Chapter 2. The Science of Infection Control

Introduction
A comprehensive understanding of how microbes move through the environment and into our bodies, and of the roles that cleaning, sanitizing, and disinfecting have in safely preventing our exposure to these microbes provides the foundation for planning infection-control strategies and developing work practices.

What is a microbe?
Microbe is a collective name for microscopic organisms, and includes bacteria (e.g., Staphylococcus aureus), viruses (e.g., influenza A and B, which cause the flu), fungi (e.g., Candida albicans, which causes some yeast infections), and some parasites (e.g., Toxoplasma species, which cause toxoplasmosis). The term microbe is used throughout the Infection Control Handbook for Schools when discussing bacteria, viruses, and fungi.

Microbes that can cause disease and/or infection are pathogens. Pathogenic microbes may be bacteria, viruses, fungi, or parasites. Enough pathogenic microbes must be present to cause disease.

What types of microbes are there and what is their effect in schools?

Bacteria
What are they? Bacteria are microorganisms that are found “on our skin, in our digestive tract, in the air, in soil, and on almost all the things we touch every day. Most are harmless (nonpathogenic). Many are helpful because they occupy ecological niches (both within our bodies and in the external environment) that could be occupied by harmful (pathogenic) bacteria. These helpful strains keep harmful microorganisms in check. They also help our digestion to function efficiently and stimulate the development of a healthy immune system.” Beneficial bacteria are also used in the fermentation process that creates bread, wine, cheese, yogurt, and other foods and beverages.

What illnesses do they cause? Pathogenic bacteria can cause common infections, including food poisoning, acne, sinusitis, ear infections, or more serious diseases such as tuberculosis, whooping cough, staph infection, bacterial pneumonia, and bacterial meningitis. Some bacteria—for example, methicillin-resistant Staphylococcus aureus (MRSA), Clostridium difficile, and vancomycin-resistant enterococci—have become antibiotic resistant and can cause serious infectious diseases that are hard to treat, such as tuberculosis.

Viruses
What are they? Viruses are microorganisms that are smaller than bacteria, and cannot grow or reproduce without a living host cell (animal, human, plant or bacteria). They invade a living cell and use the host cell’s chemical machinery to stay alive and replicate themselves. Viruses may be transmitted to people through the air, by indirect contact with contaminated surfaces, by direct contact with an infected person and with infected body fluids.
What illnesses do they cause? Viruses are responsible for a variety of illnesses, including the common cold (rhinoviruses and human coronaviruses), intestinal and respiratory flu (noroviruses), human immunodeficiency virus (HIV), hepatitis B, hepatitis C, influenza A subtype H1N1 (swine flu) and SARS-CoV-2 (COVID-19).

Viruses do not respond to antibiotics, which makes them more difficult to control.

Fungi

What are they? Fungi are parasites that feed on living organisms or dead organic material, and reproduce by means of spores. Examples of fungi are yeasts, molds, and mushrooms.

What illnesses do they cause? Common fungal infections include ringworm, athlete’s foot, and yeast infections such as Candida or thrush.

Where do these microbes live in schools?

Microbes live or survive for a time everywhere throughout the school, in the air, in dust, on living things and on soft and hard surfaces.

Common “high-touch” surfaces in schools

High-touch surfaces are those that are frequently touched by a variety of hands. A surface such as a desktop that is touched daily by only one student might be touched often, but it is not considered a surface to be managed for infection control because no one else would be exposed to those microbes. Surfaces that might be touched frequently by many different hands and that might be considered high-touch surfaces of concern include but are not limited to:

- Office – a shared computer mouse and keyboard
- Music room – shared musical keyboards and instruments
- Hallways and entrances – security pads, doorknobs, elevator buttons, light switches, door push bars, handrails
- Bathroom/Restroom – faucet handles, toilet handles, towel dispensers, hand dryers
- School bus – doors and railings
- Kitchen and break rooms – handles on coffeepots, microwave doors, refrigerator doors, and vending machines

