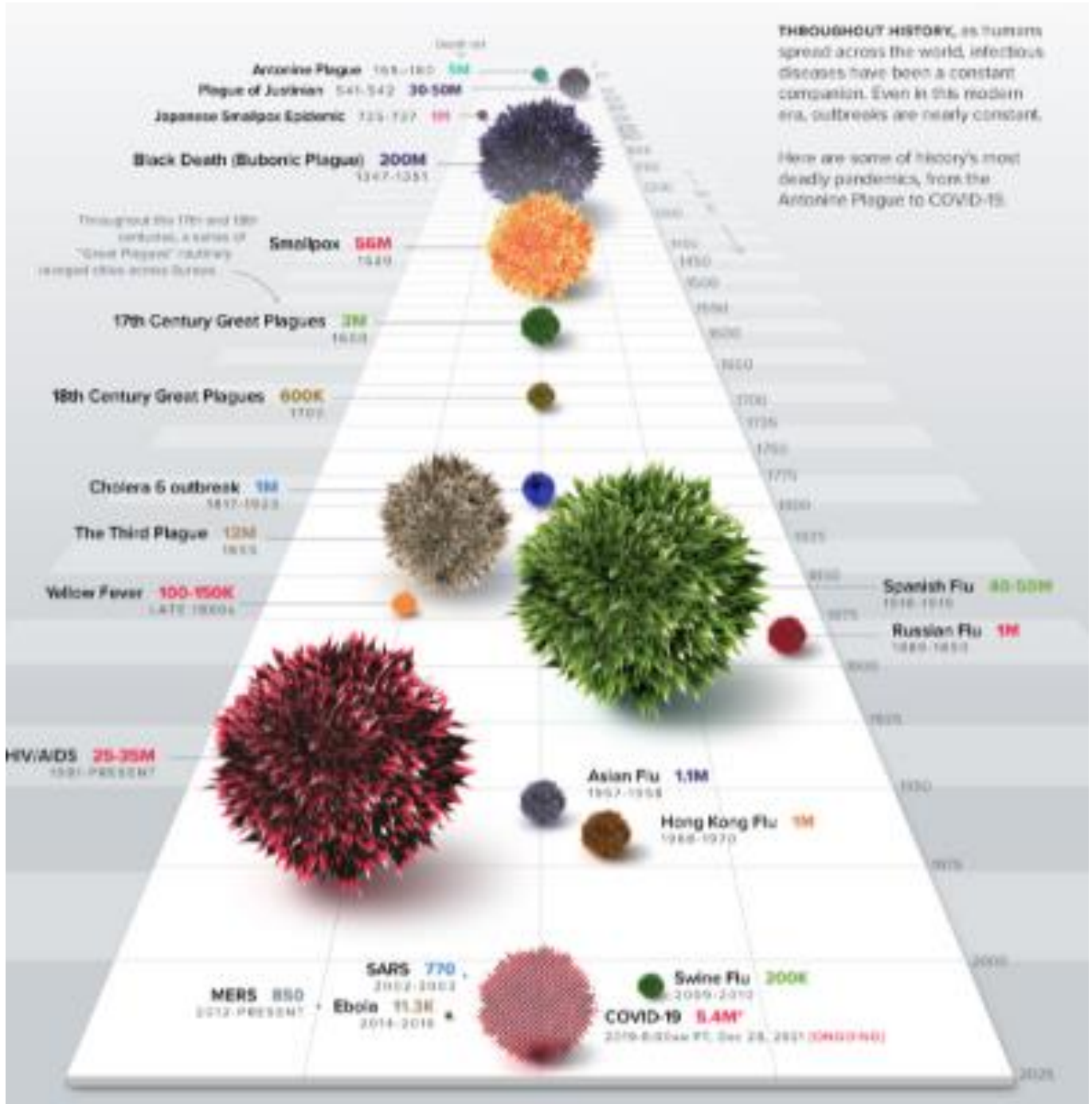
