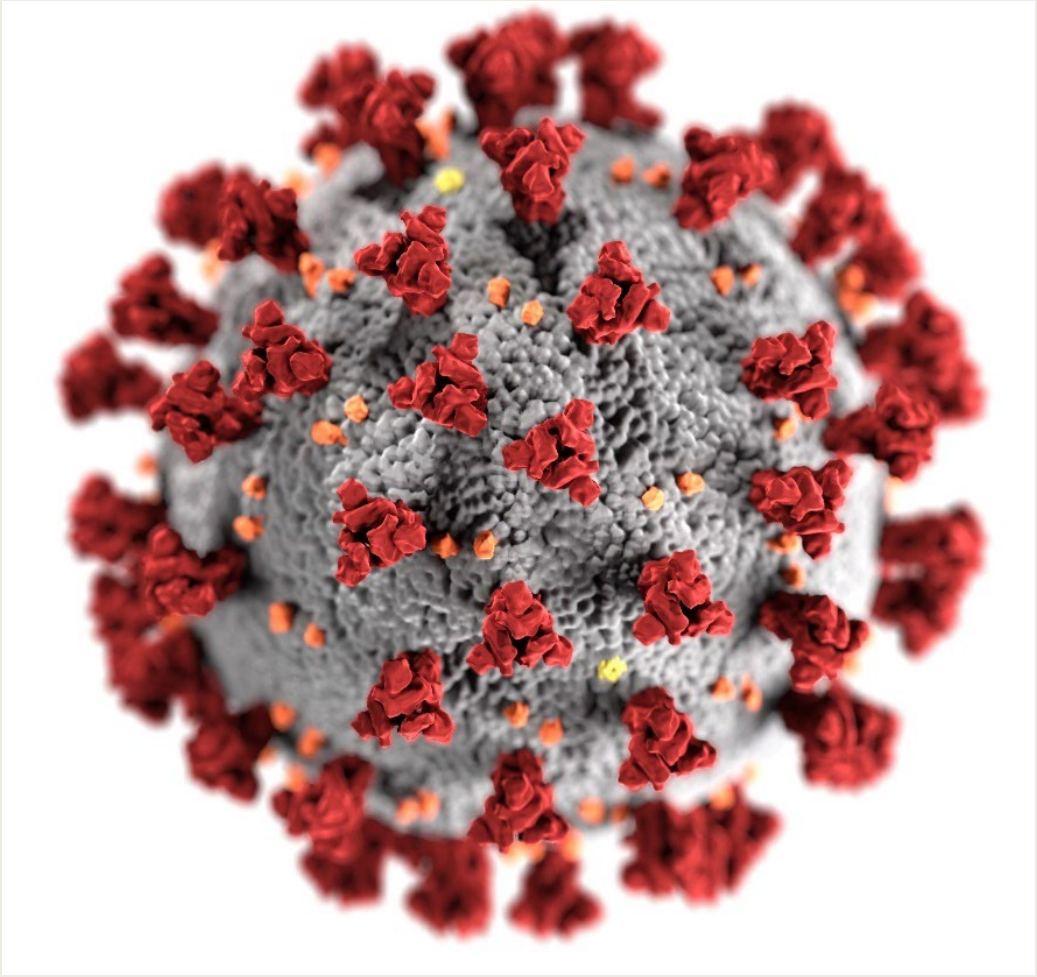
Transmission of Infectious Diseases by Aerosols

William G. Lindsley, PhD
Research Biomedical Engineer
National Institute for Occupational Safety and Health (NIOSH)
Centers for Disease Control and Prevention (CDC)
wlindsley@cdc.gov



cdc.gov/coronavirus

What is an aerosol?

- **“Aerosol” is a general term for small airborne solid or liquid materials.**
- **Examples:**
  - Dust
  - Smoke
  - Clouds
  - Diesel soot
- **“Particle” and “aerosol particle” are used for aerosols that are solid, liquid, or a mixture.**
- **Aerosols are usually defined as airborne particles less than 1/10 of a millimeter (100 micrometers) in diameter.**
  - 100 micrometers (µm) is around the smallest individual dot that an average person can see.
  - Human hair ranges from around 17 to 180 µm in diameter.

Photo credit: Kelly Cornwall/U.S. Forest Service

Photo credit: US Environmental Protection Agency

Many infectious respiratory diseases can be spread by aerosols

- **Most infectious respiratory diseases can spread in several ways.**

  Aerosols can be an important route of transmission.

