Microbiology essentials for the SPD

by Sandra Beauclair

Biology is the study of processes that occur in living things such as plants and organisms. It also includes the study of microorganisms, which are living, typically single-celled organisms visible only with a microscope. Microorganisms surround us and live inside us. They are in our soil, water, air, sediments, plants and animals. In fact, as Neil deGrasse Tyson, an American astrophysicist, science communicator and director of the Hayden Planetarium at the Rose Center for Earth and Space says, within one linear centimeter of the human lower colon live and work more bacteria (about 100 billion) than all humans who have ever been born. Yet many people continue to assert that it is we who are in charge of the world! Although we generally live in peace with the “friendly” microorganisms within us, not all microorganisms are friends to humans. Many are the source of human diseases that can lead to death. As healthcare professionals, it is not our responsibility to be microbiologists, but we should have sufficient knowledge about disease-causing organisms to determine what we can do in our daily practices to prevent harm to our patients.

Microbiology discoveries

One of the best ways to understand where we are today is to briefly retrace the history and origins of microbiology as a science.

1. Antonie van Leeuwenhoek (1632 – 1723): Considered “the father of microbiology,” van Leeuwenhoek was a Dutch businessman and scientist. He developed the first microscope, through which he observed single-celled microorganisms that he called “animalcules” (now known as microorganisms).

2. Edward Jenner (1794 – 1823): In 1796 Jenner, an English country doctor, investigated why milkmaids never caught smallpox, but because of their close contact with cows they did contract cowpox. Jenner supposed that cowpox produced an immunity to smallpox in these women.

3. Ignaz Semmelweiss (1818 – 1865): In 1850, this Hungarian obstetrician made the connection that puerperal fever was being transferred by medical students and junior physicians, who were delivering babies immediately after performing autopsies, without washing their hands. He ordered them to do so and the mortality rate dropped significantly. The “morbid poison” that Semmelweiss believed was being transferred is now known as Group A hemolytic streptococcus.

4. Louis Pasteur (1822 - 1895): In 1859, this French chemist and microbiologist developed the process of pasteurization after he discovered that microbes soured alcohol. By heating beverages and allowing them to cool he observed that the microbes were killed. He also contributed to the creation of the anthrax and rabies vaccinations through his work in germ theory.

5. Robert Heinrich Hermann Koch (1843 – 1910): A German physician and one of the founders of bacteriology, Koch was best known for receiving the Nobel Prize in 1876 for his discovery of the tubercle bacillus Mycobacterium tuberculosis, which causes tuberculosis.

6. Hans Christian Gram (1853 – 1938): A Danish physician, he studied pharmacology and bacteriology but is famous for his 1884 development of bacterial staining. Based on different cell wall constituents, bacteria, when stained, can be identified as either Gram-positive or Gram-negative.

7. Dimitri Ivanovsky (1864 – 1920): In 1892, this Russian scientist discovered viruses when he was looking for the cause of tobacco mosaic disease. He believed the disease was not caused by a bacterial agent but possibly by a toxin or other life form undetectable by the naked eye.

8. Martinus Beijerinck (1851-1931): This Dutch microbiologist and botanist discovered viruses in 1899, and discerned that viruses reproduce and are different from other microbes.

9. Walter Reed (1851 – 1902): Reed, a U.S. Army pathologist and bacteriologist, proved in 1900 that yellow fever is transmitted from the bite of a mosquito.

Hate them when they cause us harm (pathogenic microorganisms)

11. Robert Gallo (1937 -) and Luc Montagnier (1932 -): Dr. Gallo, an American biomedical researcher, and Dr. Montagnier, a French virologist, shared credit for the discovery of the human immunodeficiency virus (HIV) in 1984.

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13. Raymond Krchalovic (1940 – 2013): An American microbiologist, Krchalovic conceived and developed the first process for low-temperature liquid sterilization, which was needed for delicate medical instruments that could not tolerate the standard steam sterilization process.

14. Bayer (Established 1863): Founded in 1863 in Barmen, Germany, this company’s microbiologists developed ciprofloxacin hydrochloride, which was cleared by FDA in 2000 for use in treating biological-agent induced infections such as anthrax.

How we relate to microbes

The interaction between microorganisms and humans can be described as a love-hate relationship. We love them when they’re nonpathogenic (don’t cause disease), but hate them when they cause us harm (pathogenic). Resident microbes are those that live with us daily. For the most part, we get along because they aid with food digestion and protect us from diseases. They are often referred to as normal flora. In contrast, transient microorganisms are passed from person to person, surface to person or environment to person. They are picked up from surfaces and environments, or pass through our bodies.

One could say that all microorganisms have a competitive nature. Under certain conditions, both resident and transient microorganisms can have a negative effect on humans. For example, in individuals with a compromised, weakened or disrupted immune system (such as someone with HIV/AIDS), normal flora can become opportunistic or pathogenic. They take advantage of the situation and grow in number until they overtake the person and cause harm.

