to first describe the structure of bacterial cell walls and the two types. These are important for discussion because they play a big role in the virulence of bacteria, virulence meaning their ability to cause disease. Although it varies, most bacteria can be placed into one of two categories based on their cell wall structure: gram-positive or gram-negative. A gram-positive bacterial cell will contain a very thick peptidoglycan layer, while a gram-negative bacterial cell will contain a very thin peptidoglycan layer and will contain an extra part in their cell wall called the LPS, lipopolysaccharide. Gram-negative bacteria also contain an outer membrane, which is not found in gram-positive bacterial cells. These two types of bacterial cells are very important to know as they help us to identify bacterium and also say a lot about the virulence of the bacterium and how they go about acting in our bodies when we become infected. When trying to determine if a bacterial cell is gram-positive or gram-negative we perform a test called a Gram Stain. A gram stain involves three basic solutions: Crystal violet, decolorizer and safranin. Crystal violet is purple and when poured over a sample of bacterial cells it will stain purple if the said bacteria is gram-positive. This occurs because the thick peptidoglycan layer in gram-positive bacteria absorbs the crystal violet. When a decolorizer is added, this will either completely wash away the purple color or it will stay. After the decolorizer, safranin is added, which is a red dye. If the bacteria stain a light pink and not purple this means that the bacteria you are observing are gram-negative. The exact steps of the gram stain procedure are listed below.

**Gram Staining Procedure:**

**Step 1)** Sample of bacterium is placed on a glass slide and dried.

**Step 2)** Crystal violet is poured over the sample of bacterium and left standing for 1 minute.

**Step 3)** Gently wash slide with water.

**Step 4)** Gram’s iodine is poured over sample and left standing for 1 minute.

**Step 5)** Gently wash slide with water.

**Step 6)** Use a decolorizer, acetone, by placing it drop by drop on the slide for about 10 seconds.

**Step 7)** Rinse immediately with water.

**Step 8)** Pour the counterstain, safranin, over the sample and let stand for 45 seconds.

**Step 9)** Gently wash with water and dab dry.

**Step 10)** View under a light microscope. If the bacteria is purple it is gram-positive, if it is more light pink and red it is gram-negative.

**Pathogenic vs. Commensal Bacteria**

What is a pathogen? A pathogen is bacterium that are capable of causing disease. We hear bacteria and we automatically assume bad, this is not always the case. We, as humans, live with bacteria every day and these bacteria are not harmful, they are actually essential to our bodies and aid in our overall health. These ‘good’ bacterium are called commensal bacterium. These are the bacterium that live in and on our bodies and they are a part of what we call our microflora. They exist on our skin, mucous membranes and in our gastrointestinal tract. These bacteria help to maintain our bodies and they are in symbiosis with our bodies, which is why they are called ‘commensal’ bacteria because we receive benefits from them and these bacteria receive benefits from us. They inhabit our bodies so as to further protect us from highly harmful bacteria. A main example of a bacteria that is commensal and found on every human is *Staphylococcus aureus*. While *S. aureus* is commensal, it can also be harmful in the right circumstances. To help control the ‘bad’ bacteria that infect our bodies and cause a lot of damage we have come up with antibiotics that help to target and stop the harmful bacteria. Antibiotics can backfire because it has been seen that many pathogenic bacteria can develop resistance to antibiotics by genetically changing so the medication cannot affect them. *S. aureus* exists as a huge problem because it has evolved into what we know now as MRSA, Methicillin-resistant *Staphylococcus aureus*. *S. aureus*, along with other common bacterial pathogens will be discussed in this chapter.

**General Characteristics: *Staphylococcus aureus***

As stated earlier in the chapter, bacterium come in many shapes and forms and this is called their morphology. The morphology of *Staphylococcus aureus* appears clearly in its name, it has a coccus shape, meaning it is round. In a lab setting, many bacterium can be grown on a plate called an agar plate. After the bacterium has grown on the plate a sample of it can be placed under a microscope, when *S. aureus* is viewed under a microscope you will either see individual round, cocci cells, or they will be in clusters and have a form similar to grape clusters. *S. aureus* is a gram-positive bacteria, which means its cell wall consists of a thick peptidoglycan structure. This thick peptidoglycan structure aids *S. aureus* in its virulence and helps prevent desiccation of the cell. Desiccation is a state of extreme dryness and this occurs when bacterium are in an extreme environment and placed without nutrients. Because of this thick peptidoglycan layer, *S. aureus* can live on dry surfaces for long periods without dying or dessicating. *S. aureus* is a part of every individual’s microflora. This means that it lives on and within our bodies. Although it is a normal part of our microflora, *S. aureus* is also highly infectious, especially in hospitals in patients that are immunocompromised, the elderly, infants or patients that have undergone surgery. *S. aureus* is spread via person-to-person contact, meaning the passage of bodily fluids or through an open wound. It can also spread from contaminated fomites. Fomites are inanimate surfaces (non-living) that a person comes into contact with and becomes infected with *S. aureus*.