- **Whenever people cough, sneeze, talk, sing, or breathe, they expel aerosols and droplets from their mouth and nose.**

  Aerosols are 100 µm or smaller.

  Droplets are larger than 100 µm.

- **If a person has some types of respiratory infections, these aerosols and droplets can contain infectious viruses or bacteria.**

- **Under the right conditions, these aerosols and droplets can infect other people. For example:**

  SARS-CoV-2

  Measles virus

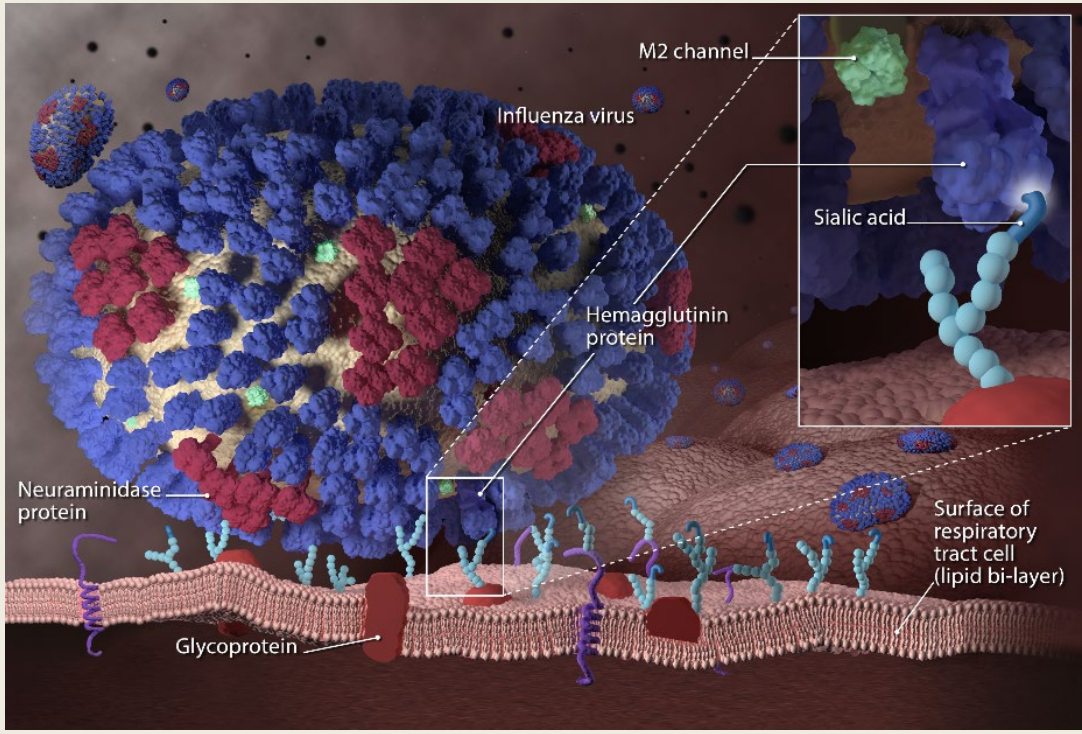
  Streptococcus pyogenes bacteria

  Mycobacterium tuberculosis bacteria

Aerosols and droplets produced during a sneeze.
Source: CDC Public Health Image Library
https://phil.cdc.gov

How does aerosol transmission occur for respiratory viruses?

