Efficiency and synergy of simple protective measures against COVID-19: Masks, ventilation and more

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Outline

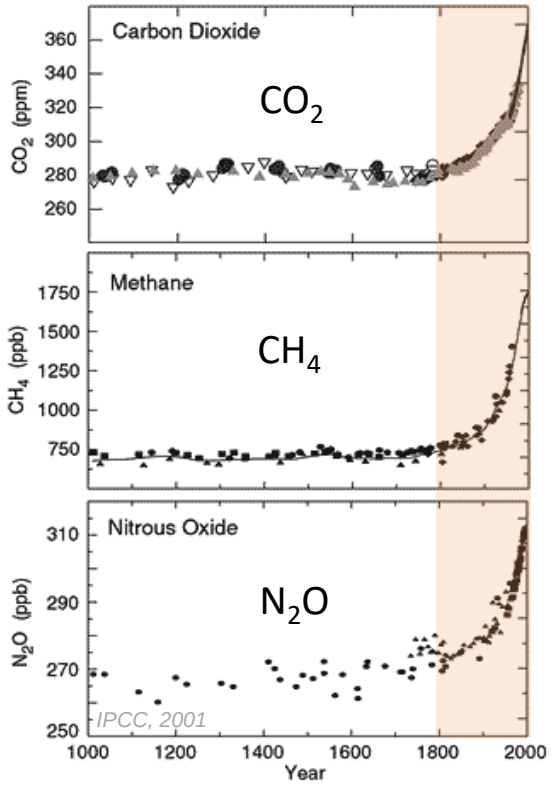
Introduction & Motivation

- Research Background in Earth System & Aerosol Science

Protective Measures

- Respiratory Aerosol & Droplet Transmission
- Effectiveness & Synergies of Masks, Distancing & Ventilation, Testing & Isolation etc.
- Efficient Classroom Ventilation

The Anthropocene: A New Era in Earth & Human History



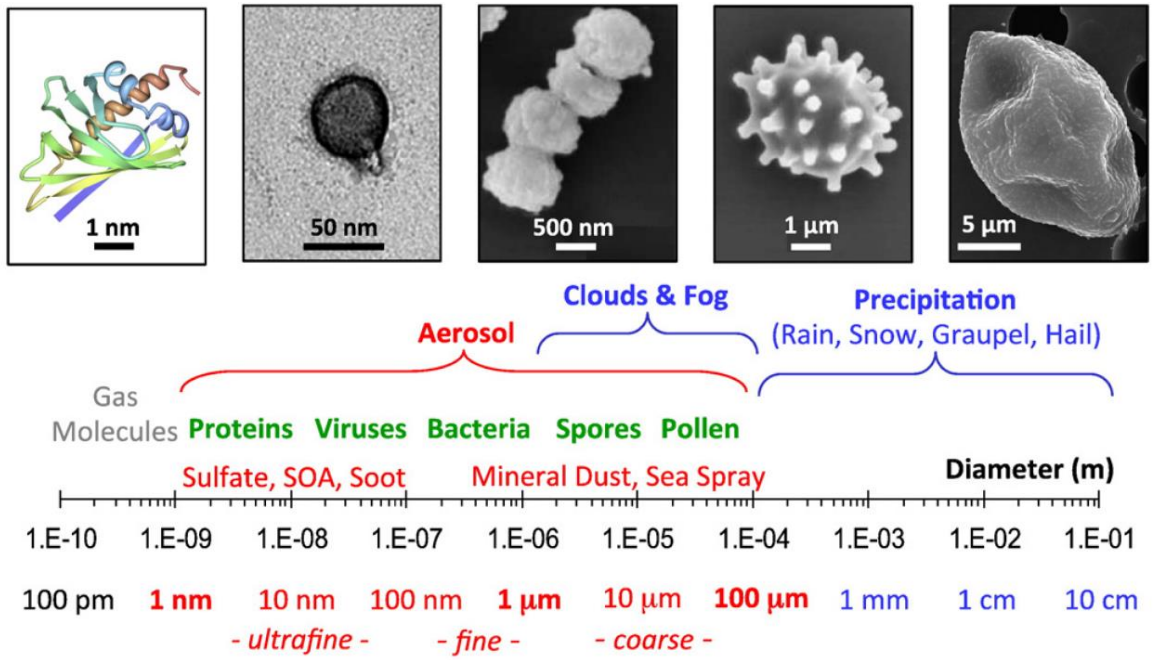
THE ANTHROPOCENE

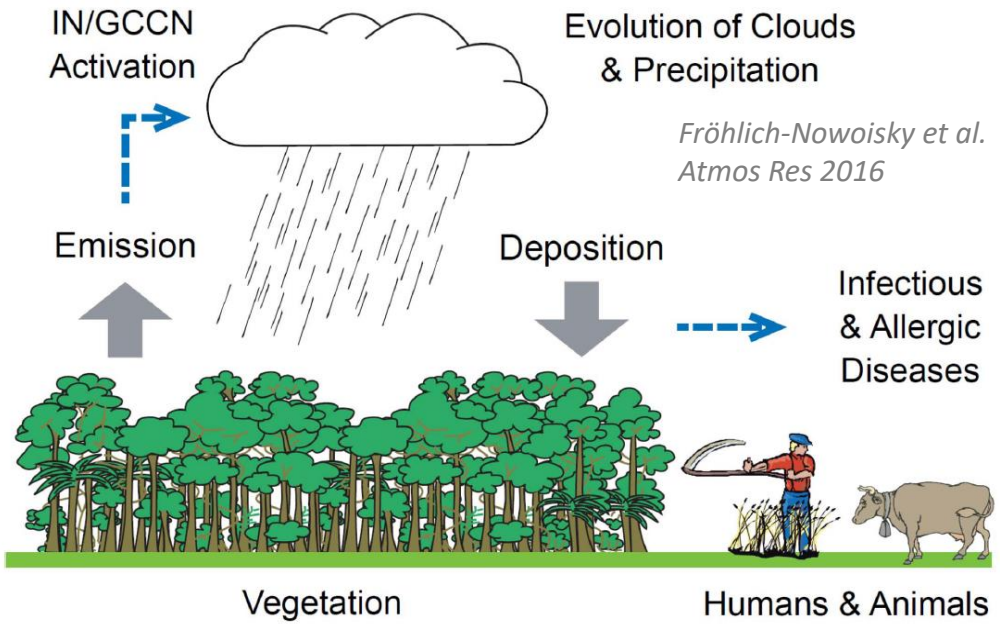
Globally pervasive & steeply increasing anthropogenic influence on planet Earth:
scientific curiosity & discovery meet practical challenges & philosophical questions - from air quality, ozone hole & climate change to public health & human well-being ("planetary health")

Scientific & societal message: we are shaping the planet, so let's try to get it right

Crutzen, Nature 2002; Pöschl et al. Chem Rev 2015, PAS 2017, Springer 2020, 2021; www.mpic.de/4677594/trauer-um-paul-crutzen#Condolences

