Someone is sick in a room w/ a virus that spreads only through the air.

Will others get sick?

- Show example of "non-traditional" chemical process
- Demonstrate that we can model real-world situations
- Discuss Covid stuff
- Encourage you all to wear really good masks!

- NOTE: Very simplified model!

Assumptions

- Virus spreads only through the air
- Constant air exchange rate
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- Particles all stay in the air
- Air entering room is free of virus
- Virus particles take up no volume

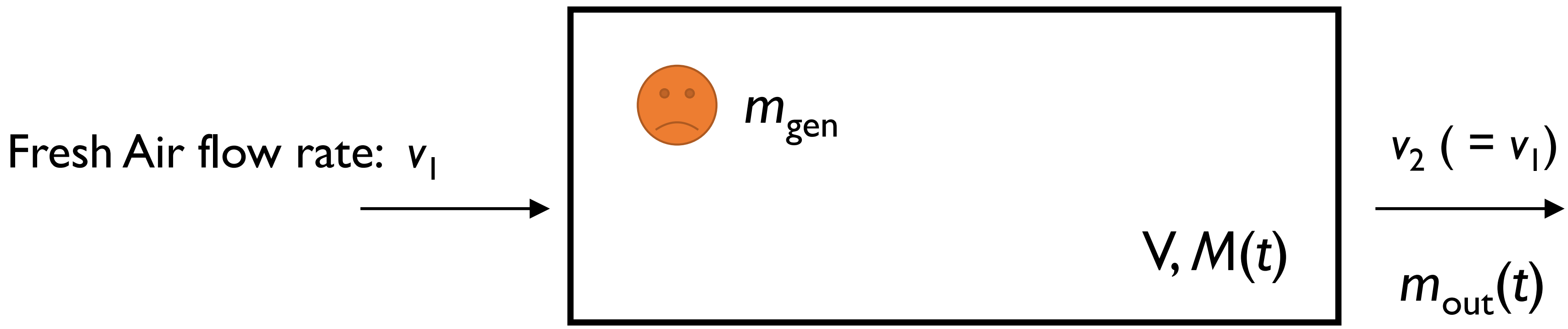
- People get sick based on the # of particles they inhale (M_{in})

$M_{in} < M_{crit}$ → ☺

$M_{in} > M_{crit}$ → ☹

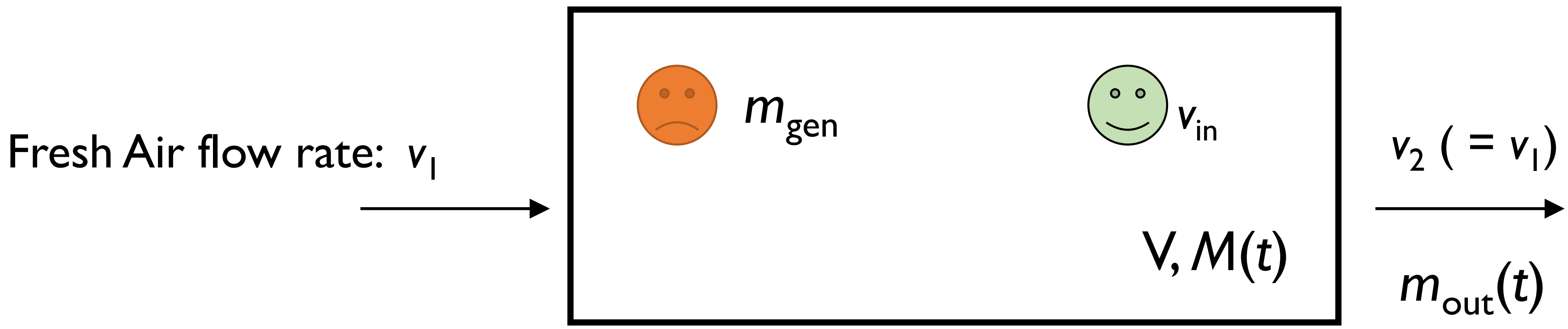
M_{crit} : some critical mass of virus that gets you sick

Define the System



- V: volume of the room
- v_1 and v_2: air flow rate into and out of room
- $M(t)$: total mass of virus in room
- m_{gen}: mass generation rate of virus in room
- $m_{out}(t)$: mass outflow rate of virus

Define the System



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- v_{in}: Inhalation rate

Inhalation

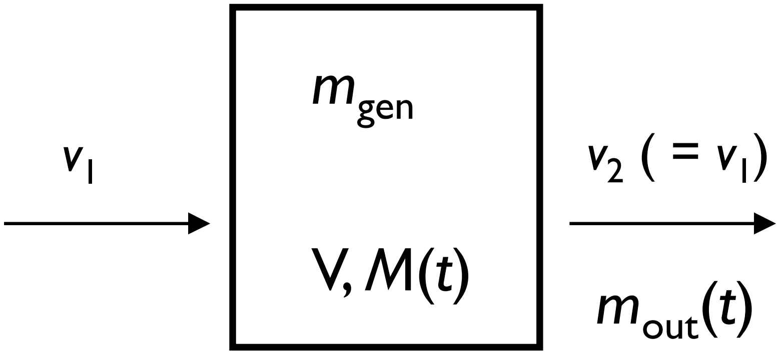
$M_{in}(t)$ = Total mass particles inhaled in time t

$$= \int_0^t \text{(conc. in room)(inhalation rate)}\,dt$$

$$= \int_0^t \left(\frac{M(t)}{\mathrm{V}}\right) v_{\mathrm{in}}\,dt$$

$$= \frac{v_{\mathrm{in}}}{\mathrm{V}} \int_0^t M(t)\,dt$$

What is *M*(*t*)?