Common "high-risk" areas in schools

Some areas of the school building are of greater concern for possible transmission of disease because there is an increased likelihood of skin-to-skin, object-to-mouth, or fecal-to-oral contact. Also considered high risk are areas where food is prepared, sick or preschool children are cared for, or special events or incidents (such as blood or body-fluid spills) occur. These areas include:

- Athletic departments – gym mats, exercise equipment, shower and locker rooms
- Kitchens – cafeterias, break rooms and prep areas
- Nurses’ offices, waiting areas, treatment rooms and isolation areas
- Childcare and preschool centers
How do these microbes make us sick?

The *chain of infection* is a series of events that needs to occur before a person develops an infectious disease. All of these elements must be in place and breaking any of the links of the chain can interrupt the transmission of disease from pathogenic microbes. Below is an example of the Chain of Transmission using COVID-19 as an example.

**Infographic created by Lynn Rose**

The *reservoir* is the place where microbes live—in humans, animals, soil, food, plants, air, or water. The reservoir must provide the right conditions to meet the needs of the microbes for them to survive and multiply.

One reservoir, which forms on surfaces that are constantly wet, is a biofilm created by bacteria. The bacteria create the right conditions and form a community within a protective shell to increase their ability to survive and proliferate. The biofilm develops within hours after microbes colonize, tightly attach themselves to surfaces, and grow. This shell protects the bacteria from disinfectants, which can kill only the bacteria on the outer layer. Once formed, the bacteria within biofilms are up to 1000 times more resistant to antimicrobials than the same bacteria in suspension (not part of a biofilm).

To reach the microbes within the biofilm, friction or some other process such as steam vapor must be used to break down the shell. Microfiber cloths, mops, or brushes can be used to penetrate the biofilm. Key places in schools where biofilms develop are continuously damp or wet areas around sink faucets or drains.
The **source** is the place from which the infectious agent is transmitted to the host. Sources may be animate (living) or inanimate (nonliving). The source is often contaminated by the reservoir. For example, *Legionella* may exist in a school tap-water system, which acts as the reservoir; the humidifier filled with the contaminated tap water may be the source of transmission.

The **pathway** of exposure is the path the organism takes to move through the environment. Possible pathways include:

1. **Air** – Microbes can move through the air in a room, or through the air ducts of a building.
2. **Water** – Microbes can move through water systems.
3. **Surfaces** – Microbes can either land on surfaces from the air, or from contact by an infected person, where they can remain and survive when the conditions are optimal.

A **route** of exposure is the primary way that the infectious agent enters the host (person) and causes disease. The route may be oral (through ingestion), dermal (skin), or respiratory (through inhalation).

The **susceptible host** is the person who may become infected. Not everyone becomes ill after the same exposure to microbes. Our bodies have natural defenses that fight against disease. People who have compromised immune systems are not able to fight infections as well as those who have strong immune systems, and they may be more susceptible to infectious diseases.

**Transmission** describes the movement of microbes from the source to the host. Spread may occur by one or more of the following different routes of entry:

1. **Contact transmission** can happen in one of two ways:
   - Direct – involves body-to-body contact and the physical transfer of microbes from an infected person to a susceptible host (person).
   - Indirect – involves contact of a susceptible host (person) with a contaminated object (usually inanimate).
2. **Droplet transmission** occurs when large particle droplets (>10 microns) containing microbes from an infected person are propelled short distances (three to six feet) through the air and are deposited on a susceptible host’s mucous membranes (in the eyes, nose, or mouth).
3. **Airborne transmission** occurs when microbes in airborne droplets (<10 microns) survive after the droplets evaporate, and remain in the air for long periods (hours to days). Depending on the organism, these airborne microbes can remain infectious for days, and when they come in contact with a susceptible host, they can cause infection in the respiratory tract and the mucous membranes of the eyes, nose, or mouth.
4. **Common-vehicle transmission** occurs when a contaminated inanimate vehicle, such as food, water, or equipment, serves as a vector to spread an infectious microbe to multiple persons. An example of common-vehicle transmission would be the spread of salmonella from a lunchroom cafeteria food processor.
5. **Vector-borne spread** occurs when mosquitoes, flies, rats, and other pests transmit infectious microbes.
### How long do microbes live outside of the body?

