Microbes and People

 Every day, interactions between the human body and invisible organisms occur. They determine health, aid in body processes, and are unique to each individual. Microscopic organisms are also responsible for disease in plants and other animals. They make food spoil, and alcohol ferment. What are these tiny living things?

Microbes

 **Microbes** are living things that are too small to be seen by the naked eye. The study of these organisms, **microbiology**, looks at how they function, reproduce, and impact the environment around them. Archaea, viruses, fungi, prions, protozoa, algae, and bacteria are all types of microbes. These organisms are involved in needed processes like nutrient cycles and degradation of biologic and organic material. They also impact climate disease and are responsible for disease in plants, animals, and people, as well as food spoilage.

# Archaea

 **Archaea** can be single-celled or clustered and any shape—spherical, rod, spiral, lobed, rectangular, or irregular. They are found in extreme environments like places with high pressure, high salt concentrations, or extreme high or low temperatures. These organisms have been found in the hot springs and geysers of Yellow Stone Park and in the ice caps of the Arctic circle.

# Viruses

 **Viruses** are the smallest of all the microbes. The virus that causes the common cold, the rhinovirus, is estimated to be so small that 500 million of them could fit on the head of a pin. The genetic material of a virus is surrounded by protective coat of protein called a **capsid**. Viruses are only able to multiply inside of the cells of other organisms. They use the host and then leave by one of two methods: budding or lysis. In **budding**, the virus pushes against the plasma membrane of the host cell until it is enclosed in it. This uses the host’s cell membrane while also protecting the virus. In **lysis**, the virus causes the host cell to burst in order to escape.

# Fungi

 **Fungi** (singular fungus) can be single celled or multicellular. They mostly live on land but can be found in most habitats on Earth. Many fungi are important decomposers that are essential to the carbon cycle. Fungi can be parasites to plants; fungal diseases like rust and mildew often kills crops and causes monetary loss to farmers. The number of fungal diseases in humans and animals are small and mostly skin related, like ringworm and athlete’s foot in people and thrush in animals.

 Fungi are classified based on their life cycle. **Multicellular filamentous molds** grow fine threads called hyphae from the tip of the organism. These hyphae divide repeatedly to create branches. They also form networks of threads called mycelium. **Spores**, which are like plant seeds, are formed with a protective coating on the branches of the hyphae. They are then spread by wind, rain, or other organisms and will grow when conditions are favorable. **Macroscopic filamentous fungi** grow mycelium below ground and produce visible fruiting bodies, known as mushrooms. **Yeasts** are small and single celled; they are about the same size as a human red blood cell. They reproduce by budding daughter cells from parent cell. They have short reproduction cycles, so they are often used as a model organism for genetic studies.

# Prions

 **Prions** are proteins that can cause disease by triggering brain proteins in animals to fold incorrectly. They contain no genetic material. These microbes are known for their causation of bovine spongiform encephalopathy, commonly called mad cow disease.

# Protozoa

 **Protozoa** are also single celled. They live in a variety of habitats, but they must be kept moist. They are motile and move via three methods. **Cilia** are tiny hair-like structures on the outside of the organism that move like oars. **Flagella** (singular flagellum) are long thread-like structures that protrude from the cell surface and move like whips. Amoeboid movement uses temporary protrusions that fill with cytoplasm to move.

# Algae

 **Algae** can exist as single cells or in chains or as many cells together. They live in fresh water or sea water and can be free floating like plankton or attached to the bottom of the water source. Algae can grow on surfaces like rocks and vegetation when enough moisture is present. These microbes contain chlorophyll a and make food via photosynthesis like plants.

# Bacteria

 **Bacteria** are single-celled organisms with the simplest structure in all of biology. They contain no nucleus or other organelles encased in membranes. Their genetic material is a single circular piece of **deoxyribonucleic acid (DNA)**. Bacteria are classified based on their shape. Spherical cells are labeled **cocci** (singular coccus); rods are called **bacilli** (singular bacillus). **Spirilla** bacteria (singular spirillum) have a spiral shape. **Vibrio** are known for their comma-like shape, while **spirochetes** are corkscrew-shaped.

 Bacteria are found in nearly every type of environment on earth, including in and on plants or animals. They reproduce by **binary fission**. A single parent cell replicates its DNA, elongates, and then splits to form two identical daughter cells. Each daughter cell is an exact clone of the parent cell. In the most ideal of conditions, certain bacteria, such as *Escherichia coli*, can divide every 20 minutes. This is why bacterial pathogens can make humans sick so quickly.