Accumulation = (Input – Output) + (Generation – Consumption)

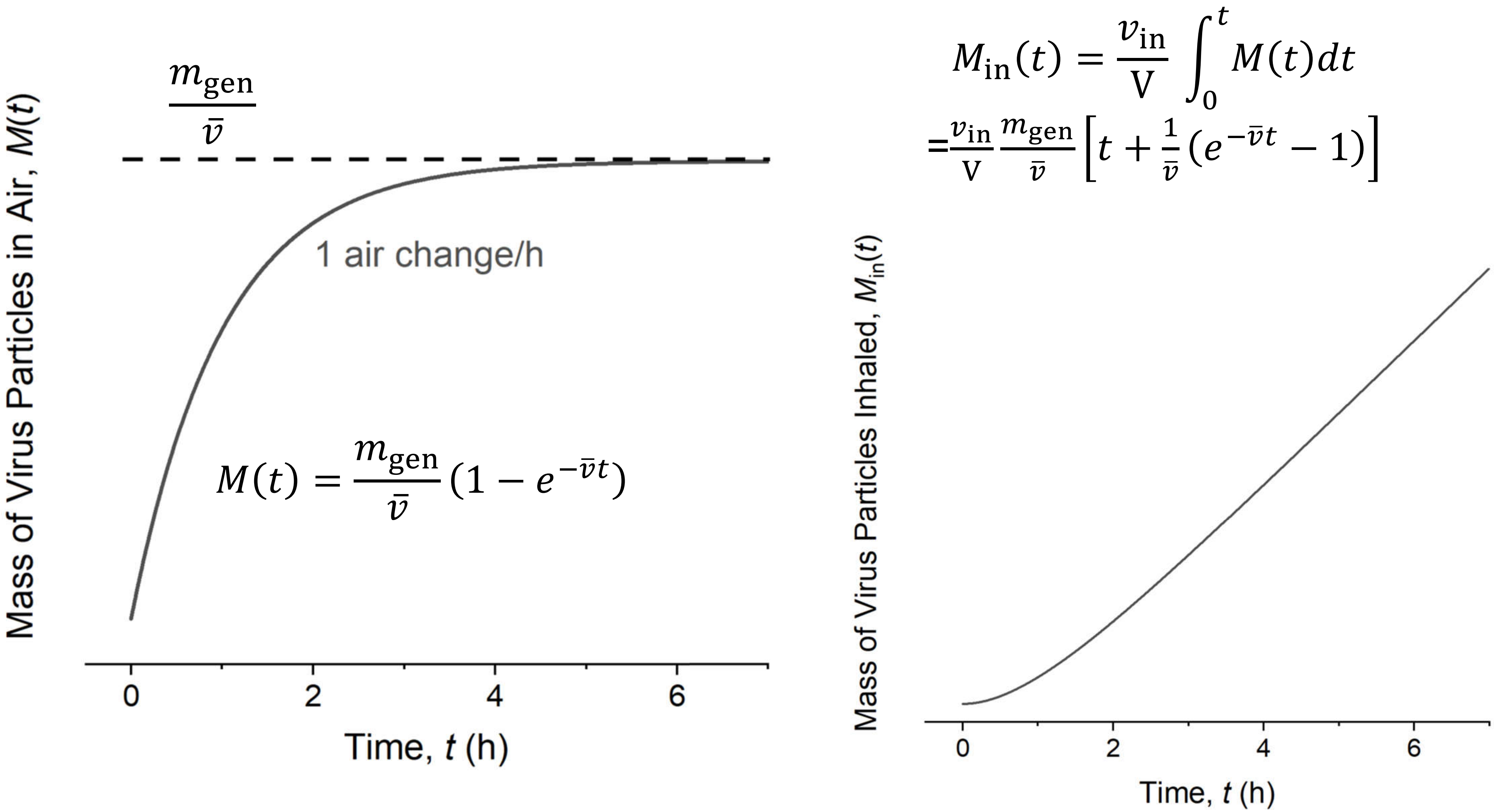
$$\frac{dM(t)}{dt} = m_{\text{gen}} - m_{\text{out}}(t)$$

$m_{\text{out}}(t)$= (mass conc.)(vol. flow rate) = $\left(\frac{M(t)}{\text{V}}\right) v_1 = M(t)\bar{v}$

$\bar{v} = \frac{v_1}{\text{V}}$ = Air exchange rate of room

$$\frac{dM(t)}{dt} = m_{\text{gen}} - M(t)\bar{v}$$

Solving ODE ➔ $M(t) = \frac{m_{\text{gen}}}{\bar{v}}\left(1 - e^{-\bar{v}t}\right)$



