School Building Ventilation and COVID-19

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Objectives

- Science brief on Covid transmission mode
- Ventilation as a prevention strategy
- Current CDC ventilation recommendations
- Ventilation considerations
- Ventilation/Covid case study
- Code compliant ventilation guidelines
- Ventilation pitfalls

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CDC Science Brief on Transmission Modes

- The largest droplets settle out of the air rapidly, within seconds to minutes.
- The smallest very fine droplets, and aerosol particles formed when these fine droplets rapidly dry, are small enough that they can remain suspended in the air for minutes to hours.

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CDC Science Brief on Transmission Modes

- Infectious exposures to respiratory fluids carrying SARS-CoV-2 occur in three principal ways (not mutually exclusive):
  - Inhalation
  - Deposition
  - Touching

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Inhalation

- **Inhalation** of air carrying very small fine droplets and aerosol particles that contain infectious virus. Risk of transmission is greatest within three to six feet of an infectious source where the concentration of these very fine droplets and particles is greatest.

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Depostion

- **Deposition** of virus carried in exhaled droplets and particles onto exposed mucous membranes (i.e., “splashes and sprays”, such as being coughed on). Risk of transmission is likewise greatest close to an infectious source where the concentration of these exhaled droplets and particles is greatest.

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Touching

- **Touching** mucous membranes with hands soiled by exhaled respiratory fluids containing virus or from touching inanimate surfaces contaminated with virus.

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Infection Risk

- Varies according to the amount of virus to which a person is exposed
- The risk for infection decreases with increasing distance from the source and increasing time after exhalation.
  - **Decreasing concentration of virus in the air**
  - **Progressive loss of viral viability and infectiousness**

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Decreasing Concentration of Virus in Air

- Larger and heavier droplets fall under gravity
- Fine and very fine droplets mix and become diluted with volumes of air
- Mixing is not equal and can be influenced by environmental factors

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Particle Settling in Still Air

- Time to settle 5 feet by unit density spheres
  - 0.5 µm – 41 hours
  - 1.0 µm – 12 hours
  - 3.0 µm – 1.5 hours
  - 10 µm – 8.2 minutes
  - 100 µm – 5.8 seconds
  - Human hair – 50-100 µm

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Progressive Loss of Viral Viability

- Occurs over time
  - Influenced by environmental factors such as:
    - Temperature*
      - 5.5 to 9.1 days at 20 degrees C (68 degrees F)
      - 5 to 10.5 hours at 40 degrees C (104 degrees F)
      - Surface dependent
    - Humidity
    - Ultraviolet radiation (e.g., sunlight)

* Riddell, S., Goldie, S., Hill, A. *et al.* The effect of temperature on persistence of SARS-CoV-2 on common surfaces. *Virol J* **17,** 145 (2020). https://doi.org/10.1186/s12985-020-01418-7

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Transmission from Farther than Six Feet Can Occur

- Factors that increase the risk of SARS-CoV-2 infection under these circumstances include:
  - Enclosed spaces with inadequate ventilation or air handling within which the concentration of exhaled respiratory fluids
  - Increased exhalation of respiratory fluids if the infectious person is engaged in physical exertion or raises their voice
  - Prolonged exposure to these conditions, typically more than 15 minutes

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Prevention Strategies

- Layered Approach to Reducing Exposure Potential
  - Physical distancing
  - Community use of well fitted masks
  - **Adequate ventilation**
  - Avoidance of crowded indoor spaces
  - Vaccination