Atmospheric Bioaerosols



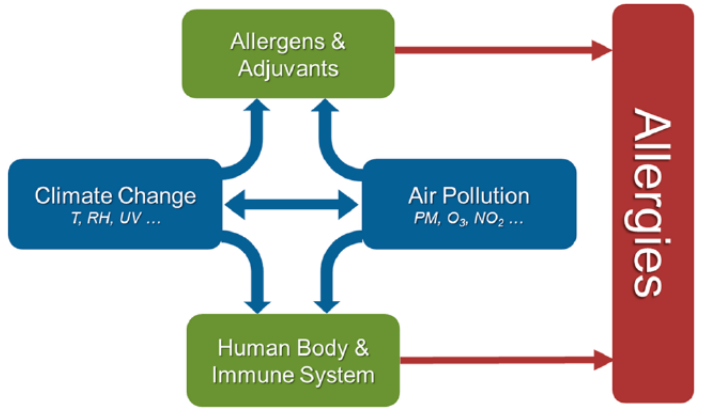


Atmospheric biodiversity: high abundance, diversity & fluxes of airborne bacteria & fungi ("life is in the air"):
~1 µg m^{-3}, ~10 L^{-1}, ~10^2 m^{-2} s^{-1}, >10^3 species (urban PM; DNA, protein & fluorescence analysis)
~10 ng m^{-3} DNA ⇒ inhalation of ~1 µg/day ≡ ~10^6 bacterial genomes/day

Cloud condensation & ice nuclei (CCN/IN): co-evolution of life & climate ⇒ bioprecipitation cycle

Pathogens/allergens: permanent challenge ⇒ infectious & allergic diseases

COVID-19/SARS-CoV-2: explain airborne transmission; quantify efficacy of protective measures



Despres et al. BG 2007, Tellus 2012, Fröhlich-Nowoisky et al. PNAS 2009, Atmos Res 2016, Kunert et al. AMT 2018, Huffman et al. ACP 2013, Morris et al. GCB 2014, Lukas et al. JACS 2020, Pöhlker et al. AMT 2012, 2013, Science 2012, arxiv 2021, Cheng et al. Science 2021, Su et al. medRxiv 2022

Disease Transmission via Respiratory Aerosols & Droplets

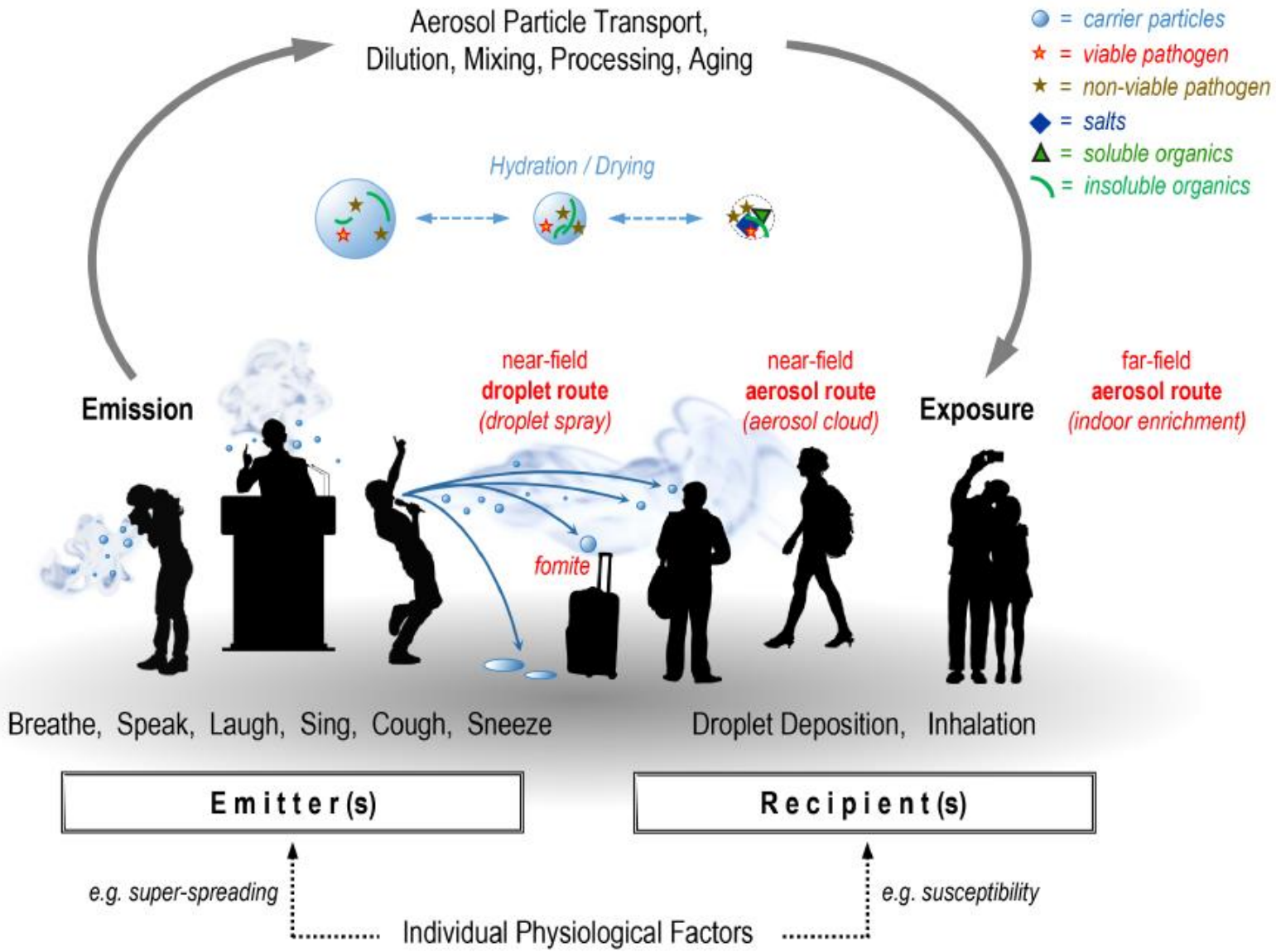
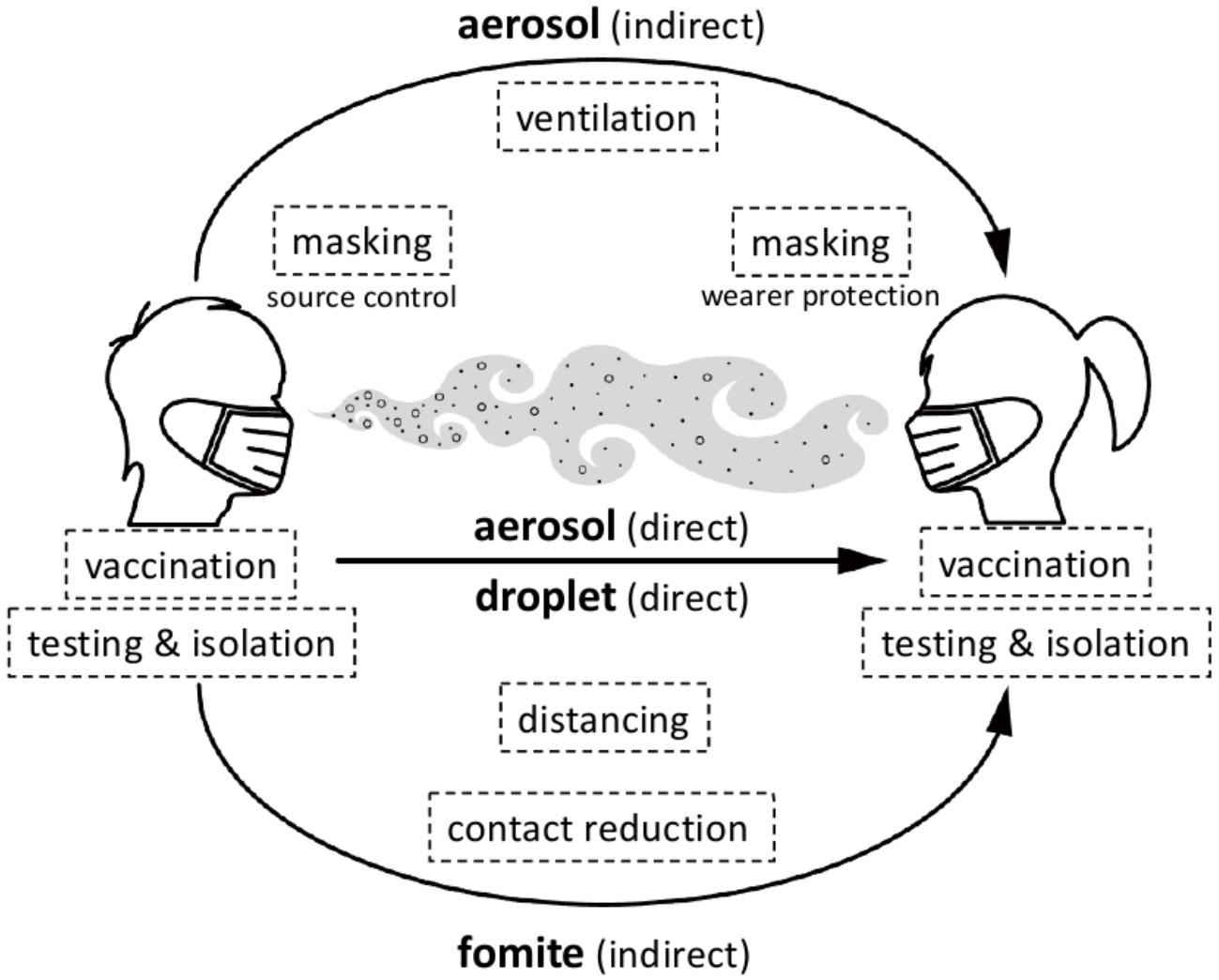


