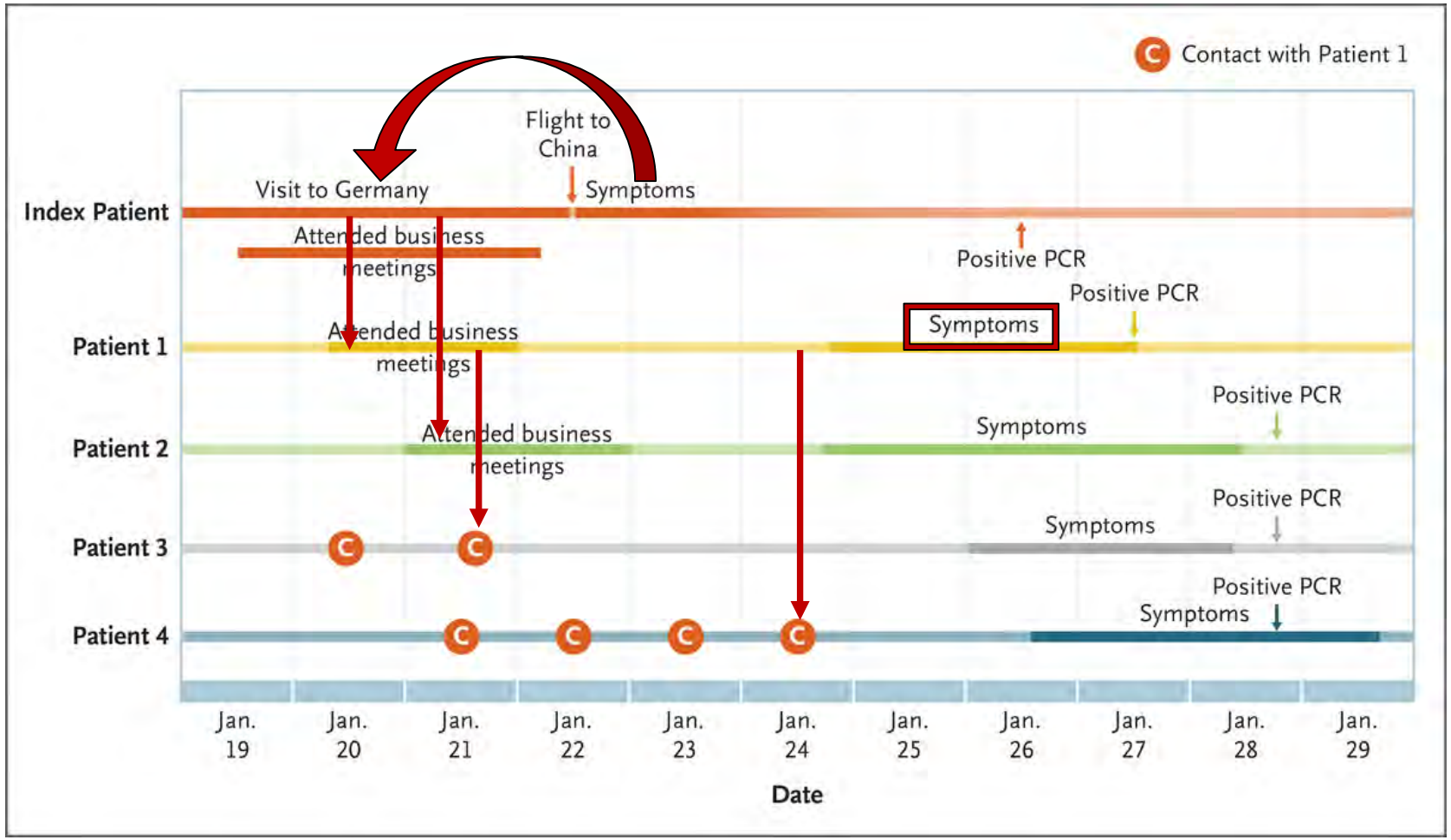
Transmission Perspective on COVID-19
and the Future of Singing

Donald Milton, MD, DrPH / Professor / Institute for Applied Environmental Health

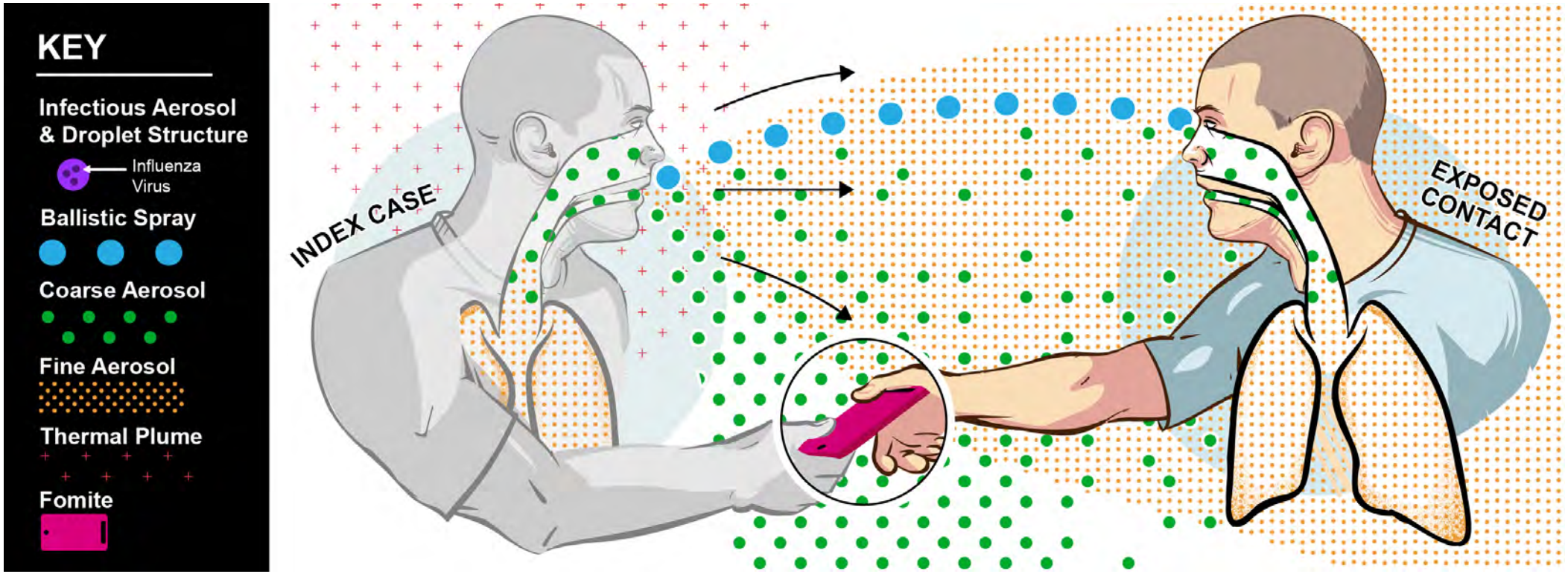
Wuhan

Timeline of Spread from Asymptomatic Patient 1 in Germany



C Rothe et al. N Engl J Med 2020. DOI: 10.1056/NEJMc2001468

Modes of Transmission?



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

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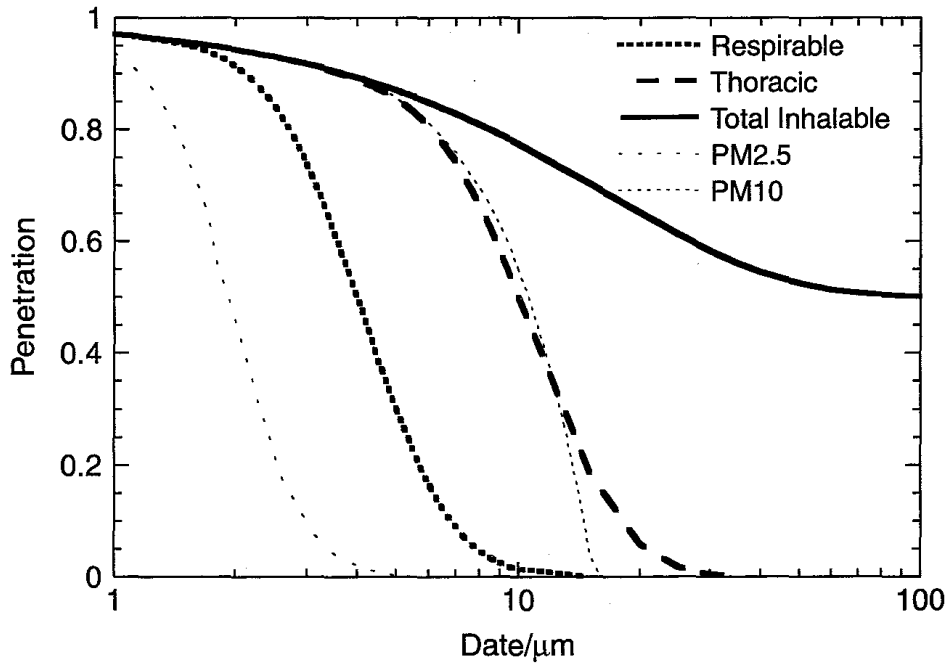
Pulmonary physiology – exposure science based categories