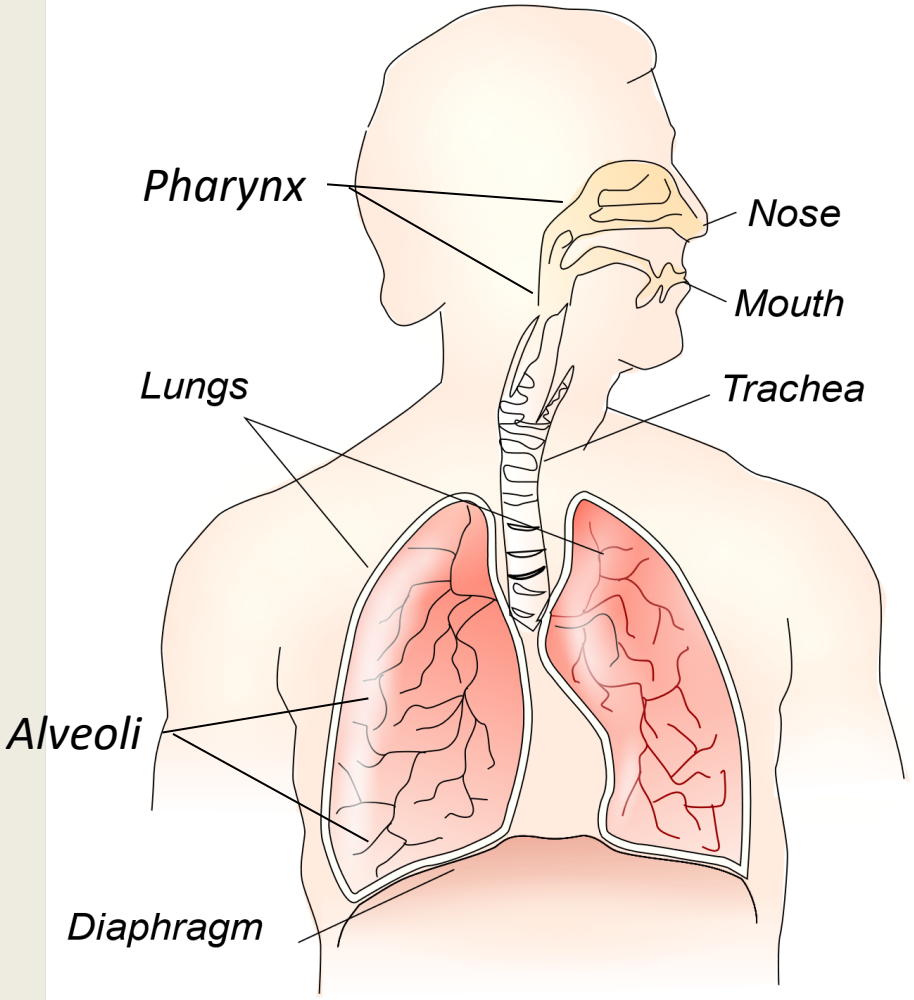
- **Transmission starts with a person with a viral respiratory infection.**
- **Respiratory viruses in the lungs reproduce by:**
  - Entering the cells in the airways.
  - Hijacking the cell's machinery to make copies of itself.
  - Bursting from the cells into the mucus lining the airways.
  - Infecting more cells.
- **Viral load: The concentration of virus in a bodily fluid like respiratory mucus.**
  - Viral load varies from place to place in the respiratory tract.
  - Depends on many factors including:
    - Species of virus.
    - Severity of infection.
    - Stage of illness.
- **When airway mucus is transported out of the respiratory tract, the virus travels with it.**



Influenza virus infecting a cell.
Source: CDC Public Health Image Library https://phil.cdc.gov Illustrator: Dan Higgins

Aerosol generation by the respiratory system

- **Coughing, sneezing, talking, singing, and breathing all produce aerosols and droplets of respiratory mucus and propel them out of the mouth and nose.**
- **The small airways in the deep parts of the lungs produce smaller aerosols.**
- **The larger airways and vocal cords produce larger aerosols.**
- **Trachea, mouth, and nose produce large aerosols and droplets.**
- **Some people produce hundreds of times more aerosol particles than others.**
- **People produce more aerosols and droplets when they are:**
  - Sick with a respiratory infection.
  - Speaking, shouting, or singing.
  - Breathing heavily such as during exercise.

