Understanding and Controling SARS-CoV2 Transmission

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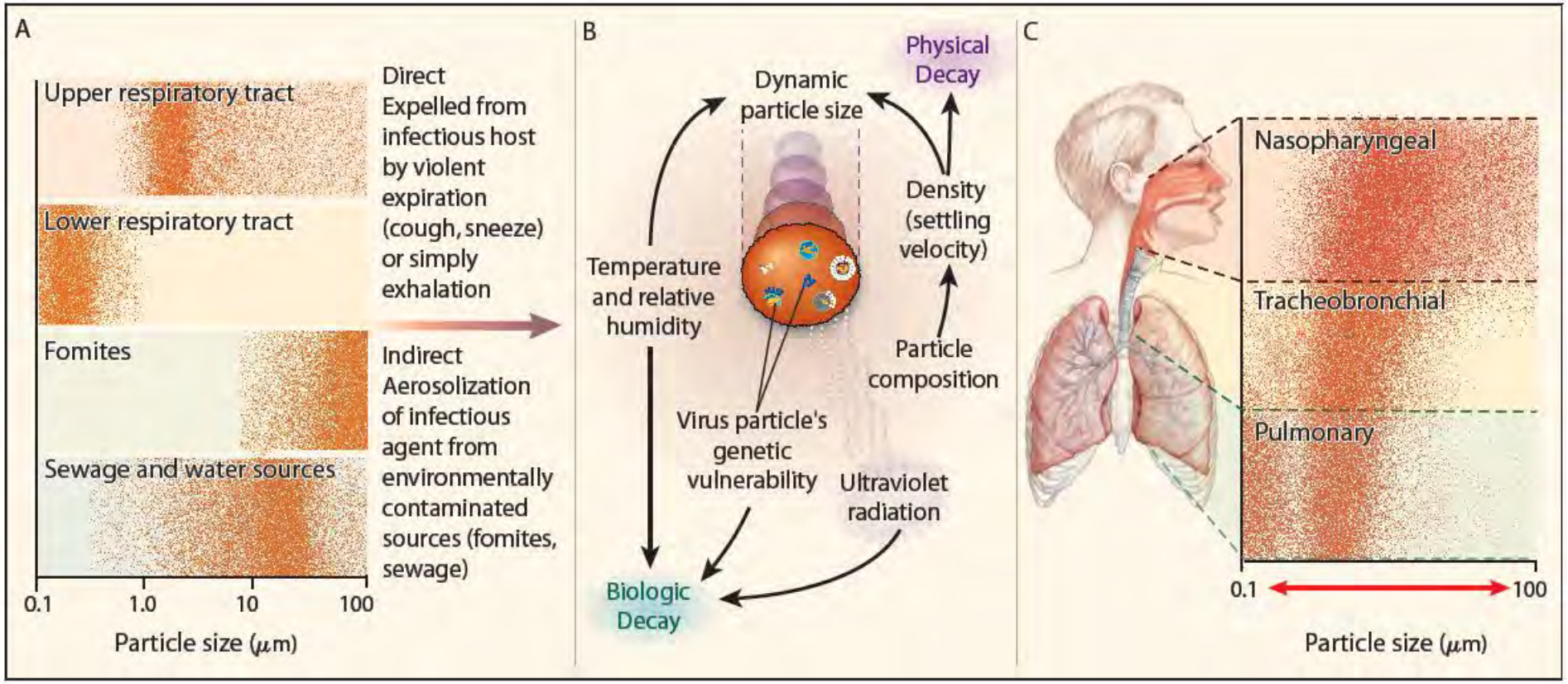
SCHOOL OF
PUBLIC HEALTH

Outline

- Understanding transmission
  - The elusive pathway and what is an aerosol anyway?
  - Humans as aerosol generators
  - How to catch a breath (sampling the elusive aerosols).
  - SARS-CoV-2 receptors
- Control
  - Source control
  - Environmental control

The Elusive Pathway

The Aerobiological Pathway for Transmission of Communicable Respiratory Disease



A: Source, B: Transport and Dispersion, C: Deposition

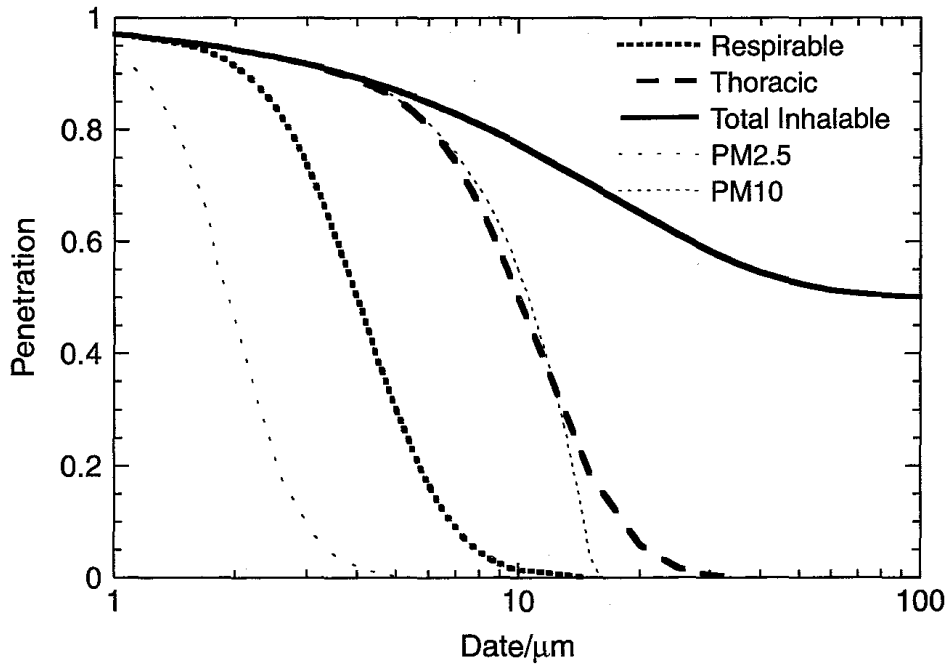
Roy C and Milton DK, New Engl J Med, 2004

Two ways to define droplets and particles that can carry respiratory viruses

Medical categories

- Respiratory droplets
  - Droplets that do not travel very far
  - Mode of inoculation unclear but generally not thought to be ‘inhaled’
  - Not considered “airborne infection transmission”
- Aerosols
  - Sometimes called droplet-nuclei
  - Less than 5 µm in diameter
  - Small enough to travel long distances and cause infection far from the source.
  - Considered the only cause of “airborne infection”

Exposure science based categories



J. C. Volkwein, A. D. Maynard, M. Harper, in *Aerosol Measurement*, P. Kulkarni, P. A. Baron, K. Willeke, Eds. (John Wiley & Sons, Inc., Hoboken, NJ, USA, 2011, pp. 571–590.