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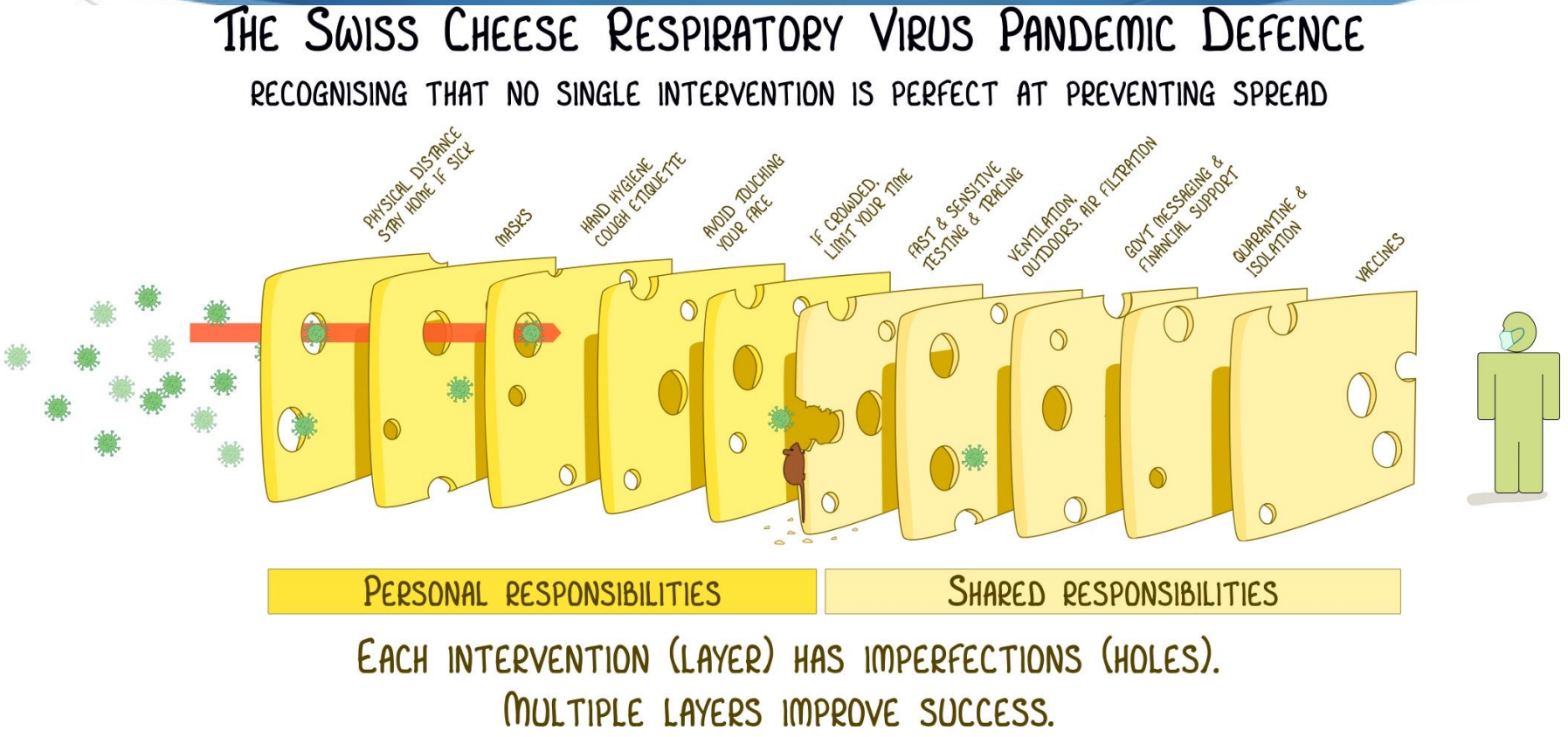
Layered Strategies



- Graphic Credit: Ian W. McKay, virologydownunder.com

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Adequate Ventilation

- Ventilation – Introduction of outdoor air to an indoor environment, measured by volume
- Ventilation is an important COVID-19 prevention strategy that can reduce the number of virus particles in the air
- Indoors, the concentration of viral particles is often higher than outdoors, where even a light wind can rapidly reduce concentrations
- Protective ventilation practices and interventions can reduce the airborne concentrations and reduce the overall viral dose to occupants

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Common Ventilation Unit Components

- Outside air damper—Damper for controlling the quantity of outside air, driven by the control strategy for ventilation, pressurization, and economization
- Supply fan—Ensures proper airflow rates to the building spaces
- Return or return/exhaust fan—Works in conjunction with the supply fan to return/exhaust the required air from the building spaces

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Ventilation Systems Common in School Buildings

- Unit Ventilators (Supplied Air System)
- Central Air Handling Systems
- Exhaust Only Systems

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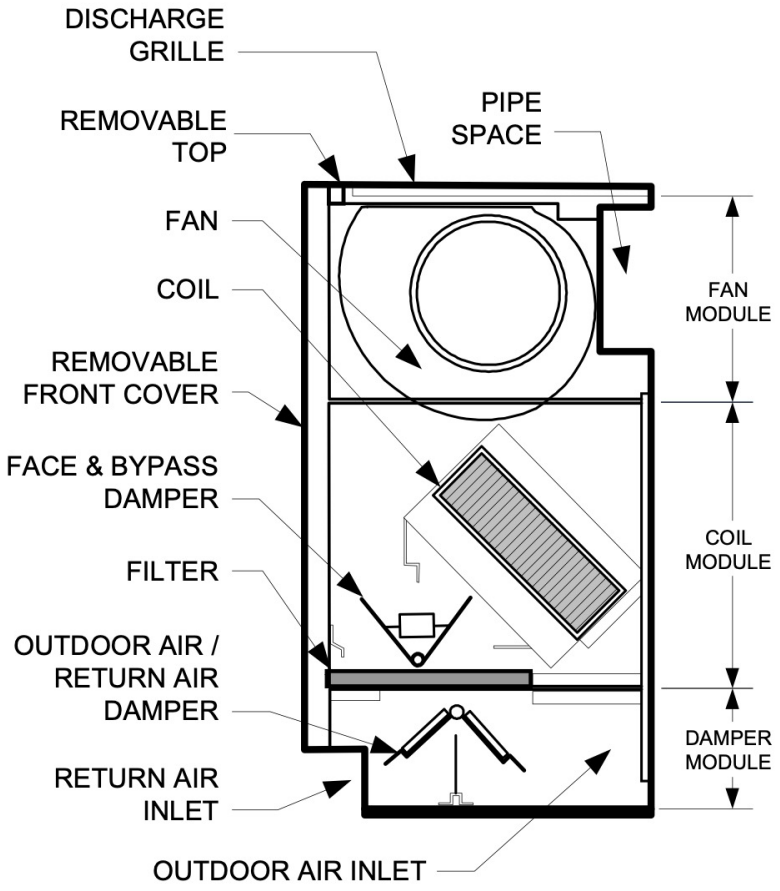
Unit Ventilators

