

The modes of transmission of SARS-CoV-2: What we know now & how to protect ourselves

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<http://tinyurl.com/covid-estimator>
<http://tinyurl.com/faqs-aerosol>
<http://tinyurl.com/preguntas-espanol>

Image from Heikki Kahila and Ville Vuorinen, Aalto University, Finland



1. What do we know about
the modes of transmission?

2. How can we protect
ourselves against infection?

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Droplets vs. Aerosols vs. Surfaces

Key

- **Respirable Aerosol**
≤ 5µm
- **Thoracic Aerosol**
≤ 10µm
- **Nasopharyngeal Aerosol**
≤ 100µm
- **Fomite**

- **Droplets:**
 - Ballistic projectiles
 - Infect by impact on eyes, nostrils or mouth
- **Aerosols**
 - Float in the air
 - Infect by inhalation

From Milton, 2020: <https://academic.oup.com/jpids/article/doi/10.1093/jpids/piaa079/5875939> (w/ update courtesy of Prof. Milton)

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WHO's messaging

FACT CHECK: COVID-19 is NOT airborne

The virus that causes COVID-19 is mainly transmitted through droplets generated when an infected person coughs, sneezes, or speaks. **These droplets are too heavy to hang in the air. They quickly fall on floors or surfaces.**

You can be infected by breathing in the virus if you are within 1 metre of a person who has COVID-19, or by touching a contaminated surface and then touching your eyes, nose or mouth before washing your hands.

To protect yourself, keep at least 1 metre distance from others and disinfect surfaces that are touched frequently. Regularly clean your hands thoroughly and avoid touching your eyes, mouth, and nose.

World Health Organization

March 28 2020

#Coronavirus #COVID19

COVID -19 IS CONFIRMED AS AIRBORNE AND REMAIN 8 HRS IN THE AIR SO BE CAREFUL YOU ARE BEING INFECTED EVERYWHERE!!

This message spreading on social media is incorrect. Help stop misinformation. Verify the facts before sharing.

This message spreading on social media is incorrect. Help stop misinformation. Verify the facts before sharing.

<https://twitter.com/WHO/status/1243972193169616898>

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THE LANCET

Ten scientific reasons in support of airborne

Trisha Greenhalgh ✉ • Jose L Jimenez • Kimberly A Prather • Zeynep Tu

15057

- 142 news outlets
- 8 blogs
- 30682 tweeters
- 10 Facebook pages
- 1 Wikipedia page
- 9 Redditors
- 2 video uploaders

ALL RESEARCH OUTPUTS	OUTPUTS FROM THE LANCET	OUTPUTS OF SIMILAR AGE	OUTPUTS OF SIMILAR AGE FROM THE LANCET
#31 of 17,575,102 outputs	#6 of 36,647 outputs	#3 of 226,351 outputs	#1 of 258 outputs

- Superspreading events
- Long-distance transmission
- Presymptomatic transmission
- Outdoors << Indoors; Ventilation works indoors
- Infections in hospitals w/ surgical masks
- Viable SARS-CoV-2 captured from the air
- Virus found in ventilation ducts and filters
- Demonstrated w/ animals (ferrets + hamsters)
- No evidence against airborne transmission
- Limited evidence in favor of or of droplets or surfaces
- (11. Likely anisotropic infection)

[https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(21\)00869-2/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)00869-2/fulltext)

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WHO was very stuck in old dogma


World Health Organization (WHO) @WHO · Mar 28, 2020

Normal 0%

FACT: #COVID19 is NOT airborne.


FACT CHECK: COVID-19 is NOT airborne

Aerosol scientists,
Health care workers,
& allies
[#COVIDisAirborne](#)

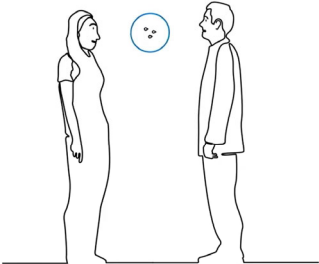

THE LANCET
 Ten scientific reasons in support of airborne transmission of SARS-CoV-2
 Trisha Greenhalgh ✉ • Jose L Jimenez • Kimberly A Prather • Zeynep Tufekci • David Fisman • Robert Schooley

1. Superspreading events
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9. **No evidence against airborne transmission**
 - **“Close contact is evidence of droplets and against airborne”**
10. Limited evidence in favor or of droplets or surfaces

[https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(21\)00869-2/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)00869-2/fulltext)
16

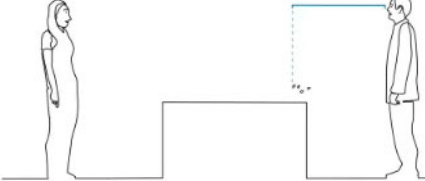

WHO: why social distance helps

Close: droplets can hit eyes / nose / mouth



These droplets can land in the mouths or noses of people who are nearby.

Far: droplets fall to the ground



These droplets are too heavy to travel far in the air – they only travel approximately one metre and quickly settle on surfaces.


WHO types: ease of infection in close proximity is proof of droplets
 → really it is only 1 of 2 plausible hypotheses

<https://twitter.com/WHO/status/1244258441880797184>
17

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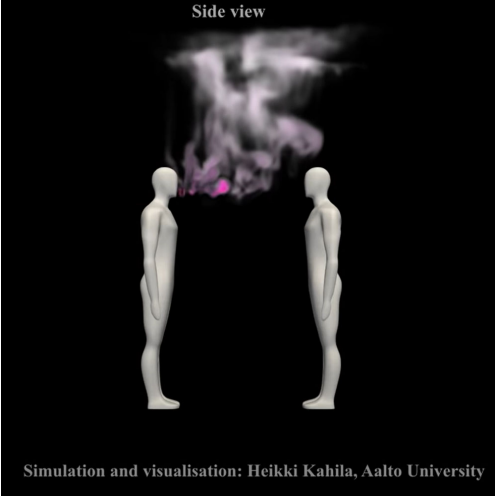
Alternative explanation of social distance

Real exhaled CO₂



CFD Simulation

Side view



Simulation and visualisation: Heikki Kahila, Aalto University



- Exhaled air when talking loses momentum in <0.5-1 m, starts rising
 - Can explain why social distance works to reduce disease transmission
- Consistent results
 - CO₂ is directly imaged (experiment) but offers less visual contrast and range than simulation

18

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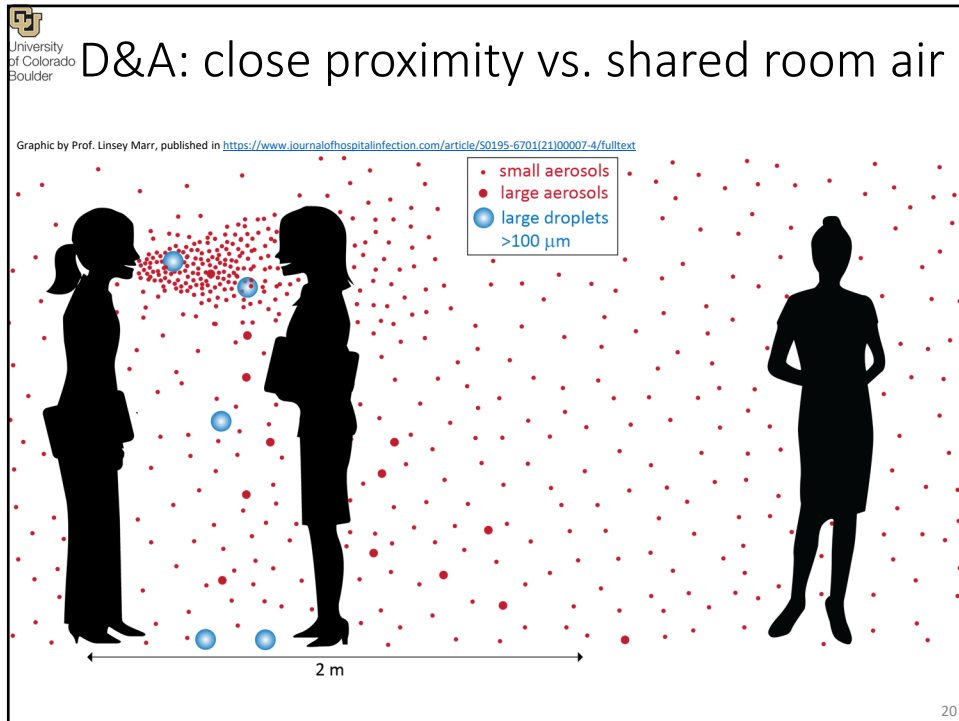
Close Proximity vs. Shared Room Air