Total & Regional Respiratory Tract Deposition

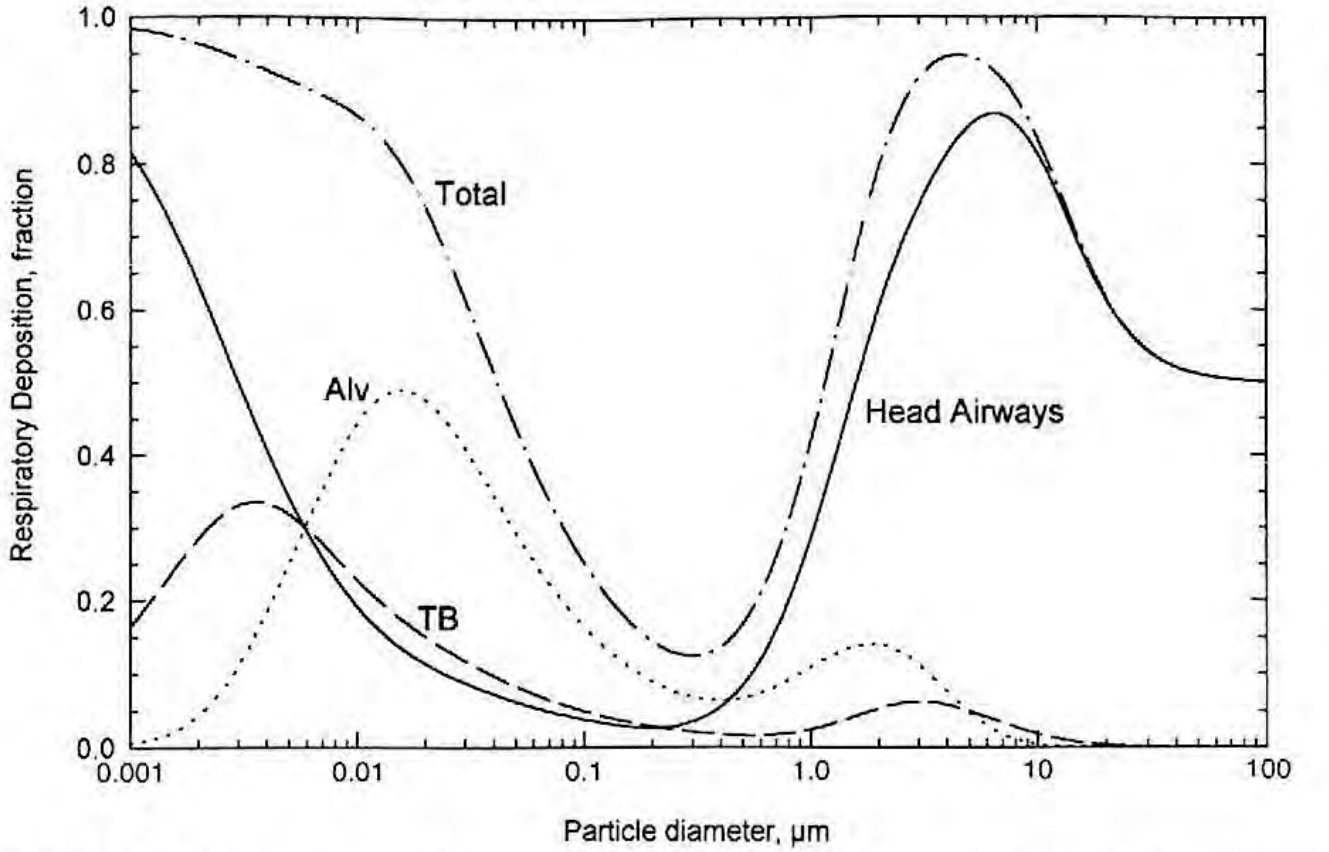


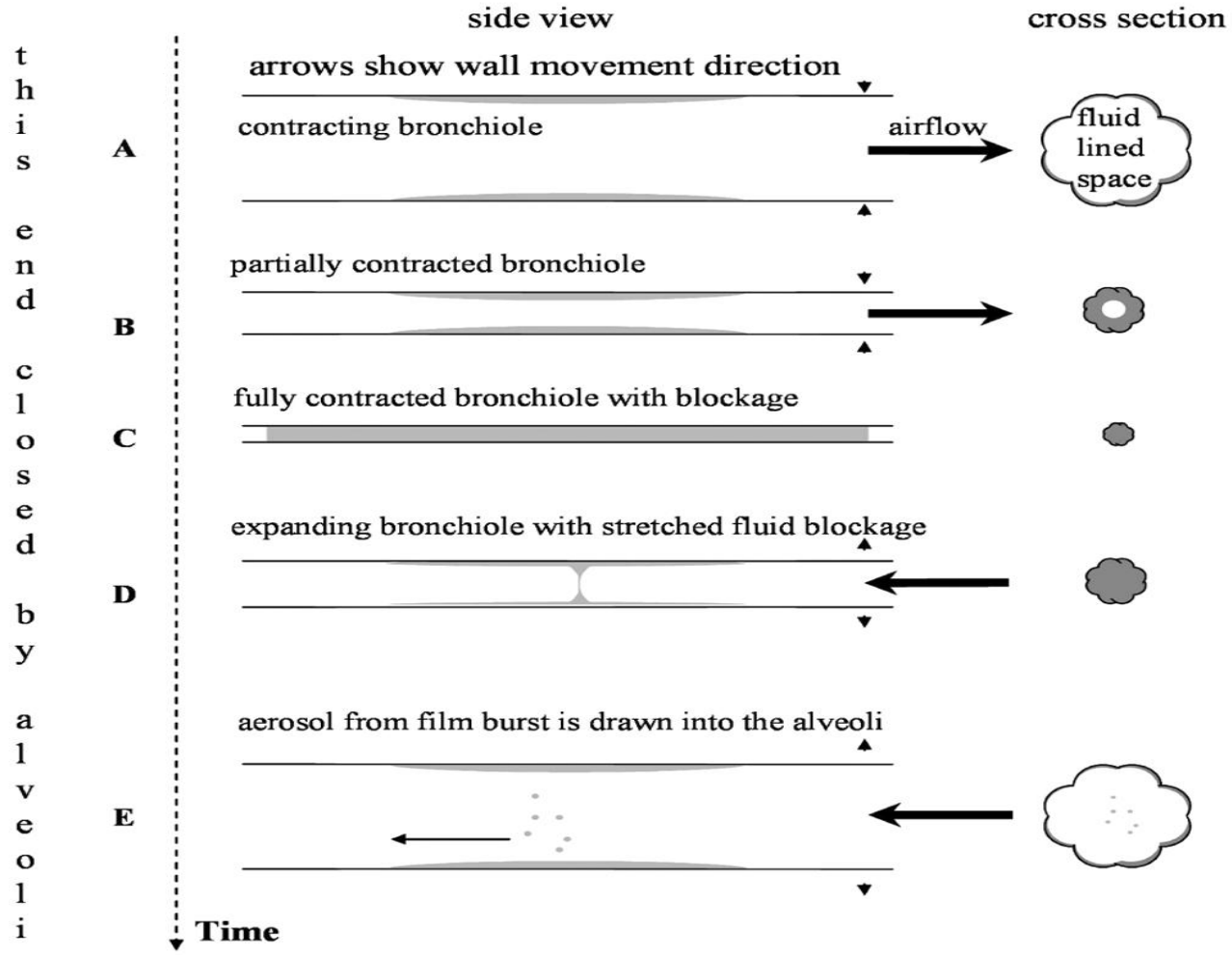
FIGURE 11.3 Predicted total and regional deposition for light exercise (nose breathing) based on ICRP deposition model. Average data for males and females.

Hines WC Aerosol Technology, 1999

Exposed to TB in coarse aerosol droplets > 5 μm Exposed to TB in fine aerosol droplets ≤ 5 μm

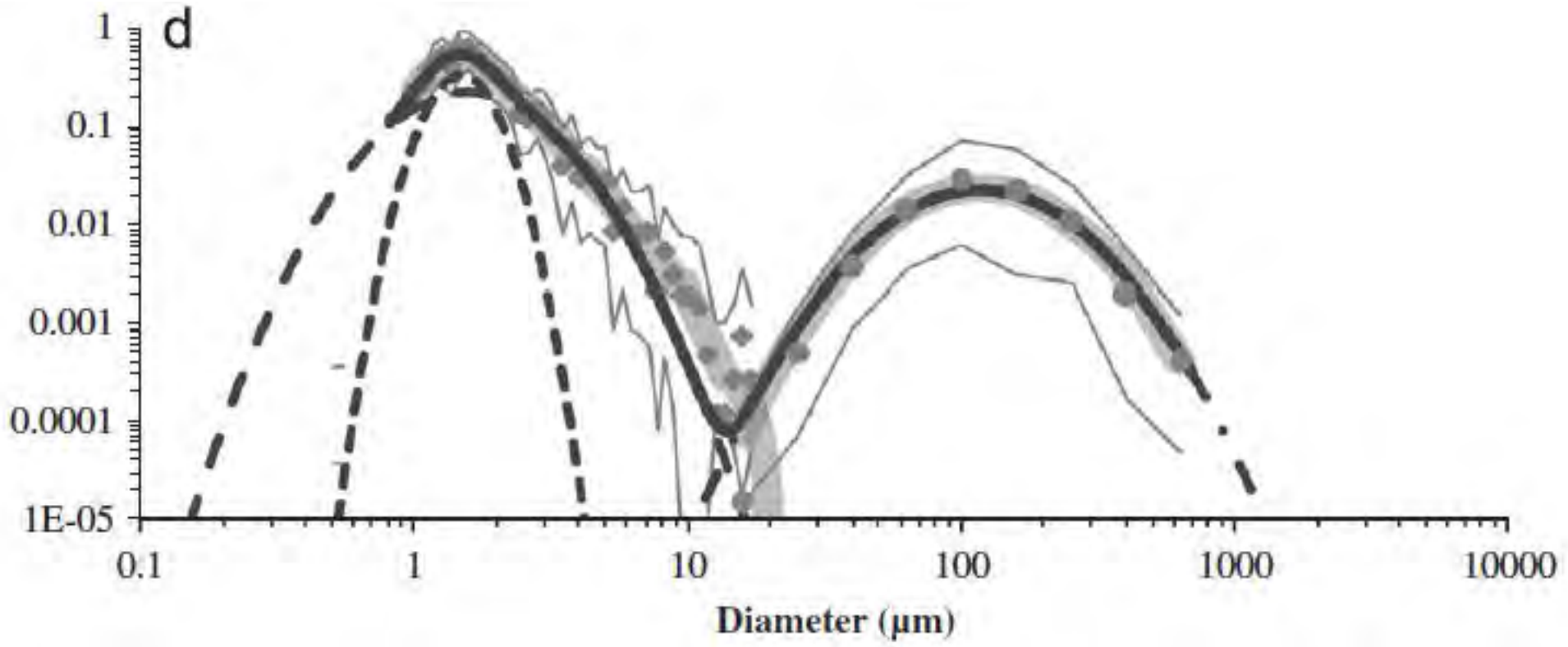
W. F. Wells, *Airborne Contagion and Air Hygiene: An Ecological Study of Droplet Infection* (Harvard University Press, Cambridge, MA, 1955).