Indoor



Outdoor

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Unit Ventilators

- System overview and benefits:
  - Supply ventilation systems use a fan to pressurize a structure, forcing outside air into the building
  - Relatively simple and inexpensive to install and maintain
  - Allows better control of the air that enters the building than exhaust-only ventilation systems
  - Allows outdoor air introduced into the building to be filtered
  - Unit ventilators are often used with exhaust fans, making them a variation of a balanced system

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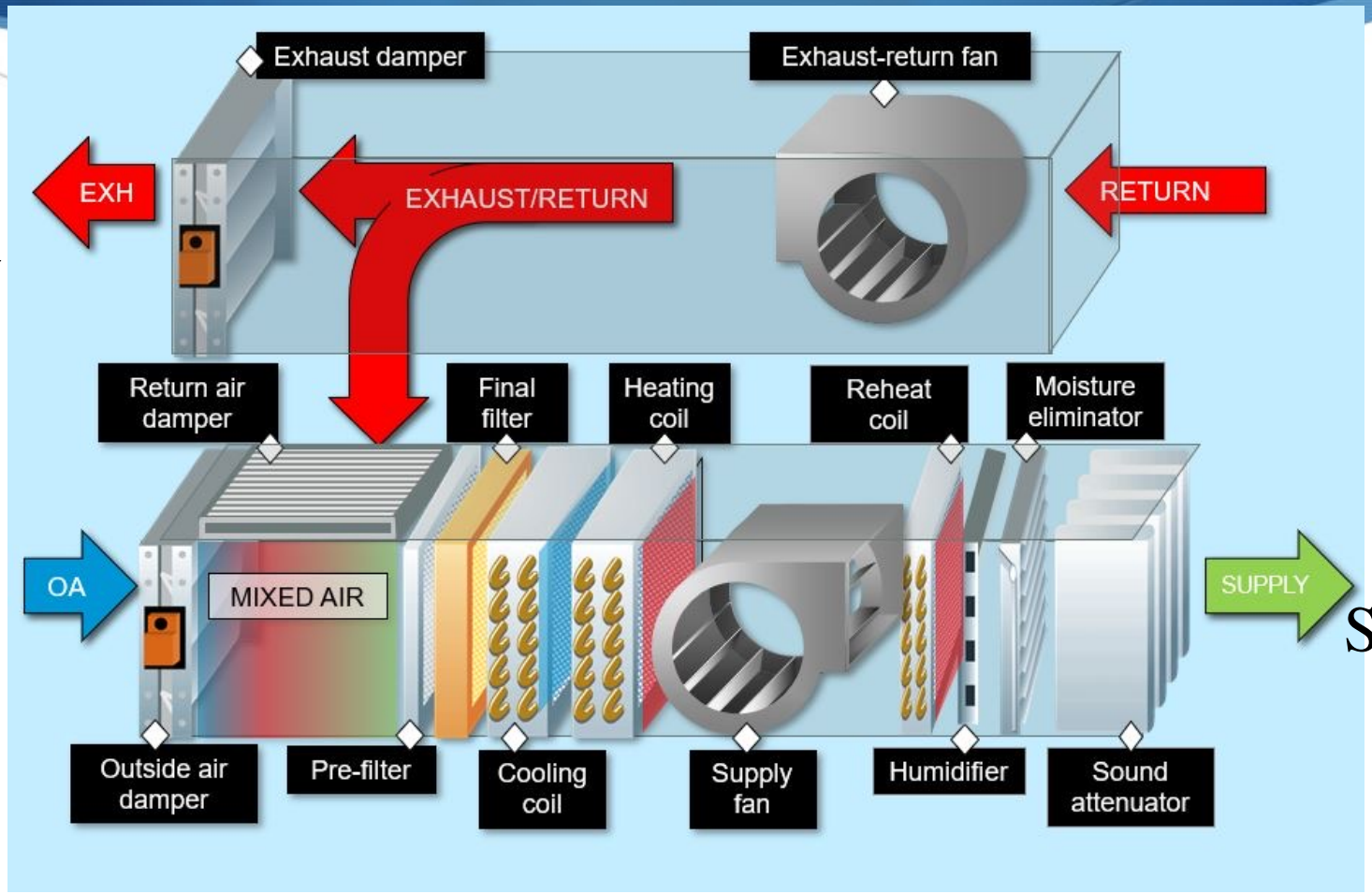
Central Air Handing Systems

Outside Exhausted Air



Outside Fresh Air

Inside Supply Air

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Central Air Handling Systems

- System overview and benefits:
  - Balanced ventilation systems, if properly designed and installed, neither pressurize nor depressurize a structure. Rather, they introduce and exhaust approximately equal quantities of fresh outside air and polluted inside air
  - A balanced ventilation system usually has two fans and two duct systems. Fresh air supply and exhaust vents can be installed in every room
  - Some designs use a single-point exhaust, and because they directly supply outside air, balanced systems allow the use of filters to remove dust and pollen

