[Narrator] Microbes are tiny living organisms like viruses, bacteria, protists, and fungi. Some microbes contribute to the diversity of organisms and support the flow of oxygen, carbon, and other nutrients through earth's ecosystems. Some help create medicines and different types of foods such as cheese and sourdough bread. Some microbes even live on and inside of you and other animals. Most of the time, they help maintain our body systems, like the bacteria in our digestive system that help break down our food. Microbes are essential for life!

However, some microbes can cause illness when they live and multiply in another organism — called a **host**. We call this type of microbe an infectious agent and the illness it causes an infectious disease.

Now, these infectious agents are not all inherently bad — most are just trying to survive and multiply like all other living things on this planet. Some agents even live and multiply in hosts without causing any harm—these agents become problematic only when they end up in hosts where they do not belong. Other microbes almost always cause disease in their hosts and, to survive, must spread to additional hosts and infect them.

When an infectious agent moves to another host, we call this transmission. Transmission requires several steps. It is helpful to think of each step as a link in a chain of infection. The infectious agent must leave its current location, move to a new host, enter the new host, then overtake the defenses of the new host to cause infection. If some action can interrupt a step or break any link in the chain of infection, it is possible to stop — or reduce — the spread of disease!

Meet Ivy, an infection prevention specialist whose responsibility is to prevent transmission of infectious agents in a variety of settings such as hospitals and other healthcare facilities. Ivy must understand how each infectious agent spreads to put appropriate prevention strategies in place. To help her visualize this, she can create a model of the infectious agent's chain of infection.

Let's look at each step of the chain of infection. First, what may be thought of as an infectious agent's "home", the place where it is typically found, is called its **reservoir**. Depending on the agent, the reservoir might be a person, an animal, or even something in the environment like water or soil.

To infect a new host or person, the infectious agent first must leave its reservoir — which may be another infected person — through what we call a **portal of exit**. For example, if the infection is in the gastrointestinal system, then the agent might exit through the anus via poop or mouth through vomit. If it is a respiratory infection, then it might exit through the mouth or nose in droplets from a cough or sneeze.

The way an infectious agent spreads between hosts is referred to as its **mode of transmission**. A given agent may use more than one mode of transmission. Relative to the microscopic size of an infectious agent like the flu virus, modes of transmission can involve incredible distances, and very few individual microbes successfully

complete the trip to a new host. A virus traveling 6 feet is roughly equivalent to a 6-foot-tall human traveling halfway from the earth to the moon on a human scale! Often, humans make the trip easier for infectious agents when they spend time close together and when they don't cover their portals of exit or practice good hygiene.

There are two main categories of modes of transmission — direct and indirect.

Direct transmission is up close and immediate.

Direct contact involves physical contact between the source or reservoir, such as an infected person or animal and a susceptible host. For some diseases, direct contact may involve kissing or other skin-to-skin contact. For agents in the soil this could be contact with contaminated soil, which can enter through a break in the skin.

Direct droplet transmission occurs via respiratory droplets produced by coughing, sneezing, singing, shouting, or even breathing. These droplets travel only a short distance and directly enter the mouth, nose, or eyes of a new potential host.

For **indirect transmission** to occur, the source or reservoir and susceptible host don't need to be near each other, and it does not have to happen immediately.

You can think of this as the difference between *directly* handing your friend a note in person or *indirectly* leaving a note on the dry erase board for them to read later. Your friend gets the message from you either way, but one is direct and the other has a little extra step.

There are three types of **indirect transmission** and they are categorized by the extra step involved.

Indirect airborne transmission can happen through airborne particles. These particles are much smaller than the droplets involved in direct droplet transmission and can stay afloat in the air for a while before falling to the ground.

So, with direct droplet transmission, the potential new host is in the direct path of a sneeze or cough, but with indirect airborne transmission, all someone must do is come into the space where airborne particles are floating and breathe them in — even after the source has left the area!

Measles is an example of a disease spread by indirect airborne transmission — respiratory particles containing the measles virus exhaled by an infected person can remain suspended in the air and be inhaled by a susceptible person several minutes later, leading to infection.

Indirect vector-borne transmission uses arthropods such as mosquitoes, ticks, or flies to transfer the infectious agent from one host to another.

For example, mosquitoes become infected with the malaria parasite from taking a blood meal from an infected person. After a period of parasite development, mosquitoes then spread the agent to the next host through a bite. Ticks can transmit the agent that causes Lyme disease from an infected animal reservoir to a human in much the same way. Or a fly can pick up an infectious agent on its feet by walking on a contaminated surface and carry it to a previously uncontaminated surface such as uncovered food at a picnic.