Mechanism of Aerosol Formation in the Lung During Breathing



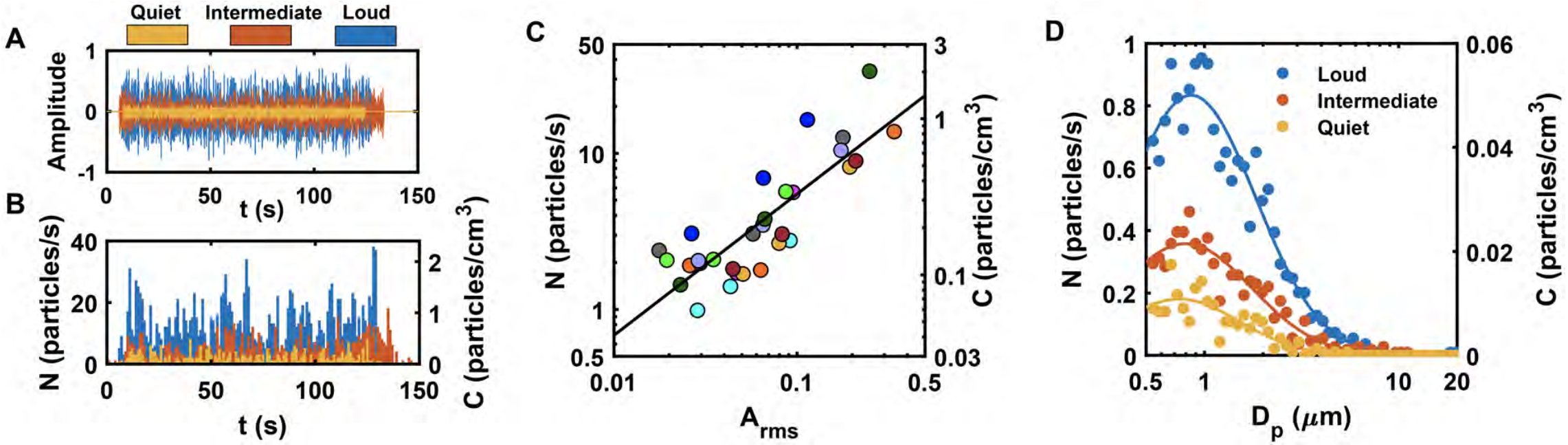
Johnson & Morawska, 2009

Size Distribution of Aerosols from Voluntary Coughing: Breath, Laryngeal, and Oral Modes



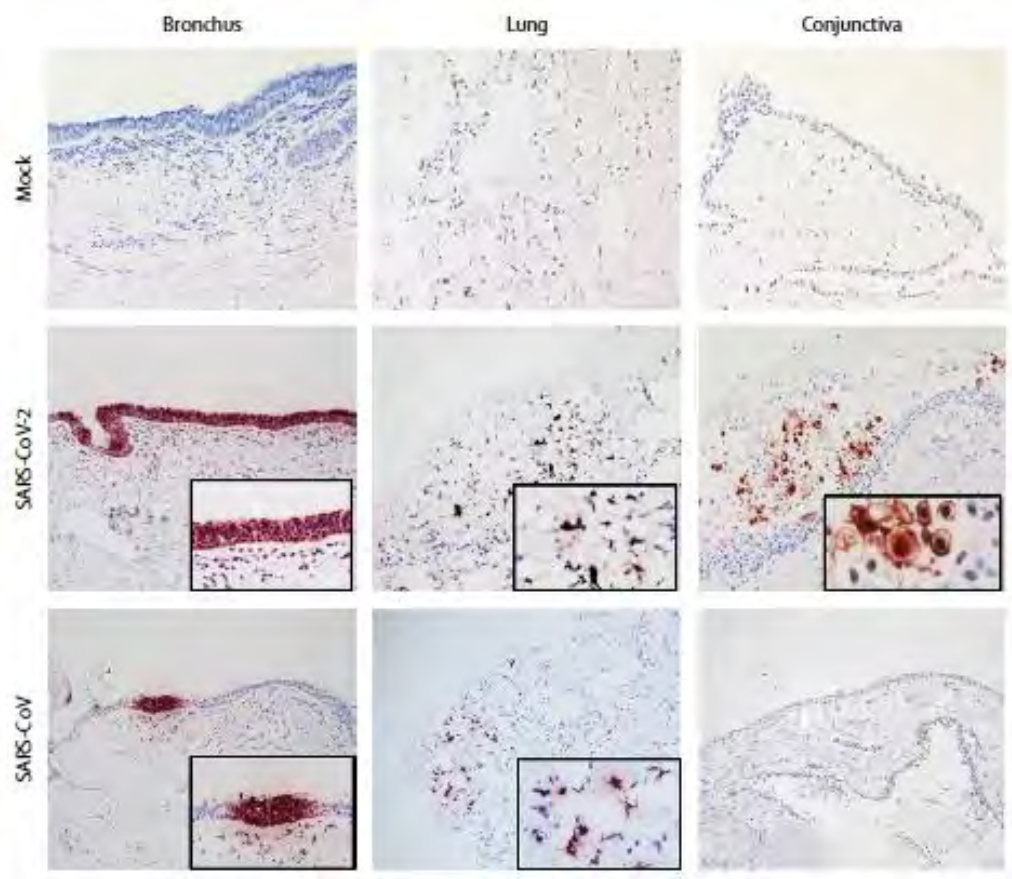
G. R. Johnson *et al.*, *Journal of Aerosol Science*. **42**, 839–851 (2011).

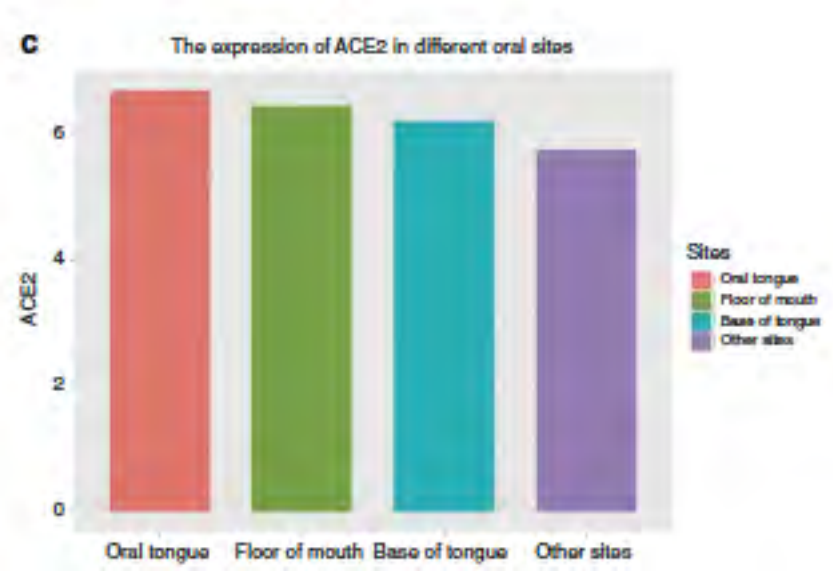
Aerosol emission and superemission during human speech increase with voice loudness



S. Asadi *et al.*, *Scientific Reports*. **9**, 2348 (2019).

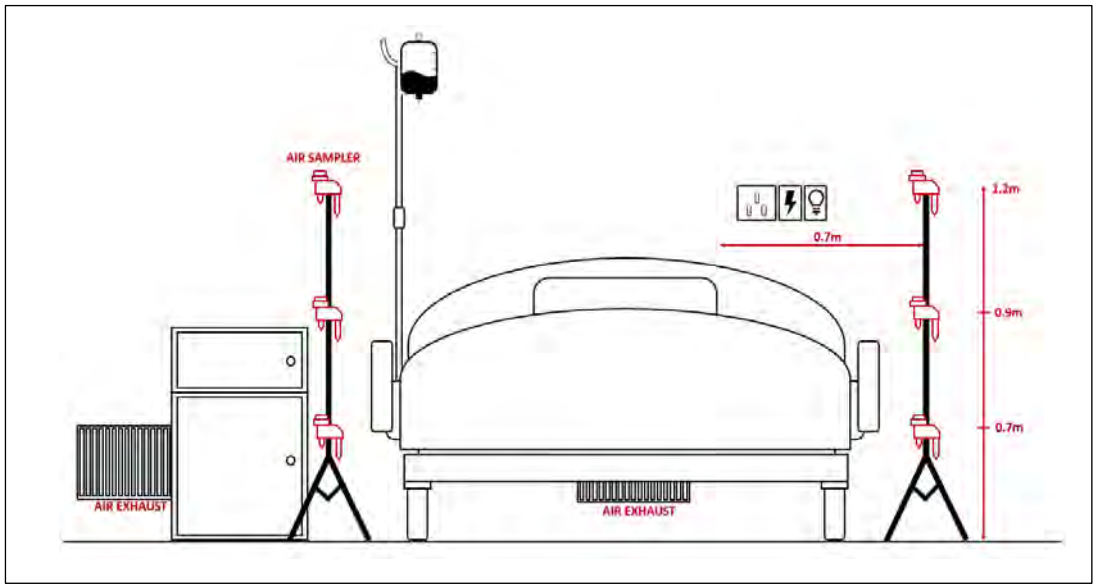
Where SARS Viruses Bind and Infect





K. P. Y. Hui *et al.*, *Lancet Respir Med* (2020), doi:10.1016/S2213-2600(20)30193-4.
H. Xu *et al.*, *Int J Oral Sci*. **12**, 8 (2020).