- Observation that social distance works *alone* does not prove droplets or aerosols
- We need to look at more evidence
- Is there infection when sharing room air?
 - A. If droplets: safe with distance
 - B. If aerosols: not safe. With time and low-ventilation, infection can happen
 - B is what happens

<https://www.kunr.org/post/dti-researchers-find-e-cigs-leave-cancer-causing-chemicals-lungs-stream/0>
<https://www.dailymail.com/stories/2019/11/16/1892717-The-Smoke-Filled-Room-Unsolicited-Advice-as-Who-Should-Be-Vic>

19



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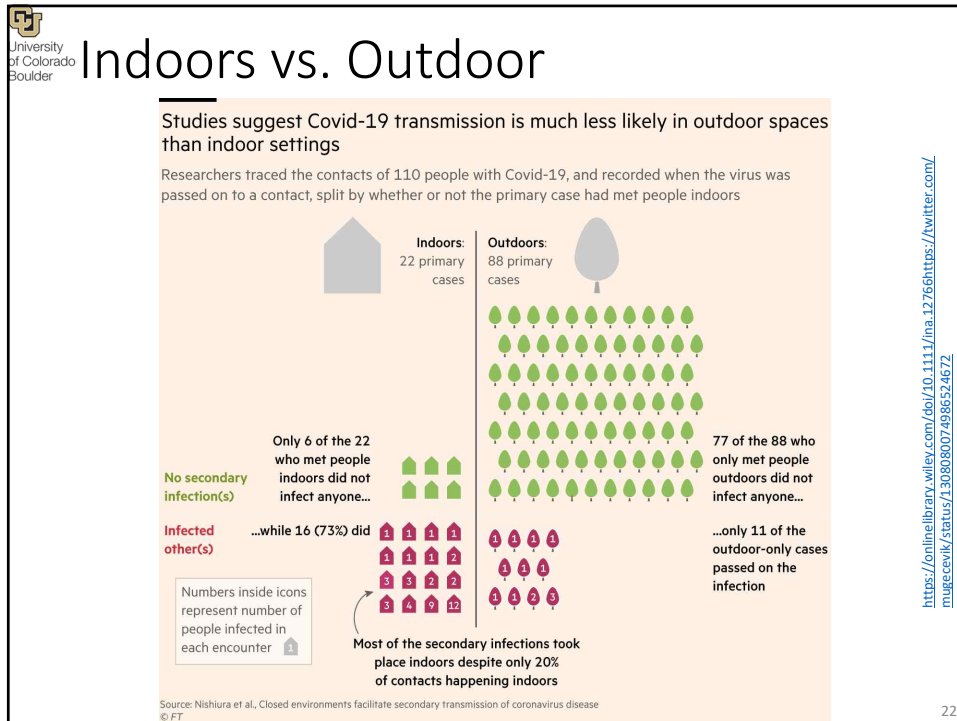
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21



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23

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Example Superspreading Event: Skagit Choir

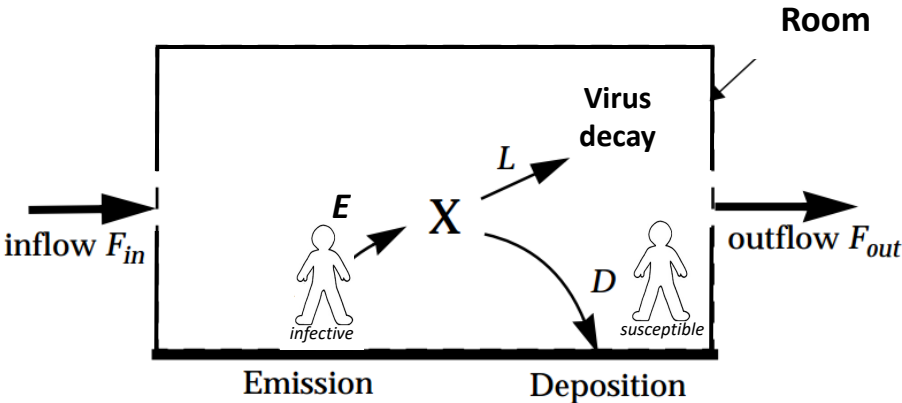


- Clearest case in my opinion
 - Choir not social w/ each other. Arrive in time, sing, 10 min break, sing, leave immediately after
 - 2.5 hr rehearsal: 1 index case, 52 new infections (13 m behind). PH & Choir: rehearsal is where it happened
- Fomites / Surfaces?
 - Agreed to be inefficient (e.g. CDC)
 - They knew about COVID-19, strong early message on surfaces. No touch, sanitizer, propped doors.
 - Index case didn't touch any objects, only ~3 people went to same bathroom
- Droplets?
 - No one 3 m in front of index. Index case didn't talk to others. Others talked to 2-3 ppl in 10 min break
 - No way to impact droplets on eyes, nostrils, mouths of 52 people
 - CDC says "15 min. of close proximity" are needed
- Aerosols?
 - Low ventilation, room well mixed, long time, no masks → easy to explain
 - Amount of virus ~10 times bus and restaurant (singing all the time vs. talking intermittently, consistent with measurements)
- All SS events point to aerosols. **None** point to fomites or droplets