The third mode of indirect transmission is **vehicle-borne**. Unlike a vector which is living, a vehicle is a nonliving object that can carry an agent from its reservoir to a susceptible host. This vehicle may be food, water, inanimate object, or surface. Depending on the agent and the vehicle, the agent may continue to grow and multiply between hosts.

For example, if a person coughs or sneezes into their hand and then grabs a doorknob, the doorknob can become a vehicle to pass the agent to the next person who uses the doorknob then touches their mouth or nose or rubs their eyes.

Vehicle-borne transmission can happen when someone who is infected shares a drink, computer, phone, or other inanimate object with a friend or when a food item becomes contaminated with bacteria such as *Salmonella*.

The next link in the chain of infection is the **portal of entry** or the way an agent enters a susceptible host. For some agents, the portal of exit and portal of entry are the same. For example, influenza virus exits the respiratory system through the mouth or nose of the infected host and enters the respiratory system through the mouth, eyes, or nose of the new host.

Once the agent enters the host, some hosts can resist infection, particularly if they have been previously infected or have been vaccinated. But many hosts are **susceptible** — which means they can get infected with enough exposure.

For example, young children are susceptible to many different infections.

Not everyone is equally susceptible to a given disease because of differences in genetics, previous exposure, age, vaccination, and general state of health.

To interrupt transmission of infectious agents, infection prevention specialists like Ivy use **prevention strategies** to break different links in the chain.

For example, rodent and mosquito control can remove reservoirs and vectors. Wastewater treatment, food preparation regulations, handwashing, mask wearing, surface cleaning, and disinfection are all examples of prevention measures based on modes of transmission. Hosts can also be made less susceptible through vaccination.

Some prevention strategies are designed specifically for infectious agents that are spread from person to person. For example, in a hospital, Ivy might isolate an infected

patient from others to prevent spread from a human reservoir to any new patients. Handwashing and mask wearing, and physical distancing are also prevention strategies used to break the chain of person-to-person transmission.

In person-to-person transmission, once a susceptible host is infected, they become a source for the infectious agent, and can transmit to yet another susceptible host!

This means one person with a disease could potentially transmit to more than one susceptible host. Infectious diseases that spread easily from person to person are also called contagious diseases.

This is how diseases can spread exponentially and why early detection and prevention measures are so important. Breaking the chain of infection early when dealing with a contagious disease can prevent illness, death, and even pandemics.

In a community, vaccination is a prevention strategy that reduces the number of susceptible hosts, meaning the infectious agent is less likely to travel from person to person and the entire community is less likely to get the disease.

Prevention strategies are more effective when they are layered. The Swiss cheese model is a way to think about this. Each slice of Swiss cheese has holes, but if a few slices are layered, more of the gaps are covered.

Similarly, each prevention strategy may have its own gaps in protection, but using several at the same time can help keep you and others more protected. Prevention strategies can be put into place at the individual or community level through policies and regulations.

Let’s put this all together in an example chain of infection.

The bacteria *Salmonella* is an infectious agent that causes what is commonly called “food poisoning” and leads to fever, abdominal cramps, and diarrhea.

Salmonella is naturally found in the digestive tract of some animals, such as chickens. *Salmonella* bacteria can also be found in the reproductive tract of chickens and inside the eggs they produce.

So, its portal of exit is the chicken’s cloaca, or opening where eggs and poop can exit its body.

Chicken meat can be contaminated with feces during butchering and processing. A person eating contaminated meat or food items contaminated with uncooked meat juice may ingest *Salmonella* bacteria. Similarly, a person eating foods containing raw egg may also ingest *Salmonella* bacteria.

In other words, indirect transmission can happen because the vehicle (the meat) is contaminated. Juice from the meat can also contaminate other food items or utensils. The portal of entry is the mouth of a susceptible host.

But several actions can prevent infections, such as using separate cutting boards to prevent raw chicken products from coming into contact with other foods, washing hands thoroughly after handling raw meat, cooking foods at proper temperatures to kill any *Salmonella* bacteria, and storing cooked food at the proper temperature to prevent any bacterial growth.

As a quick recap, we can answer the question **"How does disease spread?"** by illustrating or creating a model of the infectious agent's chain of infection. It starts with an infectious agent at its source or *reservoir.* The agent then leaves through a portal of exit and spreads either through direct or indirect mode of transmission. Finally, the agent can use a portal of entry to enter a susceptible host.

Contagious diseases spread easily from person to person because one person with a disease could potentially transmit to more than one susceptible host.

Prevention strategies can break links in the chain of infection, but no strategy is perfect. Layering strategies is even more effective in stopping the spread of disease.