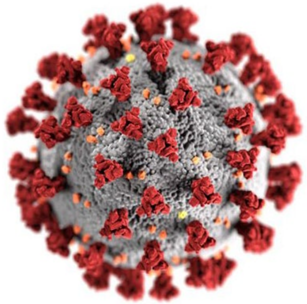


SARS-COVID-2 transmission and prevention

Glenn Morrison (and many slides from Barbara Turpin)

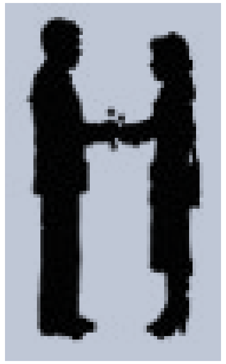
Environmental Sciences and Engineering

Gillings School of Global Public Health

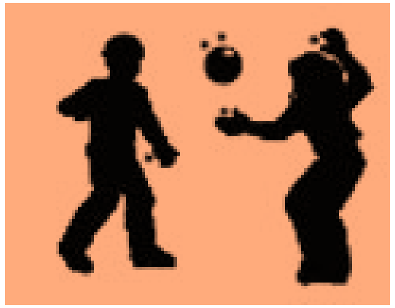
UNC | GILLINGS SCHOOL OF GLOBAL PUBLIC HEALTH

100 years
Environmental solutions for a changing world
1921-2021

Virus transmission



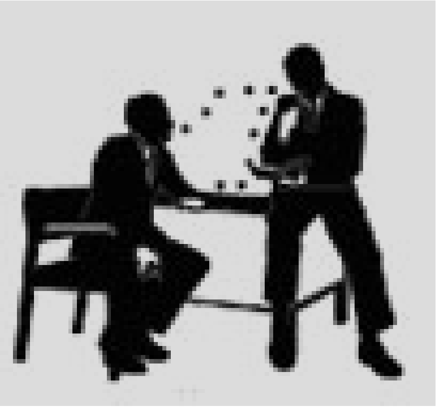
direct contact



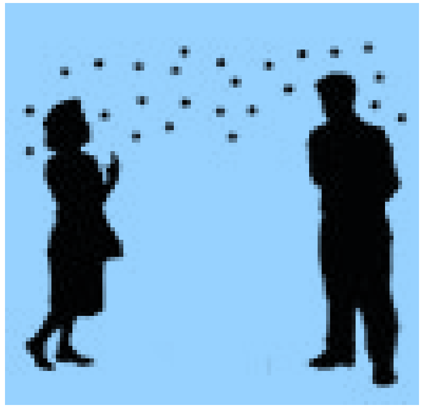
Fomite
pathway

indirect contact

close-range
only (<2 m)