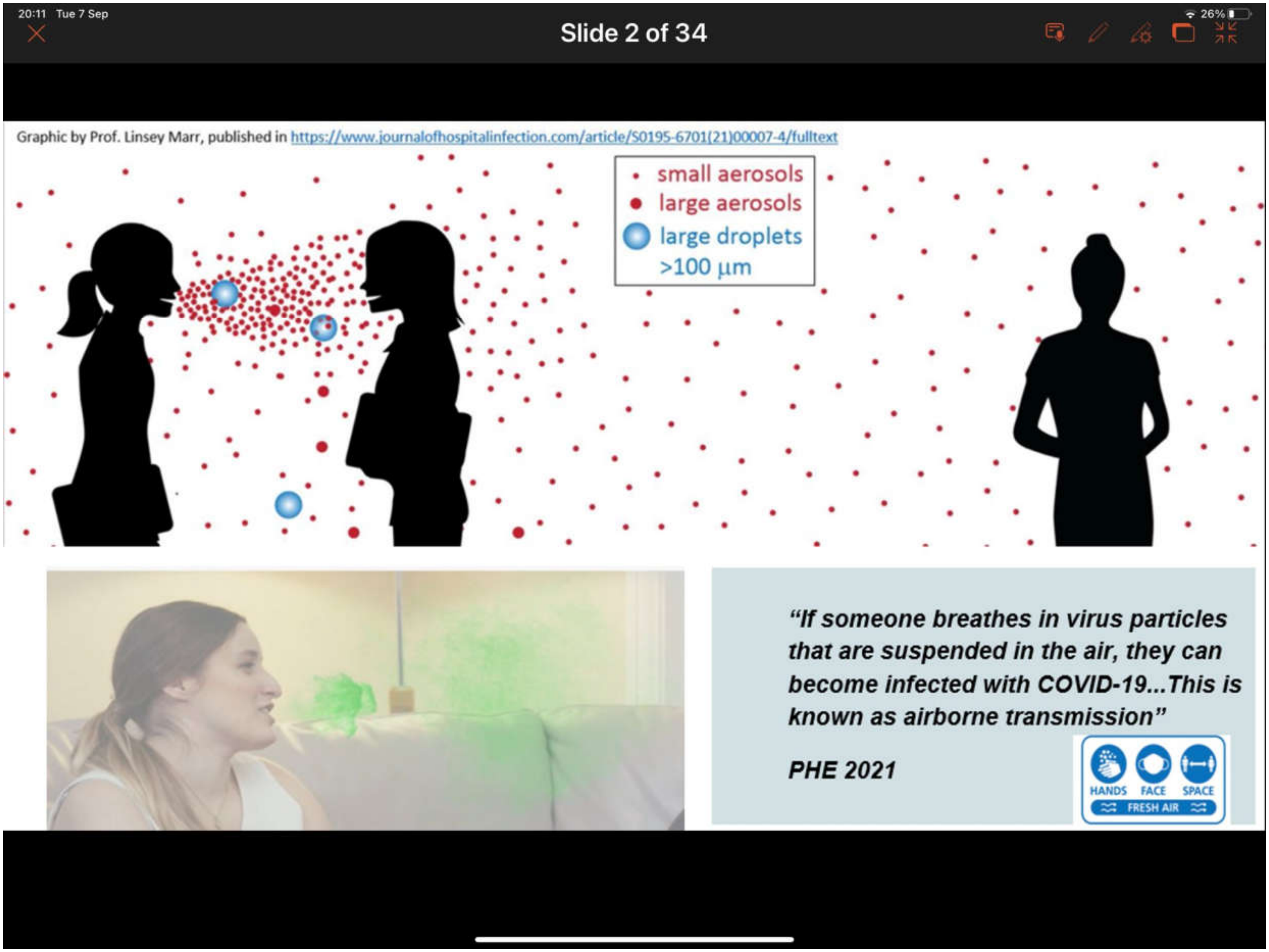
$\frac{m_{\mathrm{gen}}}{\bar{v}}$
1 air change/h
$M(t) = \frac{m_{\mathrm{gen}}}{\bar{v}}(1 - e^{-\bar{v}t})$
Mass of Virus Particles in Air, $M(t)$
0
2
4
6
Time, t (h)
$M_{\mathrm{in}}(t) = \frac{v_{\mathrm{in}}}{\mathrm{V}} \int_0^t M(t)dt$
$= \frac{v_{\mathrm{in}}}{\mathrm{V}} \frac{m_{\mathrm{gen}}}{\bar{v}} \left[t + \frac{1}{\bar{v}}(e^{-\bar{v}t} - 1)\right]$
Mass of Virus Particles Inhaled, $M_{\mathrm{in}}(t)$
0
2
4
6
Time, t (h)