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

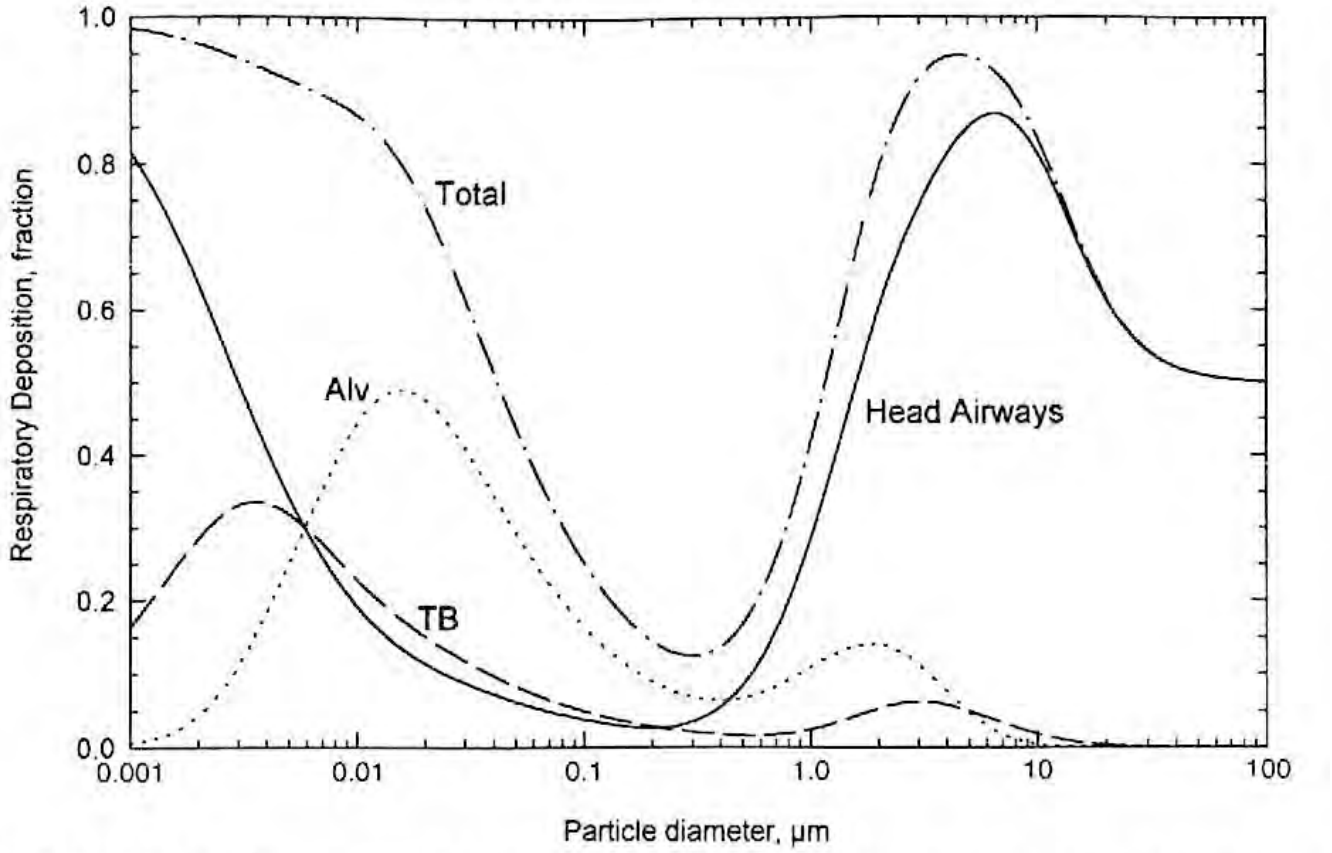
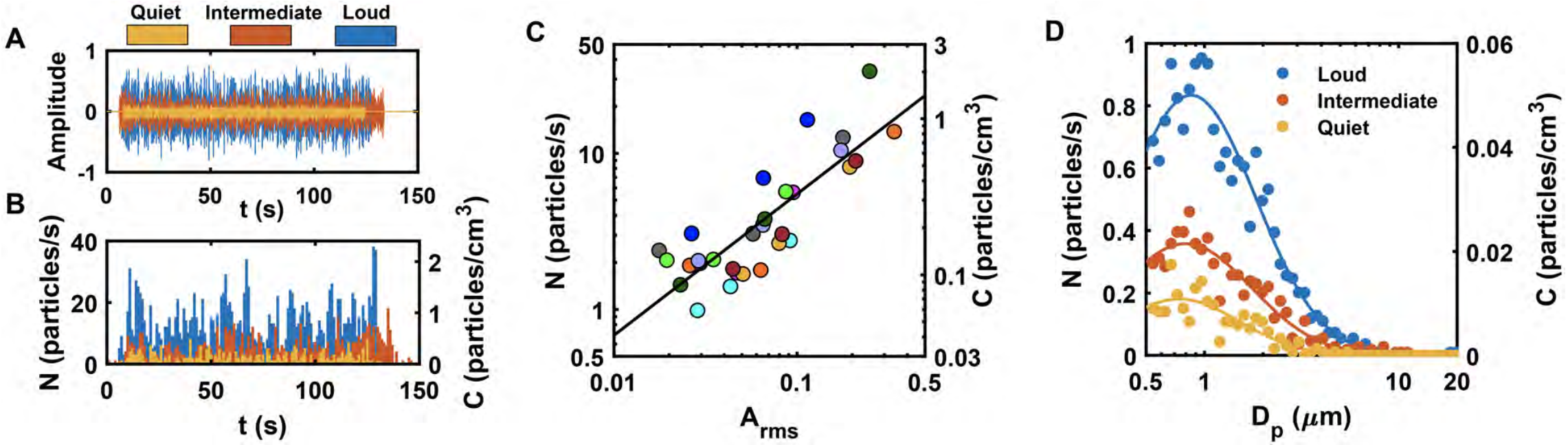


FIGURE 11.3 Predicted total and regional deposition for light exercise (nose breathing) based on ICRP deposition model. Average data for males and females.