Miller et al., Indoor Air, 2020. <https://doi.org/10.1111/ina.12751> 24

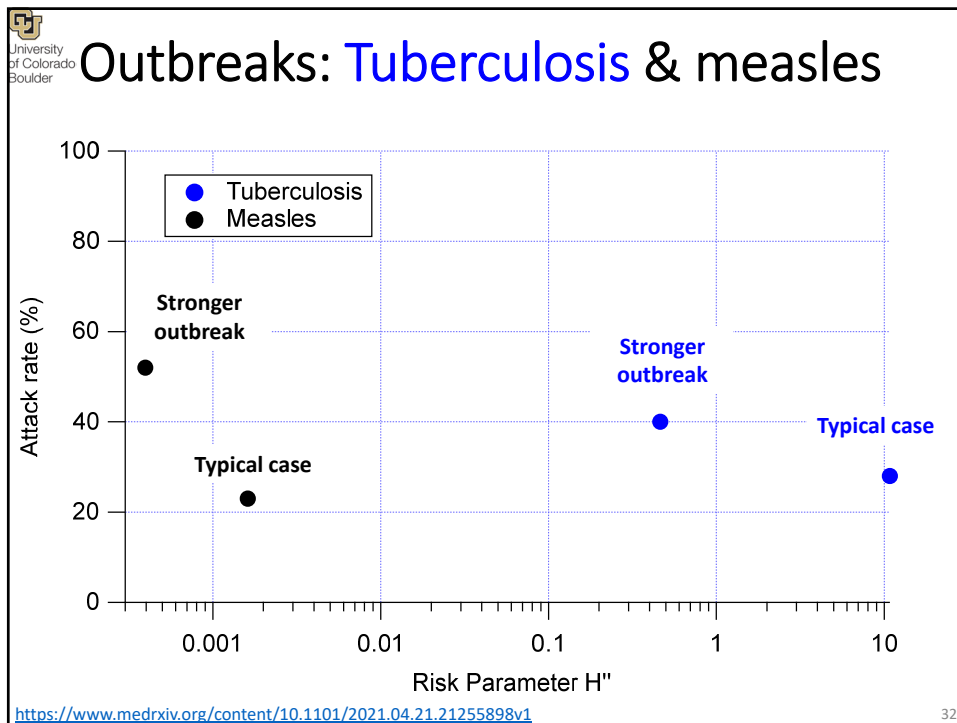
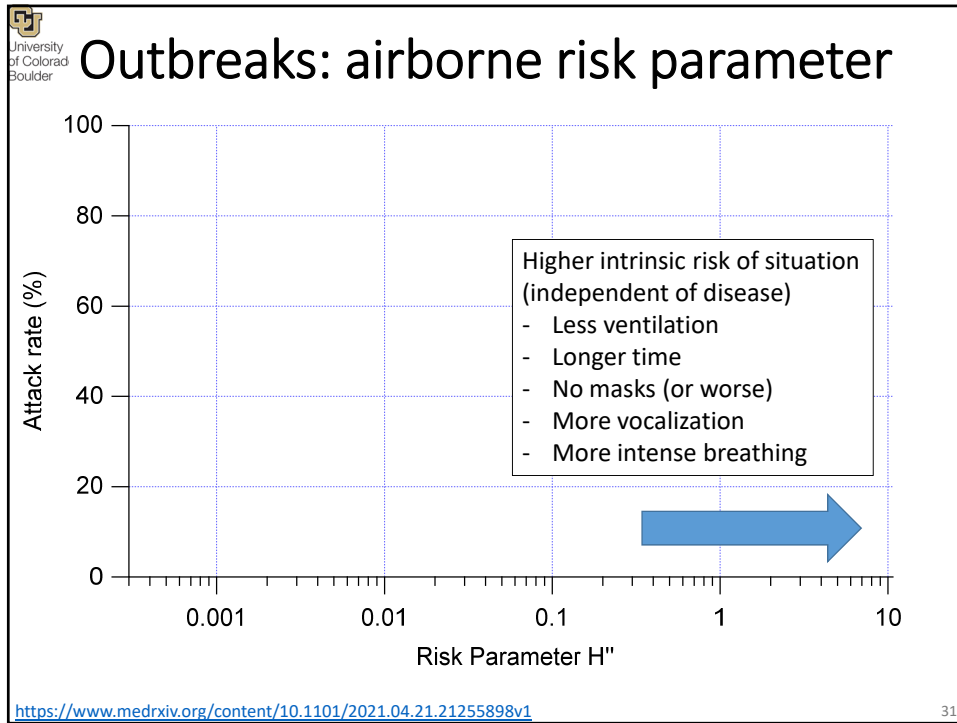
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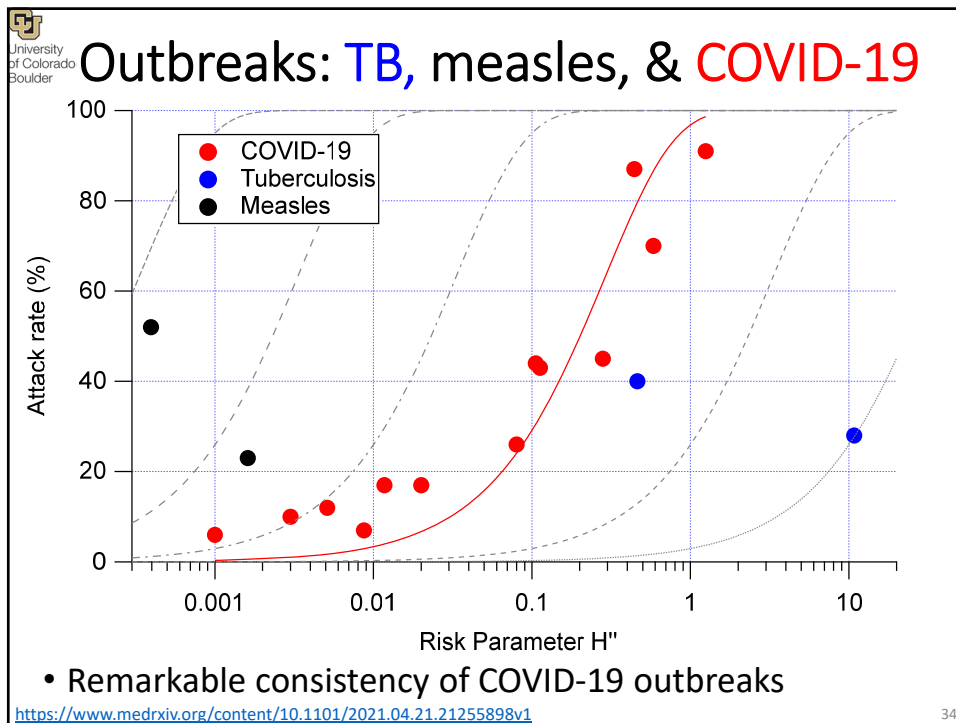
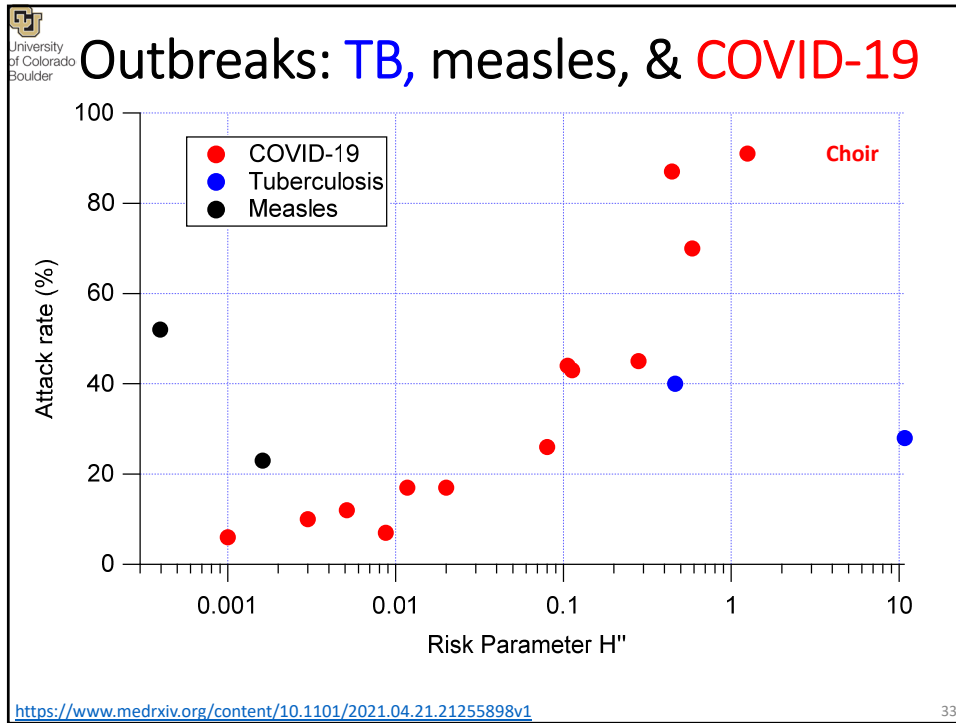
Simple "box model" of room-level transmission

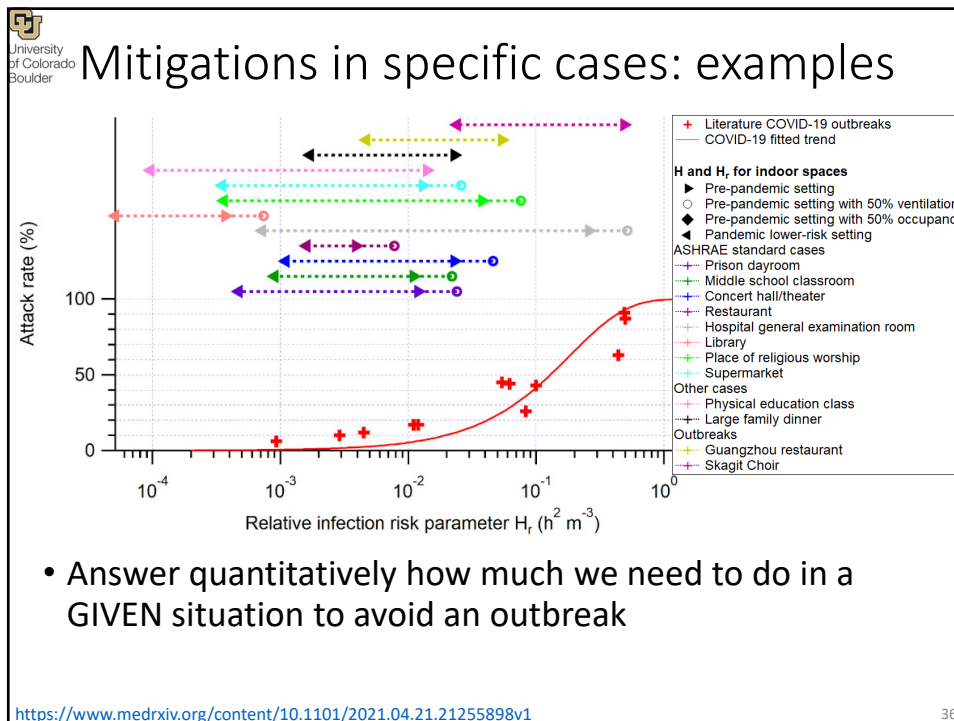
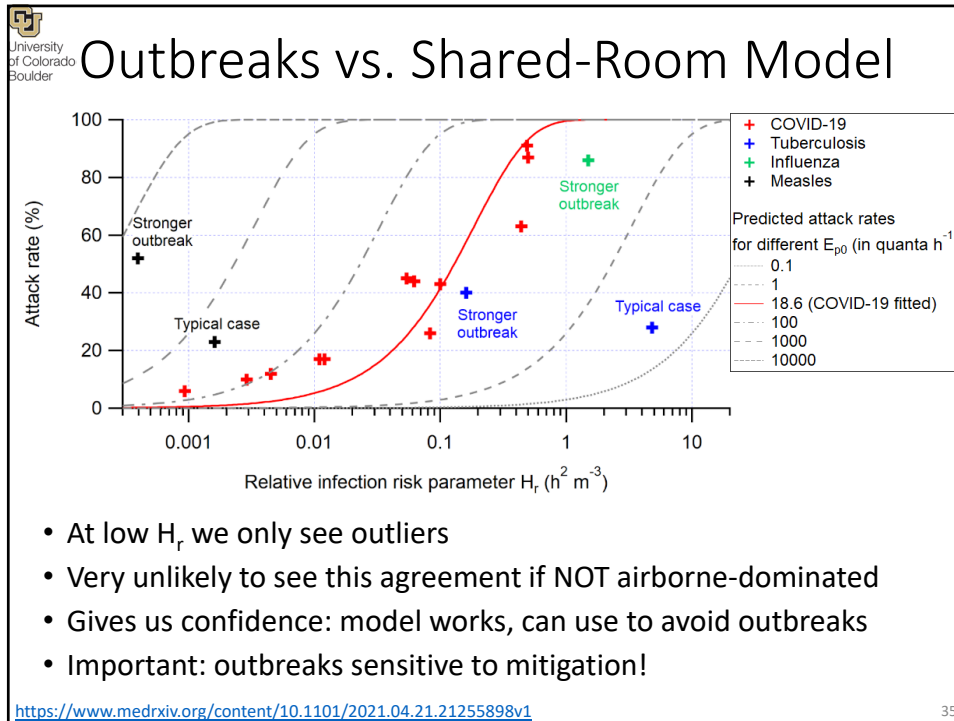