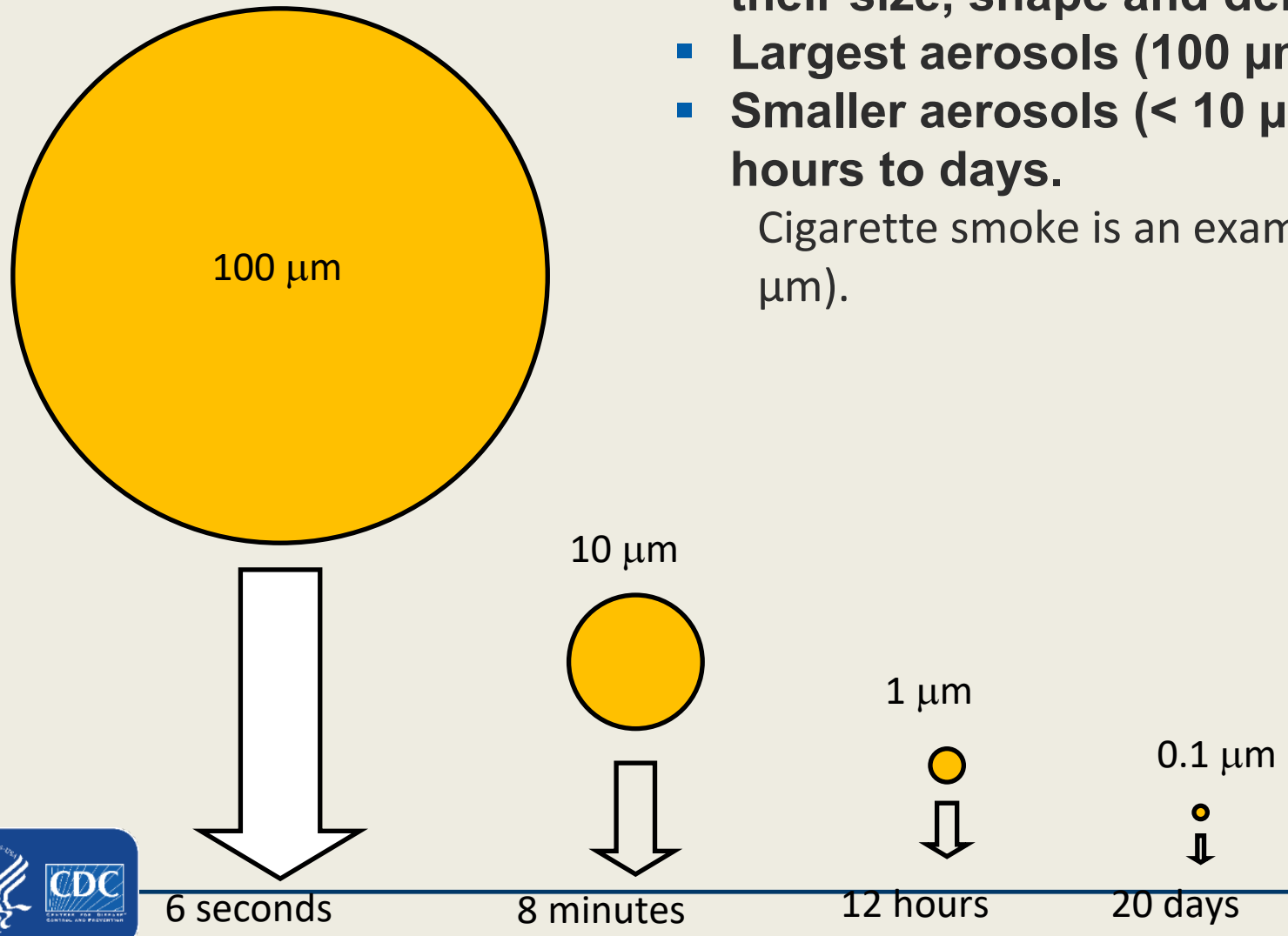


Adapted from illustration by: Theresa Knott - Own work, CC BY-SA 3.0 https://commons.wikimedia.org/w/index.php?curid=1101004

How long do respiratory aerosols remain in the air?

- **How aerosol particles behave in the air is determined by their size, shape and density.**
- **Largest aerosols (100 µm) fall to the ground in seconds.**
- **Smaller aerosols (< 10 µm) can stay airborne for minutes to hours to days.**

  Cigarette smoke is an example of an aerosol of small particles (<1 µm).



Time for spherical particles with the density of water to fall 5 feet (1.5 meters) in still air.

How far can aerosols and droplets travel?

- **At short ranges (< 6 feet; 2 meters), aerosols and droplets can easily travel from one person to another.**