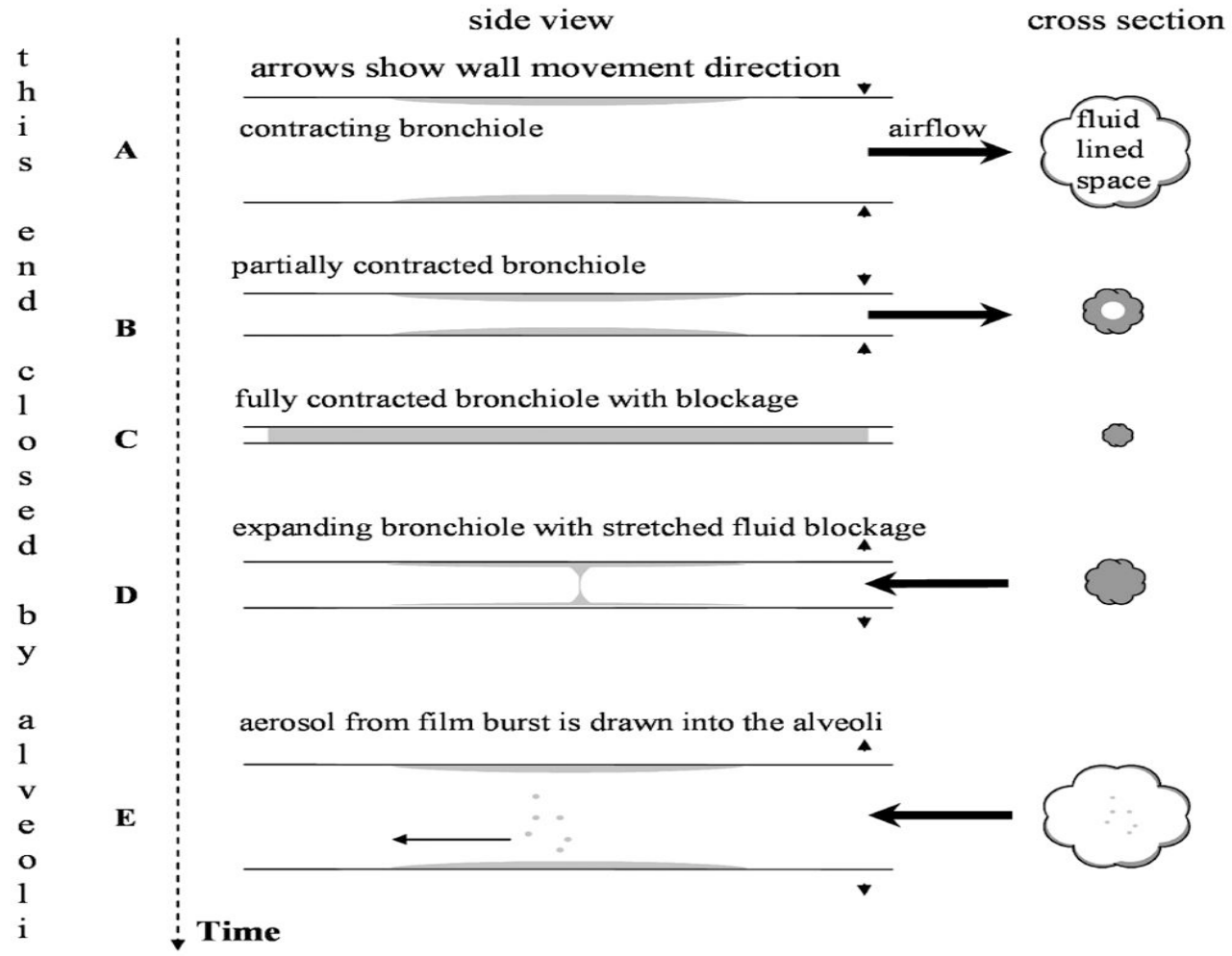
Hines WC Aerosol Technology, 1999

Aerosol emission and superemission during human speech increase with voice loudness



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

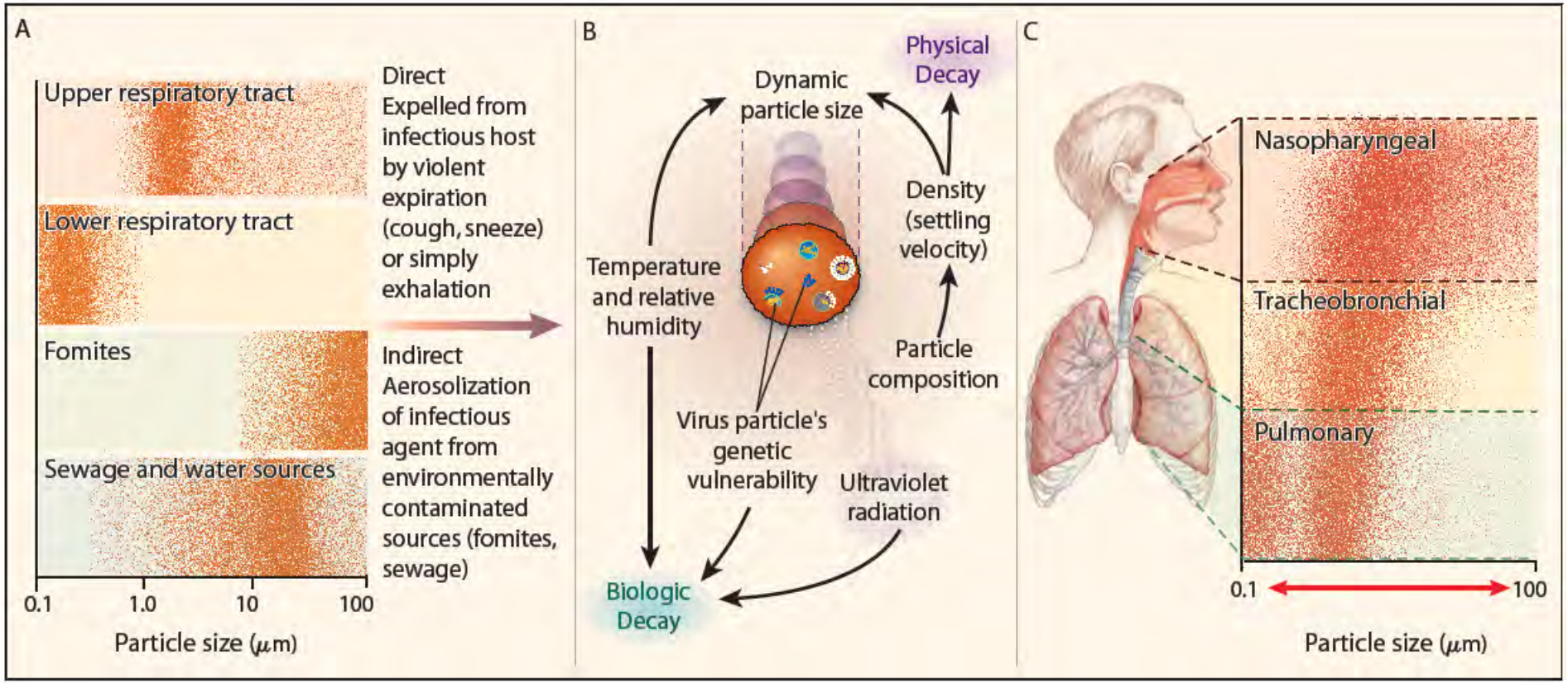
Mechanism of Breath Aerosol Formation



Johnson & Morawska, 2009

The Elusive Pathway

The Aerobiological Pathway for Transmission of Communicable Respiratory Disease

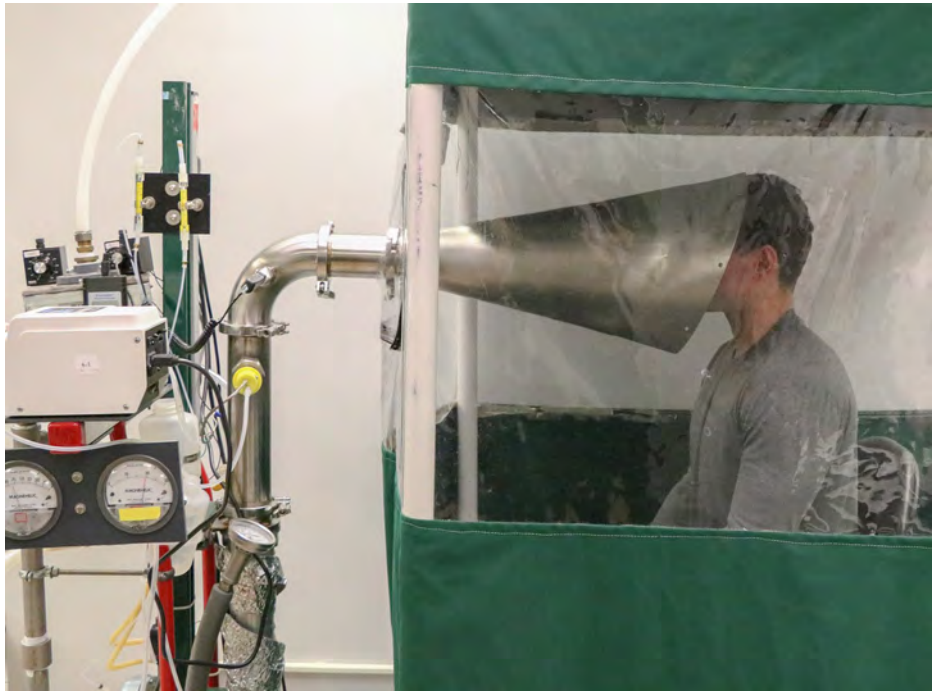


A: Source, B: Transport and Dispersion, C: Deposition

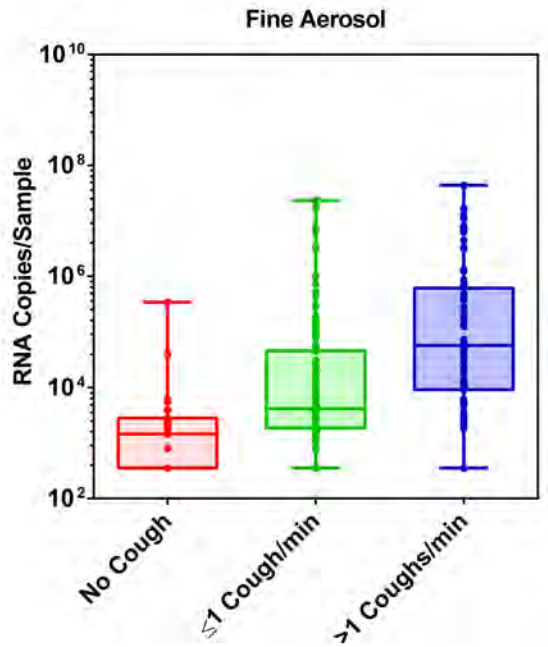
Roy C and Milton DK, New Engl J Med, 2004

Modes of Transmission?