- Infective emits virus particles, which mix in the room
 - Ignore details of mixing, which can be important at times, but are very specific to each situation (think or test with smoke)
 - Susceptible breathes in some of those particles over time, some probability of infection (Wells-Riley)
- Same as modeling radon. Ordinary differential equations, solved analytically
 - Numerical solution also possible (maybe in future version, allows more complicated events)
- Implemented in spreadsheet
 - Read "readme" and "FAQs" if you want to use it seriously <http://tinyurl.com/covid-estimator>

Adapted from Jacob Fig 3-1 <http://scmg.seas.harvard.edu/people/faculty/dji/book/bookchap3.html#fig3-1>







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Do calculations for your cases

Skagit Choir:

Airborne Infection Risk Parameters (From Peng et al., 2021, submitted)		
Infection Risk Parameter (H)	227.45	h2 person / m3
Relative Inf. risk Parameter (Hr)	3.791	h2 / m3

Subway (lower occupancy)

Airborne Infection Risk Parameters (From Peng et al., 2021, submitted)		
Infection Risk Parameter (H)	0.03	h2 person / m3
Relative Inf. risk Parameter (Hr)	0.001	h2 / m3

<https://tinyurl.com/covid-estimator> & <https://www.medrxiv.org/content/10.1101/2021.04.21.21255898v1>

37

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Reformat as time to avoid outbreak (h)

- By changing time till H = 0.05

Type and level of group activity	Low occupancy			High occupancy		
	Outdoor and well ventilated	Indoor and well ventilated	Poorly ventilated	Outdoor and well ventilated	Indoor and well ventilated	Poorly ventilated
Wear face coverings						
Silent	2142.86	42.86	4.29	214.29	4.29	0.43
Speaking	428.57	8.57	0.86	42.86	0.86	0.09
Shouting, singing	71.43	1.43	0.14	7.14	0.14	0.01
Heavy exercise	30.61	0.61	0.06	3.06	0.06	0.01
No face coverings						
Silent	750.00	15.00	1.50	75.00	1.50	0.15
Speaking	150.00	3.00	0.30	15.00	0.30	0.03
Shouting, singing	25.00	0.50	0.05	2.50	0.05	0.01
Heavy exercise	10.71	0.21	0.02	1.07	0.02	0.00

<https://www.medrxiv.org/content/10.1101/2021.04.21.21255898v1>

38

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✘
MYTH

✔
FACT

<ol style="list-style-type: none"> 1) Aerosols are droplets with a diameter of 5 μm or less 2) Everything larger than 5 μm falls within 1-2 m 3) If it's short range, then it can't be airborne 4) The virus is only 0.1 μm in size so masks won't work 5) Aerosols only matter for aerosol generating procedures 	<ol style="list-style-type: none"> 1) Aerosols can be up to 100 μm in size 2) A 5 μm aerosol can travel hundreds of meters 3) Short-range transmission is dominated by aerosols 4) Virus is carried in aerosols larger than 0.1 μm 5) Talking and coughing are aerosol generating procedures
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Slide courtesy of Prof. Linsey Marr

From our published paper in the Journal of Hospital Infection: J.W. Tang, W.P. Bahnfleth, P. Bluyssen, G. Buonanno, S.J. Dancer, J.L. Jimenez, J. Kurmitski, Y. Li, S. Miller, C. Sekhar, L. Morawska, L.C. Marr, A.K. Meikov, W.W. Nazaroff, P.V. Nielsen, R. Teller, P. Wargocki. Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus (SARS-CoV-2). *J. Hosp. Inf.*, 110, 89-96, 2021. <https://doi.org/10.1016/j.jhin.2020.12.022>

64

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How we got here

- 1910: Chapin's *The Sources and Modes of Infection*
 - "Contact Infection"
 - Germs don't live outside the body, in swamps, trash etc.
 - Germs live inside of people, contact with other people needed for infection
 - Realizes close proximity leads to infection (correct)
 - Problem for him: "It is impossible to teach people to avoid contact infection while they are firmly convinced that the air is the chief vehicle of infection"
 - "In air infection, it becomes evident that our knowledge is far too scanty, and that the available evidence is far from conclusive"
 - Solution!
 - Indication of droplets (Flügge 1894). Aerosols not measureable yet
 - "There is no evidence that [air infection] is an appreciable factor in the maintenance of most of our common contagious diseases. We are warranted, then, in discarding it as a working hypothesis, and devoting our chief attention to the prevention of contact infection."
 - To prove air infection: extraordinary claims require extraordinary evidence
 - Becomes established paradigm, till WHO today

<https://archive.org/details/sourcesmodesofin00ch>

In reviewing the subject of air infection it becomes evident that our knowledge is still far too scanty, and that the available evidence is far from conclusive. Yet it is of the greatest practical importance that we should know definitely just what danger there is of air-borne infection and in what diseases it is to be feared. Infection by air, if it does take place, as is commonly believed, is so difficult to avoid or guard against, and so universal in its action, that it discourages effort to avoid other sources of danger. If the sick-room is filled with floating contagium, of what use is it to make much of an effort to guard against contact infection? If it should prove, as I firmly believe, that contact infection is the chief way in which the contagious diseases spread, an exaggerated idea of the importance of air-borne infection is most mischievous. It is impossible, as I know from experience, to teach people to avoid contact infection while they are firmly convinced that the air is the chief vehicle of infection.

While it is not possible at present to state with exactness the part played by aerial infection in the transmission of the different infectious diseases, we are by the evidence forced to the conclusion that the current ideas in regard to the importance of infection by air are unwarranted. Without denying the possibility of such infection, it may be fairly affirmed that there is no evidence that it is an appreciable factor in the maintenance of most of our common contagious diseases. We are warranted, then, in discarding it as a working hypothesis and devoting our chief attention to the prevention of contact infection. It will be a great relief to most persons to be freed from the specter of infected air, a specter which has pursued the race from the time of Hippocrates, and we may rest assured that if people can as a consequence be better taught to practice strict personal cleanliness, they will be led to do that which will more than anything else prevent aerial infection also, if that should in the end be proved to be of more importance than now appears.

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The coming paradigm shift

- Chapin's 1910 error finally becoming obvious
 - Most respiratory diseases go (at least partially) through aerosols
 - Best in close proximity
 - Can transmit in shared room air w/ low ventilation
 - Most contagious diseases can transmit long-range
 - Wide range of contagiousness (COVID = mid + dispersion)
- Huge implications
 - For seasonal flu, future pandemics, others

Wells 1945

The ultimate goal of sanitation set by Lemuel Shattuck a century ago is to guarantee to members of society the same freedom from communicable disease enjoyed by isolated individuals. Water purification, milk pasteurization, and pure food administration during the present century have added several years to the expectancy of life at birth. Does the control of respiratory infection by sanitary ventilation seem more difficult to sanitary science than the conquest of intestinal and insect-borne parasites seemed at the turn of the century?