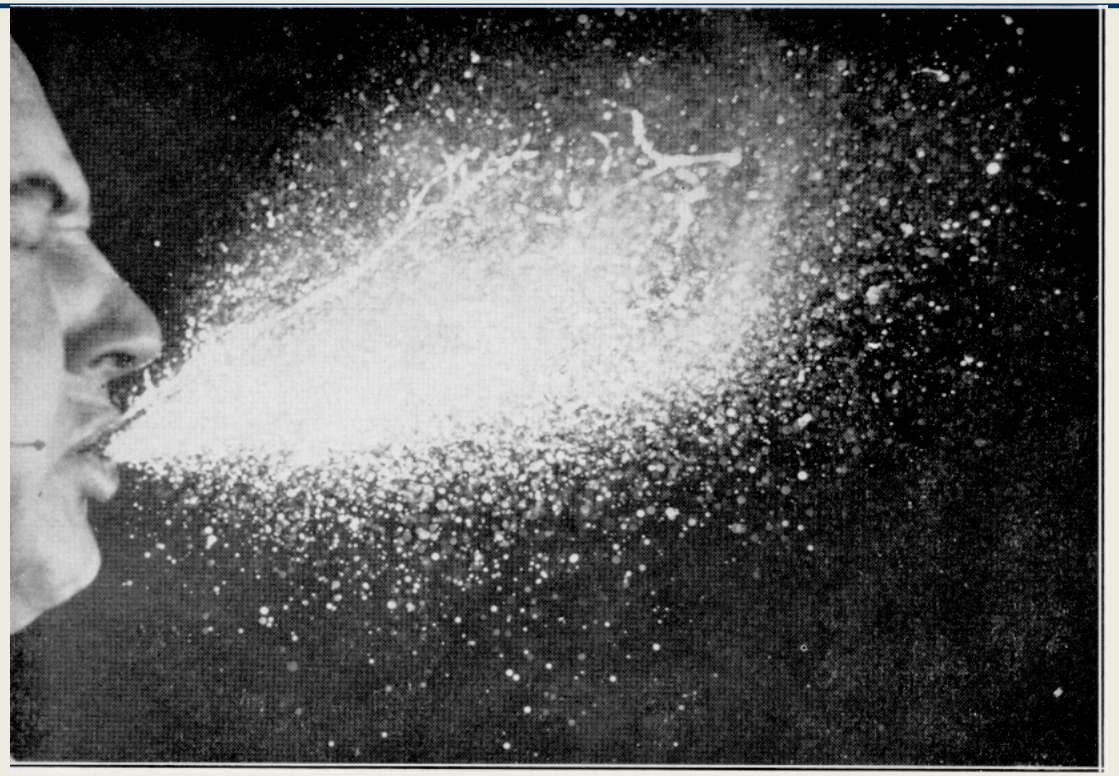
  Coughs and sneezes can propel aerosols and droplets further than speaking or breathing.

- **As the separation distance increases, droplets and large aerosols are more likely to fall to the ground before reaching another person.**
- **Smaller aerosols can remain airborne and disperse throughout an indoor location.**

  Concentration is highest close to the source and decreases as you move further away.

  Air currents and ventilation systems have a strong effect on distribution of small aerosols.

  Thermal plumes from people can loft aerosols and increase the time that they stay airborne.



Sneeze from a subject with a head cold. Source: Jennison, MW (1942). Atomizing of mouth and nose secretions into the air as revealed by high-speed photography. *Aerobiology.* American Association for the Advancement of Science: 106-128.

How long do viruses in aerosols survive?

- **The survival of airborne viruses is complex and difficult to study.**
  Different studies find different results.
- **Respiratory viruses can survive outside the body for minutes to days depending upon factors including:**
  Species of virus.
  Temperature.
  Humidity.
  Sunlight.

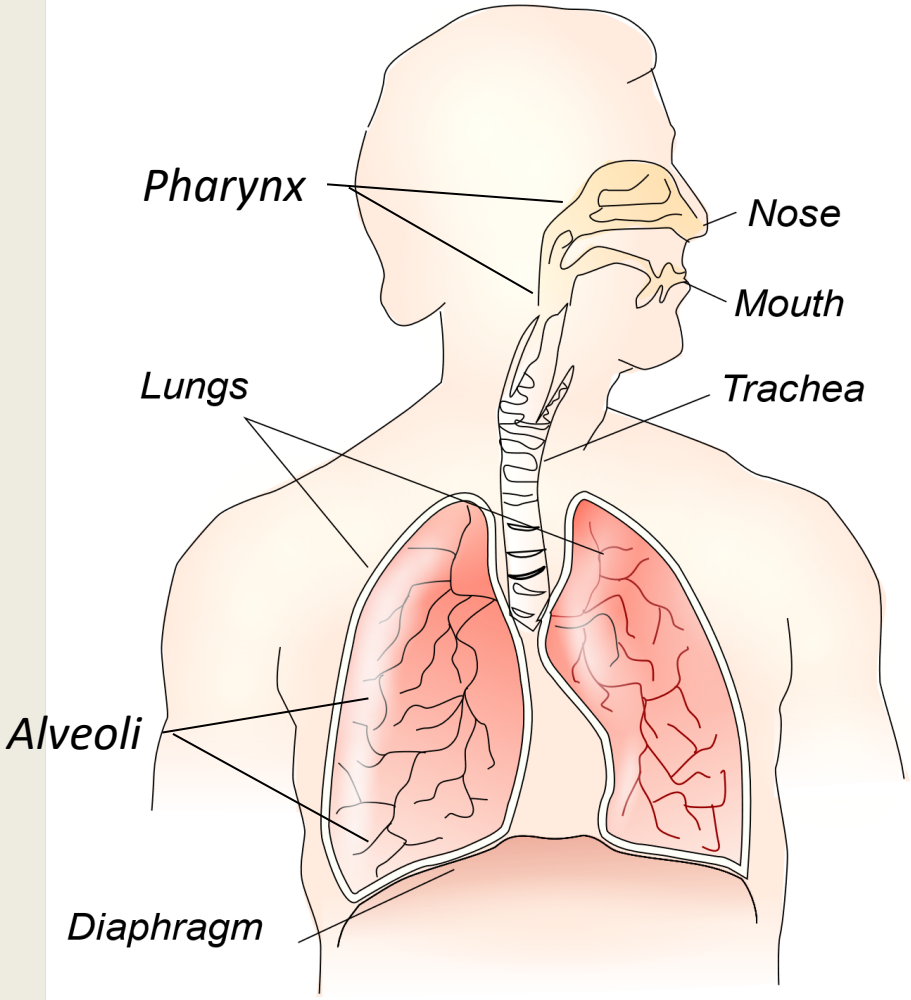
Time for 90% of airborne SARS-CoV-2 virus to lose viability at 20 °C (68 °F)