- Gesundheit-II exhaled breath sampler
- Fine aerosol = tiny particle suspended in air
- **Influenza virus is present in exhaled breath** – even without coughing.



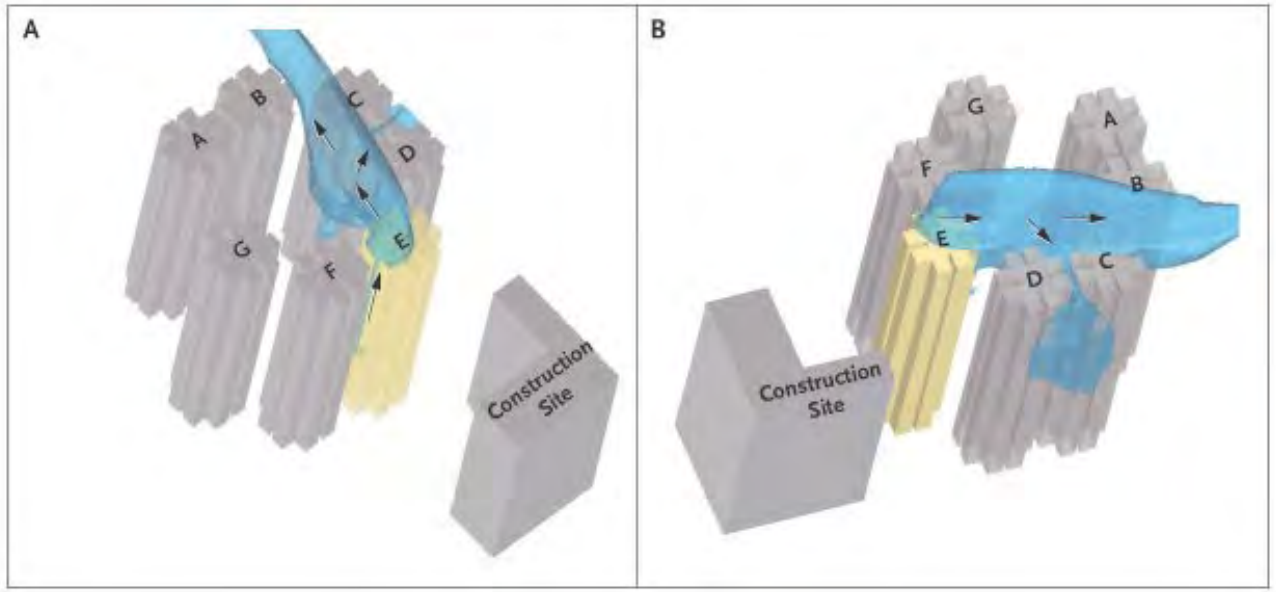
Influenza virus in exhaled breath



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

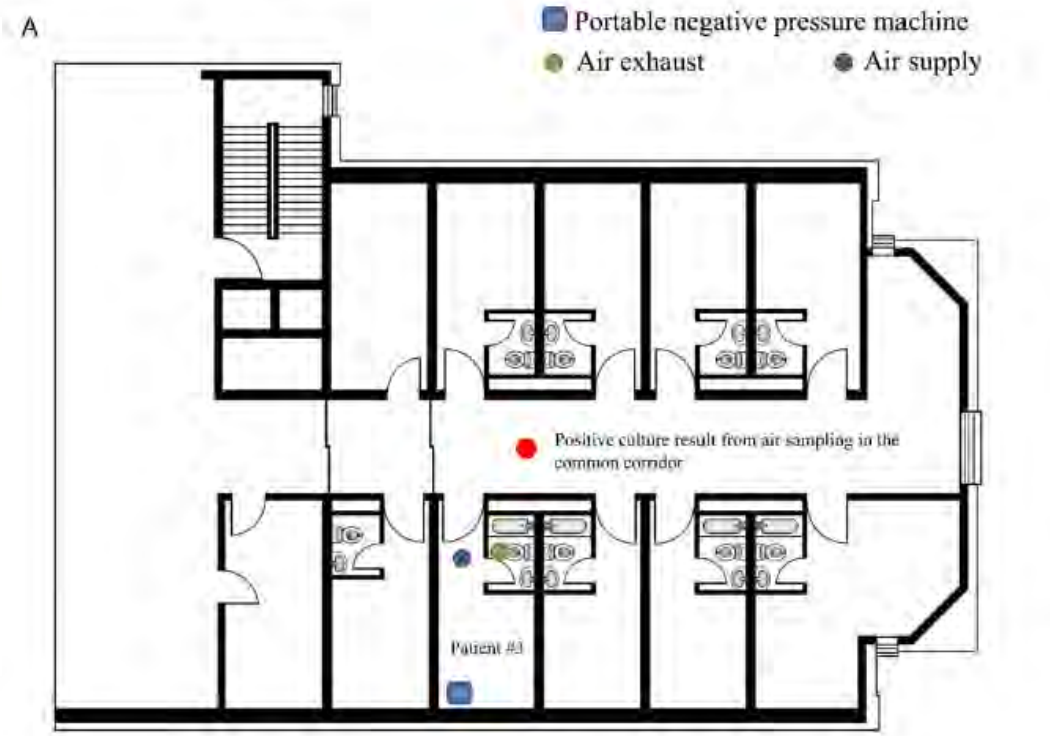
Modes of Transmission?

Amoy Gardens SARS Outbreak 187 Cases



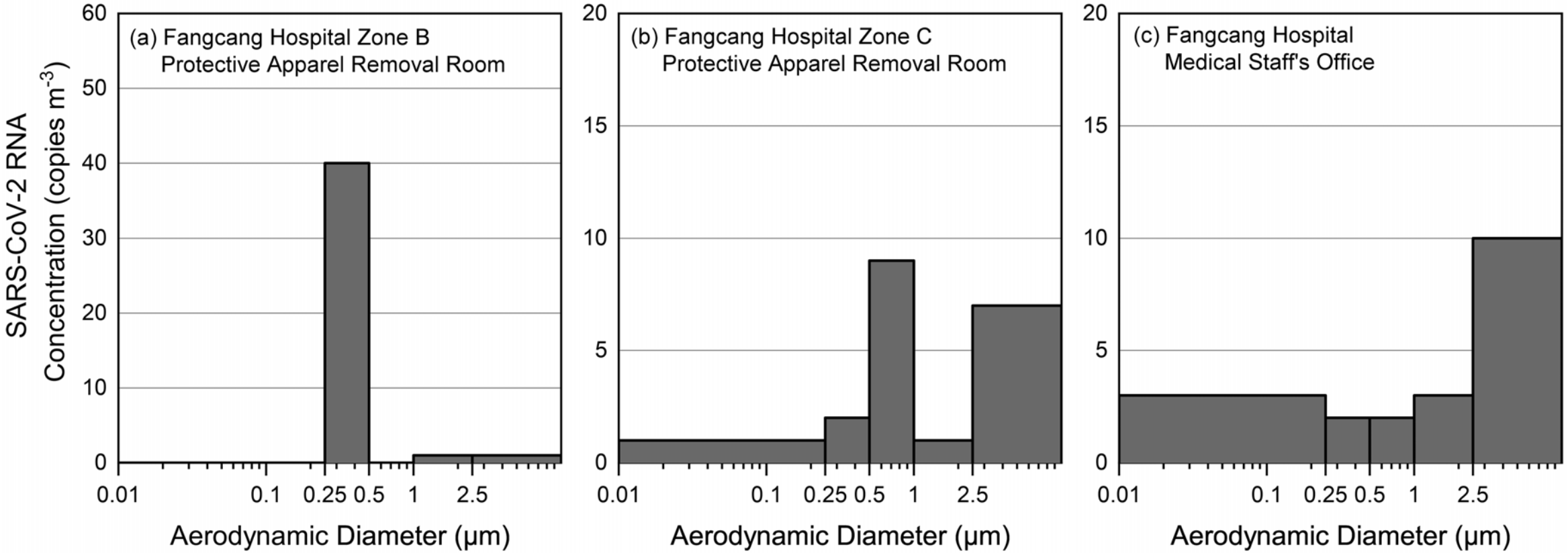
Yu, I. T.S. et al. N Engl J Med 2004;350:1731-1739