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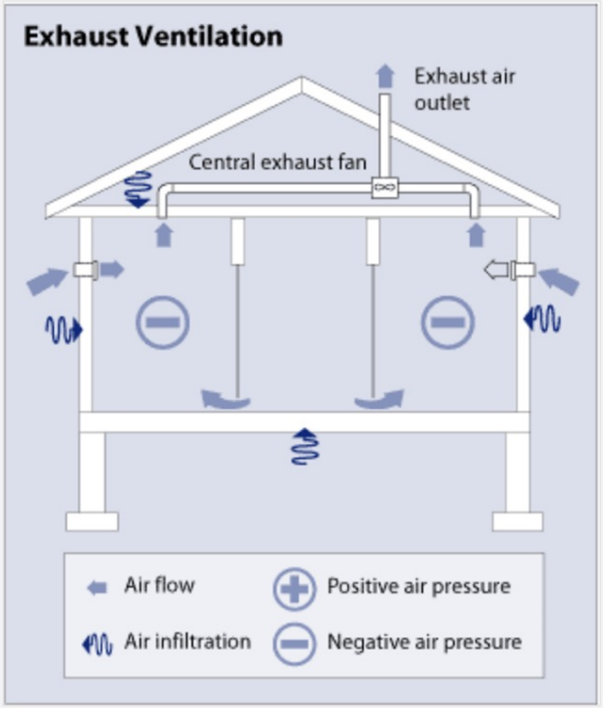
Exhaust Air Handling Systems

Outside
Exhausted Air

Outside
Fresh Air



Exhaust Ventilation System

Outside
Fresh Air

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Exhaust Air Handling Systems

- System overview and benefits:
  - Exhaust ventilation systems work by depressurizing a structure. The system exhausts air from the building, thus causing a change in pressure that pulls in make-up from the outside through leaks in the building shell or intentional, active vents in unit ventilators, to introduce fresh air
  - Exhaust ventilation systems are relatively simple and inexpensive to install. Typically, an exhaust ventilation system consists of a single fan connected to a centrally located, single exhaust point

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CDC Ventilation Recommendations

- Bring in as much outdoor air as possible
  - If safe to do so, open windows and doors
  - Use child-safe fans to increase the effectiveness of open windows

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CDC Ventilation Recommendations

- Ensure Heating, Ventilation, and Air Conditioning (HVAC) settings are maximizing ventilation
  - Make sure your ventilation systems are serviced and meeting code requirements*
  - Set HVAC systems to bring in as much outdoor air as your system will safely allow and can support
  - Increase the HVAC system's total airflow supply to occupied spaces when feasible
  - Disable demand-controlled ventilation (DCV) controls that reduce air supply based on occupancy or temperature.

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CDC Ventilation Recommendations

- Ensure Heating, Ventilation, and Air Conditioning (HVAC) settings are maximizing ventilation
  - Disable demand-controlled ventilation (DCV) controls that reduce air supply based on occupancy or temperature.
  - For simple HVAC systems controlled by a thermostat, setting the fan control switch from “Auto” to “On” will ensure the HVAC system provides continuous air filtration and distribution
  - Consider running the HVAC system at maximum outside airflow for 2 hours before and after the building is occupied to refresh air before arrival and remove remaining particles at the end of the day

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CDC Ventilation Recommendations

- Filter and/or clean the air in your school or childcare program
  - Improve the level of air filtration as much as possible without significantly reducing airflow
  - Make sure the filters are sized, installed, and replaced according to manufacturer's instructions
  - Consider portable air cleaners that use high-efficiency particulate air (HEPA) filters to enhance air cleaning wherever possible, especially in higher-risk areas such as a nurse's office or sick/isolation room

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CDC Ventilation Recommendations

- Use exhaust fans in restrooms and kitchens
  - Inspect and maintain exhaust ventilation systems in restrooms and kitchens
  - Ensure restroom and kitchen exhaust fans are on and operating at full capacity while the school or childcare program is occupied and for 2 hours afterward

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Ventilation Considerations

- Push – Good. Pull – Good. Push/Pull – Best
- Restrictions to air flow
  - Unit ventilator obstructions
  - Exhaust grill obstructions
  - Desktop/Teacher barriers
  - Dirty or overrated filters

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Ventilation Considerations

- Impact of increased ventilation on Indoor Air Quality
  - Seasonal humidity
  - Condensation
  - Microbial growth
  - Energy requirements/costs associated with heating/cooling higher volume of outside air

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Visual Ventilation Outcomes

- Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder
  - Jose-Luis Jimenez
  - CIRES Fellow, Chemistry professor, lead author
  - jose.jimenez@colorado.edu
  - June, 2020
  - Model estimates COVID-19 transmission in classrooms

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Visual Ventilation Outcomes

- Assumptions
  - No Vaccine
  - 4% Positivity Rate
  - 50 minute exposure time
  - Socially distanced (six feet)
  - Instructor is positive and asymptomatic