large droplets

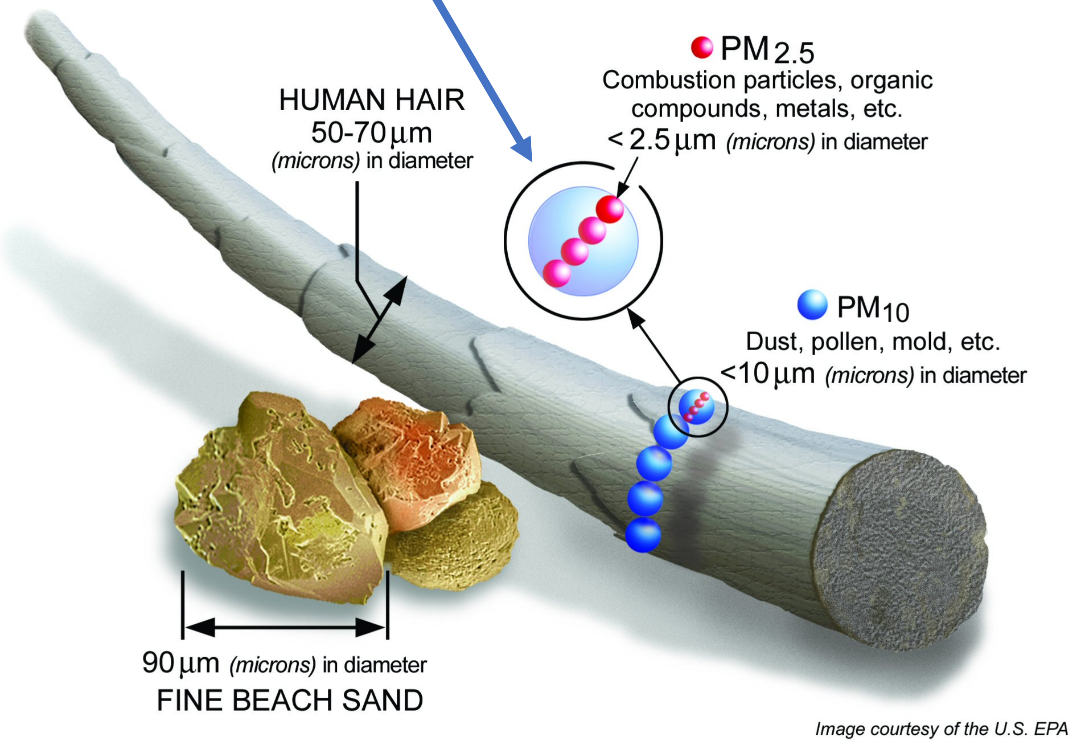


aerosols

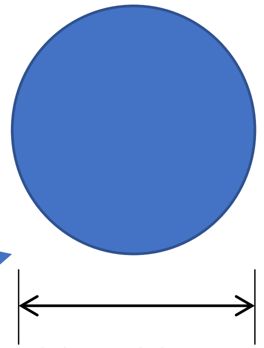
Aerosols,
Close and
long range

What are aerosols?

Aerosols: liquid or solid particles suspended in air (or other gas)



Droplets:
Large, fall to ground quickly

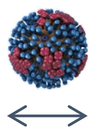


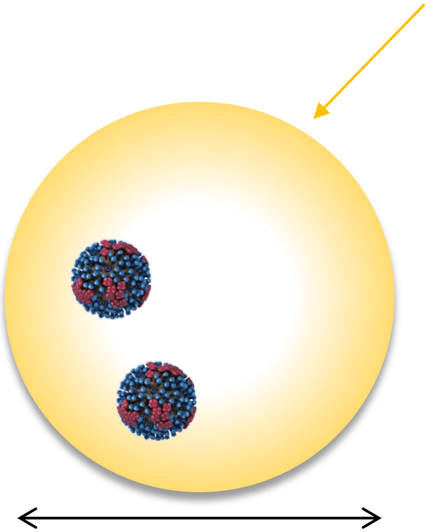
20 - 100 µm
Like cloud or rain droplets

https://www.cdc.gov/flu/resource-center/freeresources/graphics/images.htm, http://solutionsdesignedforhealthcare.com/rhinovirus, https://phil.cdc.gov/Details.aspx?pid=23312, https://pdb101.rcsb.org/motm/132

Size Matters

- Airborne virus is not naked!





- Size determines
  - Lifetime in the atmosphere
  - Where it deposits in the respiratory system

Aerosol generated by Breathing, speaking, and coughing

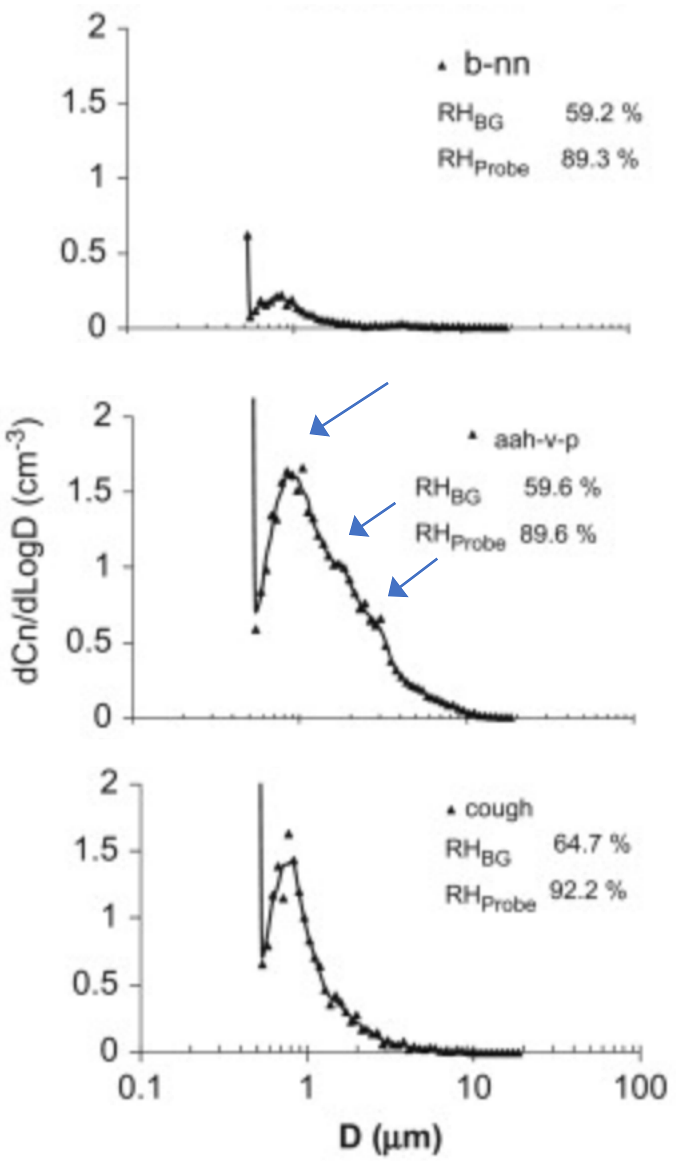
High air velocity shears respiratory fluids during expiration