Relative humidity	*Sunlight*	*Time for 90% loss*
20%	No	6.4 hours
70%	No	2.3 hours
20%	Yes	10 minutes
70%	Yes	6 minutes

Data from: Dabisch et al. (2020). The influence of temperature, humidity, and simulated sunlight on the infectivity of SARS-CoV-2 in aerosols. *Aerosol Sci Technol* 55(2): 142-153.

Where do aerosols deposit in the respiratory tract?

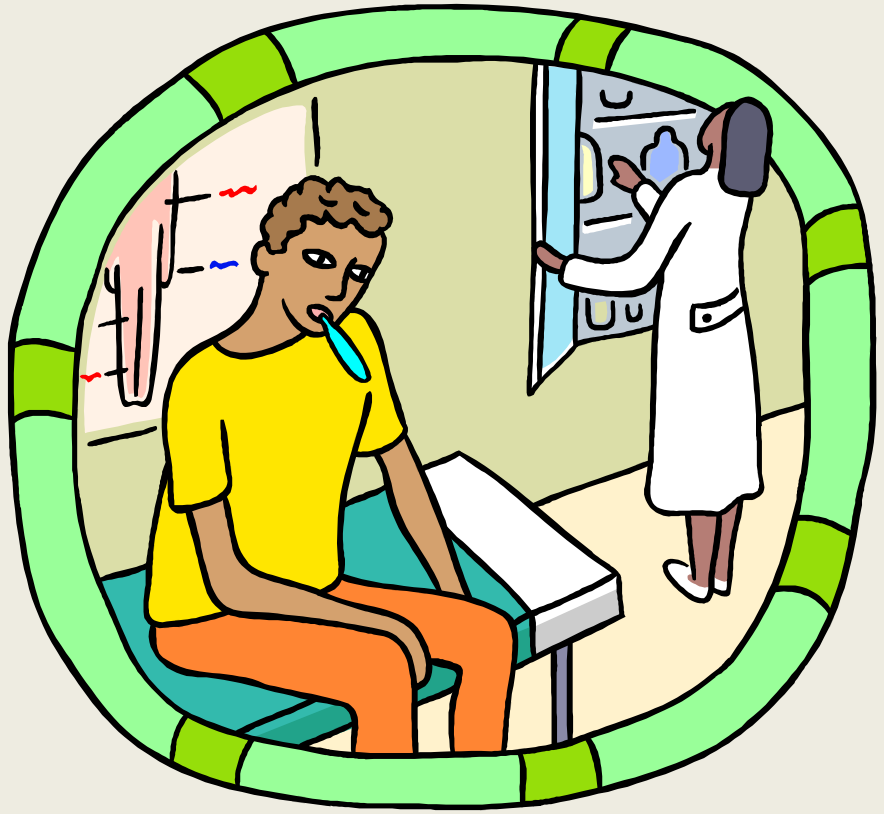
- **The size of the aerosol particles determine where they deposit in the airways.**
- **Larger aerosols (>20 µm) deposit almost entirely in the mouth, nose and pharynx.**
- **Smaller aerosols (<10 µm) can travel deeper into the lungs.**
- **If a cloud of 1 µm aerosol particles is inhaled, approximately:**
  - 29% will deposit in the mouth, nose and pharynx.
  - 3% will deposit in the trachea and large airways.
  - 12% will deposit in the smallest airways and alveoli (end of the airways).
  - Remainder (57%) will be exhaled.
- **Deposition varies depending upon factors including:**
  - Person-to-person variation.
  - Mouth vs. nose breathing.
  - Exertion level.
  - Health.