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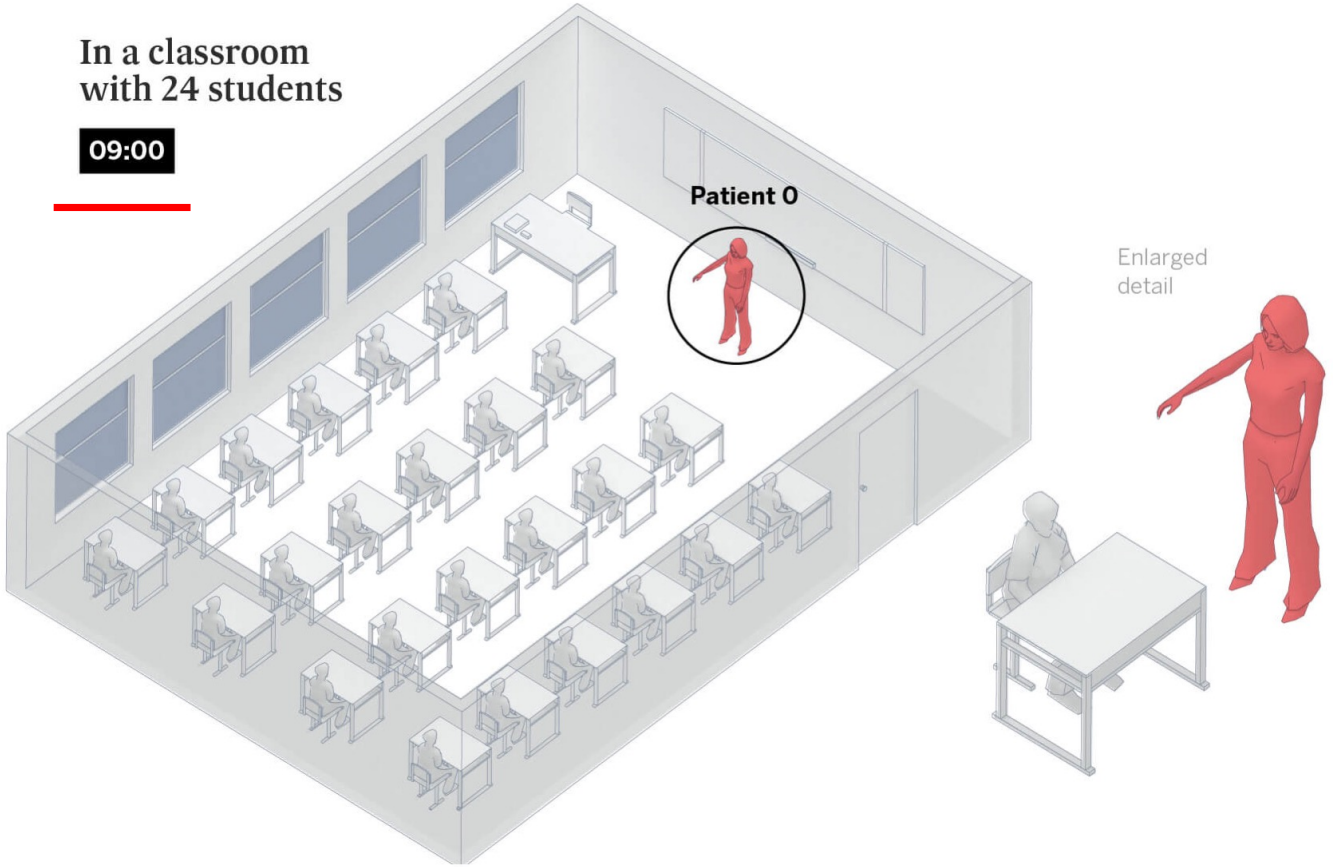
Visual Ventilation Outcomes



The riskiest scenario is a classroom with no ventilation and the teacher – patient 0 – as the infected person.

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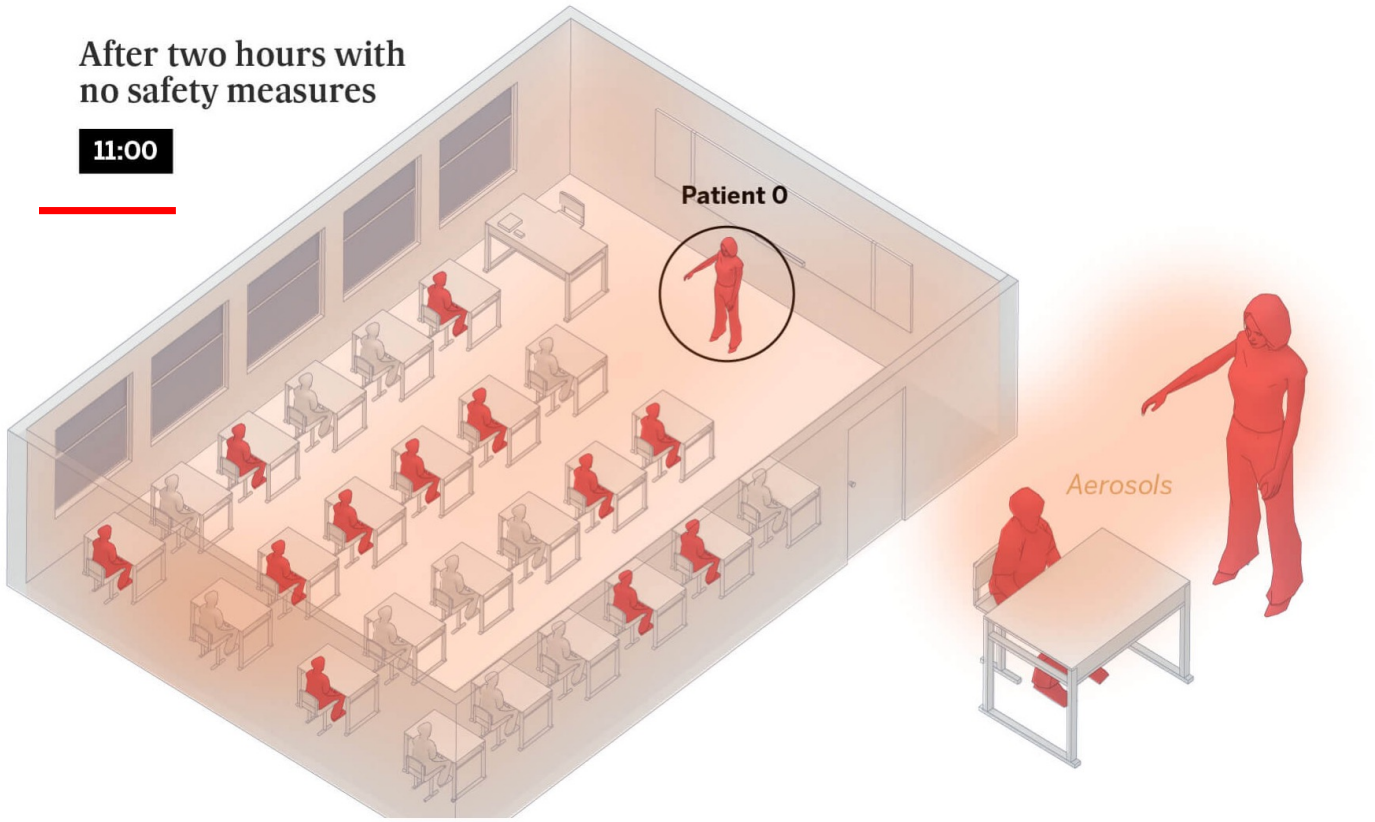
Visual Ventilation Outcomes