Modes:

0.8 μm (largest mode)
2-4 μm (two modes)
100 μm (smaller)

Droplets (100 μm):
By number, 0.8μm mode is 100 times larger (coughing)

Aerosol size distribution (by number)



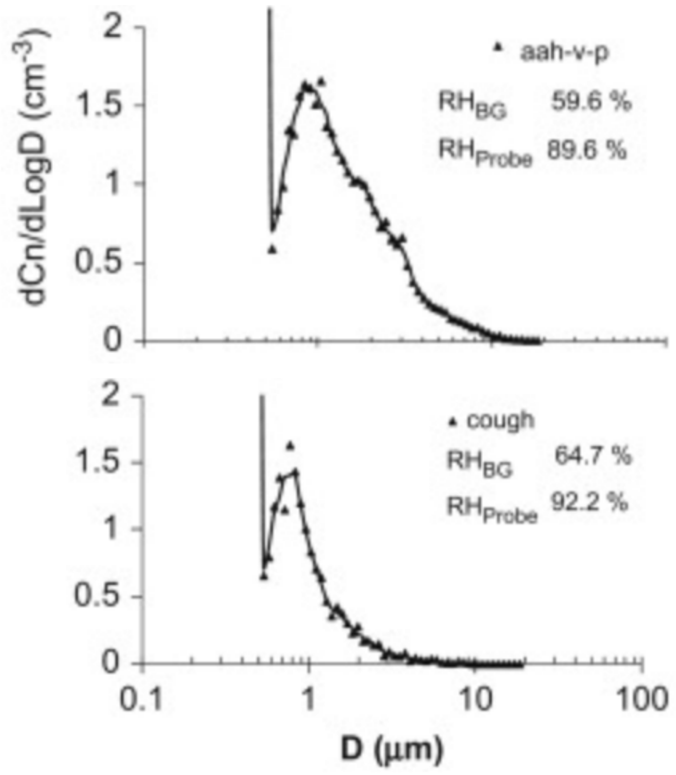
Breathing

Speaking/singing

Also droplets near 100 μm

Coughing

Morowska et al.
Journal of Aerosol Science
Volume 40, Issue 3, March 2009,
Pages 256-269