***Staphylococcus aureus*: Diseases**

*Staphylococcus aureus* causes many grotesque diseases, three of which include: scalded skin syndrome, food poisoning and toxic shock. Scalded skin syndrome is a nasty skin disease that occurs most commonly in infants. This disease presents with blisters all over the skin that results in the sloughing off of the outer layer of the skin, meaning the first layer of skin comes off and leaves the patient with oozing, raw sores all over their body. Food poisoning can also be caused by *Staphylococcus aureus*, this occurs when someone consumes food that is contaminated with the bacteria. When food becomes contaminated, the bacteria secrete toxins known as enterotoxins. These toxins are actually what causes the symptoms of vomiting and diarrhea. When these toxins are secreted into the food there is no turning back. If the food stays room temperature or is reheated it will still cause food poisoning because these toxins are heat-stable, meaning they can withstand very high temperatures. Food poisoning from *S. aureus* results in vomiting, diarrhea and stomach cramps and usually resolves itself after about 24 hours. Toxic shock is another common disease caused by *S. aureus*. Toxic shock occurs when an individual is infected with the bacteria and the infection spreads all over the body and infects multiple different organ systems and the blood. If a *S. aureus* infection results in toxic shock there is high probability that the individual could not survive. If caught early, a person can be treated with antibiotics and survive toxic shock caused by *Staphylococcus aureus*.

**General Characteristics: *Streptococcus* *A***

*Streptococcus* is another very common bacterial pathogen. Similar to *Staphylococcus*, its name gives away the morphology of the bacteria, coccus. Also similar to *Staphylococcus*, *Streptococcus* is gram-positive. Although the morphology of Strep cells is similar to Staph, they exist in different forms that can be viewed under a microscope. Strep cells exist in either pairs or in chains. The different forms of *Streptococcus* are characterized by their cell wall components. As said, they are gram-positive, but Strep is unique in that each strain has different carbohydrate components, which is how we determine which type of Strep it is. Strep is named after its unique carbohydrate component that it contains. There are carbohydrate groups A-U, so a Strep cell that contains carbohydrate A is thus called Strep A. Strep A is notorious for infections and their ability to avoid our immune system. Our immune system has the ability to engulf pathogens in a process called Phagocytosis, which leads to the death of the bacterial cell. Strep A is known for its ability to avoid being eaten. It is also known for its ability to produce and secrete toxins that lyse (destroy) leukocytes (white blood cells), erythrocytes (red blood cells) and DNA. People that are the most susceptible to Strep A are children and patients. Strep A is also spread via person-to-person contact, but mainly through droplets when a person coughs and a person that is in close proximity comes into contact with the droplets. It can also be spread if a person touches a contaminated fomite or an open infected wound. Strep A normally causes infections in the skin and the respiratory tract.

***Streptococcus A*: Diseases**

Group A Strep is also called *Streptococcus pyogenes*. This form of Strep causes many different infections including: Pharyngitis, Scarlet Fever, Pyoderma/Cellulitis, Necrotizing fasciitis, toxic shock and rheumatic fever. As stated earlier in the chapter, Strep A is a very common infection in children and it typically causes what is commonly known as Strep throat. Strep throat causes irritation in the throat and the pharynx is reddened and will typically seep fluids. If an individual has Strep throat and does not get it taken care of in a timely manner the infection can then spread and cause Scarlet Fever. Scarlet Fever appears as a rash on the chest that will then spread to the extremities (legs and arms). *S. pyogenes* also causes pyoderma and cellulitis, which are both infections of the skin and can be either localized or all over the body. It can also cause a nasty skin infection called necrotizing fasciitis, which is also infamously called flesh-eating disease. If a Strep A infection spreads to this stage it moves way deeper in the skin and will destroy muscle and fat. Like *Staphylococcus aureus*, *Streptococcus* can also cause toxic shock, called Streptococcal toxic shock syndrome. This type of infection is systemic, meaning it spreads all over the body and into the blood stream. Toxic shock syndrome has a high mortality rate (death rate) and people who usually have toxic shock also have necrotizing fasciitis. Another disease caused by Strep A is Rheumatic Fever, Rheumatic Fever causes an inflammatory response of the heart, joints, blood vessels and subcutaneous tissues (under the skin). This causes the individual to present with a fever and feel very fatigued and have painful, swollen joints. *Streptococcus A*, *S. pyogenes*, is a highly infectious pathogen that can infect and cause harm to the body in many different ways.