If two hours are spent in the classroom with an infected teacher, **without taking any measures** to counter the number of aerosols, there is the risk that up to 12 students could become infected.

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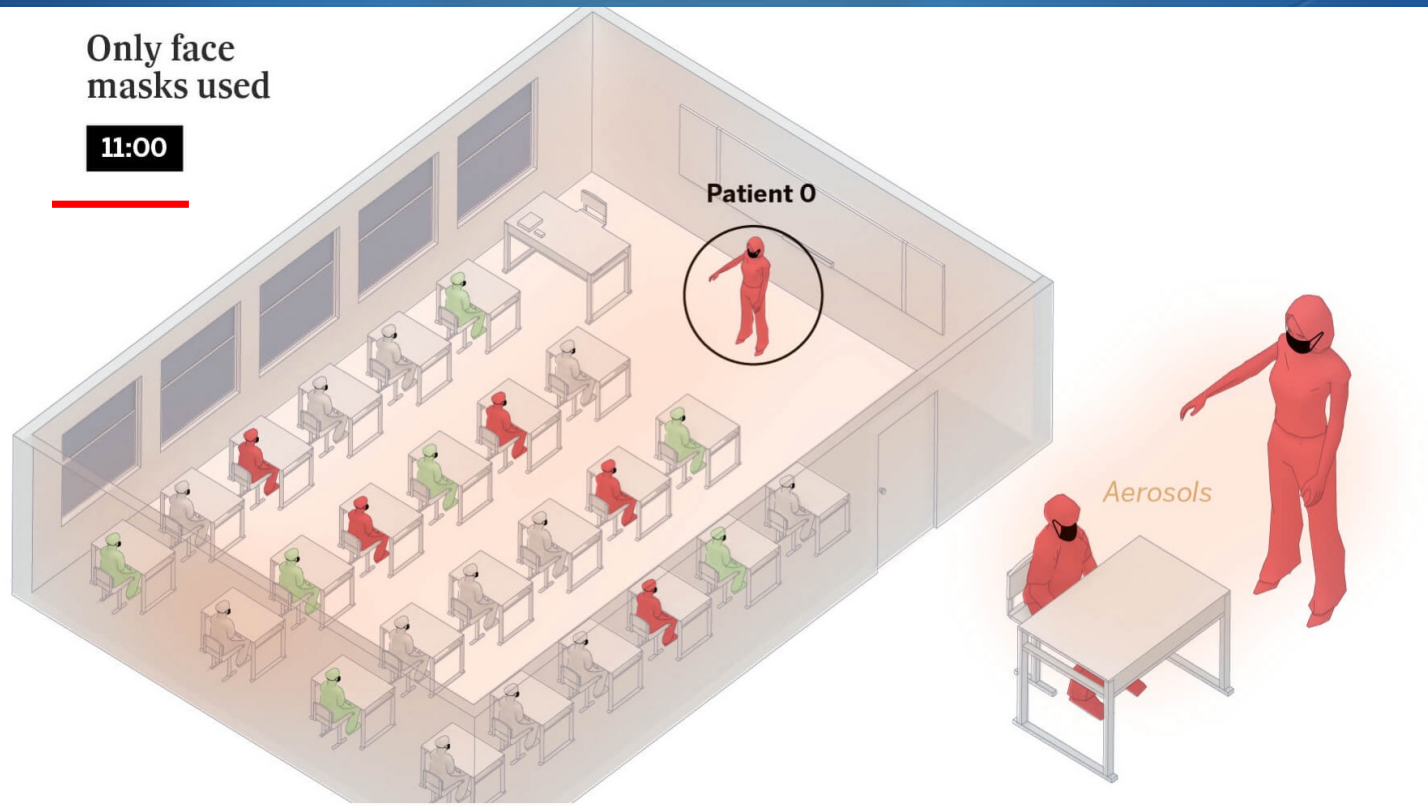
Visual Ventilation Outcomes



If everyone is wearing a face mask, the number that could become infected drops to five. In real outbreaks, it has been noted that any of the students could become infected irrespective of their proximity to the teacher as the aerosols are distributed randomly around the unventilated room.