Transient microorganisms will try to colonize in or on the human body, but are typically controlled by the person’s immune system, the competition of normal resident flora, or by physical or chemical action on the skin surface (washing).

Categories of microorganisms

Microorganisms can be organized into four major classes:

1. Bacteria
2. Viruses
3. Fungi
4. Protozoa

Important characteristics that impact their function and effect on humans include their cell structure, their DNA/RNA composition, their means of reproduction, and their size.

Bacteria are the most abundant and impactful microorganism found in the environment. They are single-cell structures that self-replicate. They contain DNA and range in size from 0.3 to 2.0 micrometers. To provide a size reference; a medium-sized grain of sand is one thousand times larger than one bacterium. Bacteria are easily viewed under a microscope using the Gram-staining technique. Some strains are beneficial to humans, and are normally found in the human digestive tract. All bacteria can exist in an actively growing or “vegetative” state, but certain special groups of bacteria are “spore-formers” (able to form a protective shell that’s very resistant to environmental stress). When environmental conditions for reproduction are present, bacterial spores become vegetative cells. Some examples of pathogenic bacteria are:

- Mycobacterium tuberculosis (Tuberculosis)
- Staphylococcus aureus (Impetigo)
- Bordetella pertussis (Whooping Cough)
- Salmonella enteritis (Food Poisoning)

Viruses, on the other hand, do not have a cellular structure. Some viruses have a lipid envelope, and this envelope makes them harder to kill. They contain either DNA or RNA, but not both. Instead of replicating themselves, they use the host cell to reproduce. Some, like Herpes simplex virus and Varicella zoster, may remain dormant (inactive) within the host cell. When they are environmentally stimulated, they reactivate and take over the host cell’s DNA or RNA by copying or reprogramming it. In the reproduction process the host cell may be killed. Viruses range in size from two (2) to 300 micrometers and can only be seen under an electron microscope. Viral infections can occur not only in humans, but in plants and bacteria as well. They are common in humans, and in some situations, can be life-threatening. Some examples of pathogenic viruses are:

- Influenza (flu). The individual’s immune system works to eliminate the viral infection. (Swine flu, an H1N1 type, mutated from a combination of animal and human strains. In 2009, it was the cause of a pandemic that led to 16,000 deaths worldwide.)
- Rhinovirus (common cold)
- Hepatitis B (liver disease). A vaccine is available to immunize this virus.
- Human Immunodeficiency Virus (HIV) can lead to Acquired Immune Deficiency Syndrome (AIDS)

Fungi (yeasts and molds) are saprophytic (obtain nutrients from dead organic matter) in nature. They are parasites (an organism that is living in, on or with another organism), which are either single (yeasts) or multi-cellular (mold) in structure. They contain DNA, are self-replicating and range in size from two (2) micrometers to one (1) millimeter. Some can be seen without the aid of a microscope. Some examples of pathogenic fungi are:

- Candida albicans (Thrush): this occurs in the mouth and gastrointestinal tract. Unless the person is immunocompromised, it is easily treated with medication.
- Trichophyton mentagrophytes (Athletes Foot): causes scaling, itching, and flaking. Over-the-counter antifungal treatments are available, and good hygiene practices can help prevent it from occurring.
- Aspergillus fumigatus (Lung Disease): Found in nature, this fungus aids in the decay of organic matter. Most people breathe in several of these spores daily. Individuals who are not immunocompromised are able to eliminate the spores from their body with no problem. However, weakened patients who contract Aspergillosis may cough up blood and suffer kidney and liver failure.

Protozoa are single-celled organisms that have DNA and are self-replicating. Some are capable of animal-like movements. They range in size from 1.5 to 80 micrometers. Some protozoa cause parasitic infections in humans or animals. Examples of pathogenic protozoa are:

- Entamoeba histolytica (Amoebic Dysentery), which takes hold in the large intestine and causes diarrhea and colitis. Dysentery is treatable with proper oral medication.
- Giardia lamblia (Gastroenteritis) affects the large intestine and causes diarrhea.
- Cryptosporidium Sp. (Diarrhea) also affects the large intestine and causes diarrhea.

Self-Study Test Answers: 1. b, 2. c, 3. b, 4. A, 5. b, 6. d, 7. c, 8. A, 9. A, 10. A

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Microbes on the move

Microorganisms need a mode of transfer to move from one environment to another. There are four modes of transfer: direct contact, indirect contact, droplet, and airborne. When healthcare workers (HCWs) are providing routine care such as taking vital signs or assisting patients in and out of bed, there is direct contact between the HCW and patient, and pathogenic and/or nonpathogenic microbes are transferred in both directions. Indirect contact happens when a person encounters microbe-contaminated inanimate objects such as call buttons, bed rails and door handles. Common examples of the indirect transfer of pathogenic microorganisms is the transfer of fungi that cause Athlete’s Foot among those who shower barefoot in a community shower; or wrestlers who get ringworm from those who shower barefoot in a community. Staphylococcus difficile, a much more serious pathogenic microorganism, is well known to be transferred indirectly from contaminated hospital beds and rails.