Infectious MERS-CoV in Hospital Corridor Air



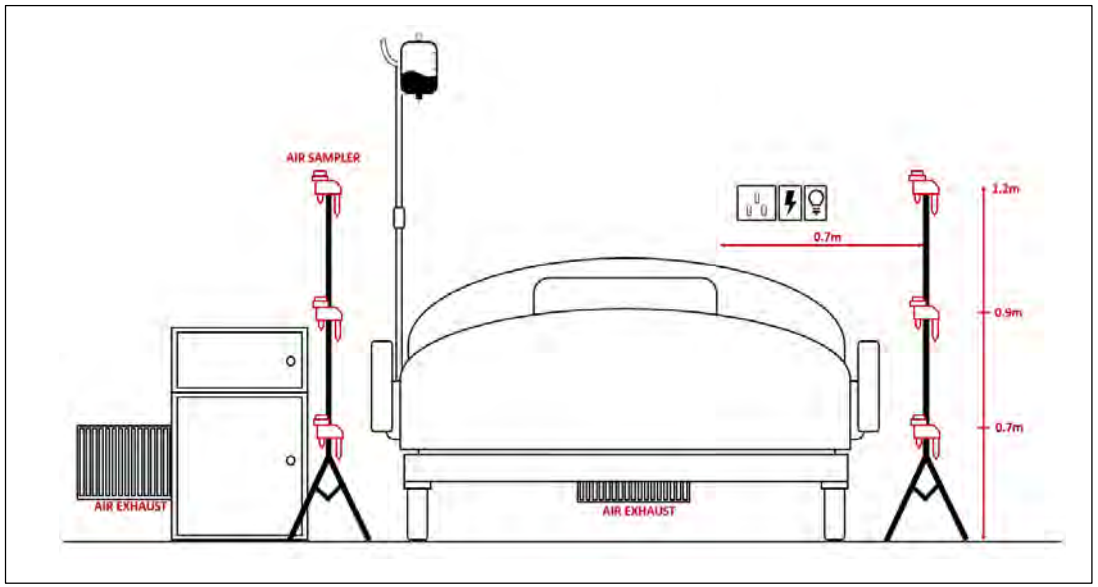
S.-H. Kim *et al.*, *Clin. Infect. Dis.* **63**, 363–369 (2016).

Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals



Y. Liu *et al.*, *Nature*, 1–6 (2020).

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

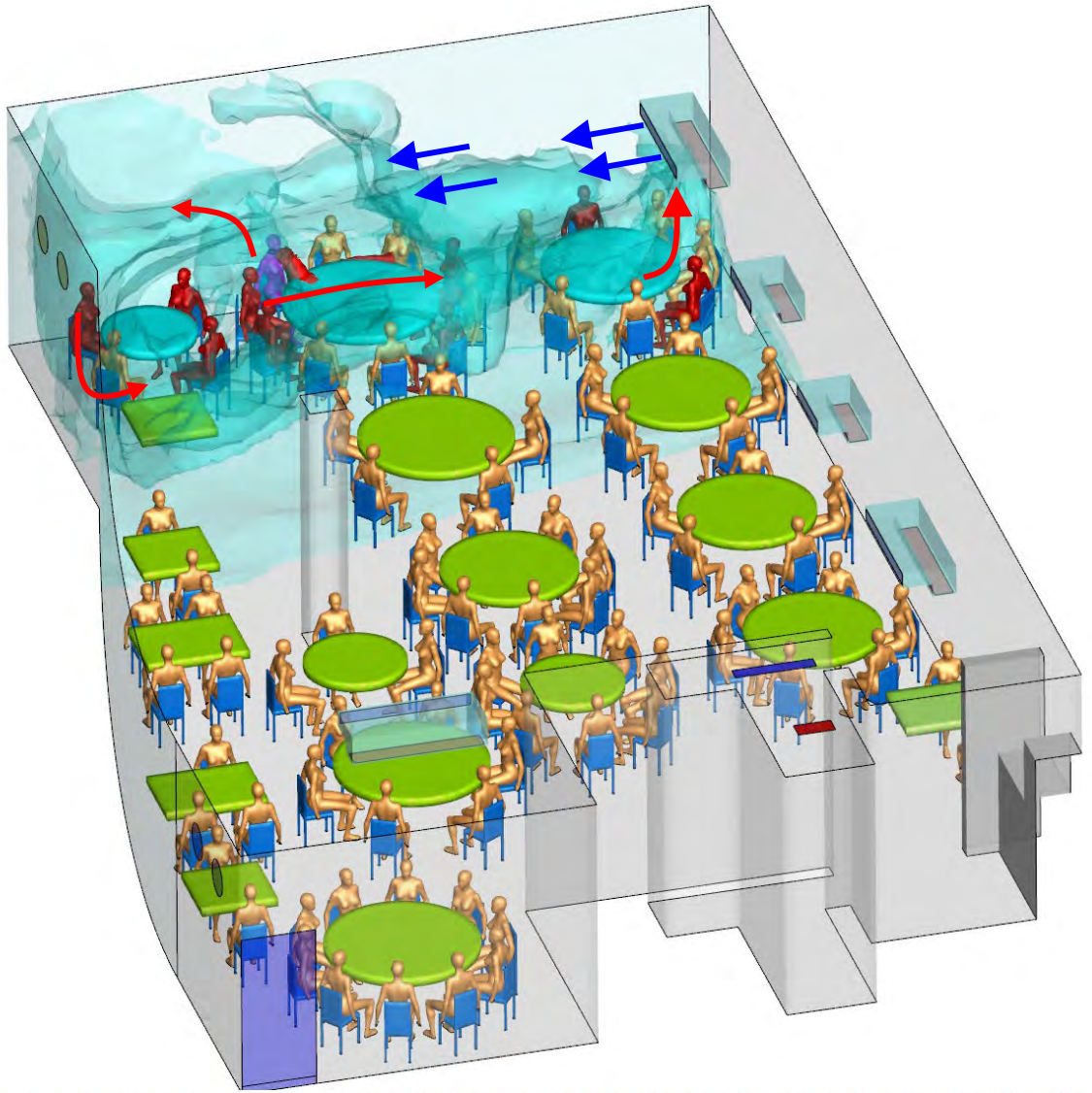
P. Y. Chia *et al.*, *medRxiv*, 2020, doi:10.1101/2020.03.29.20046557.

Transmission Potential of SARS-CoV-2 in Viral Shedding Observed at the University of Nebraska Medical Center

Location	Day	Hallway Air Samples (copies/L of air)		Personal Air Samples (copies/L of air)	
NQU	5	UND	NC		
	5	UND	NC		
	6	5.757	5.096		
	6	6.004	5.902		
	7	2.077	3.597		
	7	UND	NC		
	8	8.688	3.688		
	8	2.361	4.090		
	8	2.294	3.972		
	9			7.392	19.204
				5.366	7.150
NBU	10	UND	NC		
	10	2.994	5.186		
	10	0.979	1.695		
	18			19.174	49.817
				48.216	67.164
Percent Positive		66.7%		100.0%	