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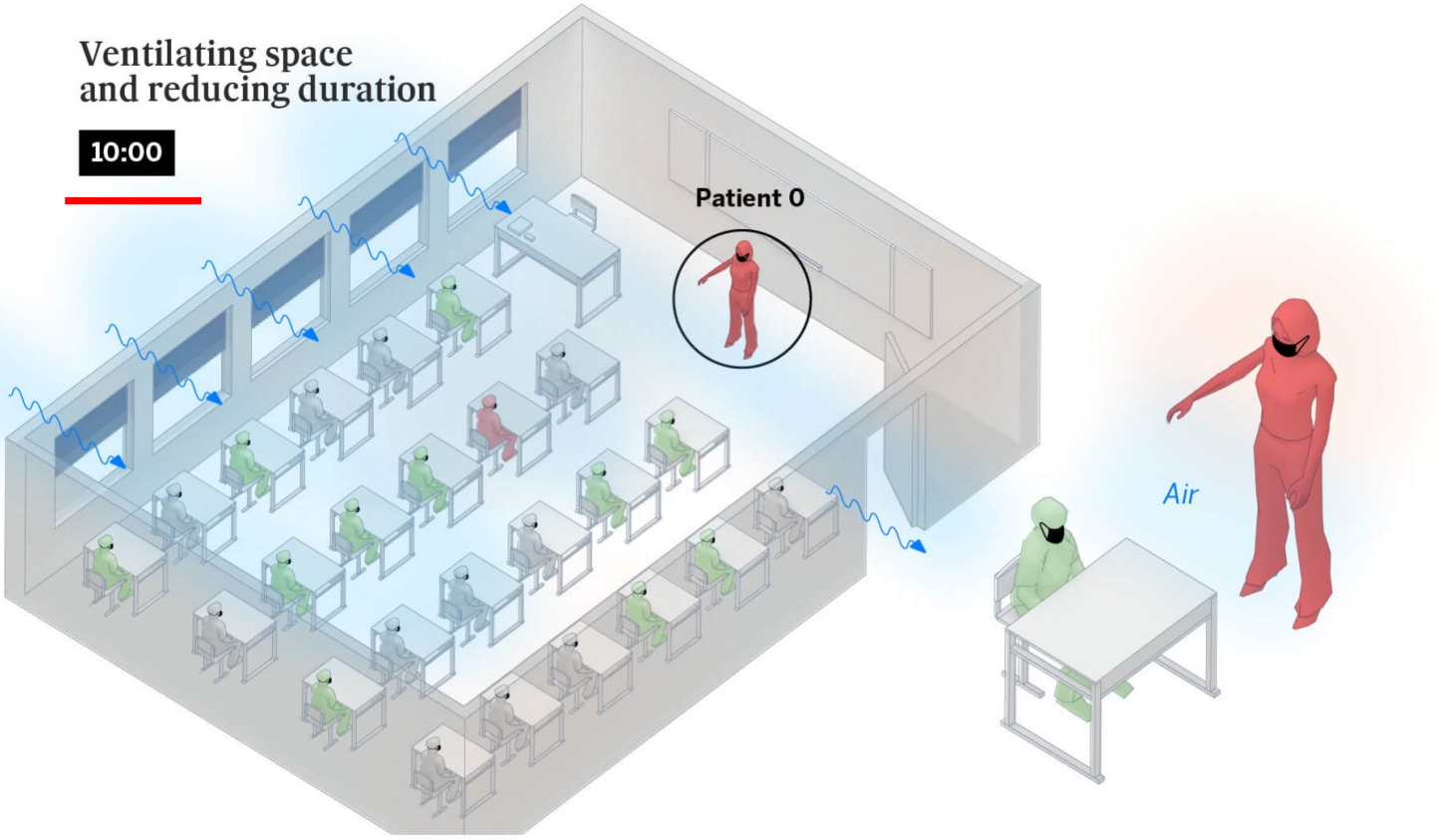
Visual Ventilation Outcomes



If the room is ventilated during the lesson, either with fresh air or mechanically, **and the class is stopped after an hour** in order to completely refresh the air, the risk drops dramatically.

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Study Conclusion

- Code compliant ventilation and distancing reduces exposure potential by 12 times
- Code compliant ventilation in conjunction with mask wearing and distancing reduces exposure potential by 29 times
- Intuitively, we have known from 2020 that schools were not "super spreaders", for these and other reasons (hygiene, screening, etc.)