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| Microbe | Number of Cells | Environment |
| Archaea | Single celled or clustered | Extreme temperature, salinity, or pressure |
| Viruses | Single celled | In hosts |
| Fungi | Single celled or multicellular | Moist habitats |
| Prions | Proteins | In hosts |
| Protozoa | Single celled | Water or moist habitat |
| Algae | Single celled, chains, or clusters | Fresh or sea water |
| Bacteria | Single celled | Nearly every environment on earth, especially hosts |

The Human Microbiome

 It is estimated that between 10 trillion and 100 trillion microbial cells can be found in and on the human body. These microbes are symbiotic; they benefit from the relationship and so does the human host. The term **microbiota** defines all microbial taxa, or groups of populations, that are associated with humans. The term **microbiome** defines the catalog of these microbes and their genes. Common human microbes are bacteria, archaea, fungi, and viruses.

# Discovery of Microbiome

 In the late 1600s, a cloth merchant name Antonie van Leewenhoek examined his personal microbiome with a handmade microscope. He is credited as the first to find single-celled organisms. He examined microorganisms from multiple body sites, finding microbes in his dental plaque and in a fecal sample. Robert Koch contributed further to the study of microbial importance in 1876 by proving that *Bacillus anthrascis*, a bacterium, was responsible for anthrax. His was the first proof that microbes caused disease, which is now known as the **germ theory of disease**. From 1878-1906, nineteen microbial pathogens were linked to disease.

# What is the Microbiome?

 Microbes colonize the human body in the oral cavity, on the skin, in the lungs, in the nasal passages, and in the urinary and reproductive tracts. The microbiome can make up 1-3% of a person’s body mass. The composition of microbiota found in humans is different than microbial communities that live independently of a host. Microbial colonization starts in fetal development, but birth is the first significant marker of microbe development. The method of delivery of the infant determines what microbes colonize their skin. Babies delivered vaginally have microbe compositions similar to that of their mother’s vagina, while babies born via Caesarean section have compositions more commonly found on human skin. Microbial diversity then begins to increase with age and is increased by certain moments in development. Studies have shown that breastfeed, development of a fever, introduction of cereal-like food, introduction of formula or table foods, and treatment with antibiotics all have impacts on a developing child’s microbiome. Similar studies show that breastmilk supplies an infant with beneficial bacteria known as **probiotics** and nutrients the bacteria need to grow and reproduce. A child’s microbiome has a more adult composition at two and a half years old. Microbes that use a human as a host are capable of responding to various factors, changing the composition. Things like diet, medication, exercise, the environment, and stress levels can all affect microbiome makeup. Certain foods containing fiber or probiotics are considered able to build a healthy microbiome. Fruits and vegetables also aid in keeping the microbe composition healthy.

## Gut Microbiome

 One of the most extensively studied aspects of the human microbiome is the microbial characteristics of the gastrointestinal tract. The human gut is known to be one of the densest areas of microbial colonization on Earth. These microbes within the larger microbiota is often called the **gut microbiome** and is essential to human health. Microbes in the gut digest many carbohydrates that intestinal cells cannot; they then make energy that can be used by themselves or by the host human. They also aid in the breakdown and use of certain drugs and help to create specific vitamins. The gut microbiota is stable throughout life once established early in development, but it does go through changes. Studies in mice have shown that changes to this microbiome are related to conditions like obesity, diabetes, cancer, heart disease, asthma, and arthritis.

## An Individual’s Microbiome

 Though the same bacteria are common among most people, the exact composition is variant from individual to individual. People who share 99.9% of their genetic material have been studied to have gut and hand microbiomes that are 80-90% different from one another. Since microbes flow freely from touched surfaces to human skin and vice versa each day, studies have looked at using microbial patterns to identify individuals. For example, the specific microbe composition left on a keyboard can identify who used the computer last and even be matched to the corresponding mouse used.

## Mapping the Microbiome

 In 2007, the United State National Institute of Health launched a 5-year project to characterize normal human microbiome and its role in health and disease. They called it the Human Microbiome Project. By 2012, they found variation from microbe composition both between different people and at different body sites. They also found that oral and intestinal colonies are often complex and diverse while vaginal colonies tend to be simpler. Interestingly, no classification of microbes was found in every body site or in every individual. This shows the diversity of microbiomes even within an individual.