J. L. Santarpia *et al.*, *medRxiv*, 2020, doi:10.1101/2020.03.23.20039446.

Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant



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

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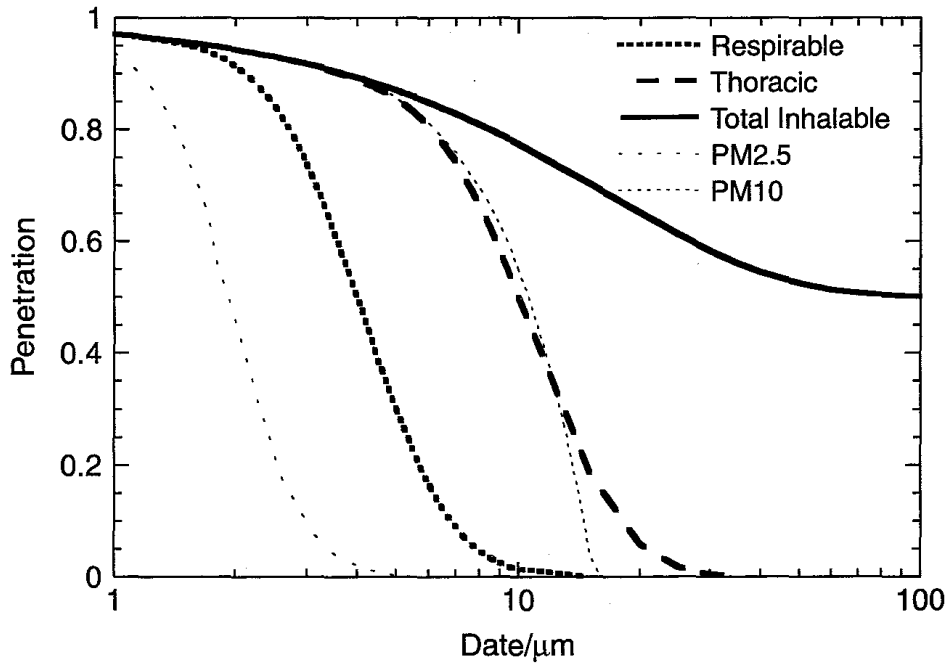

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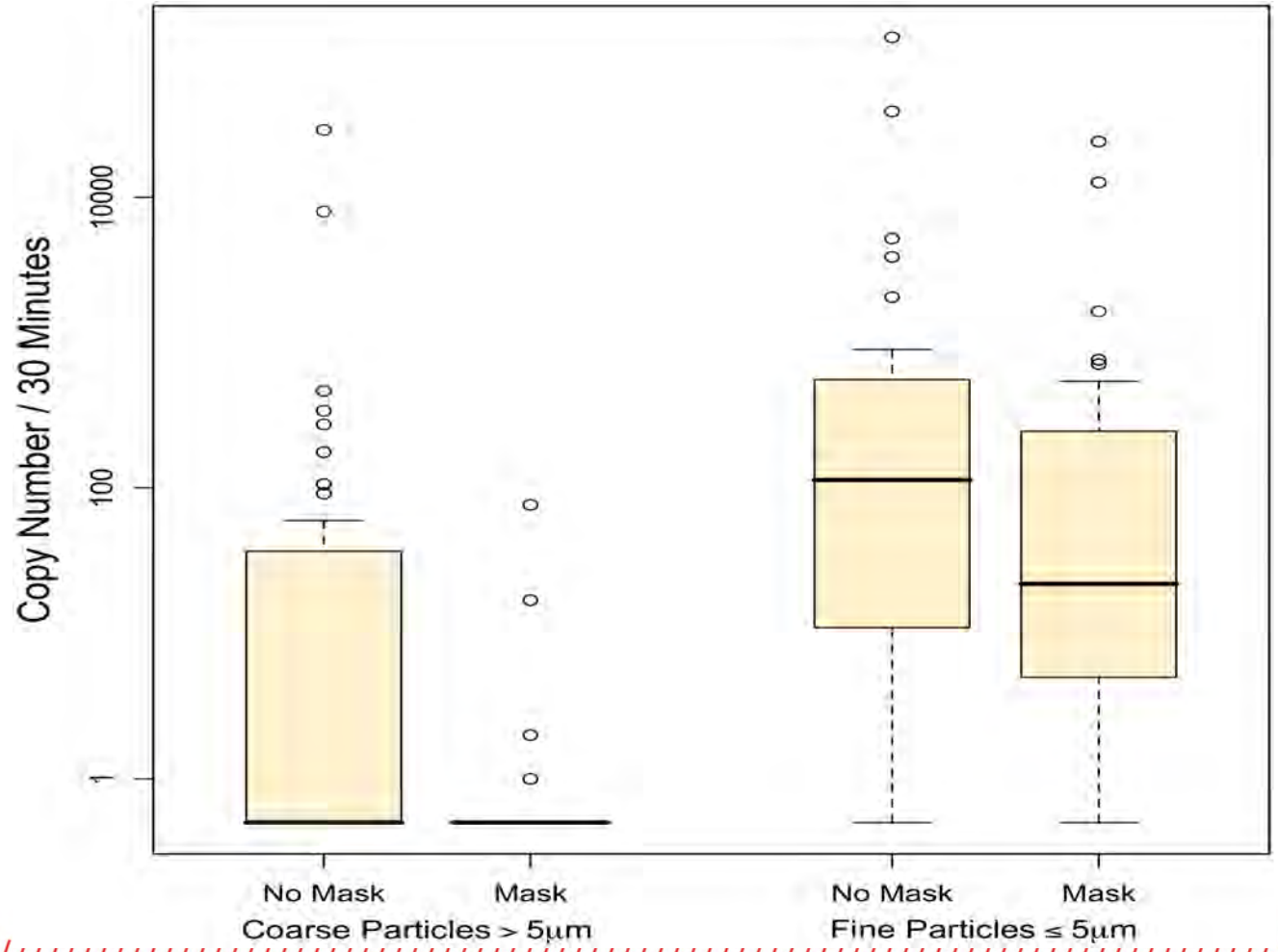
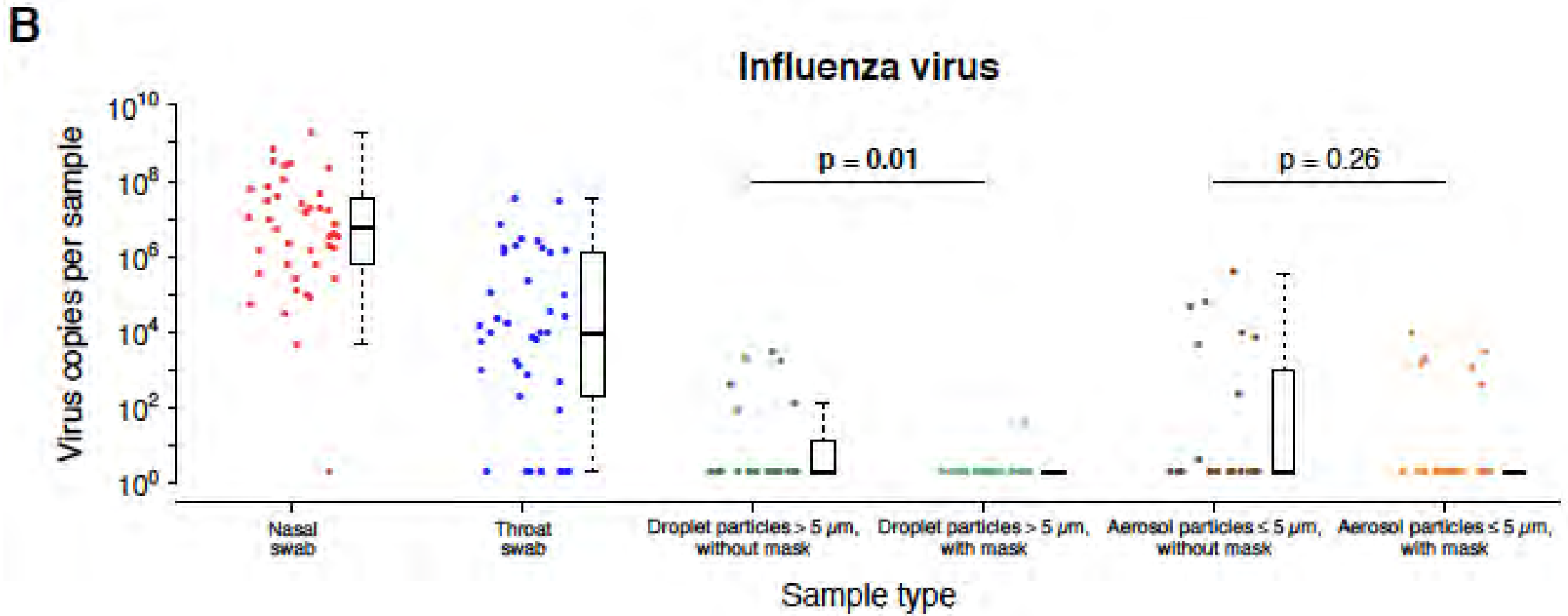
Influenza Virus Copy Number In Aerosol Particles Exhaled By Patients With And Without Wearing Of An Ear-loop Surgical Mask