FIG. 1 Conceptual scheme of the aerosol and droplet pathogen transmission routes along with relevant physicochemical properties of respiratory particles.

Comprehensive Review Article:
Pöhlker et al. arxiv 2021

Synergetic measures to contain highly infectious variants of SARS-CoV-2

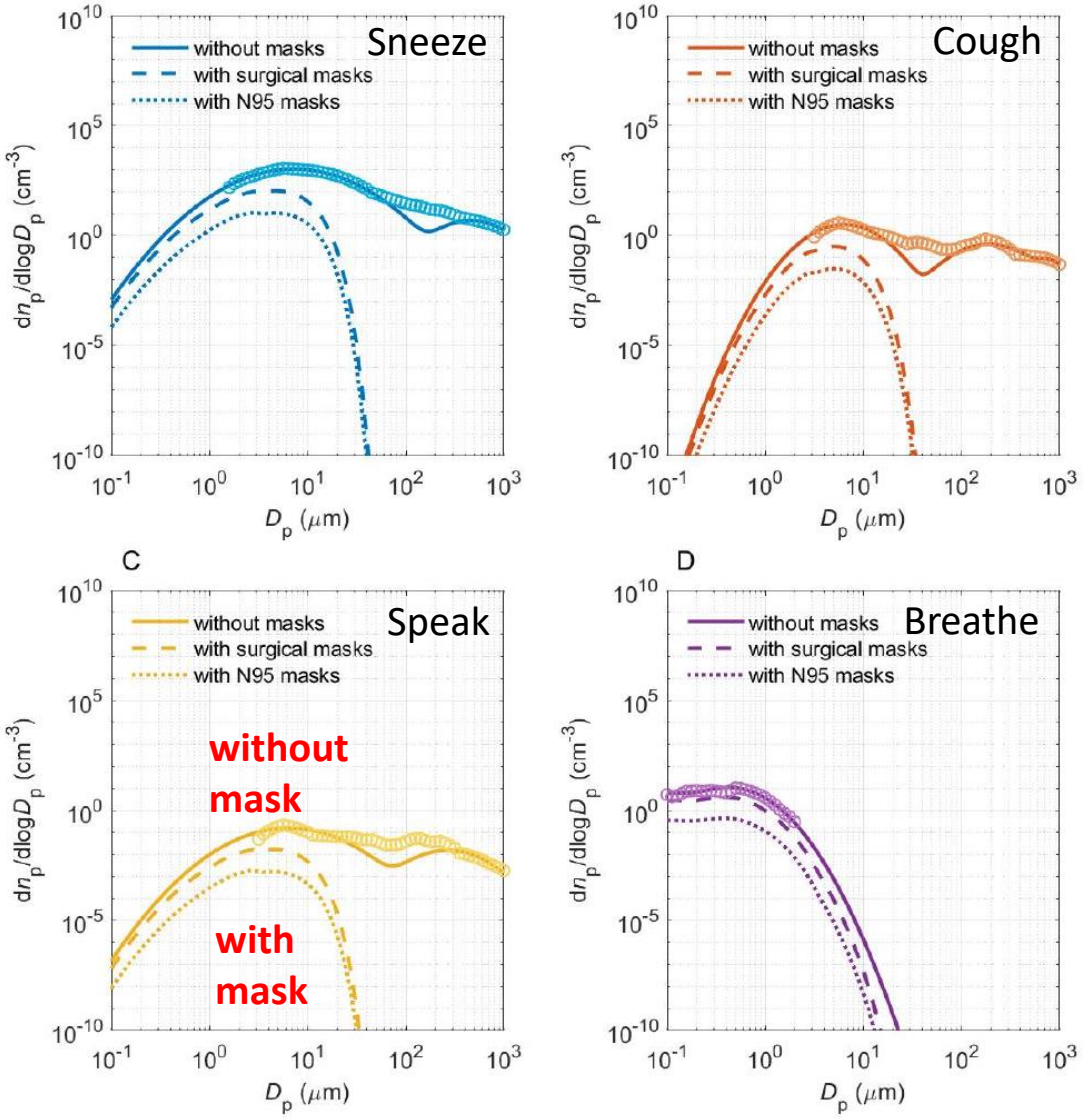


Comprehensive Quantitative Analysis:
Su et al. medRxiv 2021,
doi.org/10.1101/2021.11.24.21266824