Droplet contact is exhaled or emitted by an infected person. The microorganisms remain suspended in the air for only a short time, so the receiving person must be nearby at the time of the infected person’s unprotected cough or sneeze to transfer microbes. Whooping cough and Influenza are transferred by droplet contact.

Airborne contact occurs from the passage of microorganisms in water droplets or dust particles that are small enough to stay suspended for several minutes in the room. Tuberculosis is an airborne pathogen.

HCWs are at risk of contracting or spreading microorganisms from or to patients. They have a direct effect on patient and staff safety and the spread of healthcare-associated infections (HAIs).

Preventing transmission in your facility

Each type of infectious entity presents a different challenge to kill or inactivate. The chart below illustrates the range of difficulty, from easier-to-kill viruses and bacteria, to more resistant bacteria and fungi, to the most challenging spores and prions. You don’t have to be a microbiologist to appreciate that the harder they are to kill or inactivate, the greater the danger they pose to staff and patients. The best practice is to attempt to prevent all types of pathogens from contaminating facility environments, surfaces, equipment, and surgical instruments, to prevent them from infecting patients and staff. (See image below.)

There are a variety of techniques that HCW can use, individually and together, to help prevent the transmission of microorganisms and ensure patient and staff safety.

Appropriate hand hygiene (a general term that applies to soap-and-water handwashing, the use of an antiseptic handwash, or antiseptic handrub) removes or kills pathogenic microbes.

Wearing appropriate personal protective equipment (aprons, gloves, gowns, face masks, eye protection and shoe covers) interrupts the transmission of infectious agents.

Hospital policies and procedures that achieve effective disinfection and sterilization of medical surfaces, equipment and devices should be developed with guidance from professional and regulatory organizations (CDC, Joint Commission, AAMI, AORN, FDA) and in accordance with manufacturers’ instructions for use.

The more you know, the more you can help

Healthcare professionals with a basic understanding of microbiology, and the roles microbes play in our existence, can understand the dangers these microscopic organisms and proteins pose to staff and patients if they are not adequately controlled. They can apply this knowledge to enhance contamination reduction practices and policies, and can help to reduce the risk of pathogenic infection in their facilities.
Healthcare Central Service Materiel Management (IAHCSMM), and the Ohio Nurses Association (ONA).

References:
https://www.cdc.gov/hai/surveillance/
http://university.steris.com/course/basics-of-microbiology-within-healthcare/

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Circle the one correct answer:

1. Microbiology is the study of processes that occur in a living thing such as plants and organisms.
   A. True   B. False

2. Antonie van Leeuwenhoek developed the microscope. He called the single-celled organisms that he viewed through the microscope
   A. Miniature animals   B. Microorganisms
   C. Animalcules   D. Tiny creatures

3. Which of the following men ordered his staff to wash their hands between procedures?
   A. Louis Pasteur   B. Ignaz Semmelweiss
   C. Hans Christian Gram   D. Robert Heinrich Hermann Koch

4. In 1884, a Danish physician discovered what method that is still used today to differentiate bacteria based on wall constituents
   A. Staining of bacteria   B. Hang drop
   C. Antibiotic resistance   D. Metabolism (Aerobic/Anaerobic) needs

5. Martinus Beijerinck discovered viruses when he was looking for the cause of tobacco mosaic disease. He believed the disease was not caused by a bacterial agent but possibly a toxin or other life form undetectable by the naked eye.
   A. True   B. False

6. Robert Gallo and Luc Montagnier shared credit in the discovery of what virus?
   A. Varicella zoster   B. Influenza virus
   C. Human papillomavirus (HPV)   D. Human immunodeficiency virus (HIV/AIDS)

7. Name the microbiologist who conceived the process of low-temperature liquid sterilization.
   A. Walter Gilbert   B. Walter Reed
   C. Raymond Kralovic   D. Louis Pasteur

8. The four major classes of microorganisms are
   A. Bacteria, Viruses, Fungi, Protozoa
   B. Bacteria, Viruses, Mushrooms, Protozoa
   C. Bacteria, Viruses, Fungi, Algae
   D. Bacteria, Prions, Fungi, Viruses

9. Which of the four major classes of microorganisms found in the environment are the most abundant and impactful?
   A. Bacteria   B. Viruses
   C. Fungi   D. Protozoa

10. Microorganisms require a mode of transfer to move within the environment. The four modes of transfer are; direct and indirect contact, droplet and airborne.
    A. True   B. False

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