POLICY FORUM INFECTIOUS DISEASE

A paradigm shift to combat indoor respiratory infection

Lidia Morawska, Joseph Allen, William Bahnfleth, Philomena M. Bluyssen, Atze Boerstra, Giorgio Buonanno, Junji Cao, Stephanie J. Dancer, Andres Floto, Francesco Franchimon, Trisha Greenhalgh, Charles Haworth, Jaap Hogeling, Christina Isaxon, Jose L. Jimenez, Jarek Kurnitski, Yuguo Li, Marcel Loomans, Guy Marks, Linsey C. Marr, Livio Mazzarella, Arsen Krikor Melikov, Shelly Miller, Donald K. Milton, William Nazaroff, Peter V. Nielsen, Catherine Noakes, Jordan Peccia, Kim Prather, Xavier Querol, Chandra Sekhar, Olli Seppänen, Shin-ichi Tanabe, Julian W. Tang, Raymond Tellier, Kwok Wai Tham, Pawel Wargocki, Aneta Wierzbicka, Maosheng Yao

Affiliations are listed in the supplementary materials.
 Email: l.morawska@qut.edu.au
 - Hide authors and affiliations

Science 14 May 2021
 Vol. 372, Issue 6543, pp. 689-691
 DOI: 10.1126/science.abg2025




<https://www.jstor.org/stable/18316>
<https://science.sciencemag.org/content/372/6543/689>

74

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1. What do we know about the modes of transmission?
2. How can we protect ourselves against infection?

80


<http://tinyurl.com/preguntas-espanol>
<https://tinyurl.com/FAQ-aerosols> (62 pages)

FAQs on Protecting Yourself from COVID-19 Aerosol Transmission

Shortcut to this page: <https://tinyurl.com/FAQ-aerosols>
 Version: 1.65, 15-Sep-2020


If you want to jump over other details and go straight to the recommendations, [click here](#).

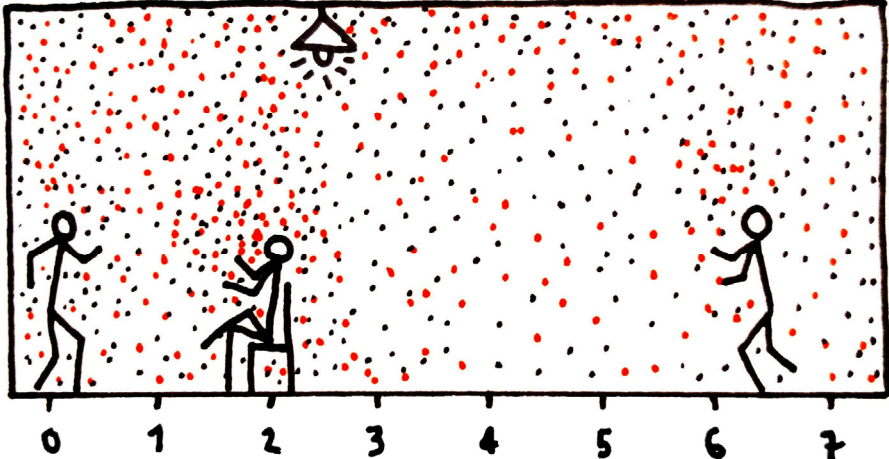
[0. Questions about these FAQs](#)

- [0.1. What is the goal of these FAQs?](#)
- [0.2. Who has written these FAQs?](#)
- [0.3. I found a mistake, or would like something to be added or clarified, can you do that?](#)
- [0.4. Are these FAQs available in other languages?](#)
- [0.5. Can I use the information here in other publications etc.?](#)

[1. General questions about COVID-19 transmission](#)

- [1.1. How can I get COVID-19?](#)
- [1.2. What is the relative importance of the routes of transmission?](#)
- [1.3. But if COVID-19 was transmitted through aerosols, wouldn't it be highly transmissible like measles, and have a very high R0 and long range transmission?](#)

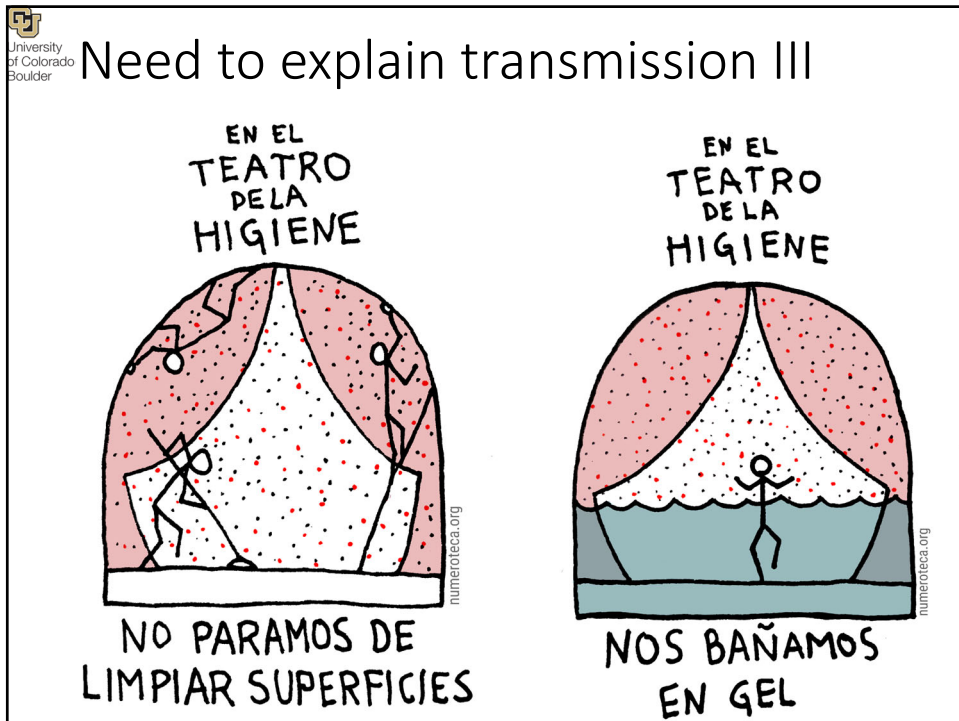
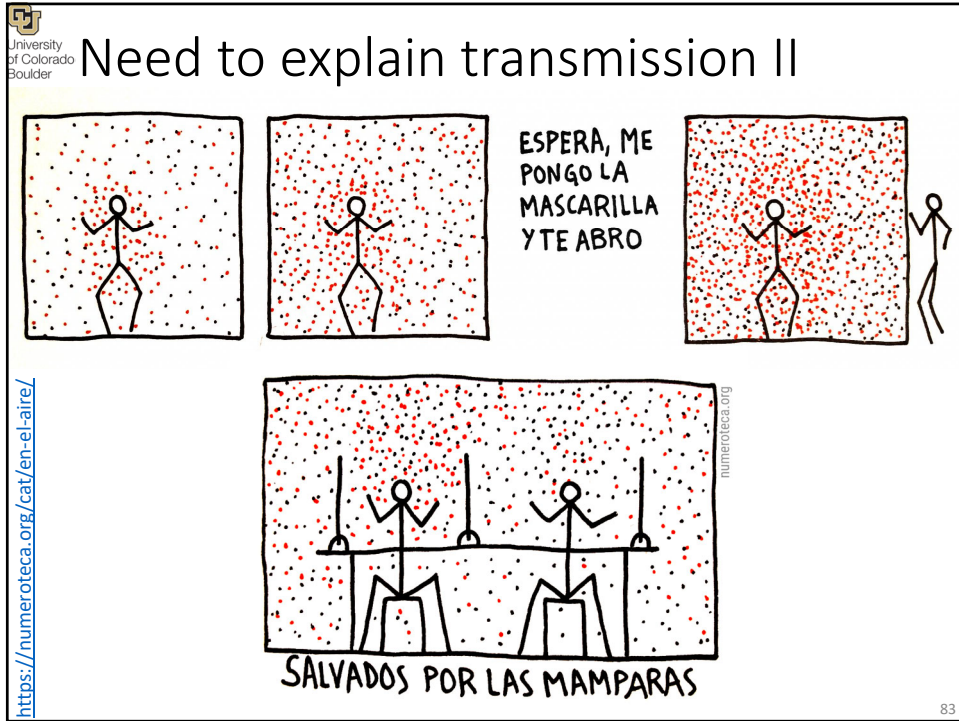

 Need to explain transmission I



A DOS METROS ME SIENTO SEGURO

<https://numeroteca.org/cat/en-el-aire/>

82





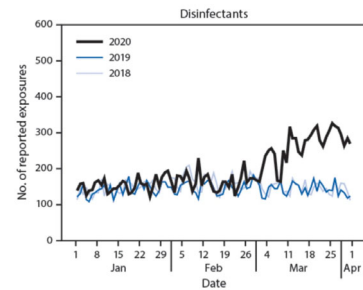
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What NOT to do? Hygiene theatre