Twitter

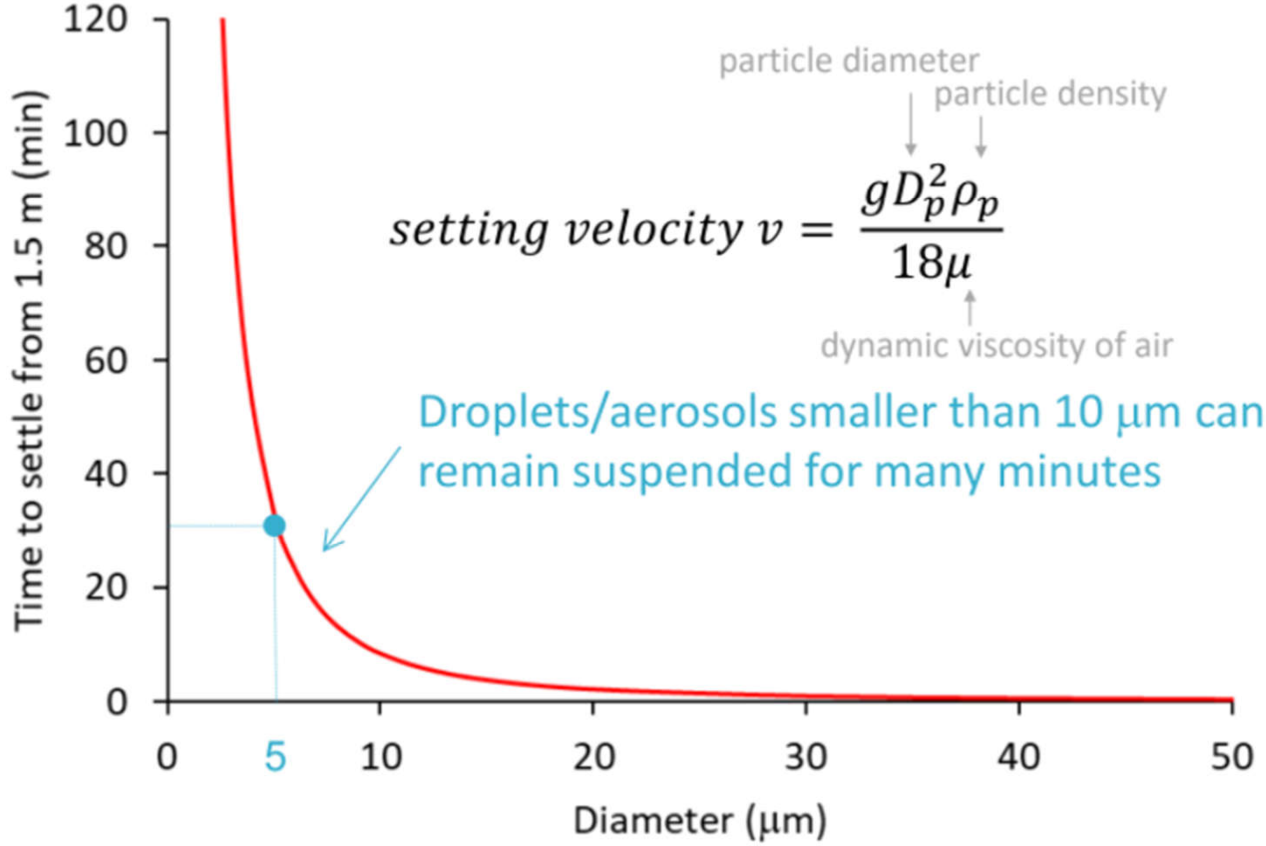
Dr Christine Peters
@microlabdoc

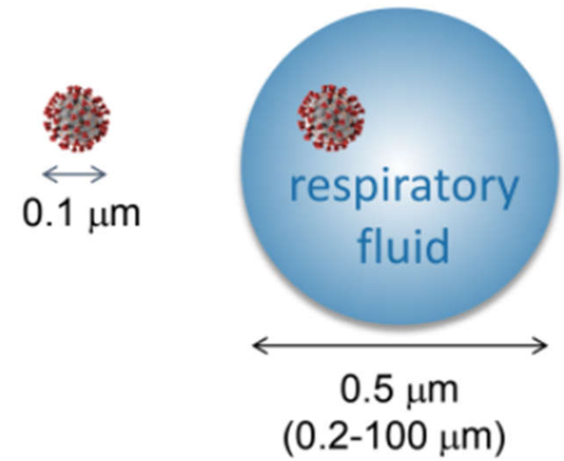
What's all this about airborne COVID?
This diagram by @linseymarr sums it up but someone indicated to me they thought this was a mere imagined model of what happens. So here is a v basic run through the overwhelming evidence


Linsey Marr
@linseymarr

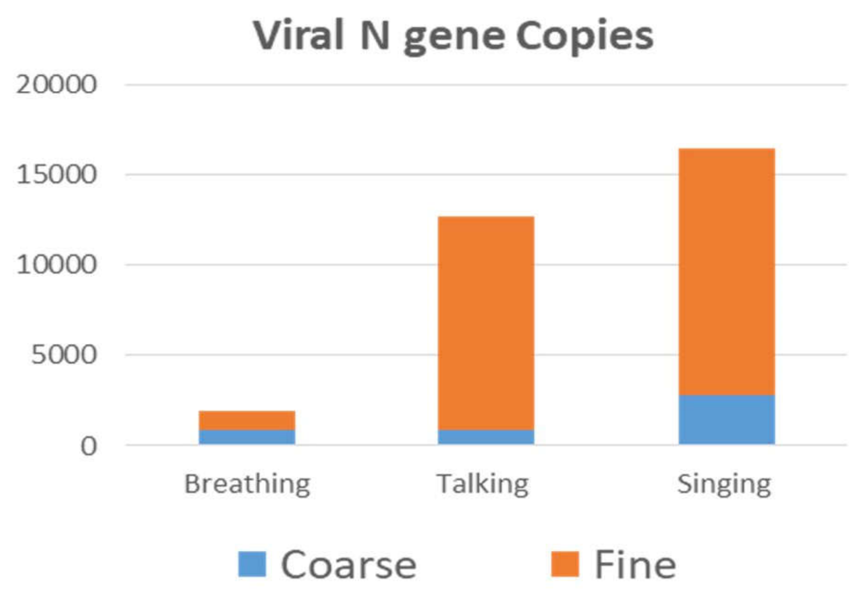

20:11 Tue 7 Sep
Slide 2 of 34
26%
Graphic by Prof. Linsey Marr, published in https://www.journalofhospitalinfection.com/article/S0195-6701(21)00007-4/fulltext
small aerosols
large aerosols
large droplets
>100 µm
"If someone breathes in virus particles that are suspended in the air, they can become infected with COVID-19...This is known as airborne transmission"
PHE 2021
HANDS
FACE
SPACE
FRESH AIR