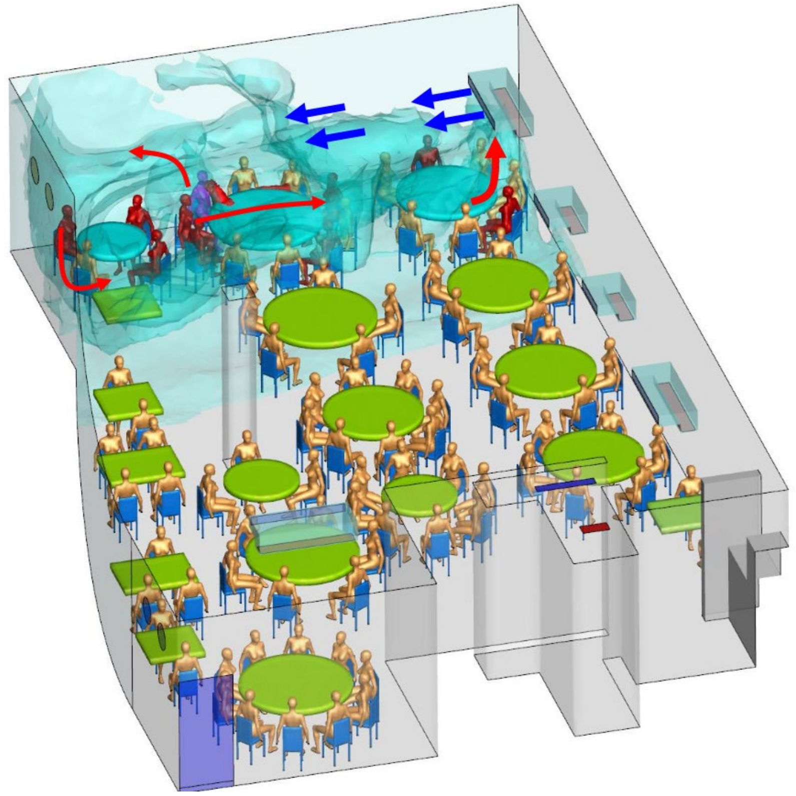


Morowska et al.
Journal of Aerosol Science
Volume 40, Issue 3, March 2009,
Pages 256-269

Large fraction of aerosols breathed out do not settle out (indoors) before being removed by ventilation

Evidence for SARS-Cov-2 transmission by aerosols

- "super spreader" events 18x more likely indoors
  - Nishiura, medRxiv 2020.02.28.20029272; doi: https://doi.org/10.1101/2020.02.28.20029272
- Dinner in China
  - Diners in local flow zone infected
  - *Li et al. (2020) medRxiv*, doi: https://www.medrxiv.org/content/10.1101/2020.04.16.20067728v1
- Skagit Valley Choir
  - Precautions to avoid contact
  - Transmission broadly spread across room
  - 52 + index case of 61 total people
  - *Miller et al. (2020) medRxiv*, doi: https://www.medrxiv.org/
  - content/10.1101/2020.06.15.20132027v2.full.pdf+html