- Stop wasting time and money on disinfecting surfaces!
- Just wash your hands frequently (forever)
- Use the saved time and \$\$ to protect against real danger



Calls due to poisoning by disinfectants



<https://www.nature.com/articles/d41586-021-00277-8>

<https://www.cdc.gov/mmwr/volumes/69/wr/mm6916e1.htm>

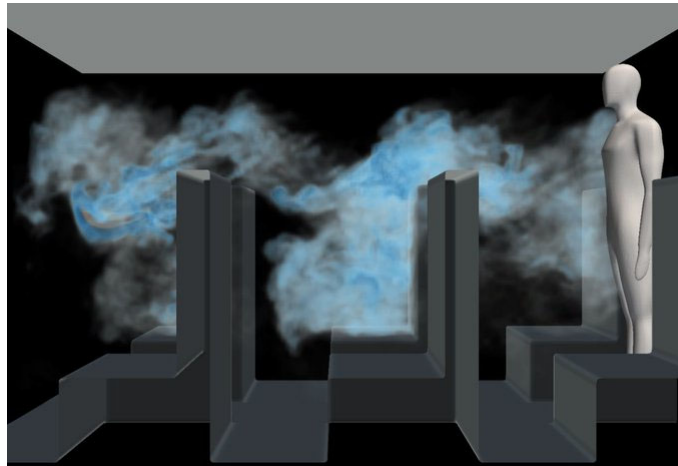
85



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Plexiglas Barriers? Not useful

- Only useful in teller / cashier situation, to break the exhaled air flow in close proximity (+ droplets, if any)



Simulation by Ville Vuorinen, Aalto Univ., Finland

<https://www.sciencedirect.com/science/article/abs/pii/S0360132313000851>


86

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Do activities outdoors when possible

nytimes.com/2020/07/17/nyregion/coronavirus-nyc-schools-reopening-outdoors.html

The New York Times



BIG CITY

Schools Beat Earlier Plagues With Outdoor Classes. We Should, Too.

A century ago, children in New York City attended classes during a pandemic. It seemed to work.

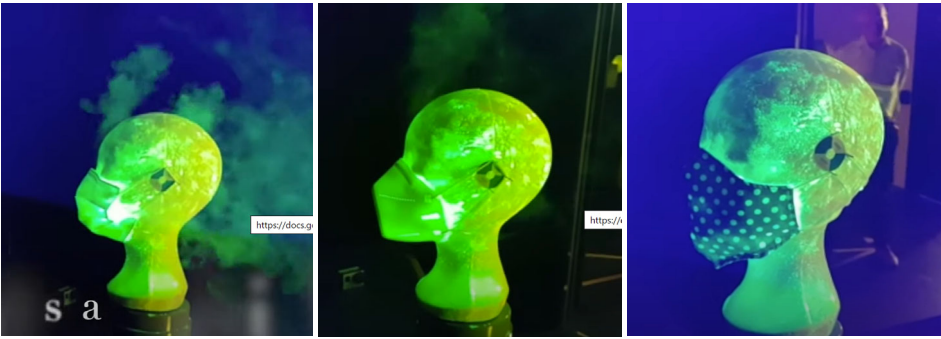
<https://www.nytimes.com/2020/07/17/nyregion/coronavirus-nyc-schools-reopening-outdoors.html>

93

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Mask Fit is Critical

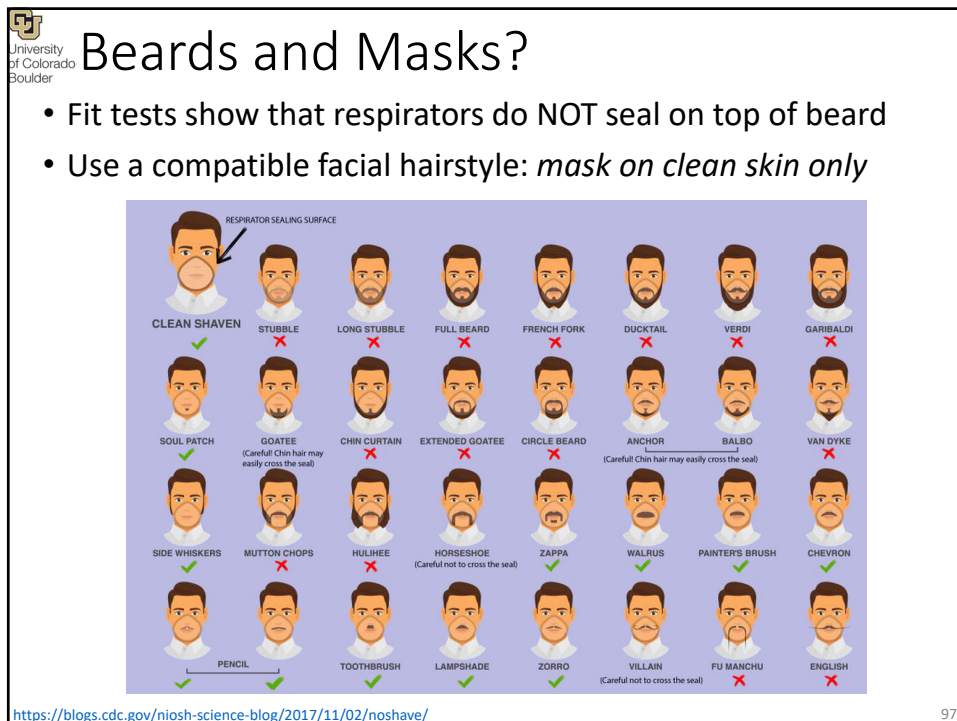
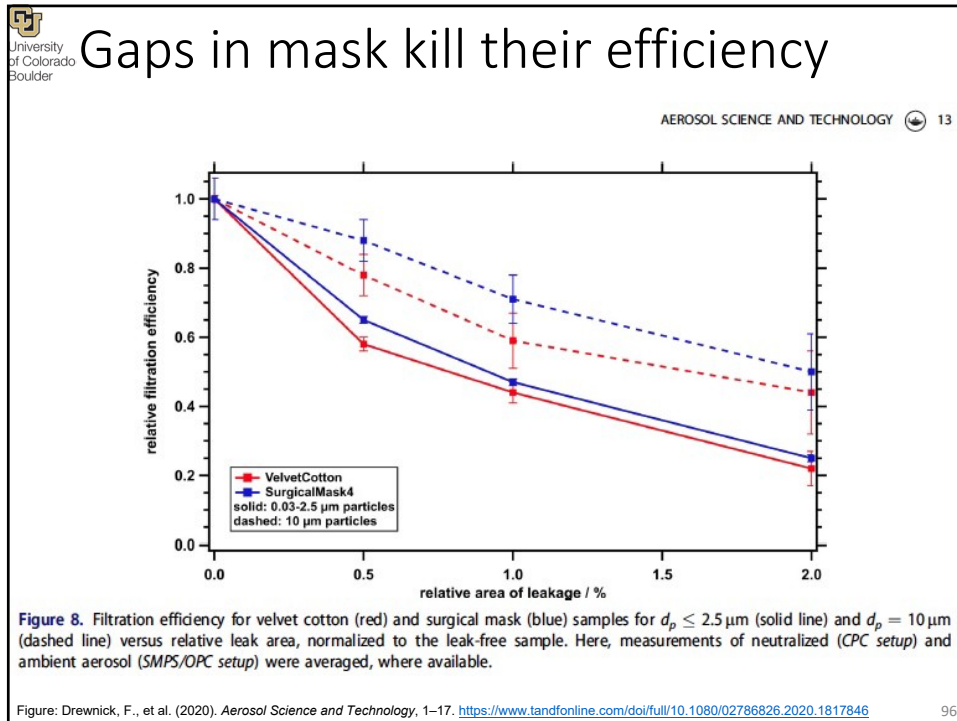
A good mask: filtering efficiency, breathability, and fit



- Pay attention to mask fit: avoid gaps, tight around the nose
 - I see lots of people w/ loose masks
 - Don't stand behind someone with a poorly-fitting mask
- Keep mask on when speaking, x10 times more aerosols than just breathing
 - 50 times more when yelling or singing loudly

Visualization by Prof. Philomena Bluyssen, TU Delft, The Netherlands <https://youtu.be/mJ81B7MvCU>