SARS-CoV-2 Aerosols in Containment Unit, Singapore

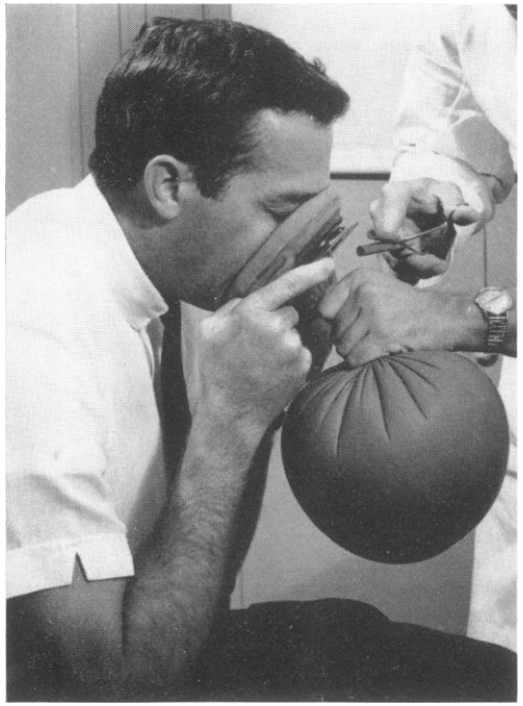


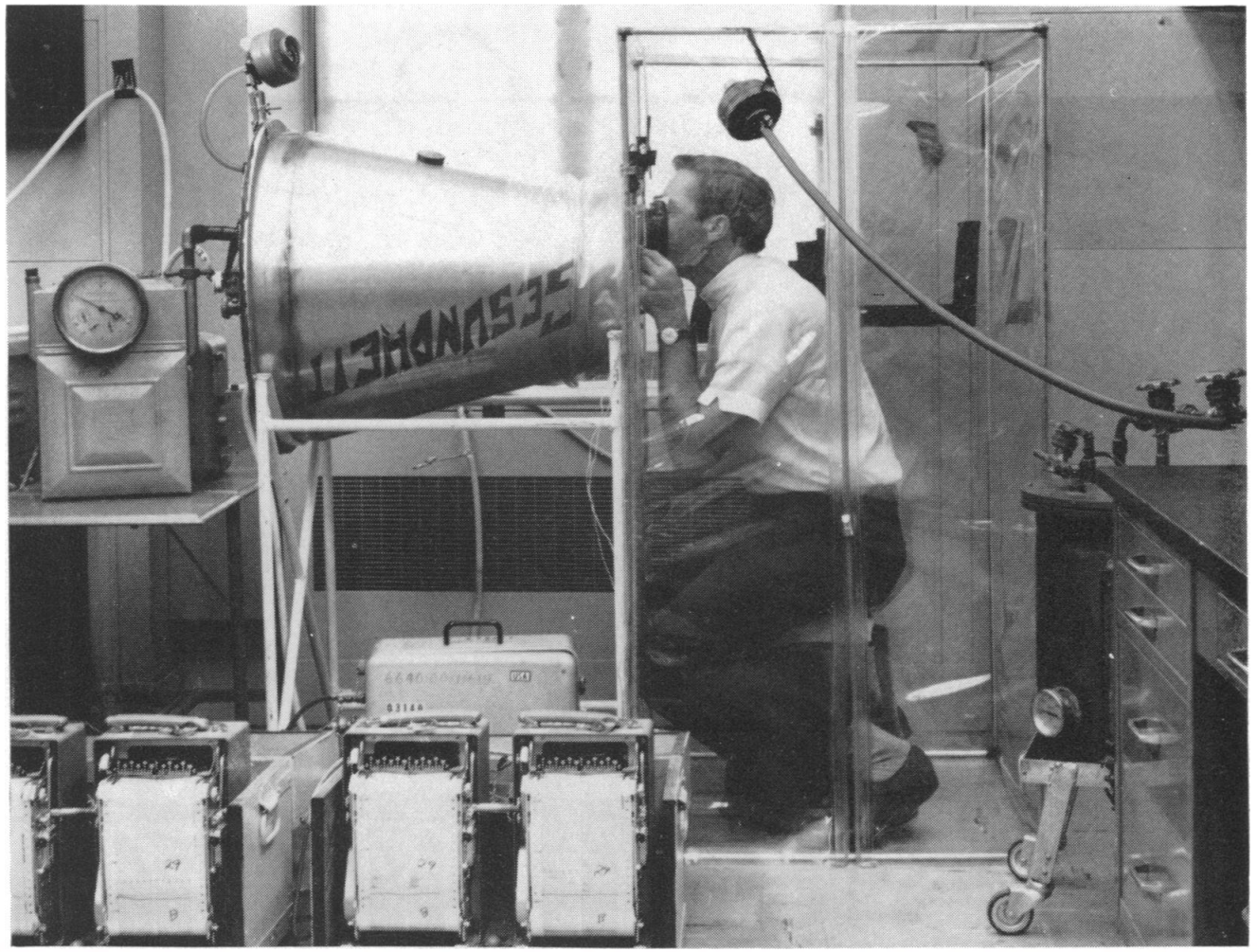
Patient	Day of illness	Symptoms reported on day of air sampling	Clinical Ct value*	Airborne SARS-CoV-2 concentrations (RNA copies m^{-3} air)	Aerosol particle size	Samplers used
1	9	Cough, nausea, dyspnea	33.22	ND ND	-- --	NIOSH SKC Filters
2	5	Cough, dyspnea	18.45	2,000 1,384	>4 µm 1-4 µm	NIOSH
3	5	Asymptomatic†	20.11	927 916	>4 µm 1-4 µm	NIOSH

Average breathing rate ~12-14 m^3 per day

P. Y. Chia *et al.*, *Nature Communications*. **11**, 2800 (2020).

Human Cough and Sneeze Collectors 1960s

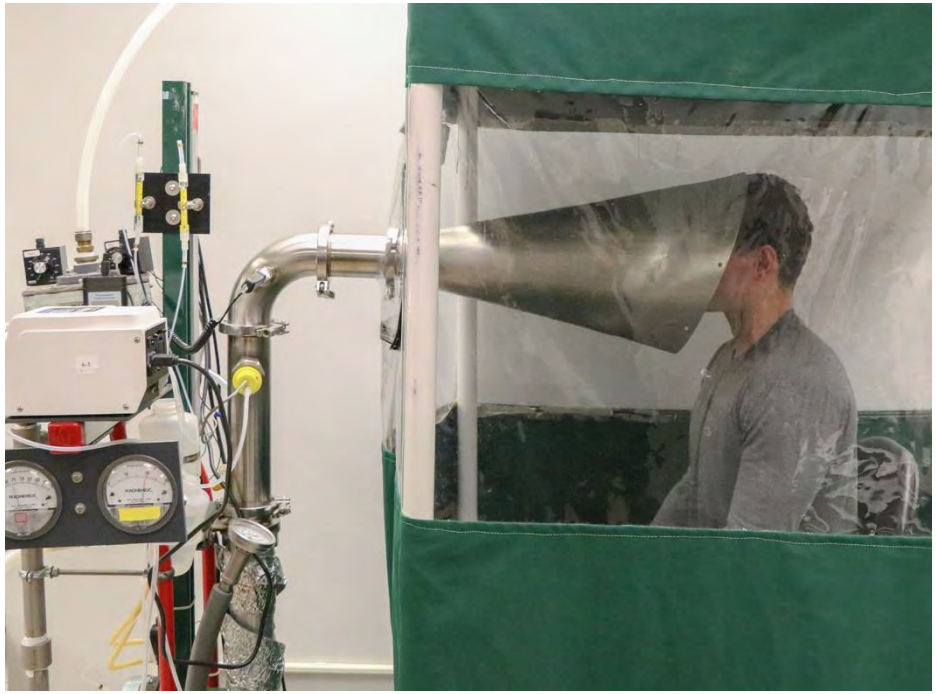




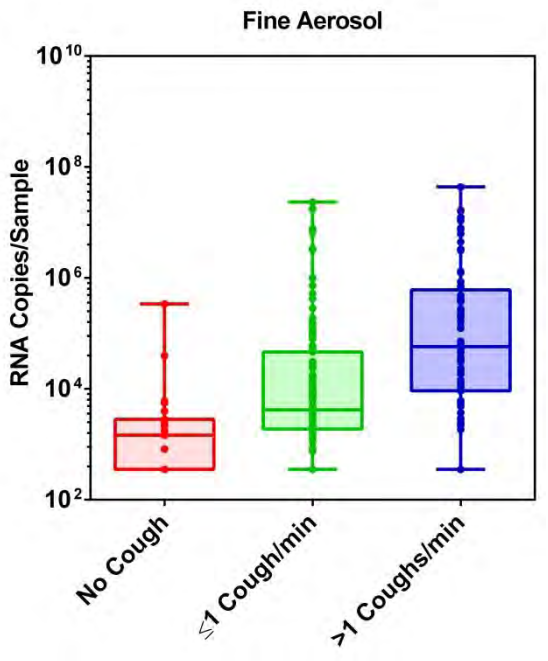
Gerone PJ, Couch RB, Keefer GV, Douglas RG, Derrenbacher EB, Knight V. Bacteriol Rev. 1966 Sep;30(3):576–88.