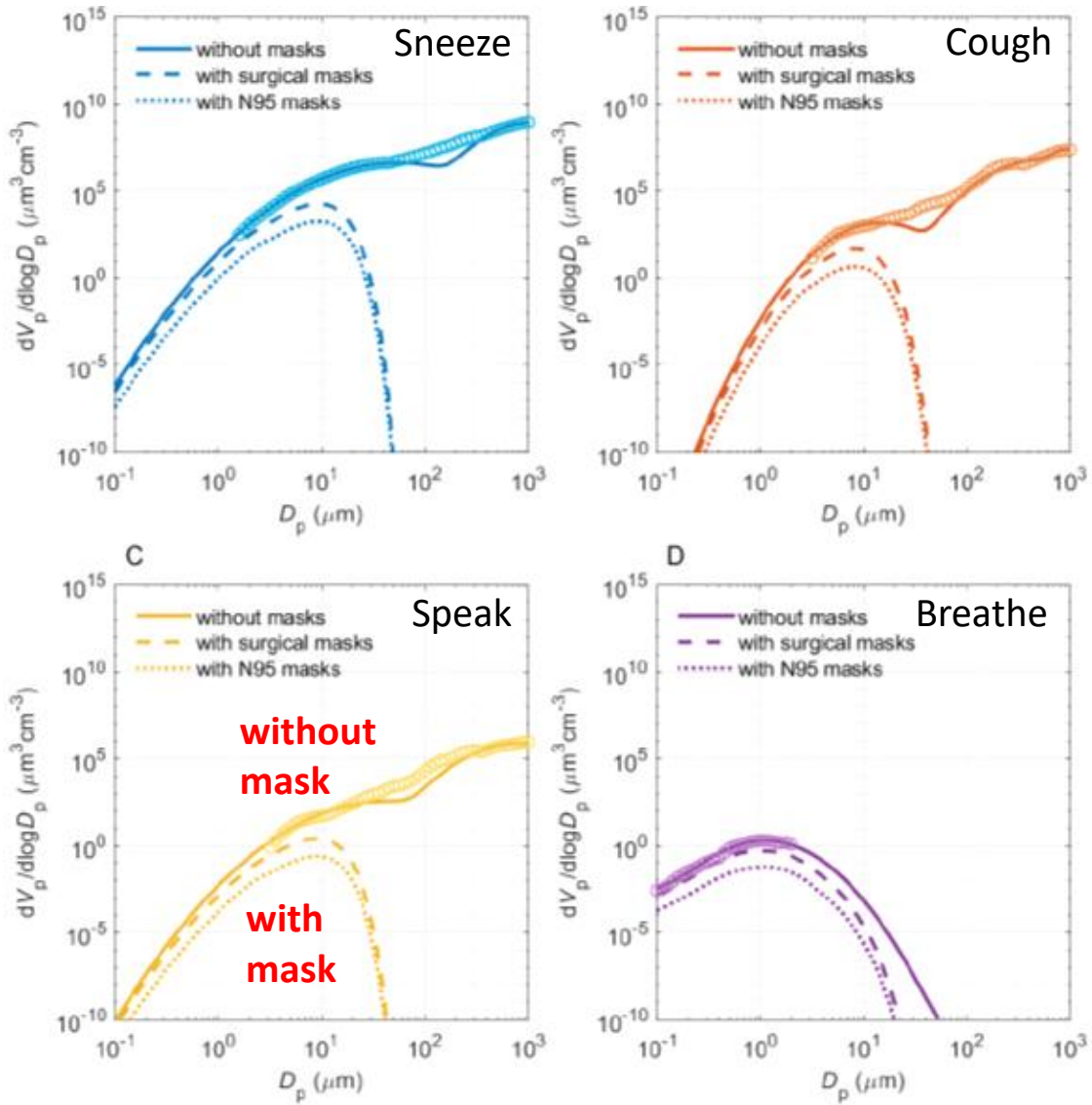
Fig. 1 Schematic illustration of different transmission pathways and protective measures.

Number & Volume Size Distributions of Respiratory Particles

Number

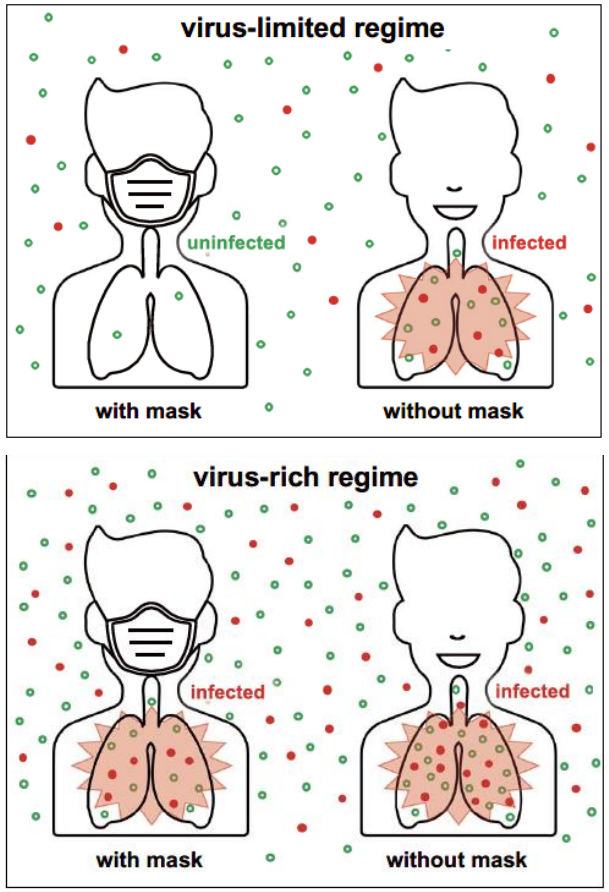


Volume



Cheng et al. Science 2021: **Face masks effectively limit the probability of SARS-CoV-2 transmission**