95



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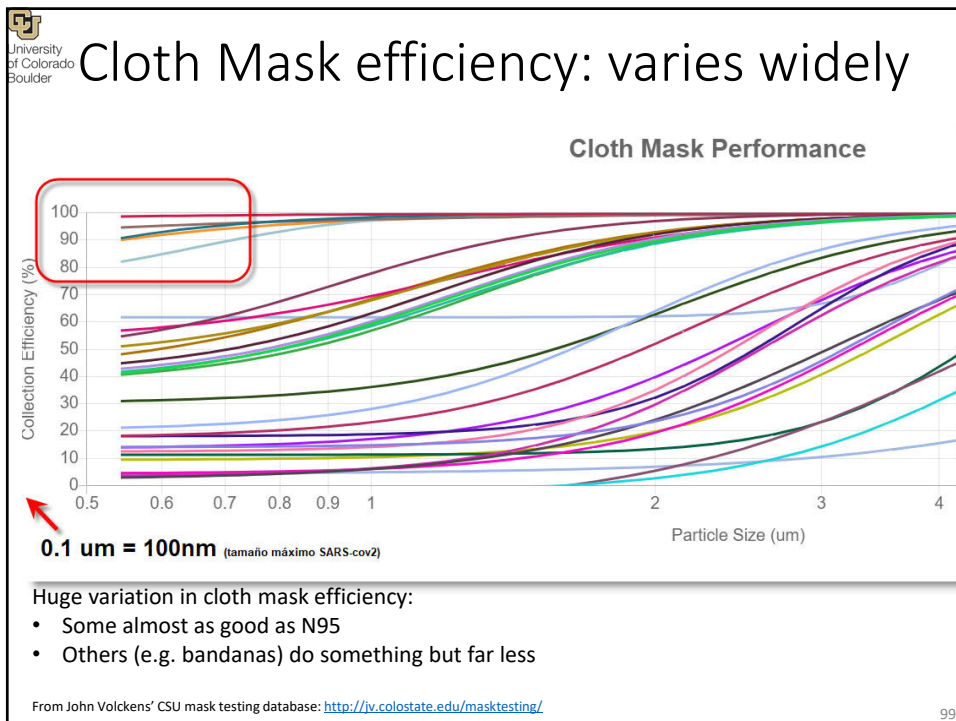
Masks: the present & the future

- A good mask needs:
 - A. Filtering efficiency
 - B. Breathability
 - C. Fit (no gaps)
- FFP2 / N95:
 - Meltblown polypropylene, good A + B
 - Difficulty with fit (“fit testing”)
- Best current masks: elastomeric half-masks
 - Filter w/ meltblown PP
 - Seal w/ thick silicone
 - Far superior in tests from my colleagues + my persona experience




US + Canada: <https://envomask.com/>
Spain: <https://kit-survie.org/boutique/es/p/mascarilla-ffp2-reutilizable/>

98





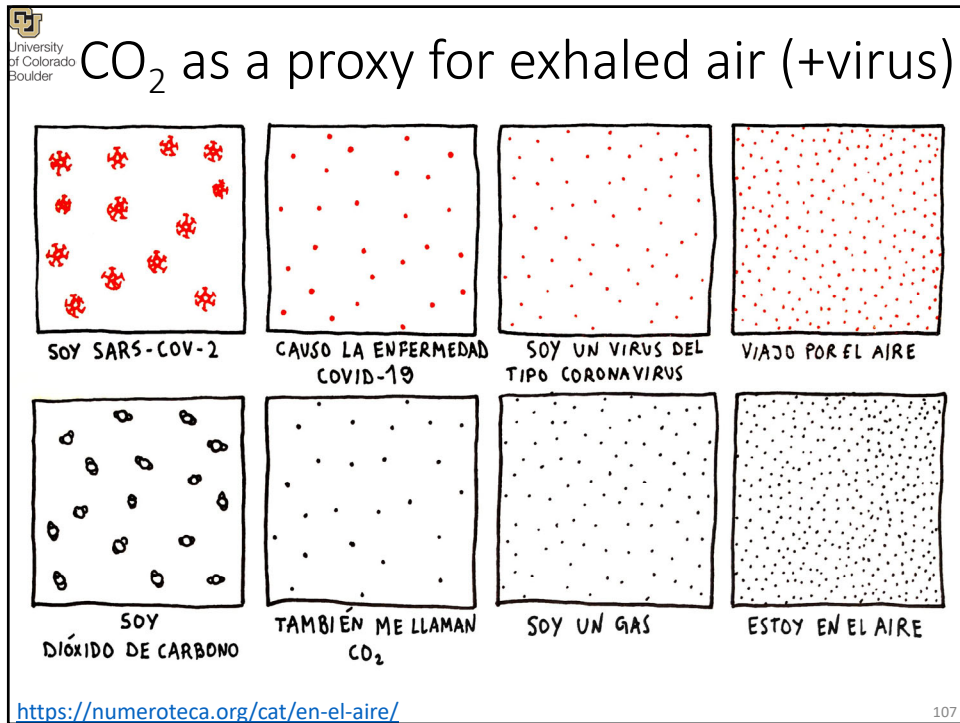
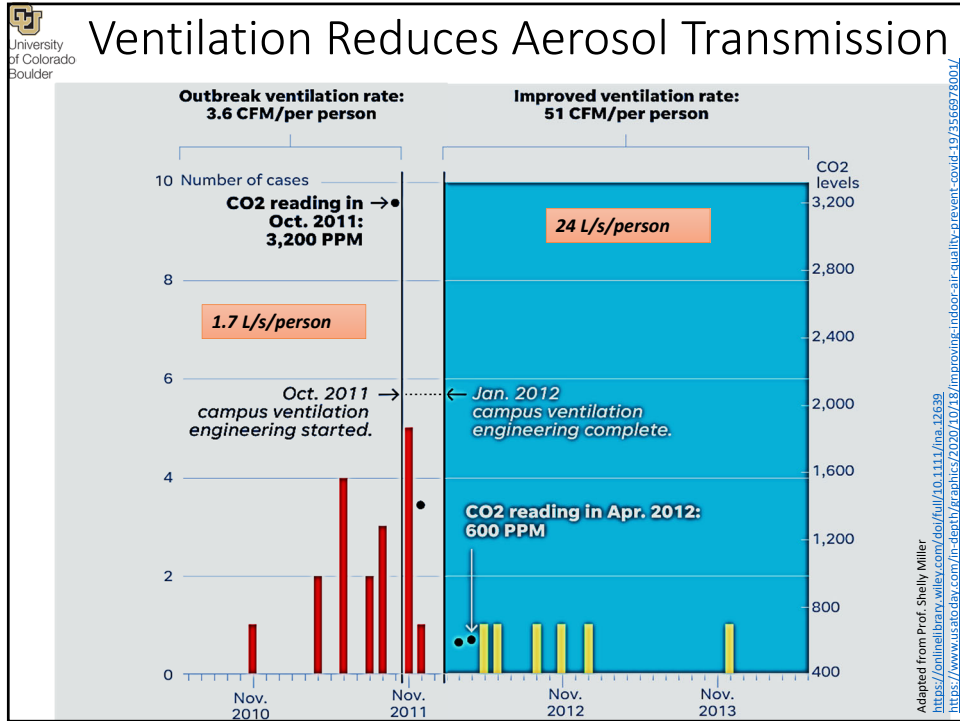
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Air Cleaning for COVID

- Recommendations in this order:
 1. Ventilation
 2. Filtration
 - Mechanical systems, portable HEPA, or fan + filter
 3. Germicidal UV
 - Only w/ professional design, installation, and maintenance
- 1. We do NOT recommend
 1. Spraying disinfectants (HOCl, ClO₂, ozone, H₂O₂, etc.)
 - ONLY when nobody is present, and when enough time will pass until people arrive for disinfectant to be gone
 2. Air cleaners based on chemistry (ions, plasmas, OH, H₂O₂, etc.)
 - Many of them do kill pathogens
 - The same chemistry that kills the pathogens also reacts with abundant VOCs indoors, and leads to formation of potentially toxic (chemical) aerosols and oxidized VOCs

<https://www.sciencedirect.com/science/article/pii/S0160412020317876> - <https://twitter.com/ijcolorado/status/1291758303089852417>
<https://medium.com/@dbc007/the-air-chemistry-behind-fogging-for-sars-cov-2-disinfection-ac3df05326bc>

103



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Using CO₂ as an Indicator (<700 ppm)

The diagram illustrates the flow of air and particles in a room. Outdoor air enters from the top. An 'Infector' on the left exhales SARS-CoV-2-containing aerosols (red arrows) and CO₂ (blue arrows). These aerosols are inhaled by a 'Susceptible' person on the right (red dashed arrows). Some aerosols are lost through ventilation, deposition, or decay (red dashed arrows). CO₂ is also ventilated out (blue dashed arrows). An 'Air filter' is shown at the bottom, capturing some particles. A legend on the right defines the symbols: SARS-CoV-2-containing aerosol (red circle with virus), Aerosol containing decayed SARS-CoV-2 (grey circle with virus), SARS-CoV-2-containing aerosol exhalation (solid red arrow), SARS-CoV-2-containing aerosol inhalation (dashed red arrow), SARS-CoV-2-containing aerosol loss (dotted red arrow), CO₂ (small red dash), CO₂ exhalation (solid blue arrow), CO₂ inhalation (dashed blue arrow), CO₂ ventilation (out) (dotted blue arrow), and CO₂ ventilation (in) (solid blue arrow).