Gesundheit-II Human Bioaerosol Collector

- Coarse aerosol (> 5 and < 80 μm)
- Fine aerosol (> 0.05 μm and ≤ 5 μm)
- **Influenza virus was cultured from fine aerosol (~1/min)**
- **Influenza virus is present in exhaled breath** – even without coughing.



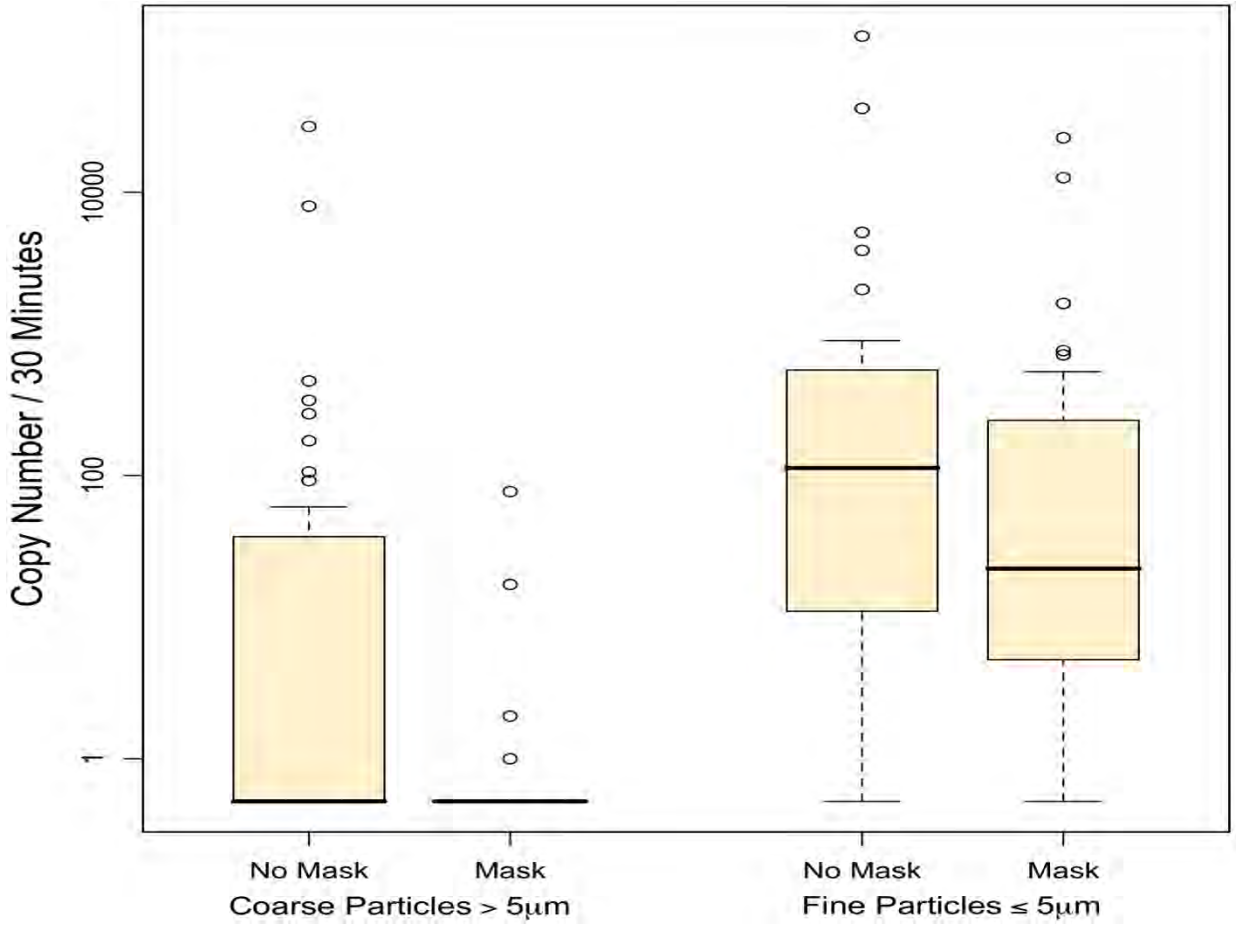
Influenza virus in exhaled breath



J. Yan *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **115**, 1081–1086 (2018)

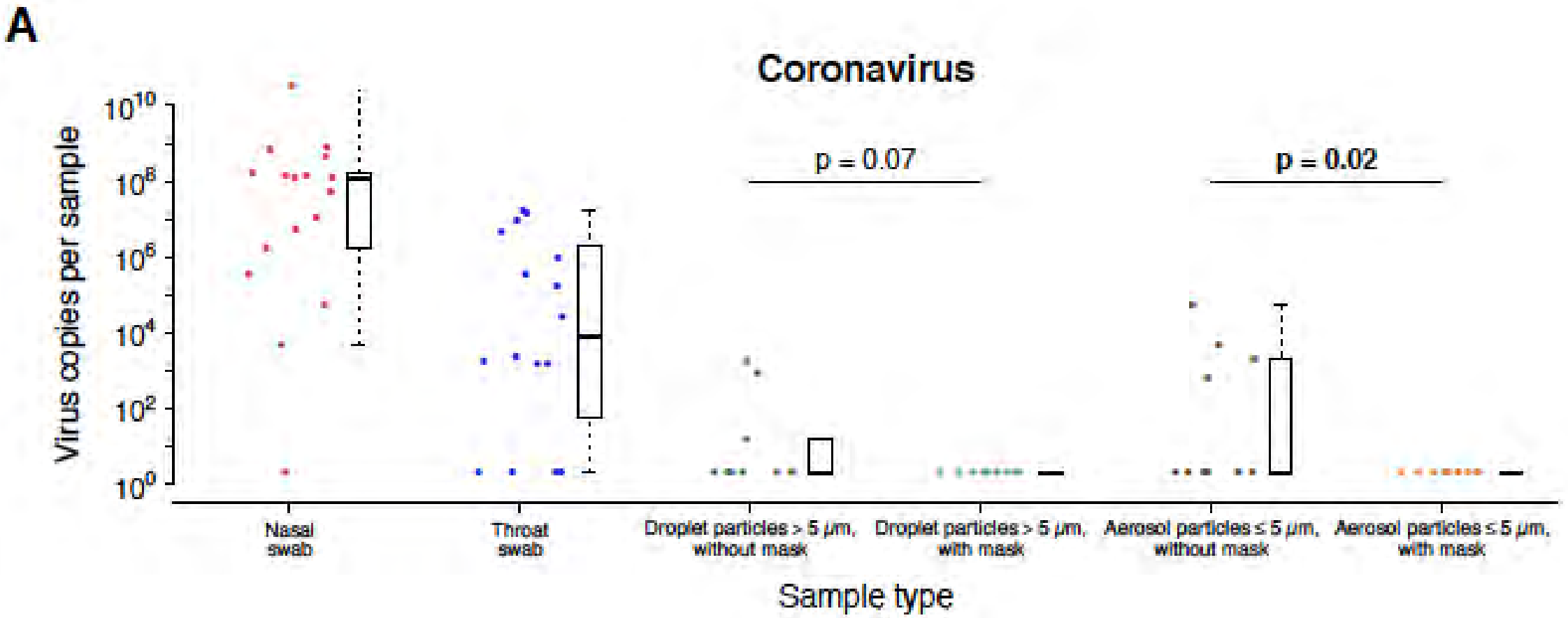
Masks as Source Control

Influenza Virus Copy Number In Aerosol Particles Exhaled By Patients With And Without Wearing Of An Ear-loop Surgical Mask