**General Characteristics: Bacillus**

The third and final pathogen that will be discussed in this chapter is Bacillus. The Bacillus species is unlike Staph and Strep when it comes to morphology. Bacillus is shaped like a rod. Bacillus is similar to the other two pathogens in that is it also gram-positive. Bacillus also varies from the other two pathogens, in that they develop endospores. Endospores are structures found in the bacteria that are dormant and tough, these endospores add to the virulence factor of Bacillus because they allow it to live in very, very harsh conditions. There are two medically relevant species that will be discussed in this chapter: *Bacillus anthracis* and *Bacillus cereus*.

***Bacillus anthracis*: Diseases**

*Bacillus anthracis* is also known as anthrax. There are three main routes of infection when it comes to anthrax: cutaneous (skin) anthrax, gastrointestinal anthrax and inhalation anthrax. Cutaneous anthrax is usually found in the soil and infects people through open wounds in the skin. A cutaneous anthrax infection presents itself as a pain-less papule that grows up on the skin and forms a black layer. This papule is very slow healing and if not treated fast can progress to a systemic infection. Gastrointestinal and inhalation anthrax have a much higher mortality rate than the cutaneous version. Gastrointestinal anthrax is caused when an individual consumes the bacteria, this type of infection will lead to ulcers of the mouth, esophagus and intestine. Ulcers are sores in the lining of the gastrointestinal tract. The symptoms that present with this type of infection involve nausea, vomiting and fatigue. If left untreated this infection can become systemic. The mortality rate of someone who has contracted this version of anthrax is 100%, meaning the chances are very high that they will pass away as a result of this infection. The third form of infection by *Bacillus anthracis* is inhalation anthrax, this too has a mortality rate of 100%. This form of anthrax is very dangerous and sneaky as it presents at first like the flu, so when an individual goes to the doctor it is hard to diagnose this type of infection. The symptoms, as said, are flu-like and include a fever, pharyngitis and swelling of the neck. If inhalation anthrax is caught extremely early it can be treated, but toxic shock and death usually occur within three days of infection.

***Bacillus cereus*: Diseases**

The second most medically relevant Bacillus species is *Bacillus cereus*. This bacteria also has three primary routes of infection: gastroenteritis, ocular infections and severe pulmonary disease. If a person consumes food that is contaminated with *Bacillus cereus* this results in gastroenteritis in two forms: emetic form and diarrheal form. The emetic form presents pretty fast and involves vomiting and abdominal pain, but usually only lasts for a very short time. If a person comes down with the diarrheal form, the onset usually takes much longer and involves abdominal cramps and a longer amount of time that the individual is experiencing diarrhea. *Bacillus cereus* can also cause infections of the eyes, called ocular infections. *Bacillus cereus* can be found in the dirt, the only way a person can get this type of infection is if they already have an open wound in their eye and it becomes infected with the bacteria. This is an infection that needs to be taken care of in a timely manner, because if left untreated it will completely destroy the eye and lead to absolute blindness in a matter of 48 hours. The third type of infection caused by *Bacillus cereus* is severe pulmonary disease. This type of infection is prominent in patients that are immunocompetent, meaning they have good immune systems. The symptoms present much like inhalation anthrax.

**Conclusion**

These are just three families of pathogenic bacteria, out of many, that exist in this world. The point of this was to give a little insight into the world of bacteria and to show how something we, as humans, cannot see with an un-aided eye affects us on a daily basis in very different ways. While bacterium tend to have a bad connotation, they exist in our lives for very beneficial purposes as well, living commensally on and within our bodies. Bacteria can also be quite harmful as seen with the few examples given in this chapter. Bacteria are so small, yet can lead to such devastating events in an individual’s life. The world of microbiology is ever-growing, it is important for people to learn of these different pathogens so as to better serve to protect themselves and their family members from infection.

**References**

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