Settling Velocity and Time



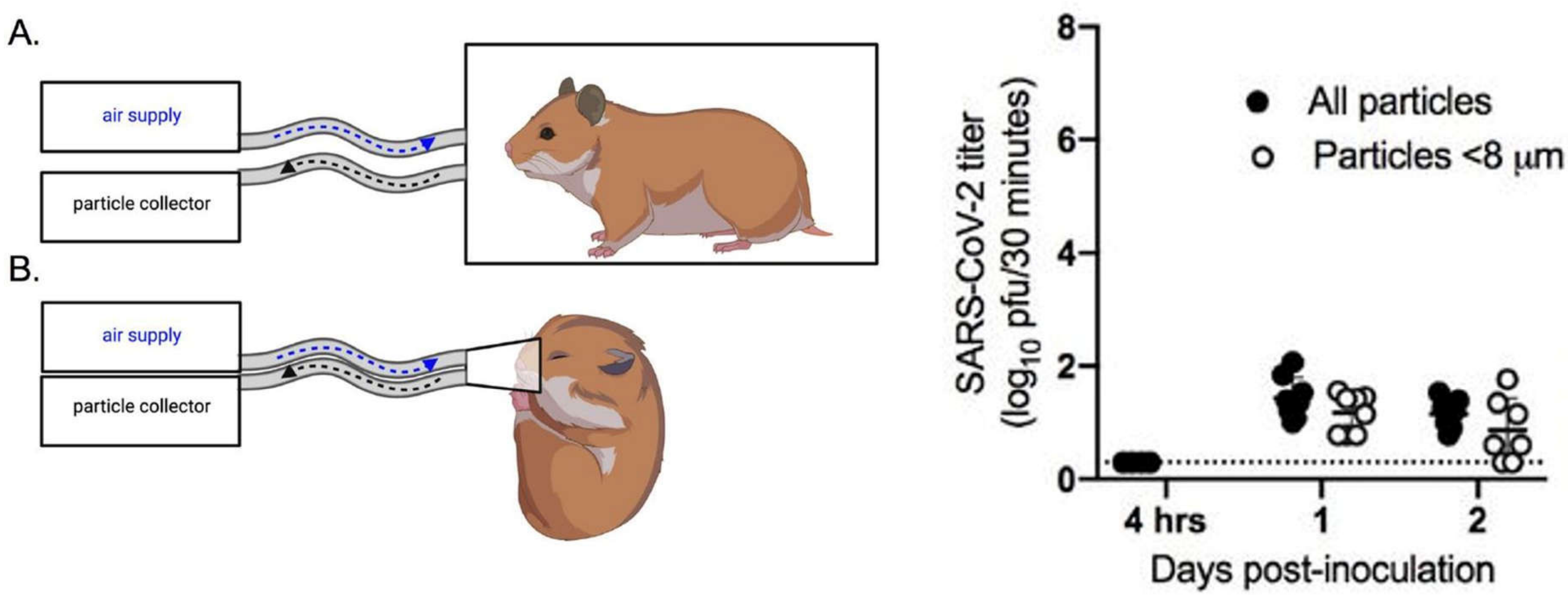


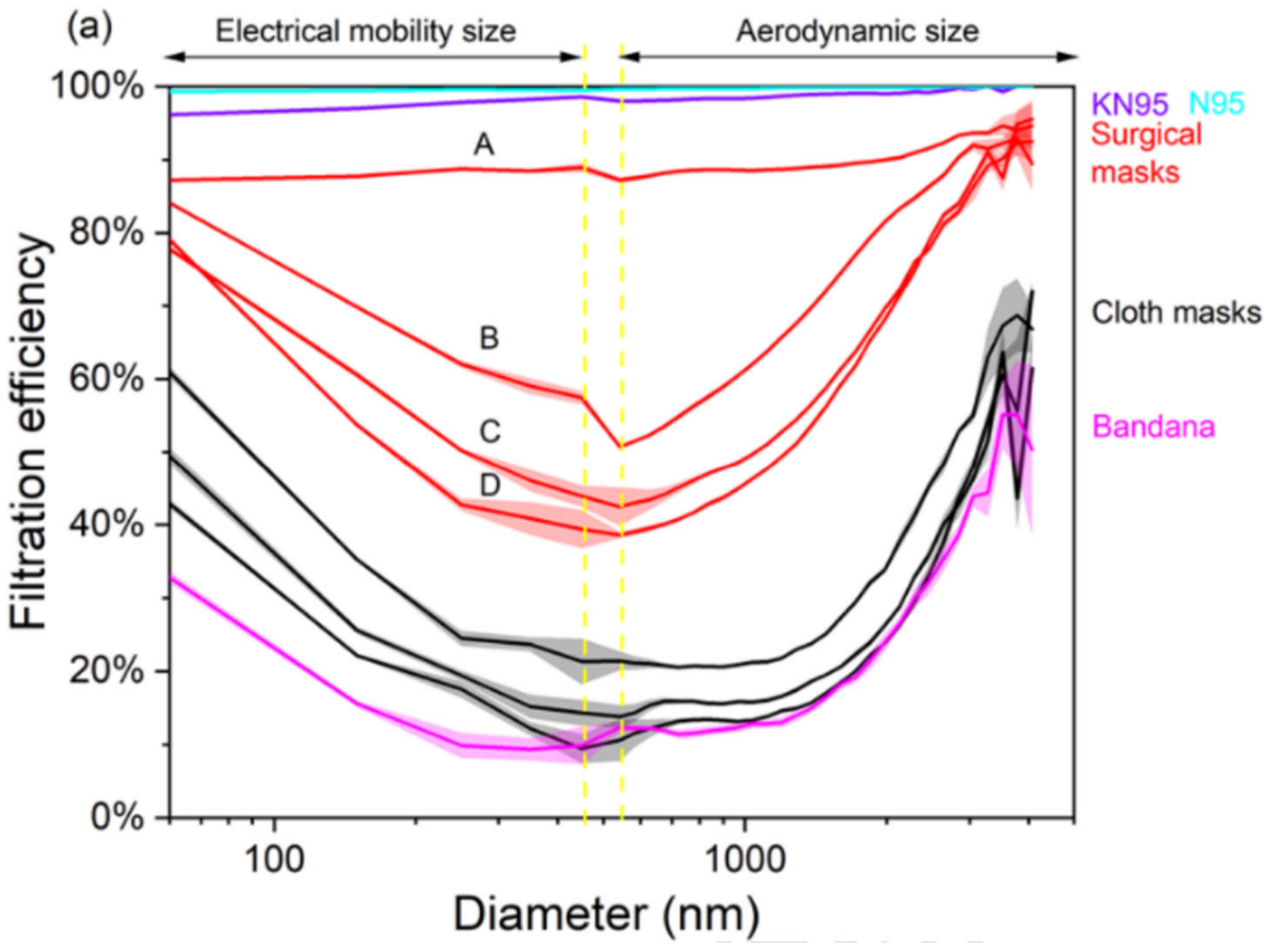
Bio aerosol Production (5 um cut off)