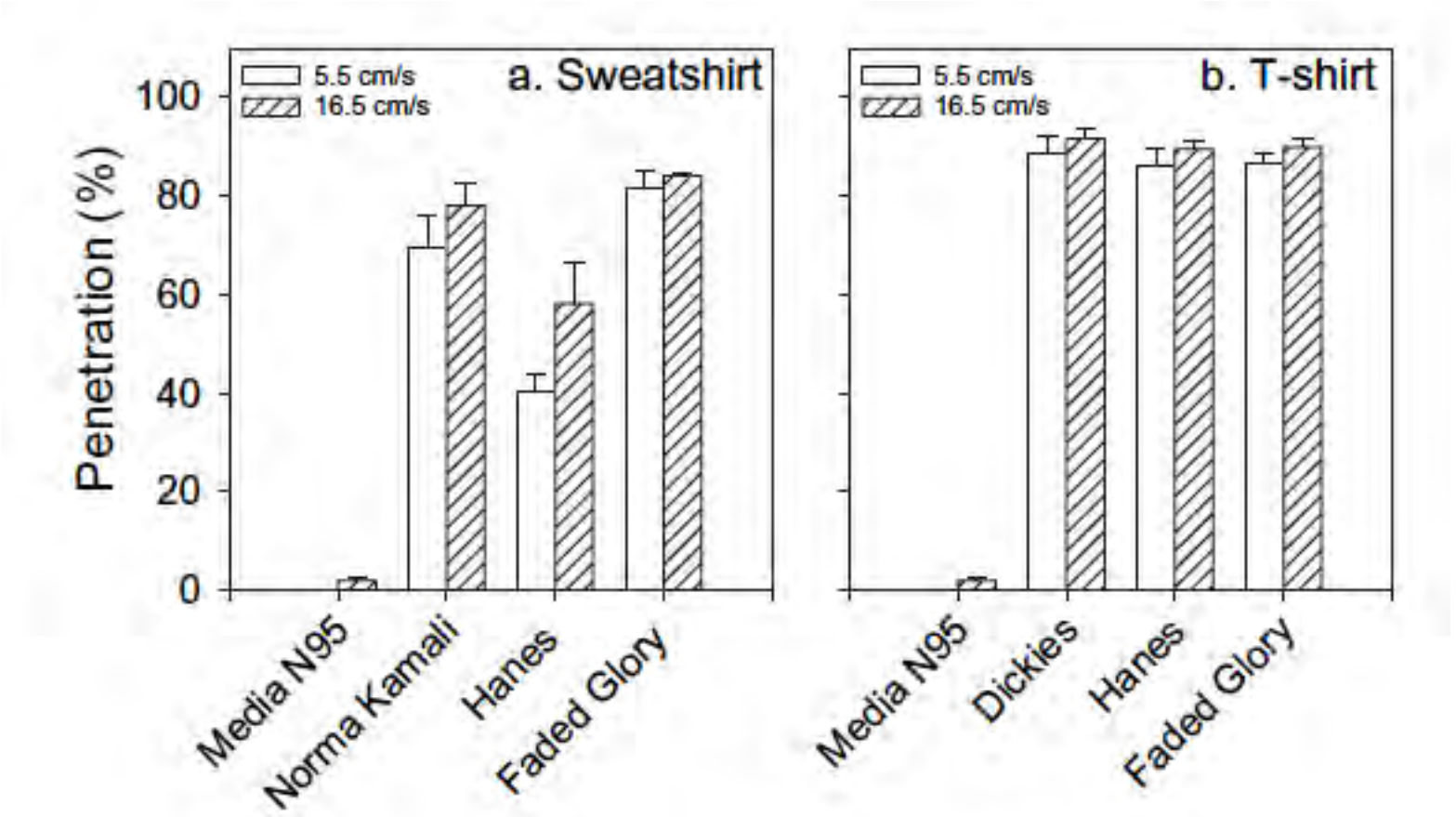
Milton DK et al. (2013) PLoS Pathog 9(3): e1003205.

Masks as Source Control



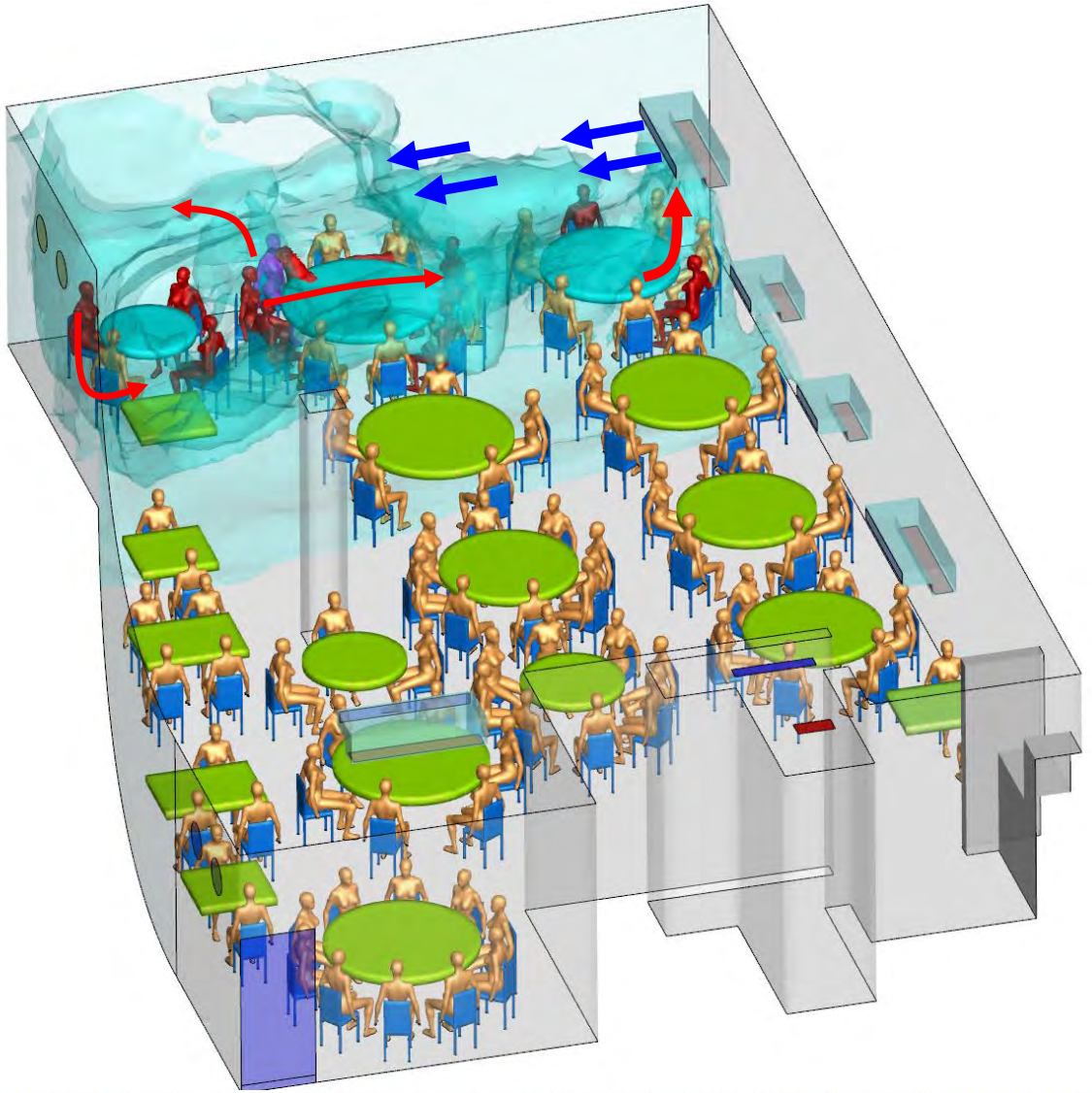
N. H. L. Leung *et al.*, *Nature Medicine*, 1–5 (2020).

Evaluation of the Filtration Performance of Cloth Masks and Common Fabric Materials



S. Rengasamy, B. Eimer, R. E. Shaffer, *Ann Occup Hyg*. **54**, 789–798 (2010).

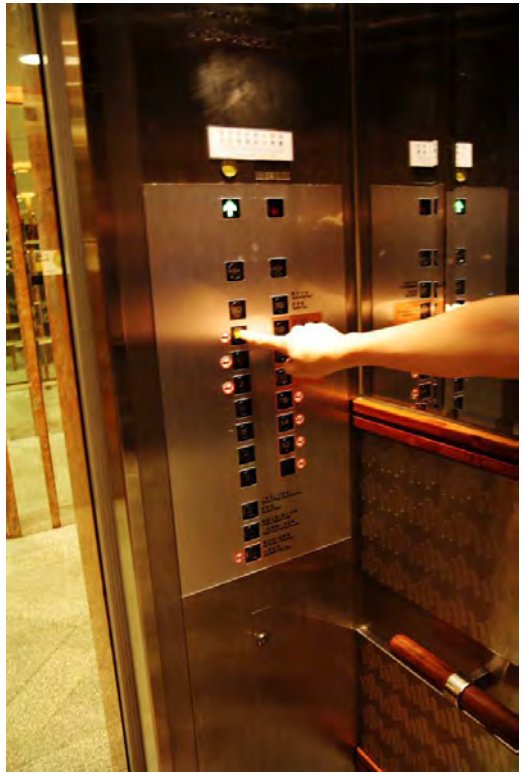
If only the exhaust vents had been open!



