PROFESSOR: So now that we've talked about the different dynamics of droplets in the air, we can think about how different types of pathogen can leverage those droplets to transmit from one person to another through respiration through the air.

So let's begin with bacteria.

So there are many different kinds of bacteria.

The typical size of a single bacterium is on the order of several microns.

So let's just say, 1 to 10 microns.

On the other hand, bacteria can also exist in colonies or larger structures.

And that does determine, to some extent, what kinds of droplets can transmit those bacteria.

So let's begin with an example of a large-drop bacteria, which is typically going to be found in large drops.

And that would be the bacteria that causes strep throat, the streptococcus.

So the streptococcus bacteria, which is shown here, has a typical size that's around two microns.

So it's on the smaller end.

And it forms chains and even larger colonies they may have different structures.

And the total size of the colonies can vary to be as big as even 500 microns.

So it may not be always that big, but it might be, let's say, 50 to 500 micron sort of colonies.

And they can often be these sort of stringy type structures.

As a result, those require fairly large droplets.

Now just simply knowing that we have large droplet, tells us a lot about how this bacteria can actually transmit and what measures must be taken against it.

Because as soon as we have large drops, then what it means is that we have fast settling.

So we know drops that are in this size range are going to fall to the ground within a few seconds.

And even if you cough them with a lot of big velocity -- which is something we'll talk about later in this and these lectures -- then still, in only a few seconds those droplets can sediment out and they really don't go very far.

OK?

And so they're fast-settling.

And so what that means is that we have either fomite transmission, where those droplets settle on the ground, or on some other surface -- somebody touches that surface, touches their eyes -- and so that's one method of transmission.

We could also have direct airborne transmission.

Where let's say, I cough or breathe on you.

And the droplets end up in your face and maybe directly on your eyes, or maybe you breathe them in -- so there could be also direct airborne transmission for some of the smaller sized droplets or for large droplets which are ejected from let's, say a cough or something.

And so what that means, that the way that we protect against bacterial transmission of disease is, for example, for the fomites, we will disinfect surfaces.

We can wash hands, of course.

And we will avoid touching eyes or nose.

So those are pretty basic measures.

At the same time, if we're worried about the direct transmission of the droplets from especially coughing or sneezing larger droplets, then what else can we do?

Well, we can have plastic shields.

Either worn over the face or maybe a barrier between yourself and some other person that you're interacting with to avoid that sort of projectile transmission of large droplets.

And also, we will get the six-foot rule.

Which is just an example of a social distancing measure, which is recommended to avoid this sort of direct airborne transmission.

Again, coming back to the idea that droplets of the size typically settle in a few seconds.

And if you look at the typical velocities of ejection, especially from coughs and sneezes, then they will settle in about six feet or so or about two meters.

Although that's not a hard rule.

The six-foot rule happens to be for the United States Centers for Disease Control, the CDC.

But there's also [the] one-meter rule, which is basically a three-foot rule, for the World Health Organization.

So this is not extremely well defined, what should be the distance.

But clearly, if you are able to stay away from people, then even if they're coughing or breathing these large droplets with only a few seconds of settling time, those droplets will hit the floor.

And it will not be able to infect you directly.

And so it's important to maintain that kind of distancing.

OK.

Now there are also other kinds of bacteria that don't form these larger colonies.

And they remain small even when they're transmitting.

And a classic example of that which can be transmitted in small drops is tuberculosis.

In fact, the original study in the 1930s -- also involving wells -- was for -- that led to this -- essentially the distancing rules and the six-foot rule in particular -- had to do with coughing and sneezing and the distance over which droplets could be transmitted containing tuberculosis.

Now tuberculosis on the other hand, as you can see in the image, is a sort of rod like bacteria that's quite small.

So the length is several microns, typically two to four.

But the radius is half a micron or even down to 0.2 microns.

So actually, we're really talking about hundreds of nanometers in length.

So these are kind of little rods like this.

And they can be contained in a pretty small droplet.

These big colonies of course, require something much larger.

So these droplets could be small.

And so there is a possibility here of larger aerosol transmission.

By larger, I mean in the range of 5 to 10 microns.

So of course tuberculosis also can be contained in much larger droplets, which, you know, fall to the ground as we've just been describing, but tuberculosis is a bit different in that these individual bacteria could be transmitted airborne in larger aerosol droplets.

And in fact, that is what is found.

If you have this size of droplet, then it turns out, for example, if my radius is let's say greater than 4 microns, then the settling velocity you can find given the density of aqueous fluids, is around 2 -- bigger than 2 millimeters a second.

And then the time to drop from a typical person's height to the ground is around 15 minutes.

So these are not the kind of aerosols that might stick around for hours like the sub-micron aerosols that are also produced by breathing and which are too small to contain tuberculosis.

But still, these times suggests that tuberculosis can linger in the air.

And in fact, long distance airborne transmission is not only possible as we've just argued based on physical grounds, but it's been directly verified.

That's been done both in humans studies and also in animal studies.

Where they can have two different compartments with a sick animal, such as a ferret or some other animal model, and the disease is spread to another animal who's had no direct contact but is sharing the same air.

So the airborne transmission is definitely verified in this case.

And now you might ask, well, what are the preventive measures?

So instead of all of these measures, like plastic shields and six-foot rule, if you're actually airborne transmission -- if there is a shield, then the air is going to go right around the shield.

And it's going to go everywhere else in the room, because the air is flowing.

In the same way that when you light a candle and you see where the smoke is going, it quickly spreads around the whole room.

It doesn't care if there's a shield there.

As long as there is a way around the shield, that's going to find that.

And so instead, when you're trying to protect against airborne transmission, your protective measures are things like ventilation, so bring in fresh air from outside or opening your windows; air filtration, where you're passing the air through a filter which is going to filter out the particles by size or by charge or some other mechanism like that; and also it becomes more and more important to wear face masks because then at least you can block these droplets at the source and also at the target, as we shall discuss in much more detail.

So what we see here is just knowing simply the size of the pathogen and understanding the physics of droplets in the air, helps us to understand the modes of transmission, which are written here in blue.

and also, the appropriate protective measures, which are written here in pink, to protect against these different types of transmission.