Effectiveness & Synergy of Face Masks

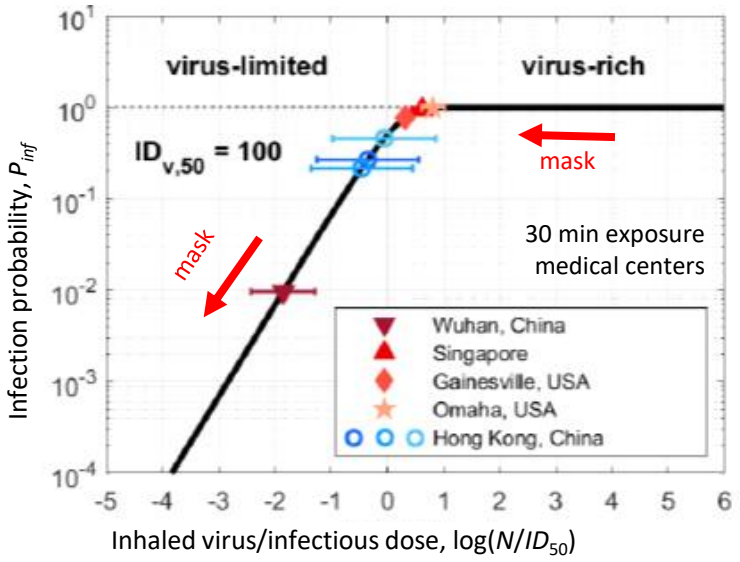


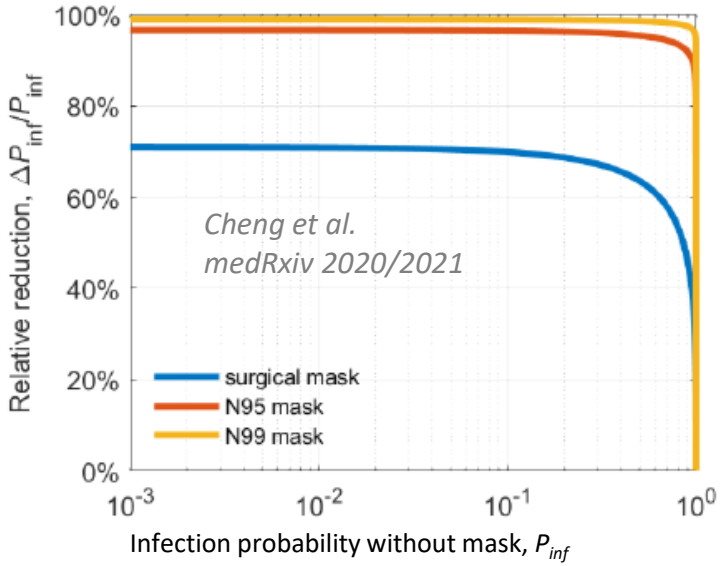
Variations explained by different regimes of virus abundance relative to median infectious dose (ID_{50}):

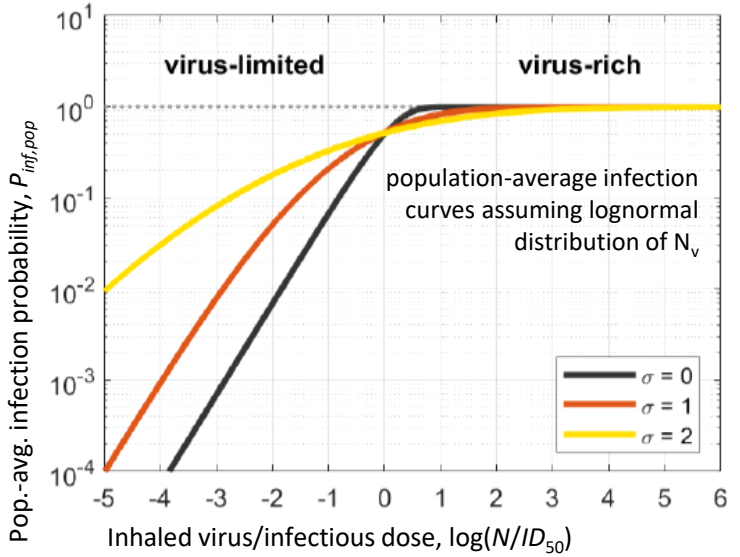
→ virus-limited for most environments:
simple masks help

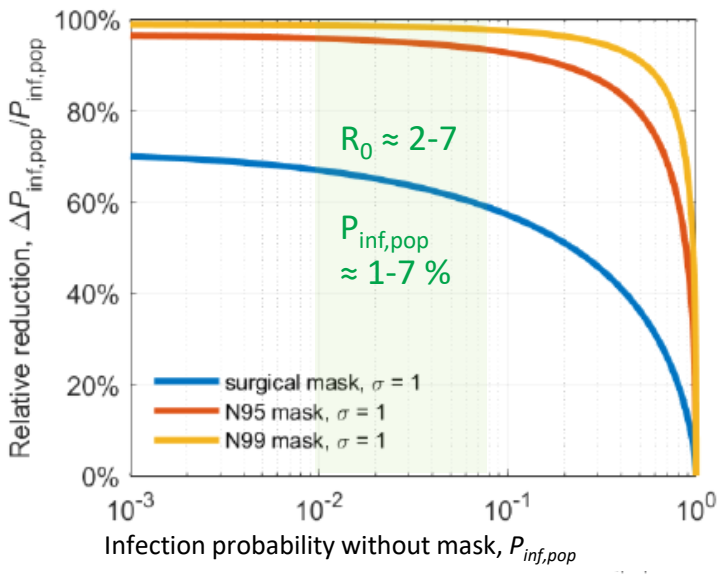
→ virus-rich (e.g., med. centers):
better equipment needed

→ synergistic effects & population-average link to reproduction number









Cheng et al. Science 2021: **Face masks effectively limit the probability of SARS-CoV-2 transmission**

Synergy of Masking, Distancing & Ventilation, and Vaccination for $R_0 = 5$ (Delta)

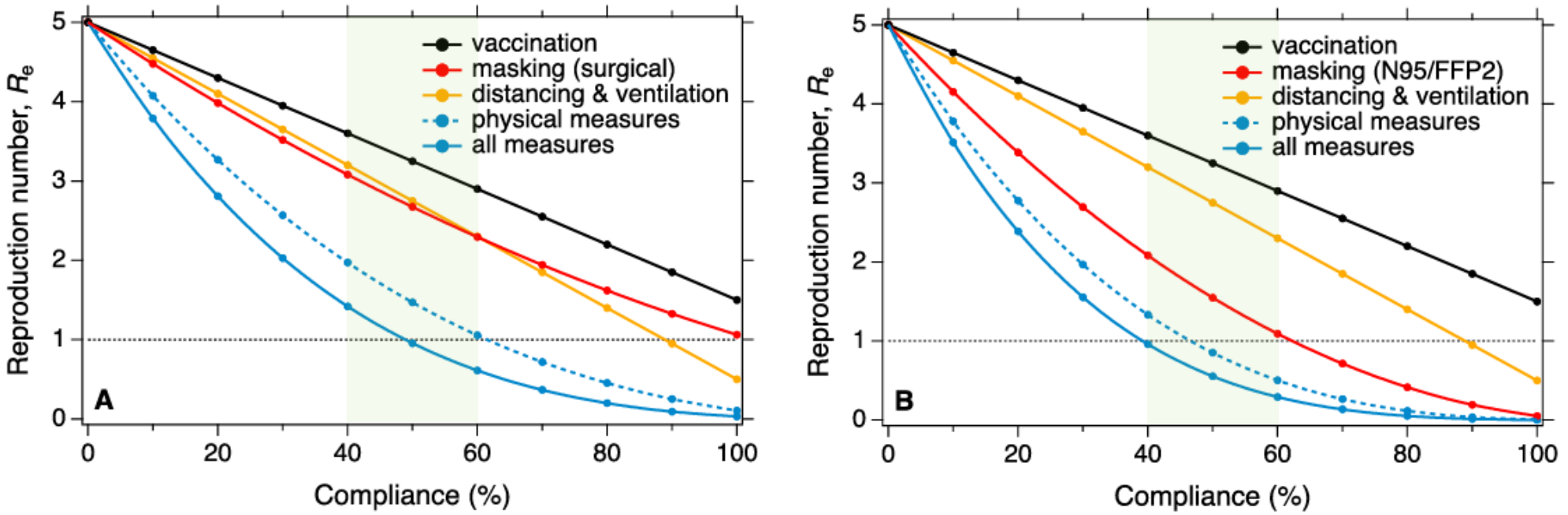


Fig. 2 Effectiveness of individual and combined measures. Reduction of effective reproduction number, R_e, as a function of compliance with different protective measures for a basic reproduction number $R_0 = 5$ approximately reflecting the transmissibility of the delta variant of SARS-CoV-2. Panels **A** and **B** refer to universal masking with surgical masks and N95/FFP2 masks, respectively. The curve labeled "physical measures" refers to the combination and synergy of universal masking plus distancing and ventilation; the curve labeled "all measures" refers to the combination and synergy of the physical measures with vaccination.