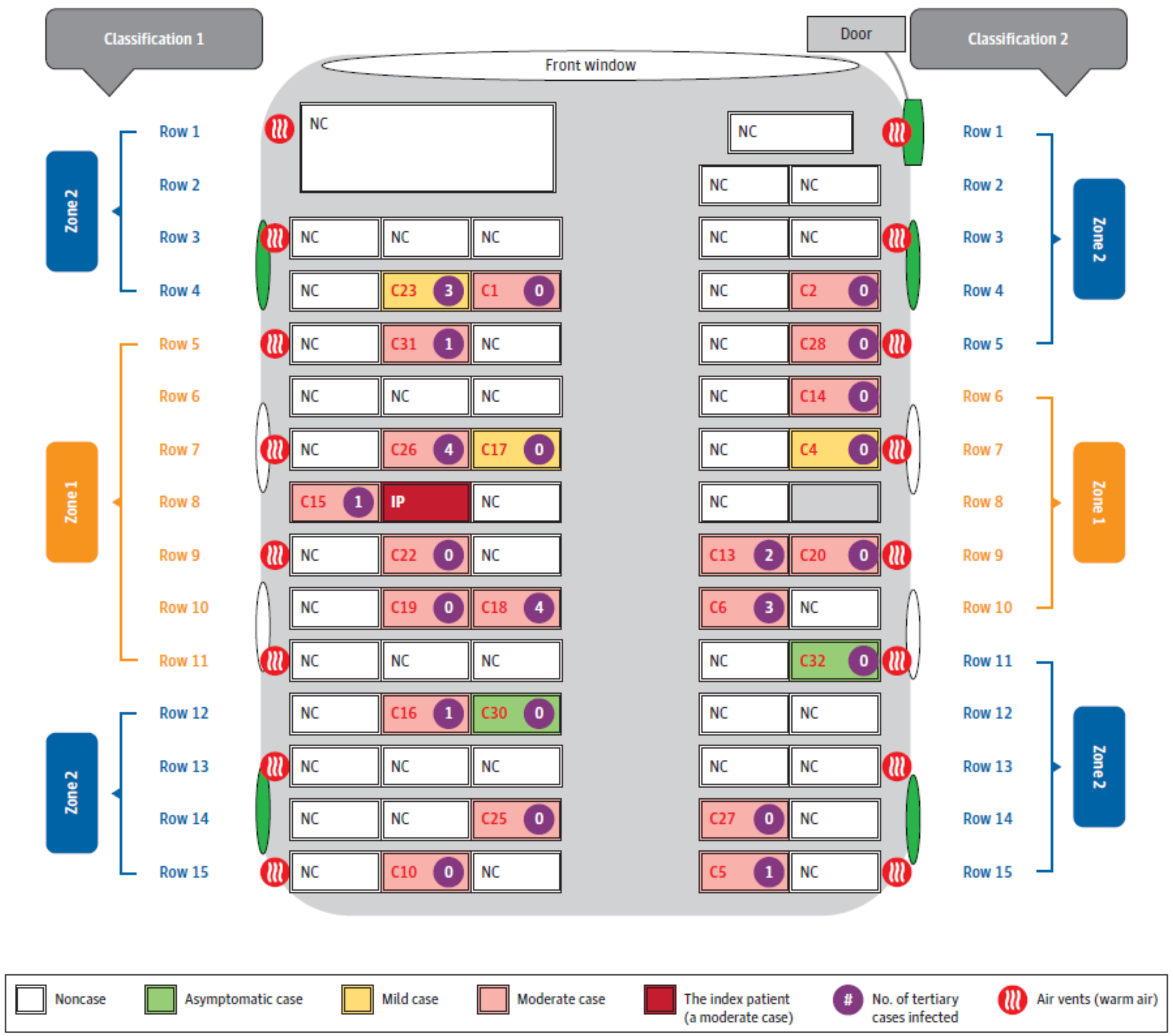


Study published THIS WEEK: probable aerosol transmission on bus

Outbreak associated with Buddhist retreat

- 100 min round trip
- no masks (early in pandemic)
- Index case from Wuhan
- Note cases distributed randomly
- Bus 1, no cases; Bus 2, 24 cases
- Shen et al. *JAMA Internal Medicine*, 2020

Figure. Schematic Diagram of Bus 2, the Bus Carrying the Coronavirus Disease 2019 (COVID-19) Initial Patient (IP)



An aerosol scientist’s perspective

Summary of Evidence vs. Modes of Transmission

	Droplets	Fomites	Aerosols
Outdoors << Indoors	X	✓	✓✓
Similar viruses demonstrated	X	✓	✓
Animal models	?	✓	✓
Superspreading events	X	X	✓✓
Importance of close proximity	✓	X	✓✓
Consistency of close prox. & room-level	X	X	✓
Physical plausibility (talking)	X	✓	✓
Physical plausibility (cough, sneeze)	✓	✓	✓
Impact of reduced ventilation	X	X	✓
SARS-CoV-2 infectivity demonstrated in real world	X	X	✓
SARS-CoV-2 infectivity demonstrated in lab	X	✓	✓
“Droplet” PPE works reasonably	✓	✓	✓
Transmission by a/pre-symptomatics (no cough)	X	✓	✓
Infection through eyes	✓	✓	✓
Transmission risk models	✓	✓	✓

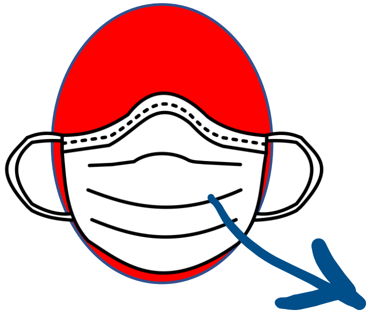
Key:
✓: evidence
✓✓: very strong ev.
X: no evidence

Only including the items that could bear on multiple pathways. See other slides for details and references

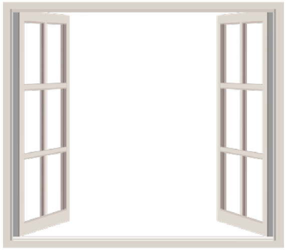
https://twitter.com/jljcolorado/status/1300438984481415175/photo/1

Control of transmission by aerosols

Source control, masks
(also limit loud talking/singing)