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Code Compliant Ventilation

- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.1-2020 forms basis of NYS Education Department Building Code
  - Classrooms*
    - 13 Cubic Feet per Minute (ages 5 to 8) per occupant
    - 15 Cubic Feet per Minute (ages 9+) per occupant
  - Offices*
    - 17 Cubic Feet per Minute per occupant
  - Typical unit ventilator specifications for classrooms 1,000 CFM, or approximately 40 CFM for 25 occupants
    - We assess to this more conservative guideline

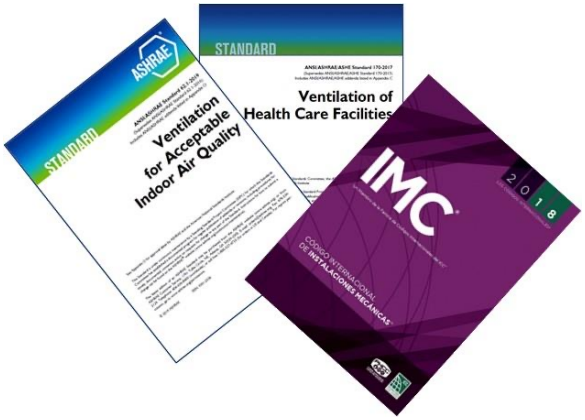

*TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone, ASHRAE Standard 62.1-2020

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Code Compliant Ventilation

[redacted]

Air Ventilation Assessment [redacted]

Room Number / Name	Anticipated # of Occupants	Ventilation Type	Area Opening (Square Feet)	Measured Flow Rate (CFM)*	Flow Rate Meets 1,000 CFM (Classroom)	Flow Rate Meets 40 CFM / occupancy rate	Vents unobstructed?	Flow velocities meet building codes?	Exhaust grilles unobstructed?	Fresh Air Dampers open?	Notes
Room 305	21	Air Handler	5.3	4552	Yes	Yes	Yes	Yes	Yes	Yes	Windows provide natural ventilation.
Room 304	21	Air Handler	5.3	4202	Yes	Yes	Yes	Yes	Yes	Yes	Windows provide natural ventilation.
Library 301-303	21	Air Handler	5.3	6899	N/A	Yes	Yes	Yes	Yes	Yes	Windows provide natural ventilation.
Room 301	10	Air Handler	5.3	620	No	Yes	Yes	Yes	Yes	Yes	Windows provide natural ventilation.
Pyschologists Office	6	Univent	2.8	1475	N/A	Yes	Yes	Yes	Yes	Yes	Windows provide natural ventilation.
Room 107	20	Univent	2.8	0	No	No	Yes	No	Yes	Yes	Windows provide natural ventilation. Univent was nonfunctional at the time of assessment.
Room 206	20	Univent	2.8	1300	Yes	Yes	Yes	Yes	Yes	Yes	Windows provide natural ventilation.
Room 208	20	Univent	2.8	2953	Yes	Yes	Yes	Yes	Yes	Yes	Windows provide natural ventilation.

*Air Flow is calculated in Cubic Feet per Minute (CFM), to determine the Flow Velocity in feet per minute, multiply this figure by the Duct Cross Sectional Area. (CFM = FPM x Duct Cross Sectional Area) Multiple registers have a cumulative effect on the total CFM of a given space.

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One more thing…

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2018

Mold closes dozens of NJ schools, some for weeks

David M. Zimmer, North Jersey Record Published 4:39 p.m. ET Sept. 11, 2018 | Updated 7:40 p.m. ET Sept. 12, 2018

LONG ISLAND / EDUCATION

Connetquot sch district con… moving studen moldy schoo…

At a public forum, some of the more t… Oakdale-Bohemia Middle School is …tinued presence of mold at

School Blames Humid Summer for Mold· … Convinced Repairs Are Enough

By Jackie Bensen and Gina Cook

Published at 11:38 PM EDT on Oct 4, 2018

Mold Forces Yonkers School to Clos…

Parents were unhappy with the contingency plan …

By Wale Aliyu

Published at 10:37 PM EDT on Sep 24, 2018 | Updated …

Mold issues grow in Stamford schools

By Erin Kayata **Updated 1:04 pm EDT, Friday, October 5, 2018**

STAMFORD — Heavy rain and humidity has caused an unusual amount of mold to grow up and down the East Coast, including in half of the city's public schools.

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Outside Air

- Continuous introduction of moisture laden outside air into building
  - Relative humidity increases even if temperature remains constant
- Depositional condensation and moisture absorption increases
- Closets, cabinets, storage rooms, interior bathrooms, music instruments
- Lack of air flow reduces dilution of moisture
- Contents become impacted by moisture and microbial growth

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Strategies

- Vary outside air when outdoor dew point nears indoor temperature to prevent microbial growth
- Keep interior doors to functional spaces and confined space doors open to increase dilution of indoor air
- Update BMS to include sensors for outdoor relative humidity and dew point, and develop set points to adjust system accordingly

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Strategies

- Reduce indoor relative humidity levels to below 60% using fans for air movement and commercial grade (128 pint/day capacity) dehumidifiers
- Take advantage of weather days where relative humidity is below 40% by opening windows to achieve natural desiccation
- Maintain aggressive custodial cleaning activities (increase staff/target contents) during high humidity periods
- Draft staff participation into awareness program (see something/say something). Insure work order program elevates mold observations to immediate priority status

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Takeaways

- Covid virus indoors is a particulate management exercise, influenced by particle size and air movement
- Code compliant ventilation is extremely effective at reducing Covid and other pollutant exposure potential
- Ventilation systems should be assessed to establish code compliance
- Introducing outside air can have ancillary effects on building air quality through moisture introduction, and should be monitored

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Questions

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