<table>
<thead>
<tr>
<th>Virus</th>
<th>Lifespan</th>
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</thead>
<tbody>
<tr>
<td>Hepatitis A</td>
<td>Fecal–oral; can survive for 12 weeks or more depending on environmental conditions. It is killed by heating to 185°F (85°C) for 1 minute.⁶</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>Bloodborne; can survive even in dried blood on environmental surfaces for at least 7 days and still be infectious.⁷</td>
</tr>
<tr>
<td>Hepatitis C</td>
<td>Can survive outside the body at room temperature for at least 16 hours and up to 4 days.⁸</td>
</tr>
<tr>
<td>HIV</td>
<td>Bloodborne; begins to die off almost immediately after it is outside of the body (exposed to air), although some research reports 3 to 5 hours.⁹</td>
</tr>
<tr>
<td>Influenza A</td>
<td>Depending on the environmental conditions, avian influenza virus can survive for 24 to 48 hours, human influenza virus can survive between 9 and 18 hours, and H1N1 can survive between 2 and 8 hours on surfaces.¹⁰</td>
</tr>
<tr>
<td>MRSA</td>
<td>Easily transmissible through a variety of environmental-surface-contact pathways. Routes of exposure can include contact with mucous membranes and open wounds, but the agent can also infect intact skin. These agents can live for several hours to days on inanimate objects under certain environmental conditions.¹¹</td>
</tr>
<tr>
<td>SARS-CoV-2 (COVID-19)</td>
<td>Depending on environmental conditions, the virus can live in the air for up to 3 hours, on copper for 4 to 8 hours, on glass up to 4 hours, on cardboard up to 24 hours and on plastic and stainless steel up to 72 hours.¹² Research is ongoing for more accurate information.</td>
</tr>
</tbody>
</table>
What influences the survival of microbes outside of the body?

To understand the least-hazardous methods of infection control, it is essential to understand the conditions that permit microbes to survive.\(^{12}\)

![Diagram of factors affecting microbial survival](image)

**Conditions of the Surrounding Environment**
- Humidity, pH, temperature, amount of microbes present, ultraviolet light exposure

**Properties of the Virus**
- Type of virus and type of medium it is suspended in

**Properties of the Object**
- Porous or nonporous, cleanliness, moisture level

**Adds up to virus survival on object**

How do we break the chain of infection?

1. **Will hand washing reduce disease transmission?** Yes. Washing hands properly (with soap, warm water, and friction for 20 seconds) frequently and after exposure to an infected person or object minimizes the opportunity for pathogenic microbes to enter our bodies and will reduce their spread to other people, objects, and surfaces.\(^{13}\) See Appendix A.5 Understanding Hand Hygiene.

2. **Will respiratory hygiene and cough etiquette reduce disease transmission?** Yes. The Centers for Disease Control and Prevention (CDC) recommend the following steps for infection control:
   a) Cover the nose/mouth with tissue when coughing or sneezing. Coughing into the elbow is an alternative when tissues are not available.
   b) Use tissues, when possible, to capture droplets and dispose of them in a waste receptacle after use.
   c) Encourage coughing or sneezing students/staff to leave a 3-foot buffer between themselves and others for viruses other than SARS-CoV-2.\(^{14}\)
   d) For SARS-CoV-2 face masks should be worn and a 6- to 12-foot buffer should be left between themselves and others.
3. **Will cleaning reduce disease transmission?** Yes. Frequent and correct cleaning of high-risk, high-touch surfaces with the proper equipment removes microbes on surfaces and eliminates the conditions (food and water) that some microbes need to survive. Microfiber cloths and mops are able to capture and remove up to 99% of microbes from nonporous surfaces and objects. (See Chapter 6.C. Using Microfiber Cloths and Mops for Infection Control for more details.) Steam cleaning machines can also reduce microbes on surfaces, and spray-and-vac machines can remove microbes and their spores.