Su et al. medRxiv 2021, doi.org/10.1101/2021.11.24.21266824

Synergy of Testing & Isolation with Other Measures for $R_0 = 5$ (Delta)

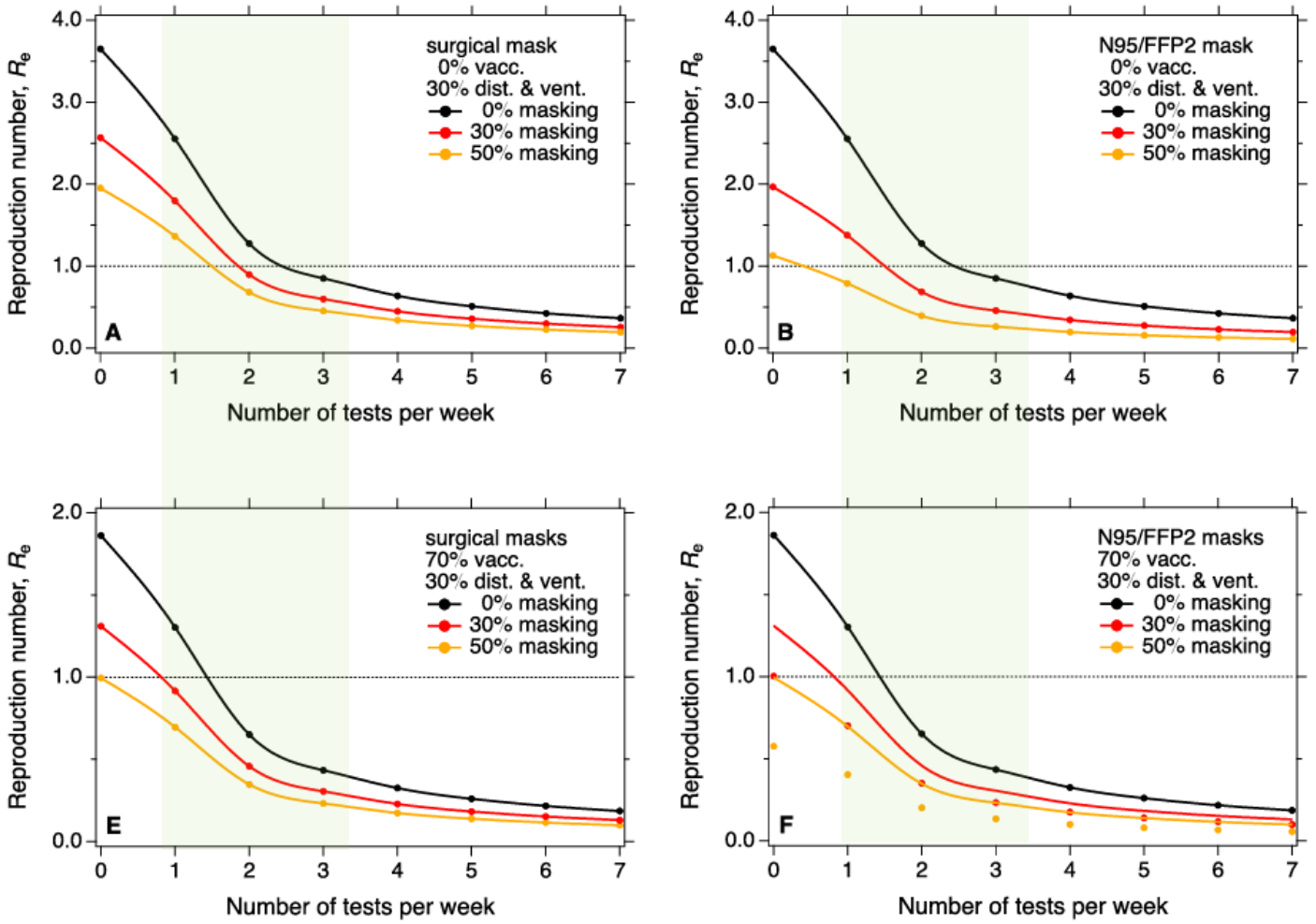
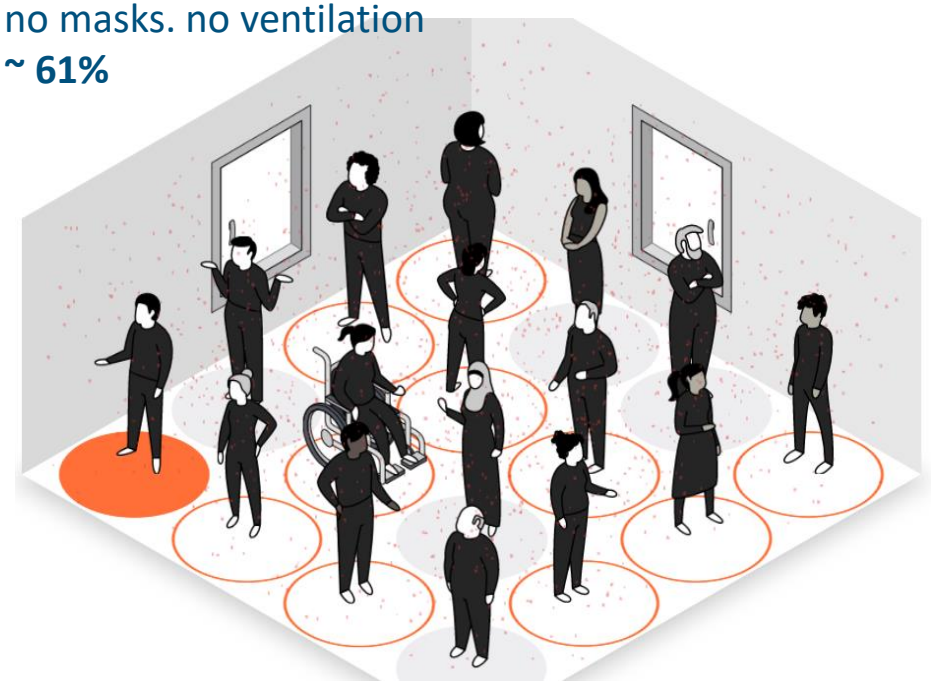


Fig. 4 Effectiveness of testing & isolation for different compliances with masking, vaccination, and distancing & ventilation. Reduction of effective reproduction number, R_e, as a function of testing frequency (number tests per week per person) for different compliances with universal masking and distancing & ventilation, as well as different vaccination rates. Basic reproduction number $R_0 = 5$; reduced starting values of R_e reflect different vaccination rates and compliances with masking and with distancing & ventilation, respectively. Left column corresponds to universal masking with surgical masks, right column corresponds to N95/FFP2 masks.

