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PROFESSOR: So this brings us to the conclusion of our Massive Open Online Course, 10.S9,5 Physics of COVID-19 Transmission.

So let's briefly review what we've learned.

We began by talking about respiratory pathogens, both bacteria and viruses.

And, in particular, we focused on viruses and understood how they can be transmitted through aerosol particles through infected indoor air.

And this includes the important case of SARS-CoV-2, the virus that causes COVID-19.

We then went on to use epidemiological models and fluid-mechanical analysis of a well-mixed room to arrive at a universal indoor safety guideline to limit transmission of the disease.

A very important conclusion is that it's not possible to bound a single variable, as in all of the current safety guidelines from various official organizations.

So, for example, you cannot only bound the distance between people, for example, 6 feet, 1 meter.

You cannot bound only the occupancy, say, 25 persons.

You can't even bound the ventilation rate, say, a minimum of 15 cubic feet per minute per person.

Or you can't bound only the time-- let's say 15 minutes or one hour-- because all of these variables are, inevitably, linked.

And the simplest way to see that is through our universal safety guideline, which shows you how to limit the cumulative exposure time, (N-1)t, which is a product of the number of susceptible people in a room times the time they're together with an infected person.

And there are a number of factors that come in.

So epsilon is a tolerance you can choose.

And then there are these factors lambda_V over -- Q_b^2 P_m^2 Cq.

And we can discuss, based on that formula and our analysis throughout this course, the most important ways of mitigating transition based on this formula.

So I've, roughly, put them in order here.

So the first thing is to wear masks and, in particular, try to wear good masks.

So these might be surgical masks, N95s, but even various cloth or silk masks, especially double-layer fabrics, can be quite effective because, as P_m goes to 0, the mask penetration factor, you can see this bound gets larger and larger, like P_m^2.

So a factor of 10% transmission can still give you a factor of 100 compared to not wearing masks in terms of filtration.

That's a very significant amount.

Secondly, we can improve ventilation.

And this can be by imposing faster mechanical ventilation with more fresh air coming in.

It could also be by opening a window and turning on a fan.

And that's increasing lambda_a.

We can also try to spend more time in larger rooms or even outside, which is, basically, increasing V and, thereby, diluting the air that is present and all the infectious aerosols.

We can also look at imposing air filtration.

We've shown that there is some benefit there.

Although, it might not be as large as you think.

Even very good air filtration doesn't buy you many orders of magnitude because it's only filtering some of the air, but not all of it, compared to masks, which are filtering at the source and at the target and, thereby, are much more effective.

We can also try to make sure the occupants of the room maintain lower activity levels if possible.

So they're breathing less heavily.

So they're exchanging air with the space and with other people less frequently and at a lower rate.

We can also try to avoid vocal exertions, which tend to lead to much larger emissions of droplets, for example, singing being a particularly bad case, but even loud voices can be a lot worse than quiet voices.

So, generally, keeping the noise in the room down-- I know this will be welcome news for many teachers-- but, in general, that is a good way to try to limit transmission to keep people calm.

We can also take measures to try to enhance the deactivation, the natural elimination of the infectiousness of the virus.

One way to do that is to maintain an intermediate, comfortable range of humidity from 50% to 80%.

So very dry air turns out to be worse, and that is one of the reasons that viral diseases tend to be seasonal, like the seasonal flu, typically, worse in winter, in addition to the fact that you're spending more time indoors.

There's also ultraviolet treatments that might be used, which is, effectively, like another form of filtration.

And then, finally, we spent a lot of time talking about the fluid mechanics of indoor spaces and of human respiration and movement, and those considerations take us beyond the well-mixed room.

And the main thing to remember there is, thinking back to our example of people who are smoking, if someone is exhaling right after breathing in a cigarette, there's sort of a narrow plume of turbulent, very smoky air, which you want to avoid.

And the same thing is true when dealing with a respiratory pathogen. You don't want to spend a lot of time in the respiratory jet of a person who is not wearing a mask if you don't know if they are sick, potentially, even asymptomatic.

So that's an important just general piece of advice, and we've given some insight into how to quantify that.

Although, any treatment of short-range transmission through respiratory jets is, inevitably, dependent upon assumptions about the activity of the room.

How much are you turning your head?

Where are people placed?

And so, hence, you can't really get a universal guideline, as opposed to this boxed formula, which is, essentially, the mass balance for the whole room.

And that is a universal guideline.

We've also talked a bit about types of ventilation.

And, as opposed to ventilation that seeks to mix the space, there may be situations where having high ceilings and trying to take advantage of buoyancy-driven thermal flows that you can sort of target the airborne aerosols to be sitting higher in a room where they could then be removed by ventilation at the top, which is displacement ventilation.

That's another strategy that may be useful.

So these are all different strategies one can use.

And which one is most effective or makes the most sense in a given space really depends on the details.

And, in order to facilitate the application of the guideline, we have provided an online app and, also, a spreadsheet, which you can use to adapt this to your own space.

And I hope that you will find the principles you've learned in this class useful and that, perhaps, even you'll find these tools useful, specifically, to combat the transmission of COVID-19 and, in the future, other respiratory diseases.