- https://medium.com/@ijose_19945/how-to-quantify-the-ventilation-rate-of-an-indoor-space-using-a-cheap-co2-monitor-4d8b6d4dab44?source=friends_link&sk=6cda52f5682a4a450a10691f07d1ad2c
- Citizen science: see #COVIDCO2 in Twitter, post data there, help your community
- Details of CO₂ level: see our paper & estimator; <https://twitter.com/iljicolorado/status/1304398049528012800>

Slide from Dr. Zhe Peng

108

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CO₂ as a tracer of Exhaled Air (& Virus)

~400 ppm = 0% / 800 = 1% re-breathing / 4400 = 10% re-breathing
 Affordable NDIR Monitors (\$90-\$200): <https://bit.ly/monitorsCO2>

Outdoors

In car, 2 people + child, 30 min.

Windows, closed, recirculated air →

Windows closed, ventilation system w/ outdoor air →

<https://www.gofundme.com/f/medidores-co2-para-espana-y-latinoamerica>

109

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Every public space should display CO₂



- Real-time indication of ventilation everywhere
 - Many people would learn what's safe and unsafe quickly
 - How to account for filtration?
- The technology exists to do this at \$200 per unit (less if massive)
 - <https://www.co2meter.com/products/csense-large-wall-co2-meter>
 - <https://www.pce-inst-benelux.nl/technische-specificaties/multifunctionele-co2-meter-pce-ac-2000.htm>

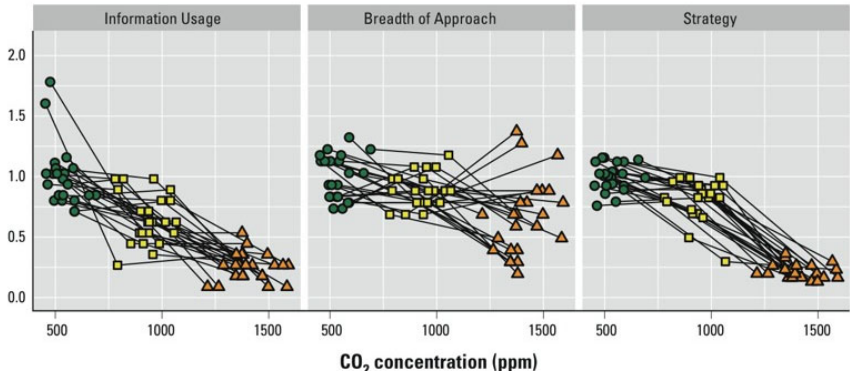
Bar pic from <https://www.graffitiindoorad.com/our-clients> First suggested to me by Bertrand Waucquez (major of Kraainem, Belgium)

110

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Cognitive Effects of High CO₂

- Degradation of multiple cognitive measures detectable at > 1000 ppm
- Taiwan and South Korea regulate indoor CO₂ < 1000 ppm



<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4892924/>

111

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Air cleaners based on chemistry?

Ionizers, plasmas, oxidation, photocat.

- These products may destroy VOCs through chemistry
 - VOCs very abundant indoors
- If they destroy VOCs, they will make oxidized VOCs and (chemical) aerosols, more toxic than VOCs
 - Not studied TMK
 - Precautionary principle → can't recommend

https://www.researchgate.net/publication/275344400_Performance_of_Air_Cleaners_for_Removing_Multi-Volatile_Organic_Compounds_in_Indoor_Air
<https://www.nature.com/articles/s41557-018-0002-2>

119

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Air cleaners by filtration really work!

Airmega 300S Smart HEPA Air Purifier by Coway

Model: 2008 SKU: co3313

List Price: \$649.00
Sale: \$515.00
 Free 3 Day Delivery to 80309
 In Stock - Order Now. Your item will ship Thursday, Apr 30th.

Quantity: 1

Add To Cart **Or see low est. \$23.77 / Month***

ACH = CADR / Room Volume
<https://calculadora-cadr.web.app/>

Cheaper Fan + Filter

Clean Air Delivery Rate
 AHAM CERTIFIED
Certified Rating

From air cleaner to air stream, calculate the CADR. First, test at suggested room size. Then refer to the dust, tobacco smoke and pollen Clean Air Delivery Rate (CADR) numbers. The higher the numbers, the better the unit cleans the air.

This air cleaner is suggested for use in a single closed room up to 120 square feet.

Room size ratings conform to the AHAM Certification Program criteria of peak smoke reduction. Higher Clean Air Delivery Rates provide improved performance in all spaces. Portable air cleaners will be much more effective in rooms where all doors and windows are closed.

Dust: 80 Tobacco Smoker: 80 Pollen: 80

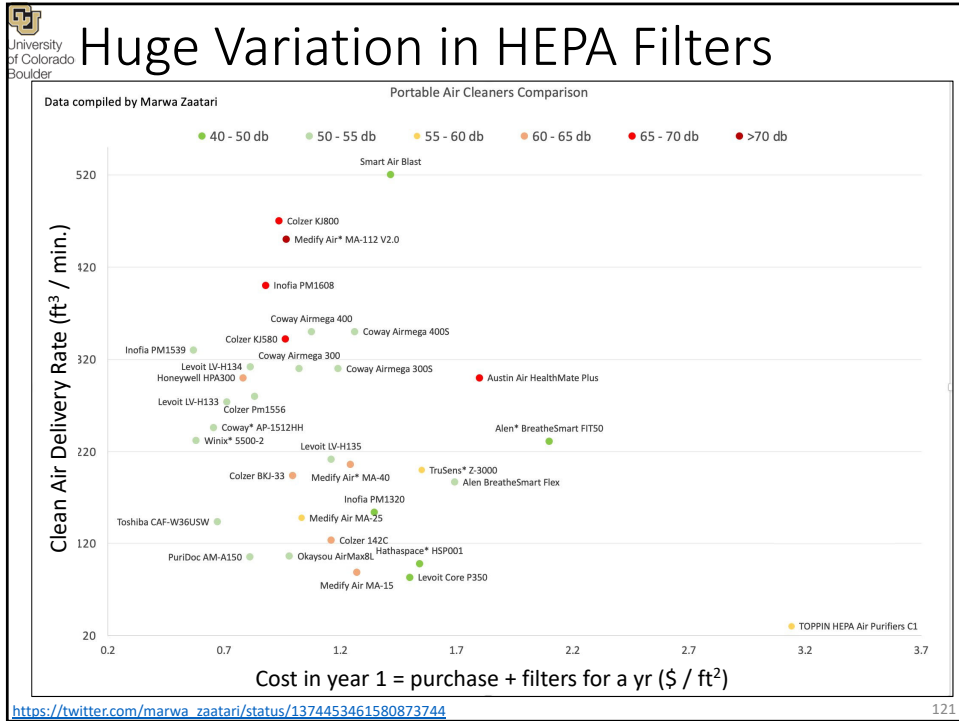
These values represent performance that can be expected within the first 12 hours of operation. Subsequent performance may vary with use.

Association of Home Appliance Manufacturers **AHAM**

- 9.5 in <https://tinyurl.com/FAQ-aerosols>
- Dr. Javier Ballester, Univ. de Zaragoza
 - tinyurl.com/yc7bpdkg

HEPA adapted from Shelly Miller / Fan + filter from Jim Rosenthal

120



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Conclusions & Ackn

Most likely aerosols dominate transmission, droplets minor
Smoke analogy: proximity & shared room air

Superspreading is important
Superspreading is airborne

Indoors: layers of protection

Conditional Probability of Infection for Each Person

Contact & more info:
<http://Bit.ly/COVID-aerosols2>
 Jose.jimenez@colorado.edu
 Twitter: @jljcolorado
<http://tinyurl.com/covid-estimator>
<http://tinyurl.com/faqs-aerosol>
<http://tinyurl.com/preguntas-espanol>

Need to fit masks well

• Thanks to the “group of 36” & the “group of Twitter” scientists: L. Morawska, D. Milton, L. Marr, J. Tang, R. Tellier, S. Miller, S. Dancer, W. Nazaroff, W. Bahnfleth, Y. Li, M. Yao, K. Prather, R. Corsi, J. Allen, X. Querol, J. Ballester, C. Haas, D. Poppendieck etc.

127