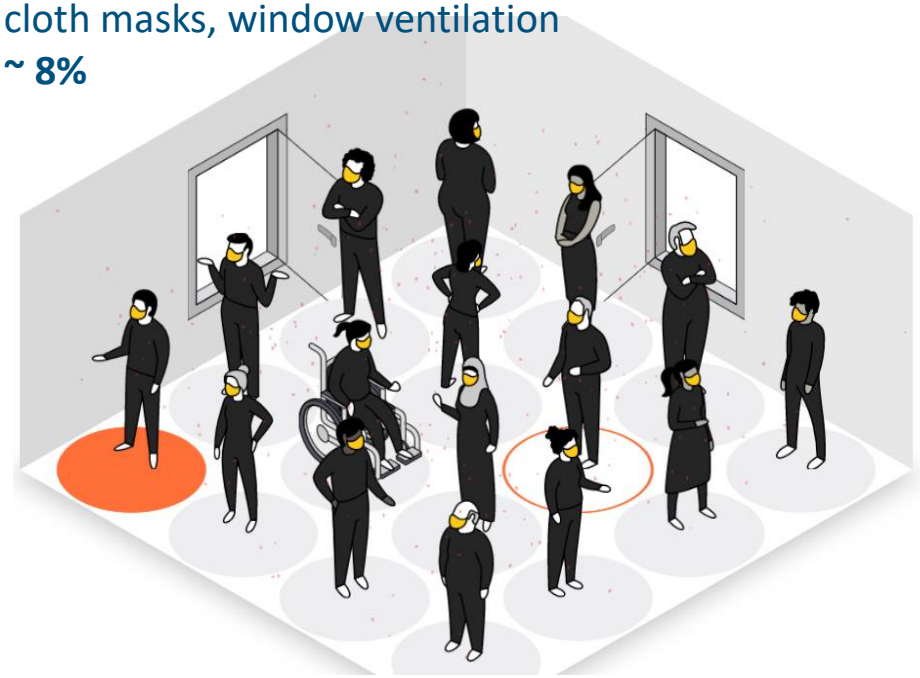
Comprehensive Quantitative Analysis:
Su et al. medRxiv 2021, doi.org/10.1101/2021.11.24.21266824

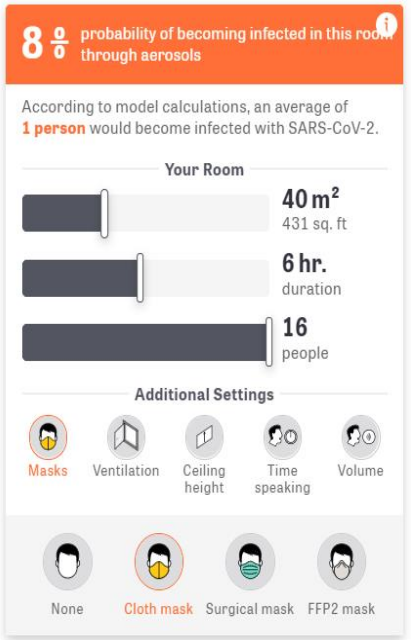
Online Risk Calculator

no masks. no ventilation
~ 61%



cloth masks, window ventilation
~ 8%



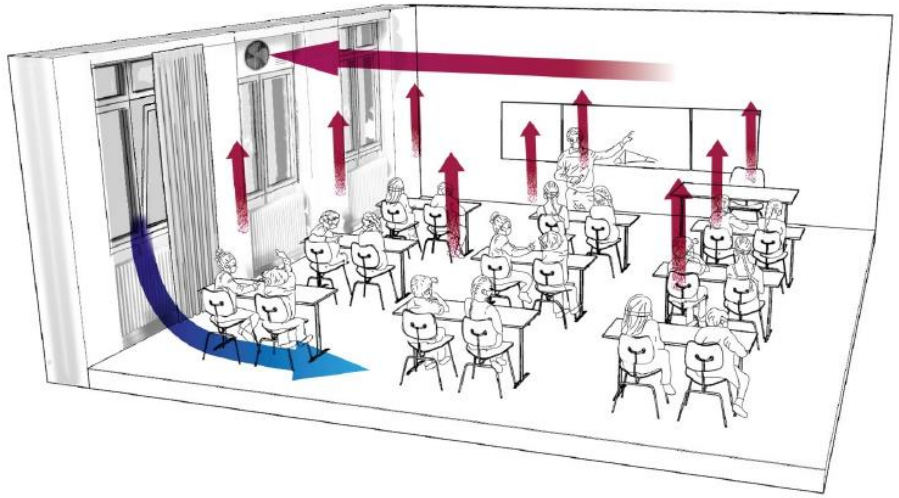


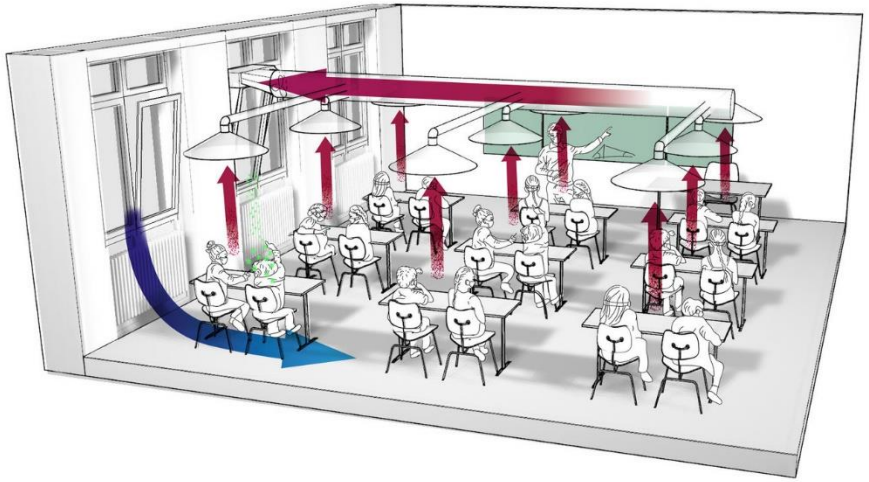
Easy & flexible risk calculator for indoor aerosol transmission
→ explain preventive measures (robust) & absolute risks (variable)

www.zeit.de/wissen/gesundheit/2020-11/coronavirus-aerosols-infection-risk-hotspot-interiors
www.mpic.de/4851094/risk-calculator

Lelieveld et al. IJERPH 2020, Dinklage et al. ZEIT 2020, Helleis & Klimach 2020/2021

Efficient Ventilation for Classrooms in Educational Institutions (and beyond)