Adapted from illustration by: Theresa Knott - Own work, CC BY-SA 3.0 https://commons.wikimedia.org/w/index.php?curid=1101004

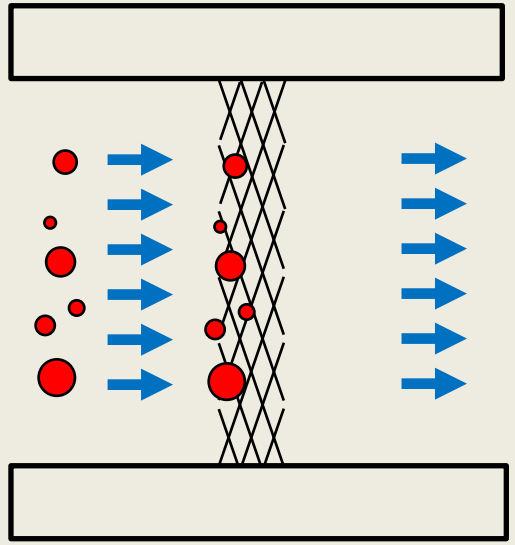
How much virus is needed to infect someone?

- **Infectious dose: the dose of virus that will infect 50% of people on average.**
- **The likelihood of a person becoming infected varies depending upon factors including:**
  - Species of virus.
  - Location in the respiratory tract where virus deposits.
  - Health of the exposed person.
  - Immunity and vaccination.



How do you stop the transmission of infectious diseases by aerosols?

- **Vaccination and pharmaceutical treatments can prevent or reduce severity of disease.**
- **Non-pharmaceutical interventions can reduce exposure to infectious aerosols and droplets.**
- **High-quality well-fitting face masks:**
  Reduce the amount of aerosol expelled by an infected person into the environment.
  Reduce the amount of aerosol inhaled by an uninfected people.
- **Limiting the number of people in indoor settings.**
- **Physical distancing.**
- **Ventilation.**
- **Air filtration.**
- **Air disinfection such as with ultraviolet germicidal irradiation (UVGI).**
- **Non-pharmaceutical interventions work best in combination with each other.**



Questions?