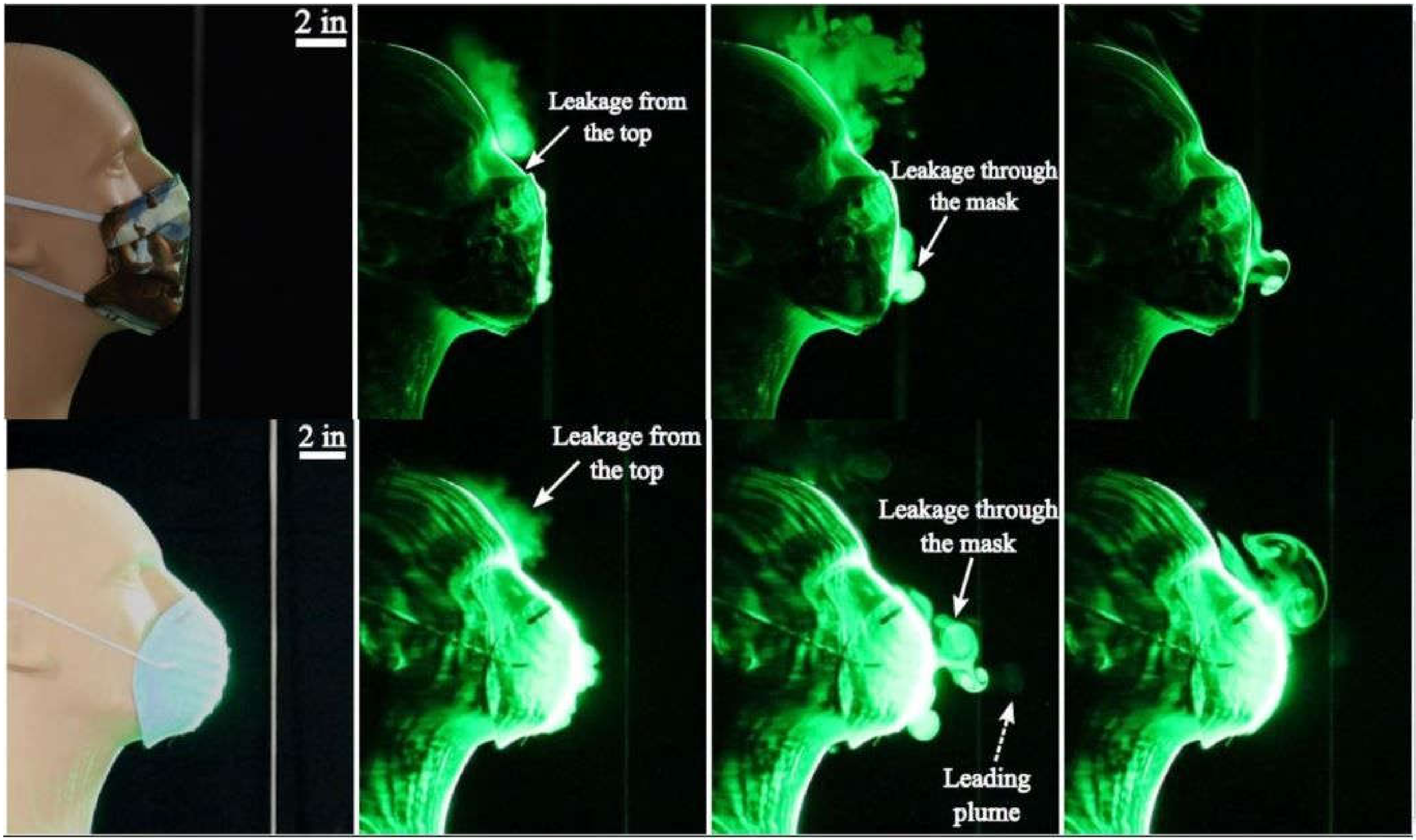
[Viral Load of SARS-CoV-2 in Respiratory Aerosols Emitted by COVID-19 Patients while Breathing, Talking, and Singing | Clinical Infectious Diseases | Oxford Academic (oup.com)]