Y. Li *et al.*, *medRxiv*, in press, doi:10.1101/2020.04.16.20067728.

Metropol Hotel Hong Kong

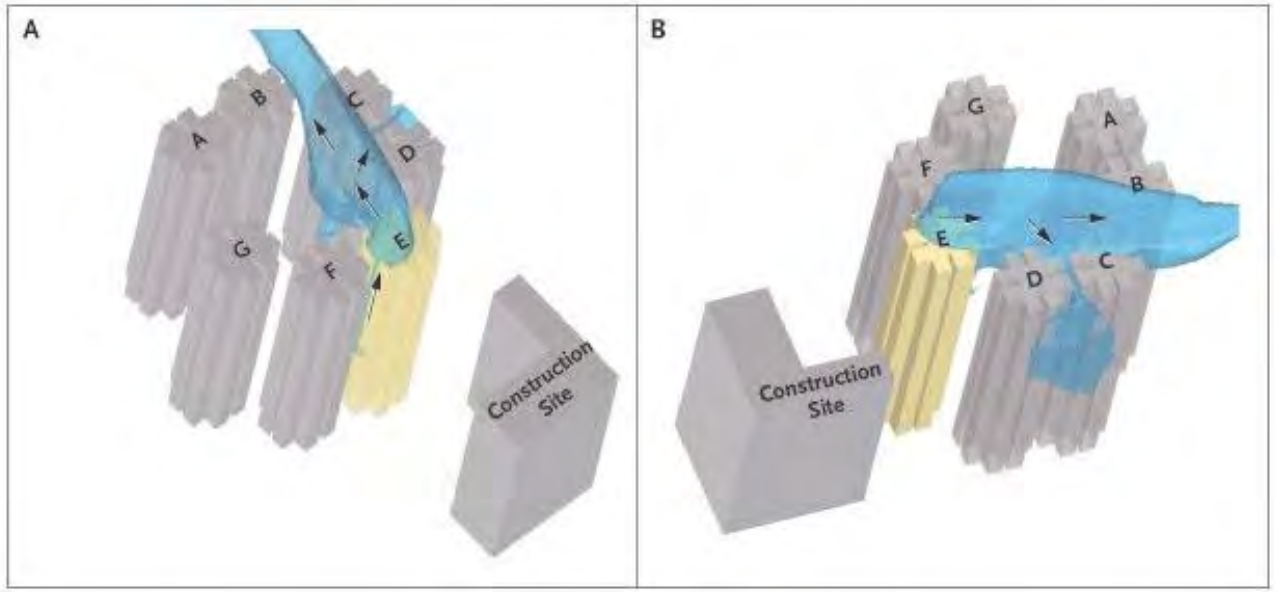
Were elevator buttons key to global dissemination of SARS?



Room 911 was renumbered as 913

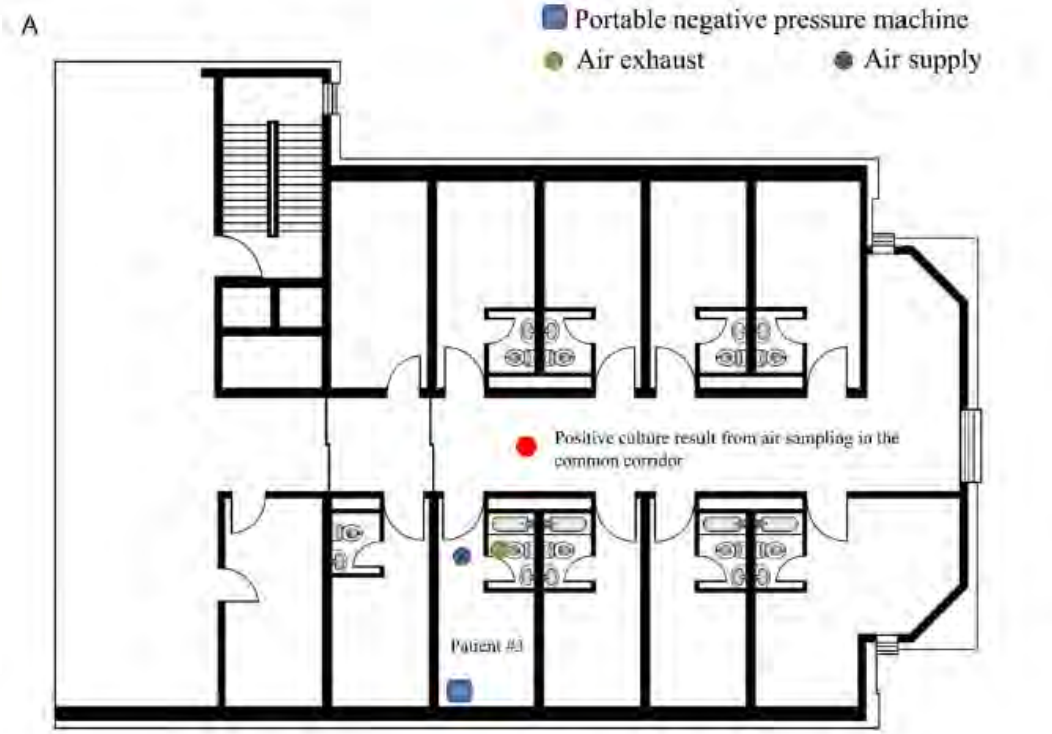
Aerosols in SARS and MERS

Amoy Gardens SARS Outbreak 187 Cases



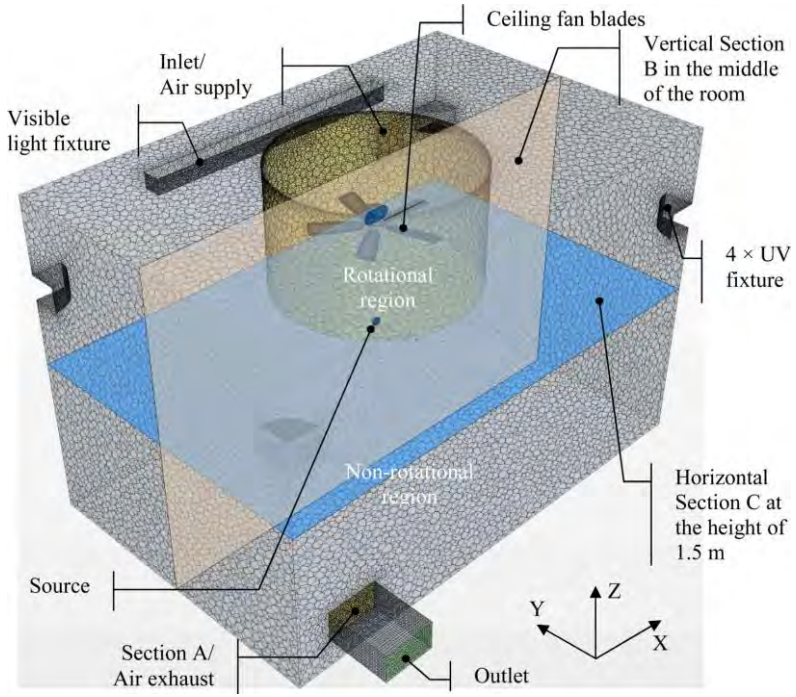
Yu, I. T.S. et al. N Engl J Med 2004;350:1731-1739