Dilution, Ventilation



Distance and density

Minimize contact time

Receptor control, masks

Type and level of group activity	Low occupancy			High occupancy		
	Outdoors and well ventilated	Indoors and well ventilated	Poorly ventilated	Outdoors and well ventilated	Indoors and well ventilated	Poorly ventilated
Wearing face coverings, contact for short time						
Silent	Low	Low	Low	Low	Low	Medium
Speaking	Low	Low	Low	Low	Low	Medium
Shouting, singing	Low	Low	Medium	Medium	Medium	High
Wearing face coverings, contact for prolonged time						
Silent	Low	Low	Medium	Low	Medium	High
Speaking	Low	* Low	Medium	* Medium	Medium	High
Shouting, singing	Low	Medium	High	Medium	High	High
No face coverings, contact for short time						
Silent	Low	Low	Medium	Medium	Medium	High
Speaking	Low	Medium	Medium	Medium	High	High
Shouting, singing	Medium	Medium	High	High	High	High
No face coverings, contact for prolonged time						
Silent	Low	Medium	High	Medium	High	High
Speaking	Medium	Medium	High	High	High	High
Shouting, singing	Medium	High	High	High	High	High

Risk of transmission

Low (green) Medium (yellow) High (red)

* Borderline case that is highly dependent on quantitative definitions of distancing, number of individuals, and time of exposure

Jones Nicholas R, Qureshi Zeshan U, Temple Robert J, Larwood Jessica P J, Greenhalgh Trisha, Bourouiba Lydia et al. Two metres or one: what is the evidence for physical distancing in covid-19? BMJ 2020; 370 :m3223

Risk simulators available, specific to aerosols

2020_COVID-19_Aerosol_Transmission_Estimator

File Edit View Insert Format Data Tools Add-ons Help

100% View only

	A	B	C	D	E	F
1						
2	**Estimation of COVID-19 aerosol transmission in an urban bus**					
3						
4	**Input Parameters**					
5		**Value**			**Value in other units**	
6	Surface area	307	sq ft	=	28.6	m2
7	Height	7.9	ft	=	2.4	m
8	Volume				69	m3
9						
10	Passengers	40	people			
11	Breathing rate	0.8	m3 / h			
12						
13	Duration of trip	45	min		0.75	h
14						
15	Ventilation w/ outside air	3	h-1		1.4	L/s/per
16	Decay rate of the virus	0.32	h-1			
17	Deposition to surfaces	0.3	h-1			
18	Additional control measures	0	h-1			
19	Total first order loss rate	3.62	h-1			
20						
21	Fraction of population infected	0.30%				
22	Number of passengers infected	0.12	people			
23						

https://tinyurl.com/covid-estimator

http://covid-exposure-modeler-data-devils.cloud.duke.edu/

Known Parameters	Value
Number of faculty in the course	1 (fixed)
Number of students in the course	40
Number of in-person class sessions in the course	20
Duration of each in-person class session (min.)	360
Floor area of classroom (sq. ft.)	300
Height of classroom (ft.)	8

Uncertain Parameters: Specify Range	Minimum	Maximum
Percentage of faculty-age people in community who are infectious (%)	0.7	1.4
Percentage of student-age people in community who are infectious (%)	0.7	1.4
Mask efficiency in reducing virus exhalation (%)	0	0
Mask efficiency in reducing virus inhalation (%)	0	0
Room air ventilation rate w/outside air (air changes per hour)	5	10
Additional control measures (effective air changes per hour)	0	0
Decay rate of virus infectivity indoors (per hour)	0	1
Deposition rate of virus to surfaces (per hour)	0.3	1.5
Inhalation rate: Faculty (m^3/minute)	0.005	0.01
Inhalation rate: Student (m^3/minute)	0.005	0.007

FOR ADVANCED USERS ONLY

Click links below before specifying	Mean	Standard Deviation
log10[Quanta emission rate: Faculty (quanta/hour)]	1.5	0.71
log10[Quanta emission rate: Student (quanta/hour)]	0.69	0.71