Animal model 8 um cut off : Culture positive

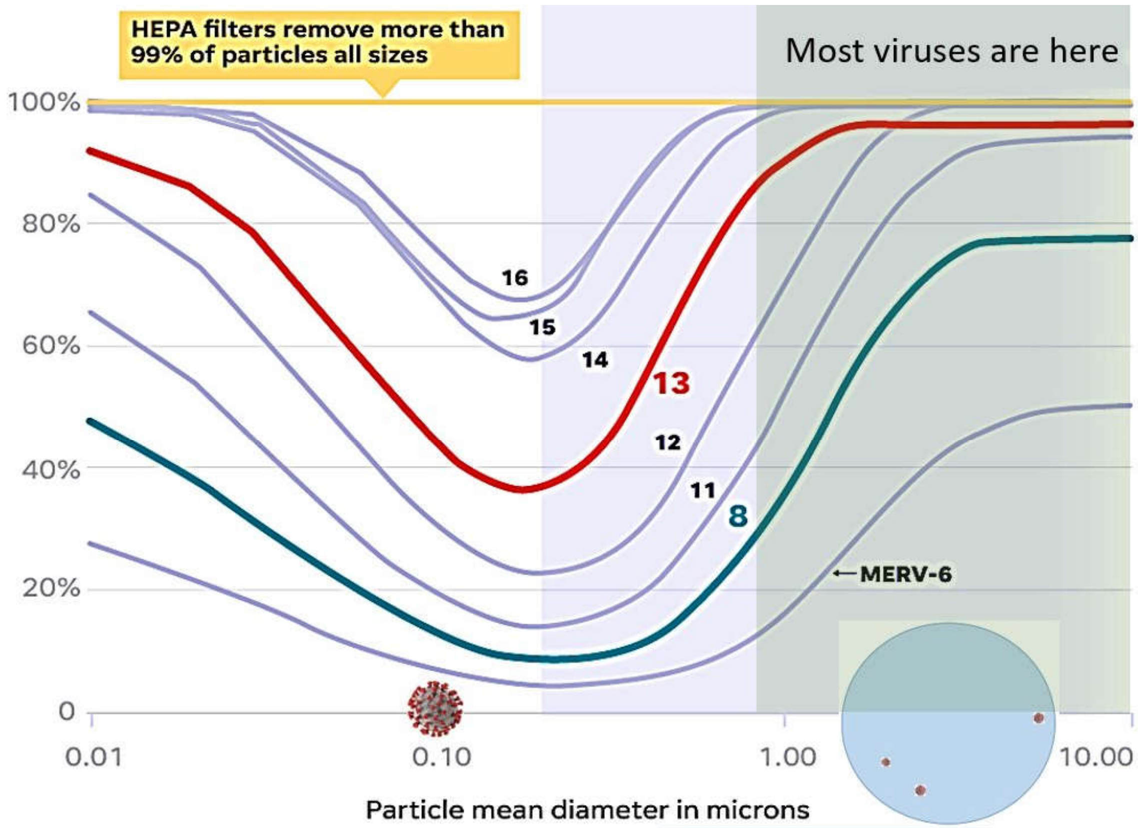




Sankhyan, S., Heinselman, K.N., Ciesielski, P.N., Barnes, T., Himmel, M.E., Teed, H., Patel, S., Vance, M.E. (2021). Filtration Performance of Layering Masks and Face Coverings and the Reusability of Cotton Masks after Repeated Washing and Drying. Aerosol Air Qual. Res. https://doi.org/10.4209/aaqr.210117