4. **Will sanitizing reduce disease transmission?** Yes. Sanitizing is a process used to reduce but not necessarily eliminate all microorganisms from surfaces to levels considered safe as determined by public health codes or regulations. Thus, it can reduce the transmission of some diseases caused by bacteria (not viruses or fungi) on nonporous surfaces under the right conditions. Sanitizing is required by regulation in food service areas and in childcare centers.

5. **Will disinfection reduce disease transmission?** Yes. Disinfecting is a process that kills or irreversibly inactivates microbes (bacteria, fungi, and viruses) present on a nonporous surface but does not necessarily kill their spores. The product label identifies which microbes a specific disinfectant has been tested to kill or inactivate. Not all disinfectants kill all microbes.

Different ingredients or combinations of ingredients in disinfectants kill different microbes. Disinfectants are registered and regulated by the Environmental Protection Agency (EPA) as pesticides. Manufacturers submit test data to EPA to document and make “claims” on the label for which microbes the disinfectant can kill.

Disinfectants are used to destroy or suppress the growth of harmful microorganisms on surfaces. Disinfectants accomplish this by breaking down the microbes’ cell walls or by otherwise deactivating them. Therefore, a disinfectant must be selected that works on the specific microbes intended to be killed, or a broad-spectrum product must be selected that works on all of the microbes that might be encountered. Some bacteria and fungi have spores, which act like seeds to ensure the survival of the microbe. Disinfectants may kill the bacteria or fungi, but not necessarily the spores.

In the case of SARS-CoV-2, the EPA has developed List N that identifies disinfectants that are effective against the virus; see [https://www.epa.gov/pesticide-registration/list-n-disinfectants-coronavirus-covid-19](https://www.epa.gov/pesticide-registration/list-n-disinfectants-coronavirus-covid-19).

Situations that do require disinfection include pandemic viruses, accidents involving vomit, feces, body fluid, or blood; some restroom surfaces; and for specific legally required activities in food preparation areas and in childcare settings.

Disinfectants are not recommended for daily use other than during a pandemic outbreak, on high-risk surfaces and where required by regulation. The surface will remain disinfected only until the next person or microbe touches that surface. Disinfectants cannot make claims for residual activity. Sanitizers can make claims for residual activity. The only time a disinfectant label would contain a residual claim is when the product is formulated as both a disinfectant and a sanitizer (typically a different contact time, and sometimes at a different concentration). In that case, the claim is only for the bacteria, not the virus.
6. **Will ventilation reduce transmission?** Yes. There are a range of options to use and enhance existing ventilation systems for microbe control. Options will depend on the type, age and condition of the ventilation system in each space. Adequate ventilation and filter changes on ventilation systems can help break the chain of infection by providing fresh air, by diluting and removing some or all of the infectious airborne microbes, and by filtering some of them out.

Heating, Ventilation and Air Conditioning (HVAC) filters are rated for what they filter. Using the highest minimum efficiency reporting value (MERV)-rated filter (i.e., with a rating of 13 and above) for the ventilation system will filter out airborne microbes. Not all systems may be able to handle this level of filtration. Find out what your system can handle.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has provided guidance on its web site to address the transmission of the SARS-CoV-2 virus; see [https://www.ashrae.org/technical-resources/building-readiness#ecip](https://www.ashrae.org/technical-resources/building-readiness#ecip). The guidance includes how to evaluate HVAC systems in order to optimize existing systems and the highest rated filter the system can handle. Check the existing equipment for MERV compatibility. See Appendix 6.D: Using Ventilation to Help Reduce Disease Transmission for more information.