Calculate Infection Probability

Predicted Infection Probabilities for the Semester

FOR FACULTY MEMBER TEACHING THE COURSE

Best Estimate of Infection Probability 27.25%

5% chance that infection probability will be less than 1.16%

25% chance that infection probability will be less than 5.72%

FOR A STUDENT TAKING THE COURSE

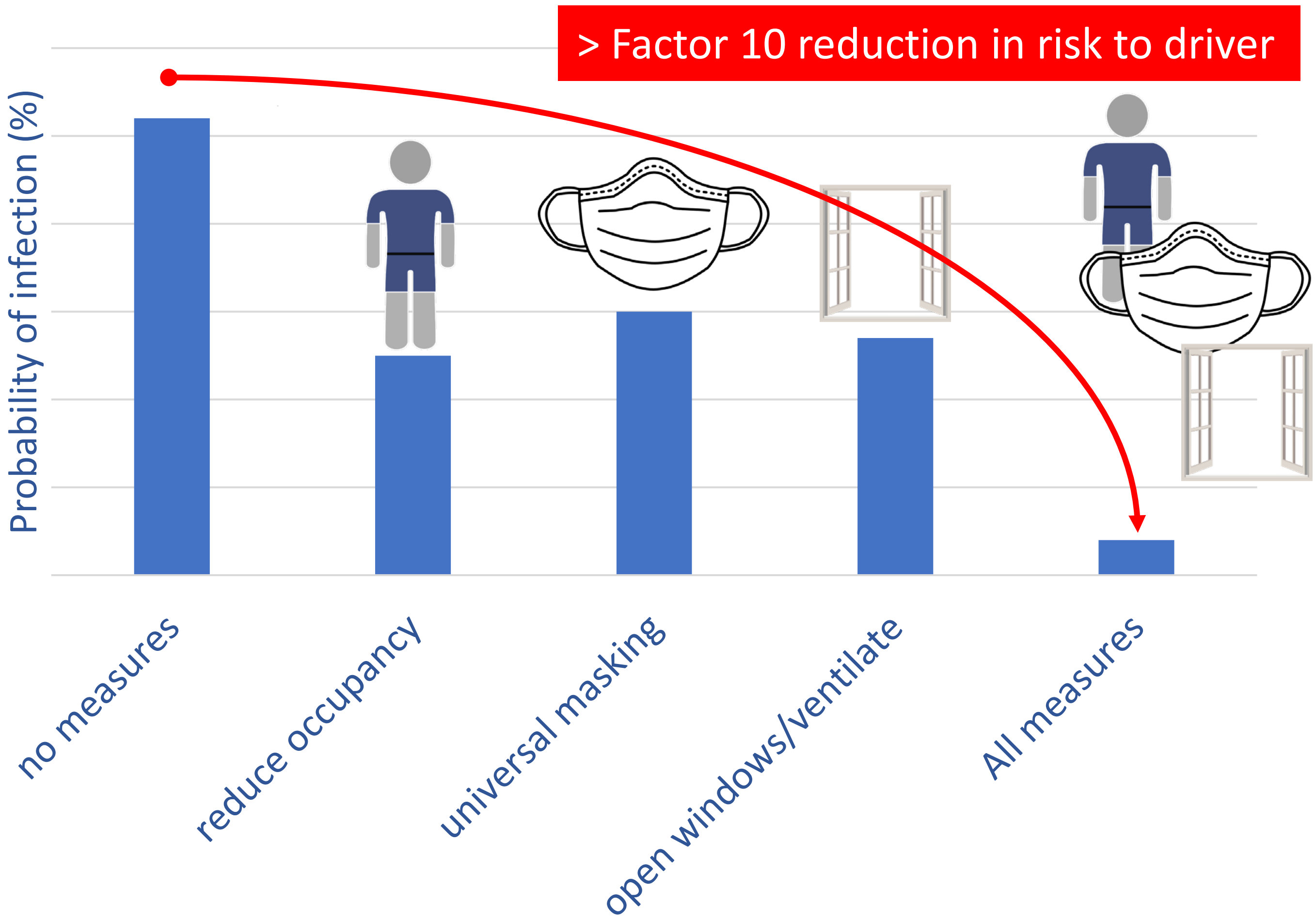
Best Estimate of Infection Probability 26.87%

5% chance that infection probability will be less than 2.50%

25% chance that infection probability will be less than 8.16%

Simulate infection probability for bus driver

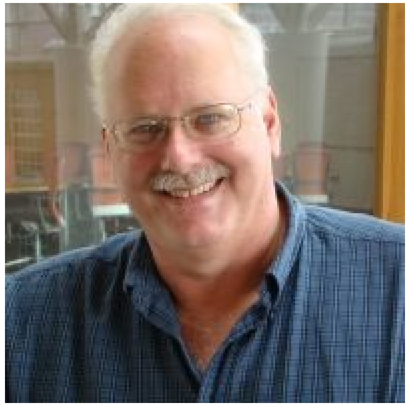
- Risk of infection to driver
  - 6 Month, 4 hours/day
- Assumptions
  - Hygiene and distancing
  - Bus size, air well mixed in bus
  - Air leakage
  - Community infection %
- Measures
  - From 40 → 10 passengers
  - No masks → universal masks
  - Closed → open windows