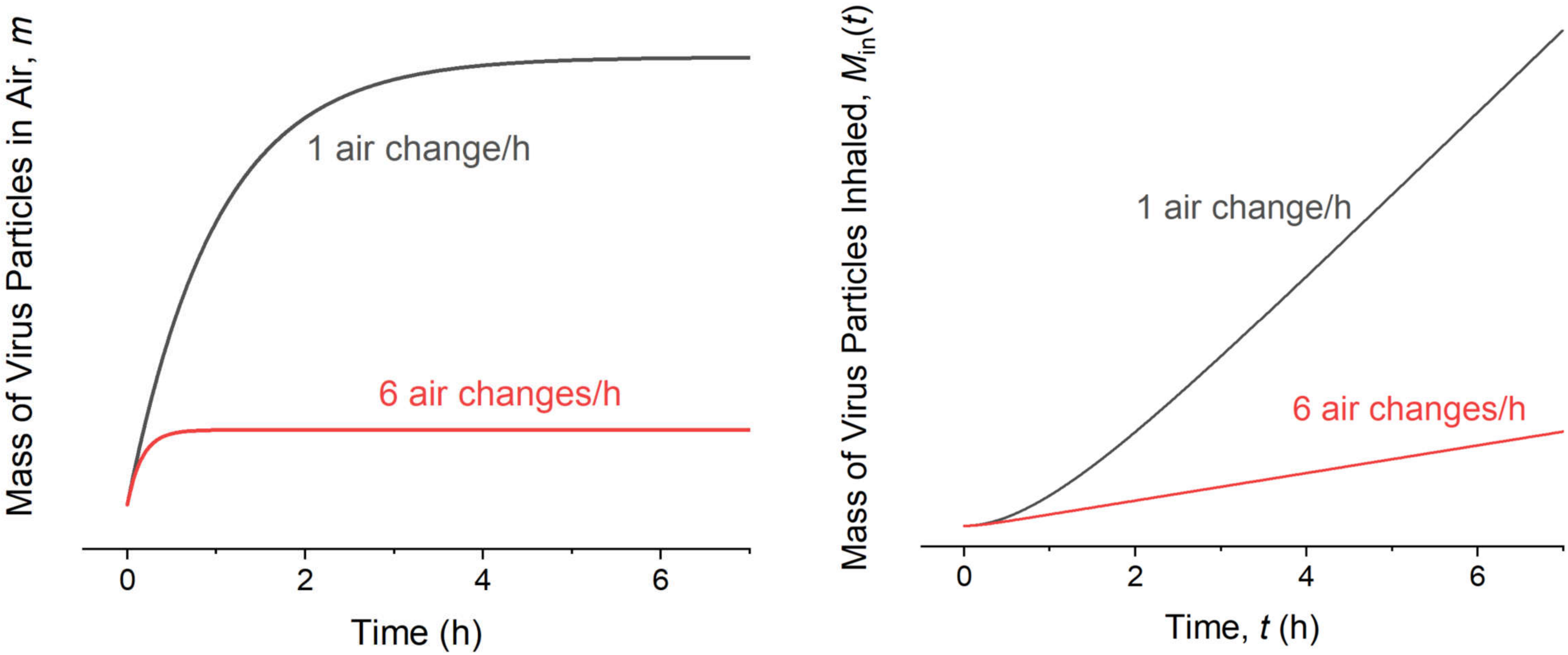

2 in
Leakage from the top
Leakage through the mask
2 in
Leakage from the top
Leakage through the mask
Leading plume

Ventilation and Filters



- Virus is not naked in the air
- Supermicron range is likely what matters most
- Going from MERV 8 to MERV 13 is a large improvement
- Most existing HVAC can't tolerate HEPA, fan not strong enough
- What matters is overall removal (flow * efficiency), not 100% in a single pass

Increased Ventilation Matters



Masks REALLY make a difference

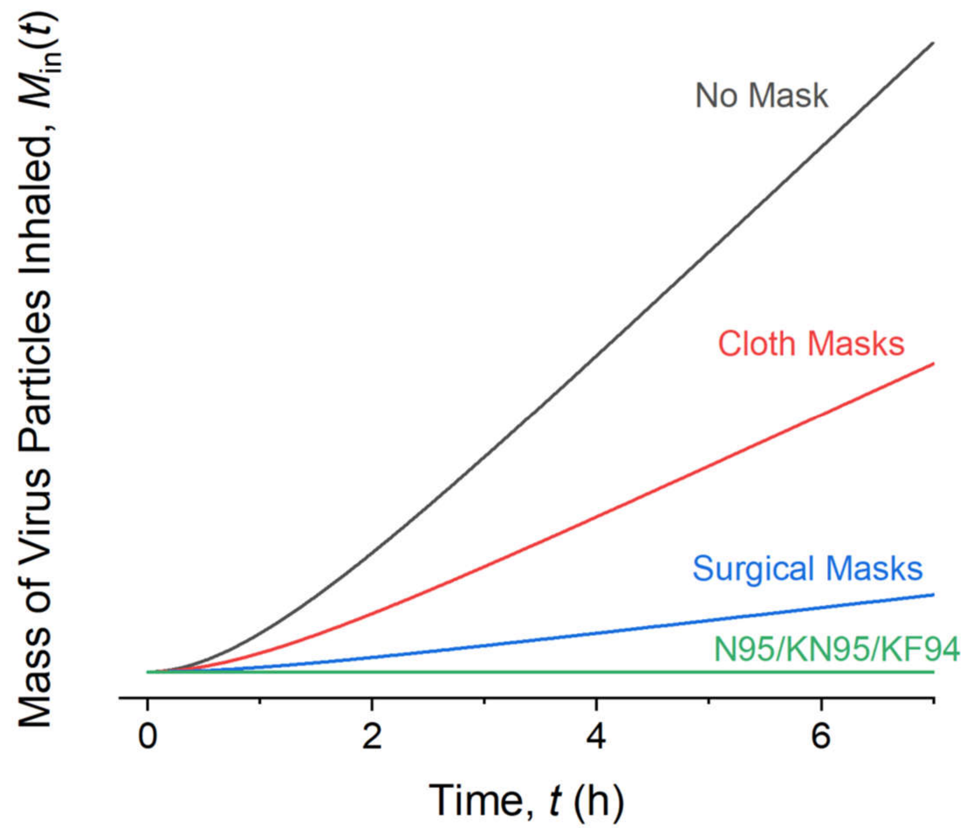
f = mask filtration efficiency

~30% for cloth, 50% for surgical, 97% for N95/KN95/KF94

$$M_{\text{in}}(t) = \frac{v_{\text{in}}}{\text{V}}(1-f)\int_0^t M(t)(1-f)dt$$

$$= \frac{v_{\text{in}}}{\text{V}}\frac{m_{\text{gen}}}{\bar{v}}(1-f)^2\left[t + \frac{1}{\bar{v}}(e^{-\bar{v}t} - 1)\right]$$

N95/KN95/KF94 would decrease inhaled particle amount by ~1000-fold
(Cloth ~2-fold, surgical ~4-fold)



for 1 air change scenario

Revisiting the Assumptions

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Linsey Marr presentation:
https://drive.google.com/file/d/1zssyx3f7cwk0RQUXylgf1EvBWxOiUNJw/view

Twitter thread: https://twitter.com/microlabdoc/status/1435340194530615299

Science review: https://www.science.org/doi/10.1126/science.abd9149

Twitter thread about the Science review:
https://twitter.com/jljcolorado/status/1430967286244970502

Improving your masks: https://www.npr.org/sections/health-shots/2021/02/03/962197192/5-hacks-to-make-your-face-mask-more-protective