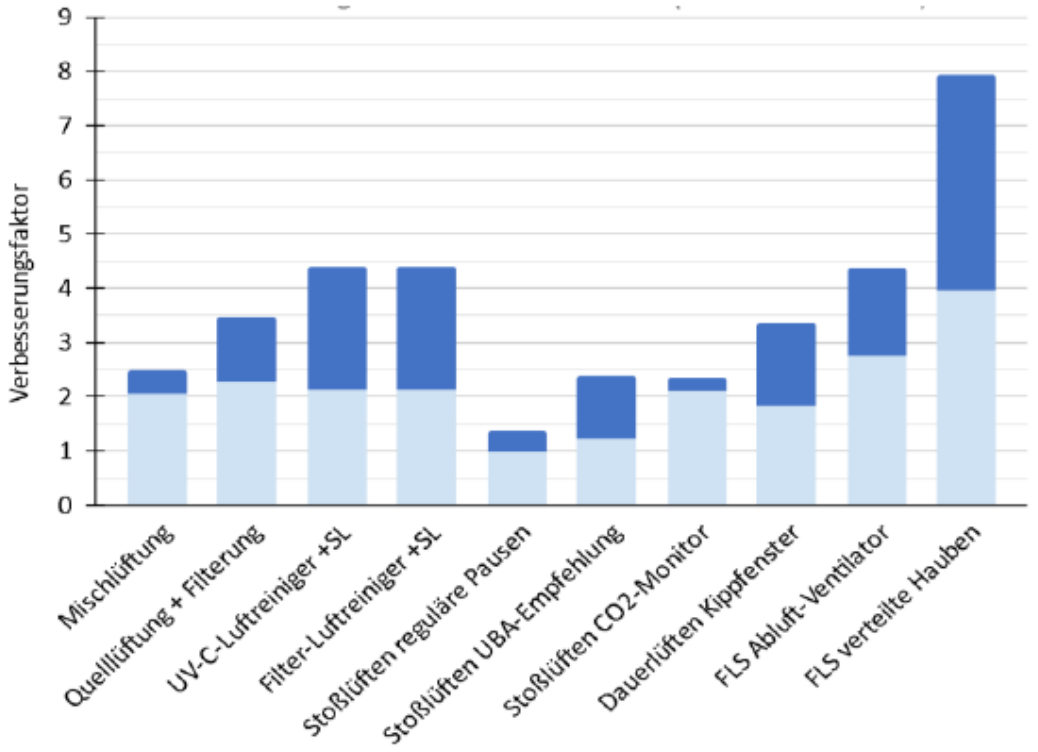
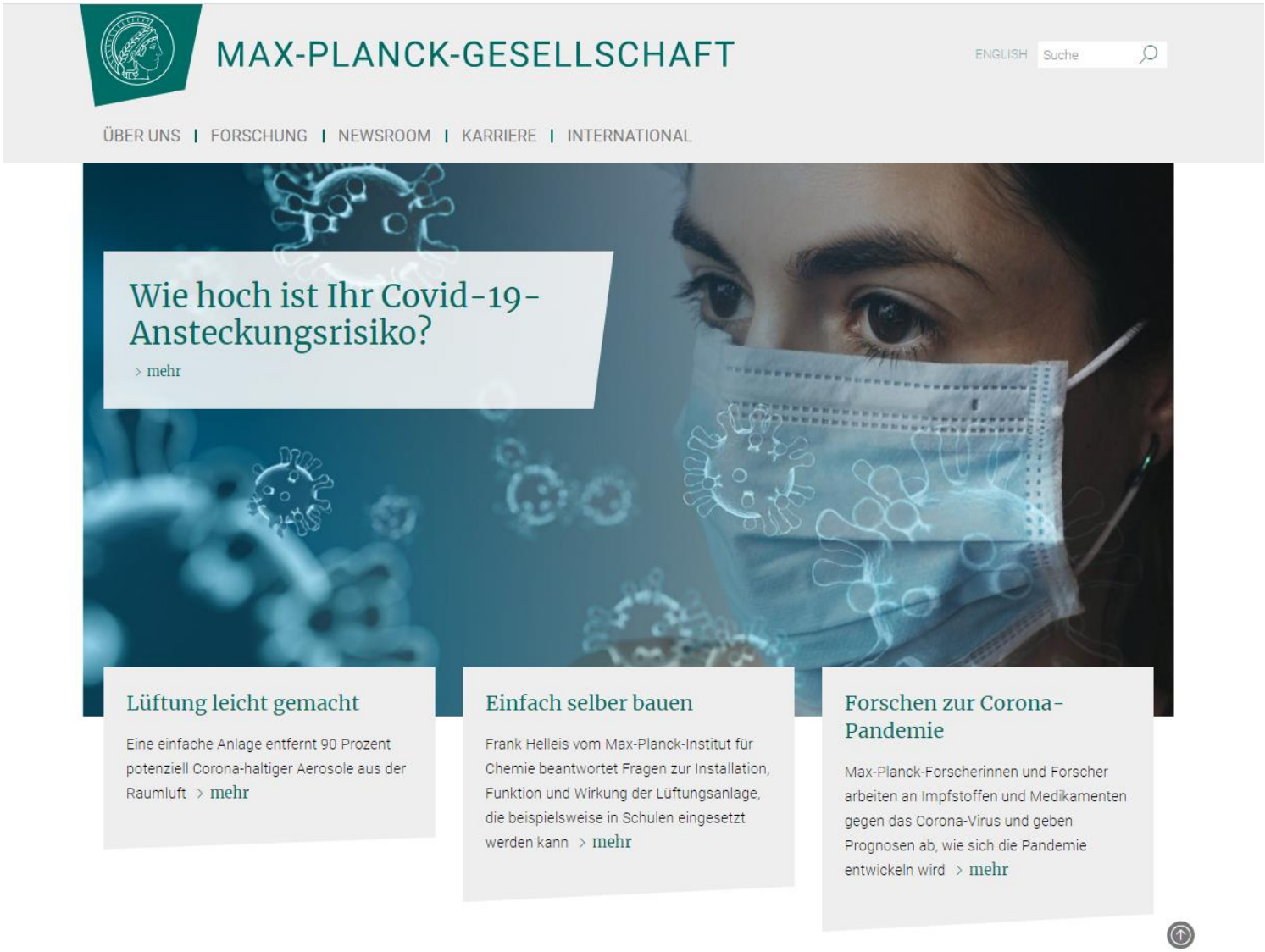


Abbildung 6: Verbesserungsfaktoren bezüglich der Dosis an Atemaerosolpartikeln, die Personen im betrachteten Klassenraum inhalieren, wenn verschiedene Lüftungsmethoden unter günstigen Bedingungen (dunkelblau) oder unter ungünstigen Bedingungen (hellblau) eingesetzt werden (Tabelle 1, Anhang A.2). Die Ergebnisse sind normiert auf einen Referenzwert von 1 für Stoßlüften in den Pausen nach jeder Schulstunde unter ungünstigen Bedingungen.

Efficient low-cost mechanical extract ventilation system, www.ventilation-mainz.de:
natural convection & simple ducts/hoods for targeted & effective removal of exhaled air

Helleis & Klimach et al. 2020/2021/2022, zenodo.org/record/6545276#.You2-9pByUk, zenodo.org/record/6049289#.You31dpByUm

Acknowledgement & References



Special thanks to Y. Cheng & H. Su, F. Helleis & T. Klimach, M. Pöhlker & C. Pöhlker, F. Drewnick, J. Lelieveld et al.

References & further studies: www.mpic.de/5081943/studien-fls?c=3477744