Research and Expertise related to SARS-Cov-2

- Aerosol Scientists
- Microbiologists
- Building/indoor science
- Epidemiology


Barbara Turpin


Ralph Baric


Jill Stewart


Karsten Baumann


Jason Surratt


Michael Fisher

Thank you

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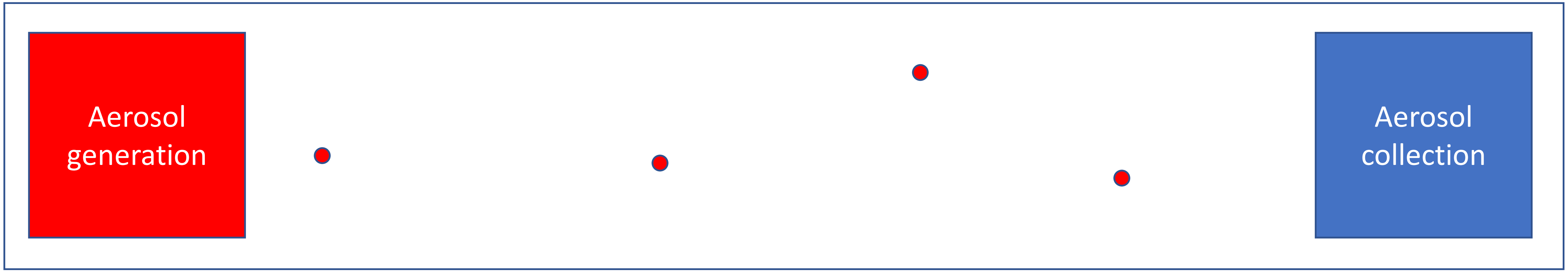
100 years
Environmental solutions for a changing world

What about UNC?

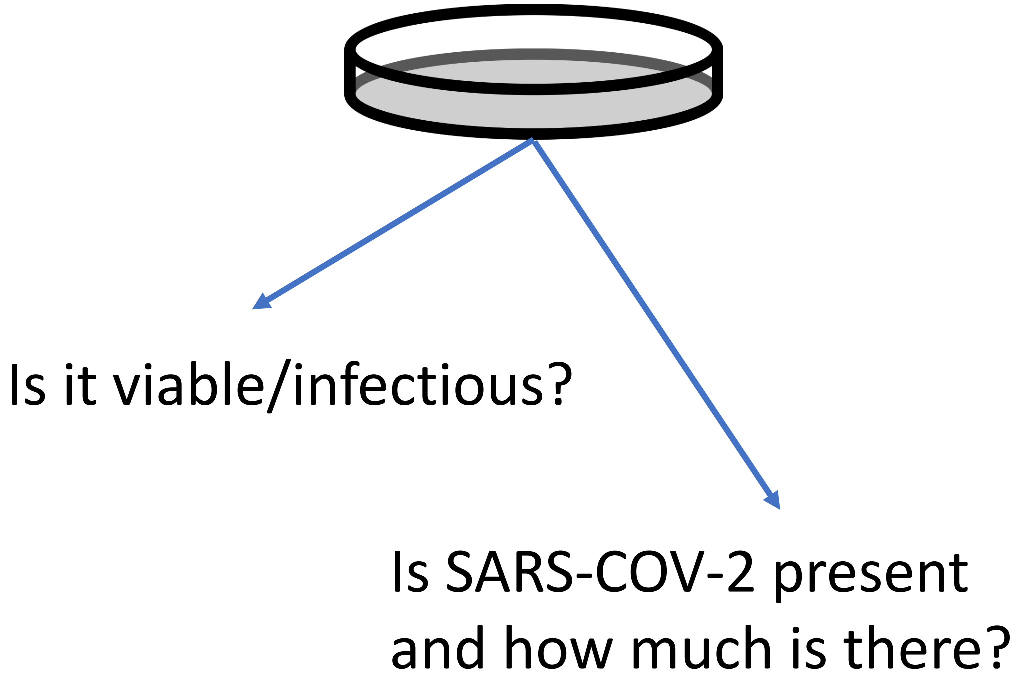
- Major question remains: how viable is aerosol SARS-Cov-2?



- Test variables
  - Environmental conditions (Temperature, Relative humidity)
  - Time
  - Oxidants such as ozone

Field measurements

- What do we see in residences of COV-positive individuals?



Field measurements

- How have aerosols moved between dorm rooms on floors with outbreaks?