7. **Will ultraviolet radiation reduce transmission?** Yes, if designed properly. Ultraviolet radiation is categorized by wavelength. The sun emits UV-A and UV-B radiation. UV-C radiation is created by using low-pressure mercury or xenon lamps. UV radiation of specific wavelengths has been known for decades to be an effective germicide. Recently the use of UV radiation as an environmental germicide has expanded in a variety of industries, including water treatment, food preparation, pharmaceuticals, and health care.

Research has determined UV-C is effective against SARS and MERS, and other forms of coronavirus, but no definitive studies have been published about its effects on SARS-CoV-2 to date.

The Environmental Protection Agency (EPA) recommends using only the surface disinfectants identified on List N against the virus that causes COVID-19. EPA does not routinely review the safety or efficacy of pesticidal devices, such as UV lights, LED lights, or ultrasonic devices.”

The installation of UV-C radiation bulbs in a ventilation system or in the upper areas of a room can reduce the overall microbe load in the space. This is called Ultraviolet Germicidal Irradiation or UVGI.

- **Pros** – The germicidal efficacy can be compared to an increase in ventilation in terms of room air changes per hour.
- **Cons** – The costs of installation and operation of UV radiation bulbs have not been fully demonstrated to outweigh the use of an effective ventilation system in schools.

Direct exposure to UV wavelengths can be a health hazard. Long term exposure to UV-C radiation can penetrate the outer surface of skin and eyes affecting the cells and
contributing to additional health issues. Ozone can also be generated by prolonged use of some UV-C devices. Unless the systems are installed and maintained properly by trained and knowledgeable professionals, it is possible that the building occupants and workers could be overexposed to hazardous UV radiation.

Which of these options should be used?

Although microbes are everywhere, most are harmless and many are helpful. The goal of an infection-control program is to prevent the spread of infectious disease by reducing contact with pathogenic microbes. This goal can be safely accomplished through implementing a three-pronged strategy that utilizes the following:

1. **Personal hygiene strategies for microbe control** – Hand and respiratory hygiene, including wearing masks and face shields (to protect eyes), and cough and sneeze etiquette, are key components of personal hygiene that help to reduce the spread of some types of infectious diseases.

2. **Cleaning for microbe control** – Comprehensive cleaning programs that use less-toxic products and updated tools and technology can help control the spread of infectious disease by removing most of the microbes and the conditions they need to survive and thrive.

3. **Disinfecting and sanitizing for microbe control** – A targeted disinfection and sanitizing program can be designed to address high-risk areas, meet regulatory requirements, and respond to special events such as pandemics or incidents in which there is a specific biological hazard. See Appendix E: Common High-Touch Points by Location.

4. **Ventilation and air treatment strategies** – These strategies will help address the airborne transmission of an infectious disease. To determine which of the wide range of available options are appropriate will involve assessing existing systems and the configuration of the space and determining available resources. Some options involve optimizing existing systems (e.g., increasing air changes per hour, conducting maintenance, increasing filtration), while other options require some capital investment (e.g., replacing components, adding in UVC), and for others, a major capital investment (e.g., installing HVAC systems).

See Chapter 1.A. Introduction for more details on the three-pronged strategy.
References


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12. S.A. Boone and C.P. Gerba, “Significance of Fomites in the Spread of Respiratory and Enteric Viral Disease, Fig. 1. Factors Influencing Virus Survival on Fomites.” Applied and Environmental Microbiology 73, no. 6 (March 2007): 1687–96.


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11. Environmental Protection Agency. Why aren’t ozone generators, UV lights, or air purifiers on List N? https://www.epa.gov/coronavirus/why-arent-ozone-generators-uv-lights-or-air-purifiers-list-n-can-i-use-these-or-other