# Microbes and Disease

 Many microbes are known to cause disease in people. While the bacteria that normally inhabit the human body are necessary and useful, these invaders cause harm. Protozoa and worms are considered parasites while viruses, bacteria, and fungi are studied as microbial disease agents**. Intracellular pathogens** must be in the host to replicate and therefore reproduce and are often viruses or certain bacteria. These often kill the cells the use, leading to disease. **Extracellular pathogens** can replicate on their own and live in the body or on surfaces like skin and mucous membranes. They often cause disease by creating toxins that disable the host’s immune cells.

## Viral Disease

 Diseases causes by viruses are labelled as **viral**. Some use DNA as their genetic material, while others use only **ribonucleic acid, or RNA**. DNA viruses cause many common human diseases. Herpesviruses cause herpes simplex infections as well as less common complications. Hepadnaviruses are responsible for the Hepatitis B virus and resulting infection. RNA viruses can also cause human disease. Picomaviruses causes polio, hepatitis A, and rhinovirus. The rhabdoviruses are the cause of rabies, while retroviruses cause HIV. The viruses that cause the common cold are coronaviruses. Vaccines inject small, weakened or dead versions of a particular virus. These are injected into the body to create memory in the immune system. Then, when the virus presents itself again, immunity can kick in and respond so that the infection is prevented or lessened. If infection does occur, treatment will only address the symptoms of illness like fever or headache. A small number of viral infections can be cleared with antiviral medication.

## Bacterial Disease

 Bacteria that are not normally found in the microbiome or in the particular body site often cause **bacterial infections**. They can be intracellular pathogens but are typically extracellular since most can reproduce without the host’s help. Different bacterial species cause different infections. *Staphylococcus aureus* is the main agent in staph infections. Staph infections are typically on the skin, but they can also affect the bloodstream, bone, and lungs. *Streptococcus pneumonaie* and *Streptococcus pyogenes* cause infections commonly called strep. The most common infection is sore throat. With it, the tonsils often swell and form white spots, and the throat is sore and red. Other infections cause by bacteria include gonorrhea, meningitis, anthrax poisoning, chlamydia, tuberculosis, and whooping cough. Most bacterial infections are treated with **antibiotics.** These medicines either kill the bacteria or stop their reproduction, halting the spread and continuation of the infection.

## Fungal Infections

 Fungi in the body can cause **fungal infections** if not part of a person’s normal microbiome. Only around half of fungi are harmful and cause complications. These microbes infect via their spores and start colonizing in the lungs or on the skin. Common diseases include athlete’s foot and yeast infections. Antifungal creams or oral medication can clear the infection.

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| Common Infection  | Type | Responsible microbe |
| Polio | Viral | Picomavirus |
| HIV | Viral | Retrovirus |
| Strep throat | Bacterial | *Streptococcus pnuemonaie* |
| Bacterial vaginosis | Fungal | Yeast |

Summary

* Scientists classify organisms too small to be seen without a microscope as microbes.
* Fungi, viruses, protozoa, bacteria, prions, archaea, and algae are all studied by microbiologist in attempts to learn how they function and the impacts they have on their environments.
* Archaea can be single-celled or multicellular and are found in extreme environments.
* Viruses are the smallest microbes and are protected by a protein coat.
* Fungi can also be single- or multi-celled; they reproduce with seed like spores.
* Prions are proteins that cause brain proteins to misfold and therefore cause disease.
* Protozoa are single celled, and they must remain moist to survive.
* Algae can be found as single cells or clusters and live in salt or fresh water.
* Bacteria are single-celled and the simplest microbe. They have no nucleus and have circular DNA.
* The human body is colonized by trillions of microbes. These microbes develop with a person and are unique to each individual.
* Factors like diet, stress, and medication can change the makeup of a microbiome.
* The gut microbiome is studied extensively and has been seen to have significant health implications.
* Projects continue to study the human microbiota and determine how and why it is important to health and development.
* Not all microbes that inhabit a human host are beneficial. Some cause diseases that range from temporarily uncomfortable to life changing. Knowing the cause of an infection determines the treatment needed.
* Microbes are not only important to microbiologist but also to the humans who host them. As science continues to learn about these important organisms, we learn more about the human body.

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