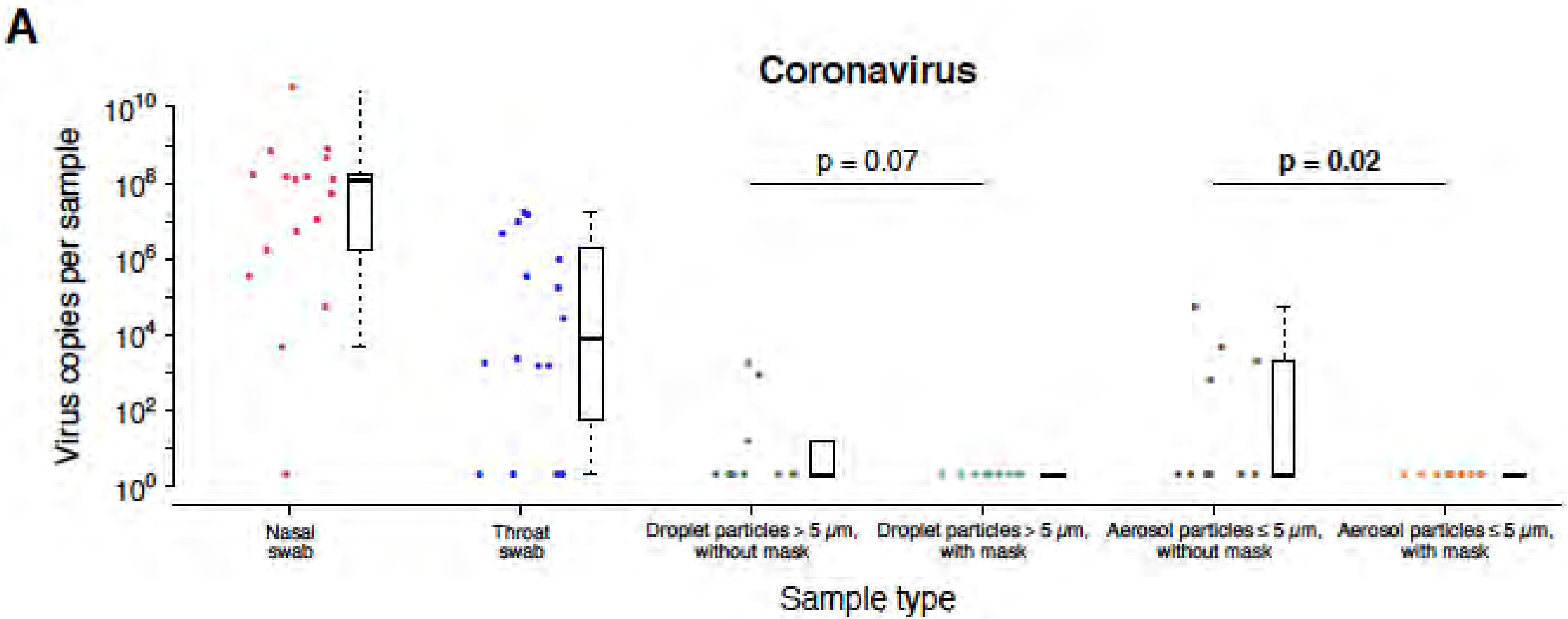


D. K. Milton, M. P. Fabian, B. J. Cowling, M. L. Grantham, J. J. McDevitt, *PLoS Pathog.* **9**, e1003205 (2013).

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

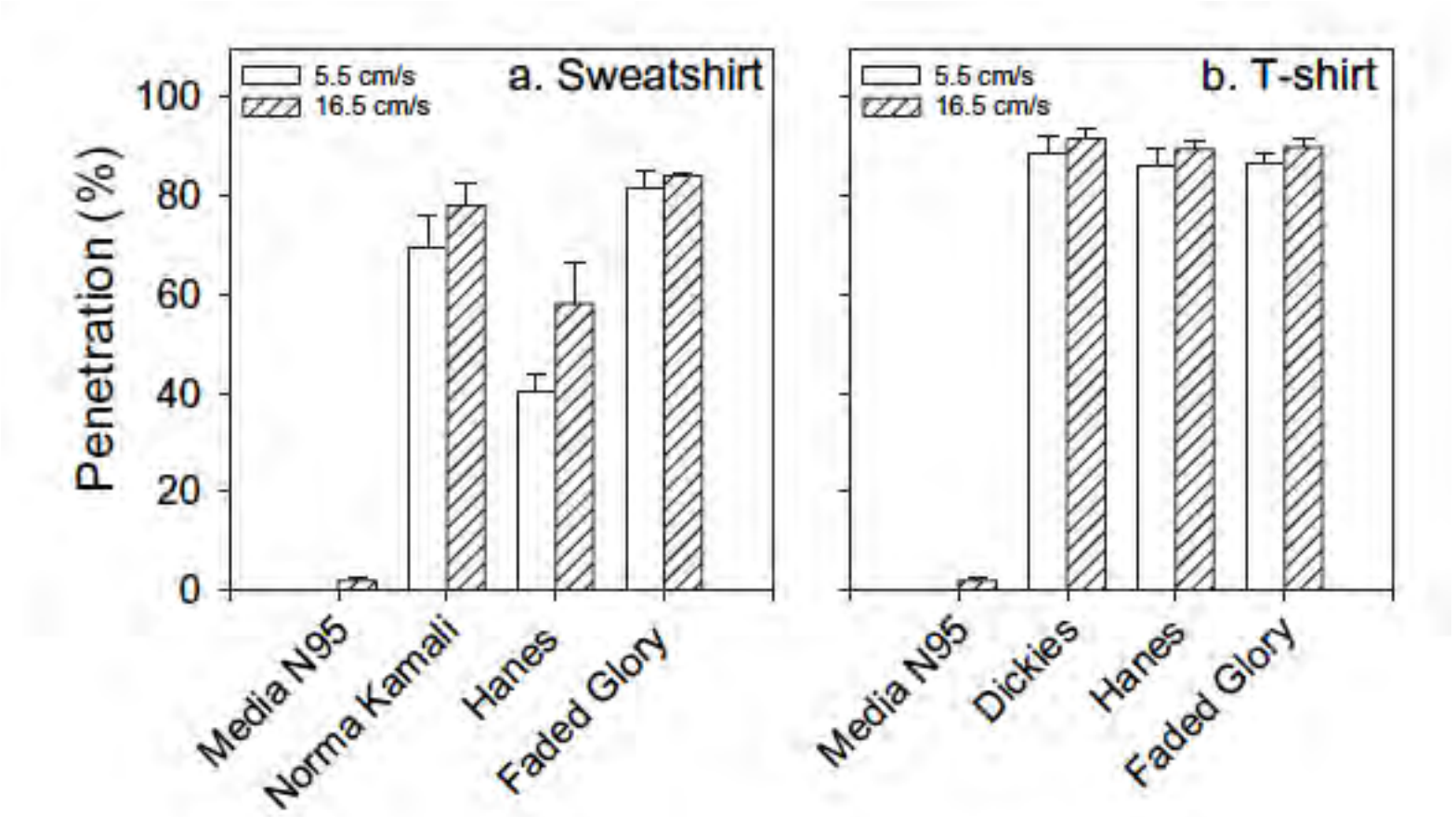


N. H. L. Leung *et al.*, *Nature Medicine*, 1–5 (2020).



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

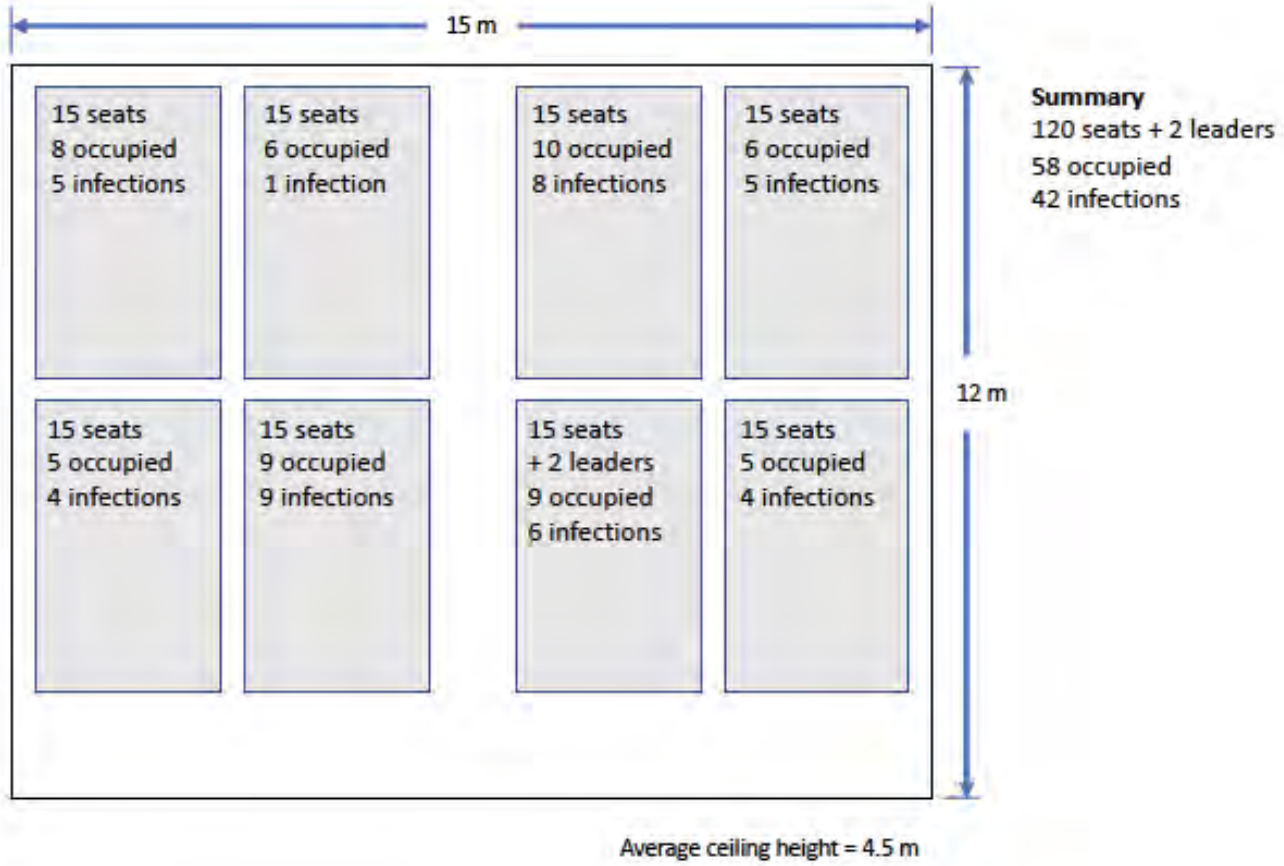
Evaluation of the Filtration Performance of Cloth Masks and Common Fabric Materials



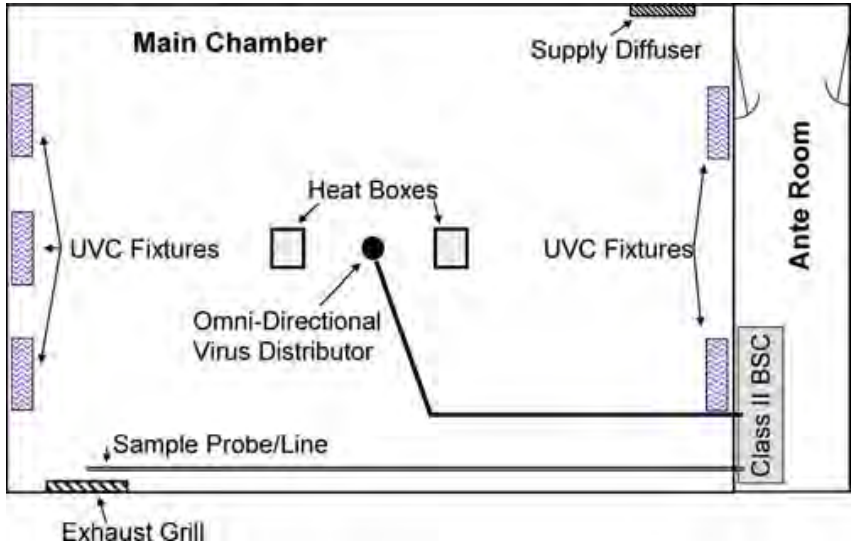
S. Rengasamy, B. Eimer, R. E. Shaffer, *Ann Occup Hyg*. **54**, 789–798 (2010).

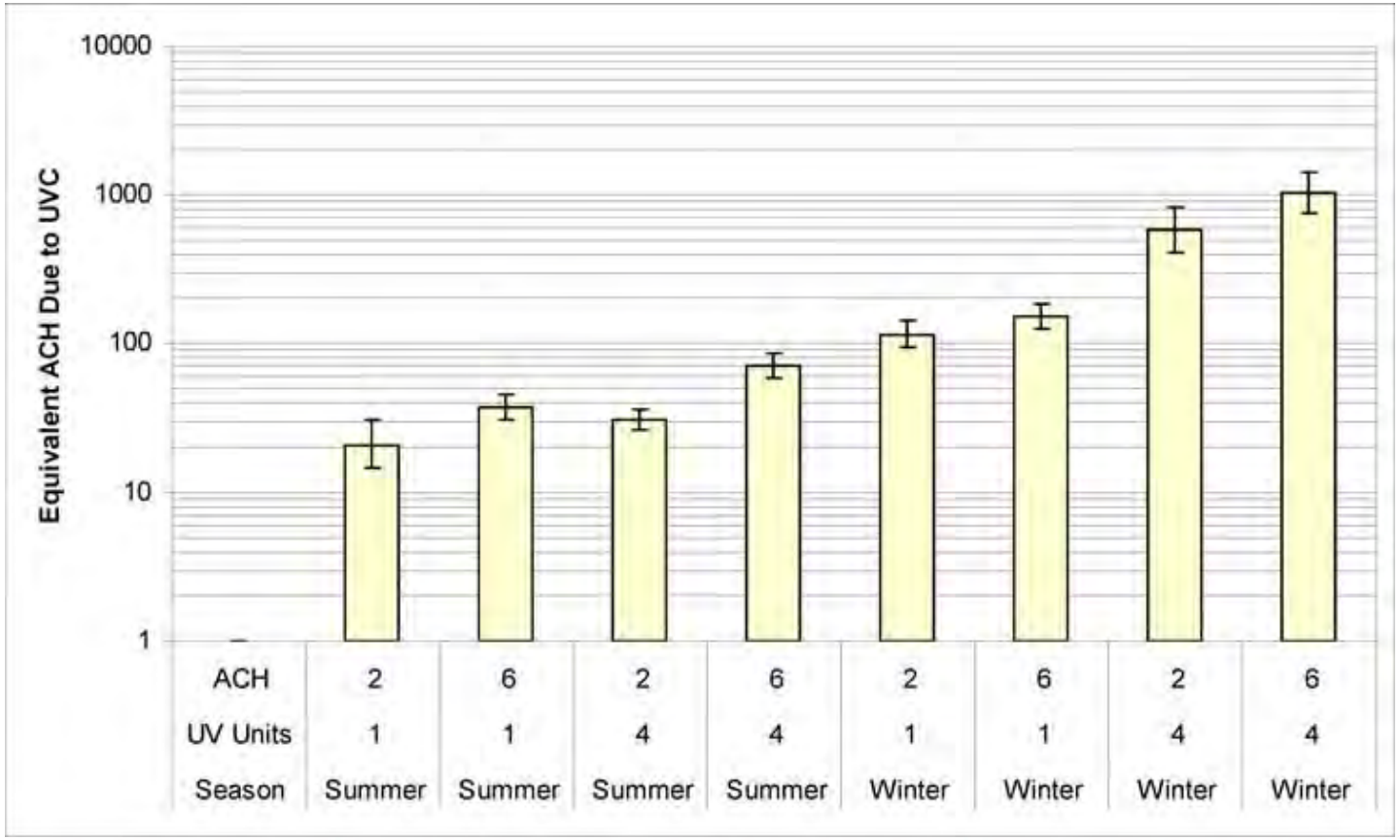
Skagit Choir Outbreak

- March 10, 2020
- “About 55 people (roughly one-half of the group) attended.”
- At the time of the rehearsal, there were no known cases in Skagit Valley, nor were any closures in effect.
- Notice to members: “Anyone showing any symptoms of illness, no matter the cause, should not attend rehearsals.”
- ~70% infection rate
- 0.5 air changes per hour estimated
- Increase to 9 air changes per hour would have reduced to 14% infected, if airborne transmission



Upper-room Germicidal UV (gUV) Light Air Sanitation





J. J. McDevitt, D. K. Milton, S. N. Rudnick, M. W. First, *PLoS ONE*. **3** (2008).