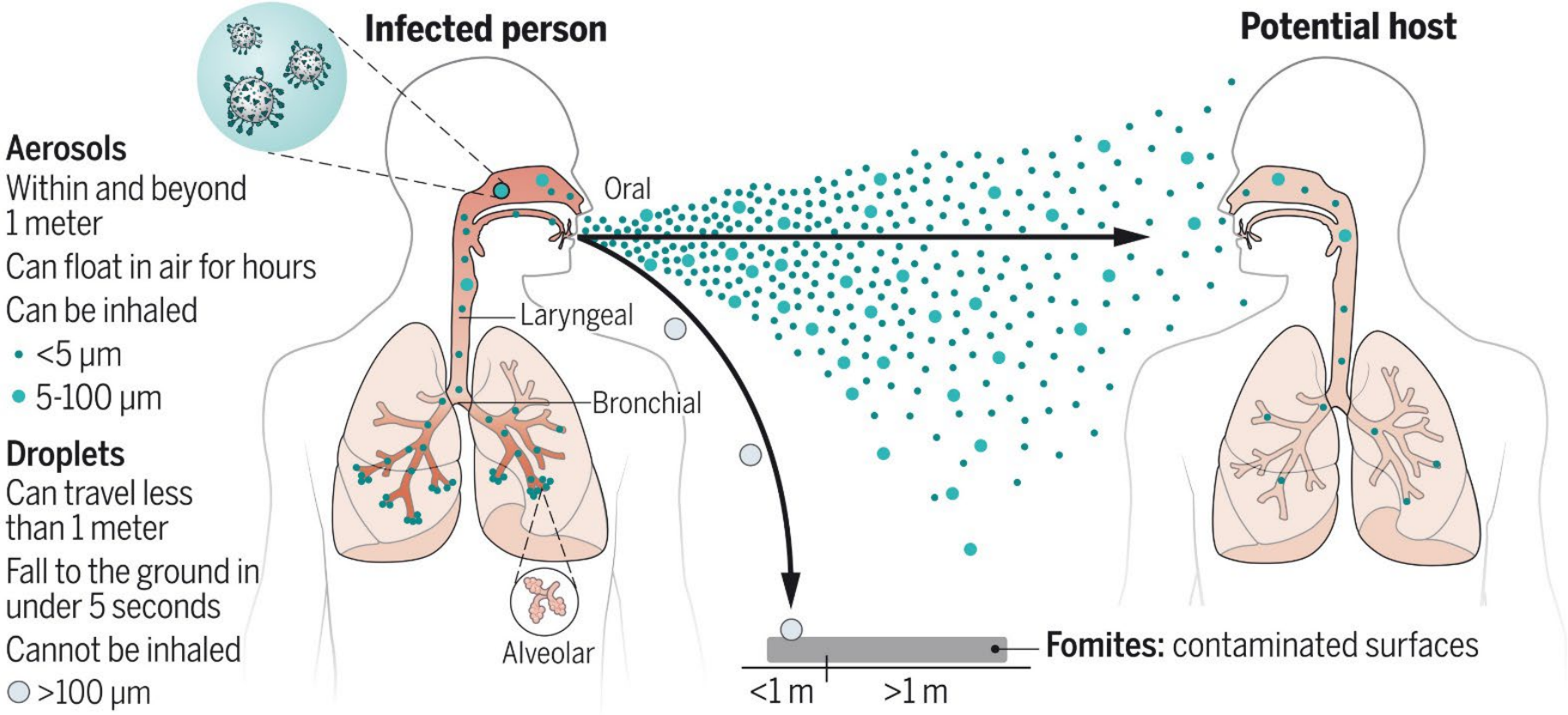
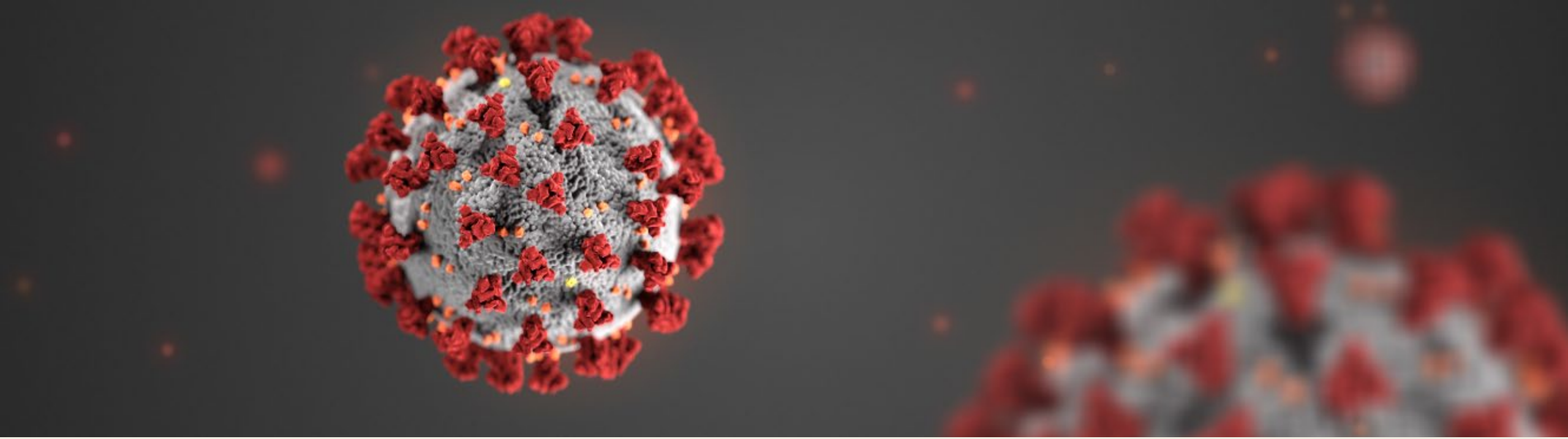


Figure from: Wang et al. (2021). Airborne transmission of respiratory viruses. *Science* 373(6558). https://doi.org/10.1126/science.abd9149
Credit: N. Cary/*Science*



For more information, contact CDC
1-800-CDC-INFO (232-4636)
TTY: 1-888-232-6348 www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.