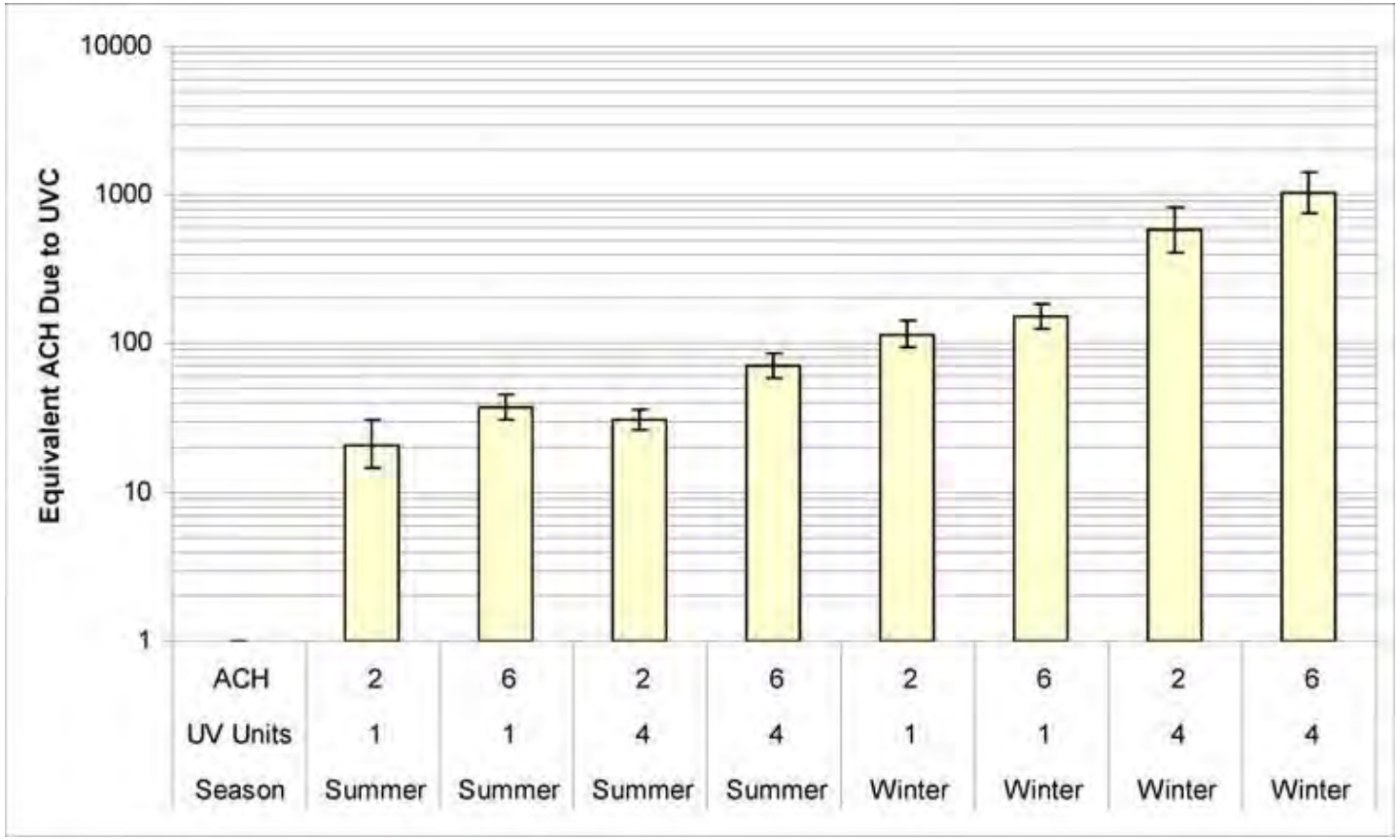
Infectious MERS-CoV in Hospital Corridor Air



S.-H. Kim *et al.*, *Clin. Infect. Dis.* **63**, 363–369 (2016).

Upper-room Germicidal UV (gUV) Air Sanitation: Additional Air Changes per Hour Equivalent (ACHe) Vaccinia Virus

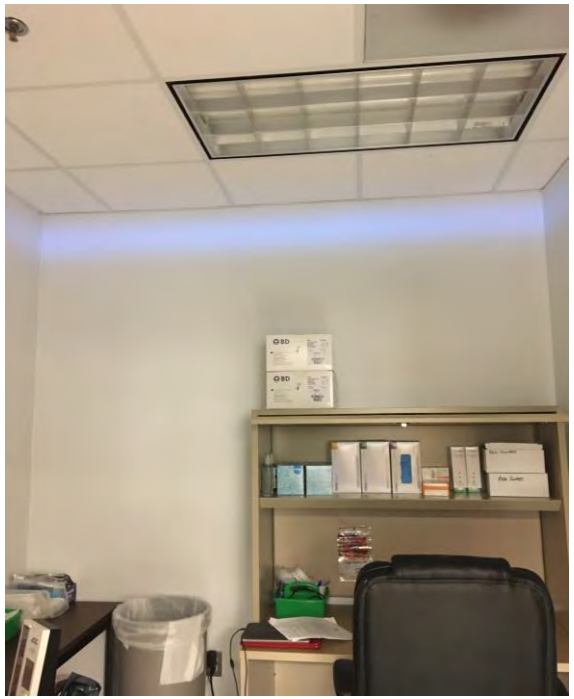




J. J. McDevitt, D. K. Milton, S. N. Rudnick, M. W. First, *PLoS ONE*. **3** (2008).
S. Zhu, J. Srebric, S. N. Rudnick, R. L. Vincent, E. A. Nardell, *Photochem. Photobiol.* **89**, 782–791 (2013).

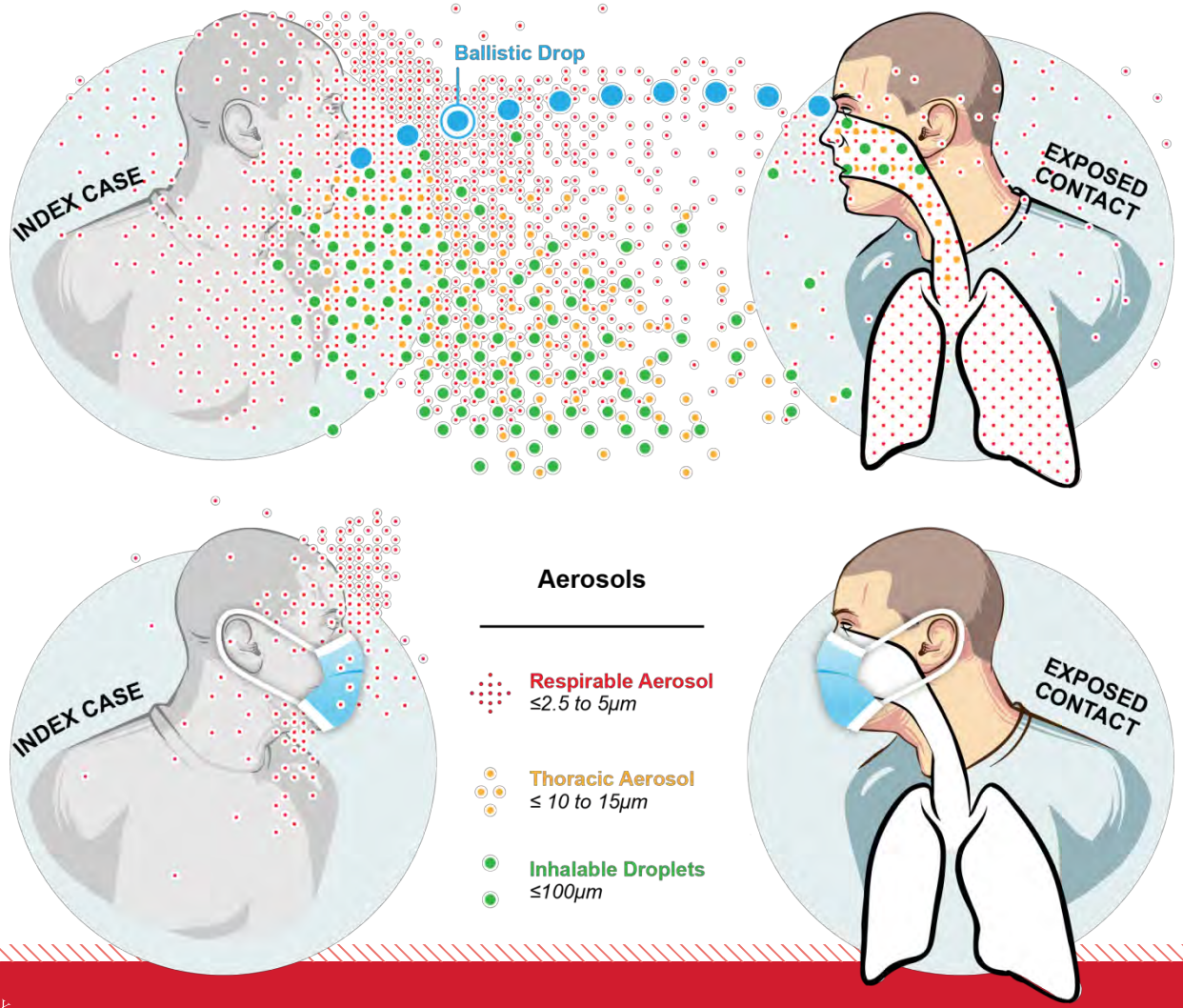
Research Clinic at University of Maryland with gUV

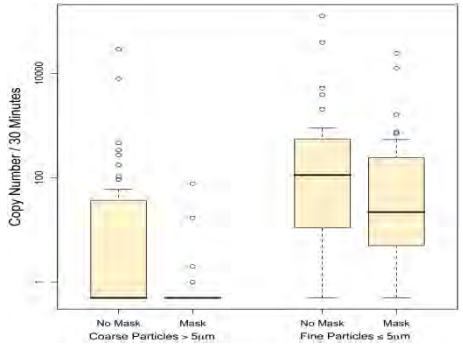
- Coronaviruses are ~ 1/5th as sensitive to gUV as Vaccinia
- ACHe Vaccinia
  - Summer 1 fixture 20
  - Winter 4 fixtures 1000
  - With ceiling fan
- 480 ACHe for Coronaviruses
  - Half-life = 5.25 sec.
  - 99.9% removal in 37 sec.



Classroom with UV Lights and Mixing Fan

Masks and SARS-Cov-2?





Milton DK et al. (2013) PLoS Pathog 9(3): e1003205.

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