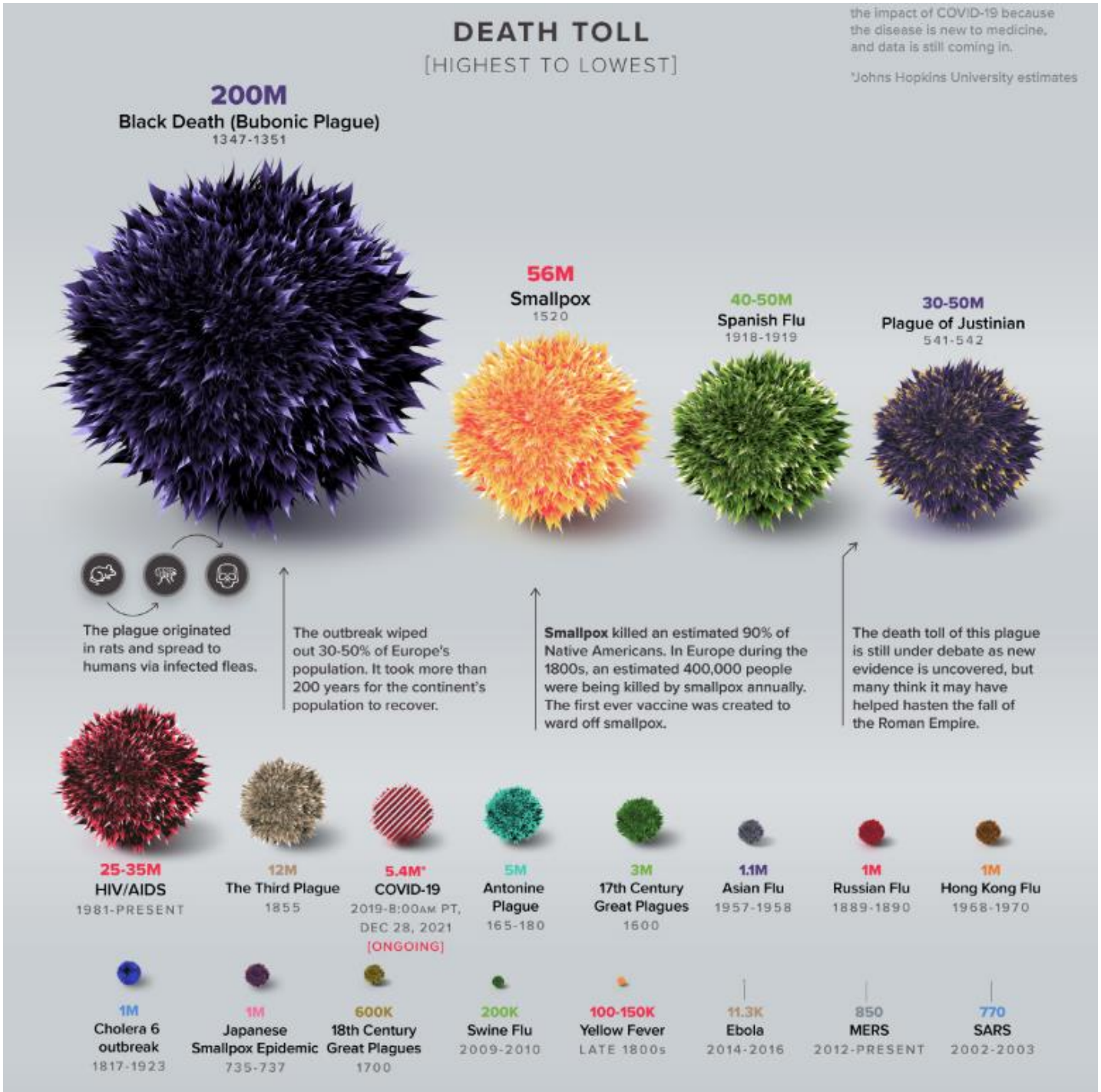
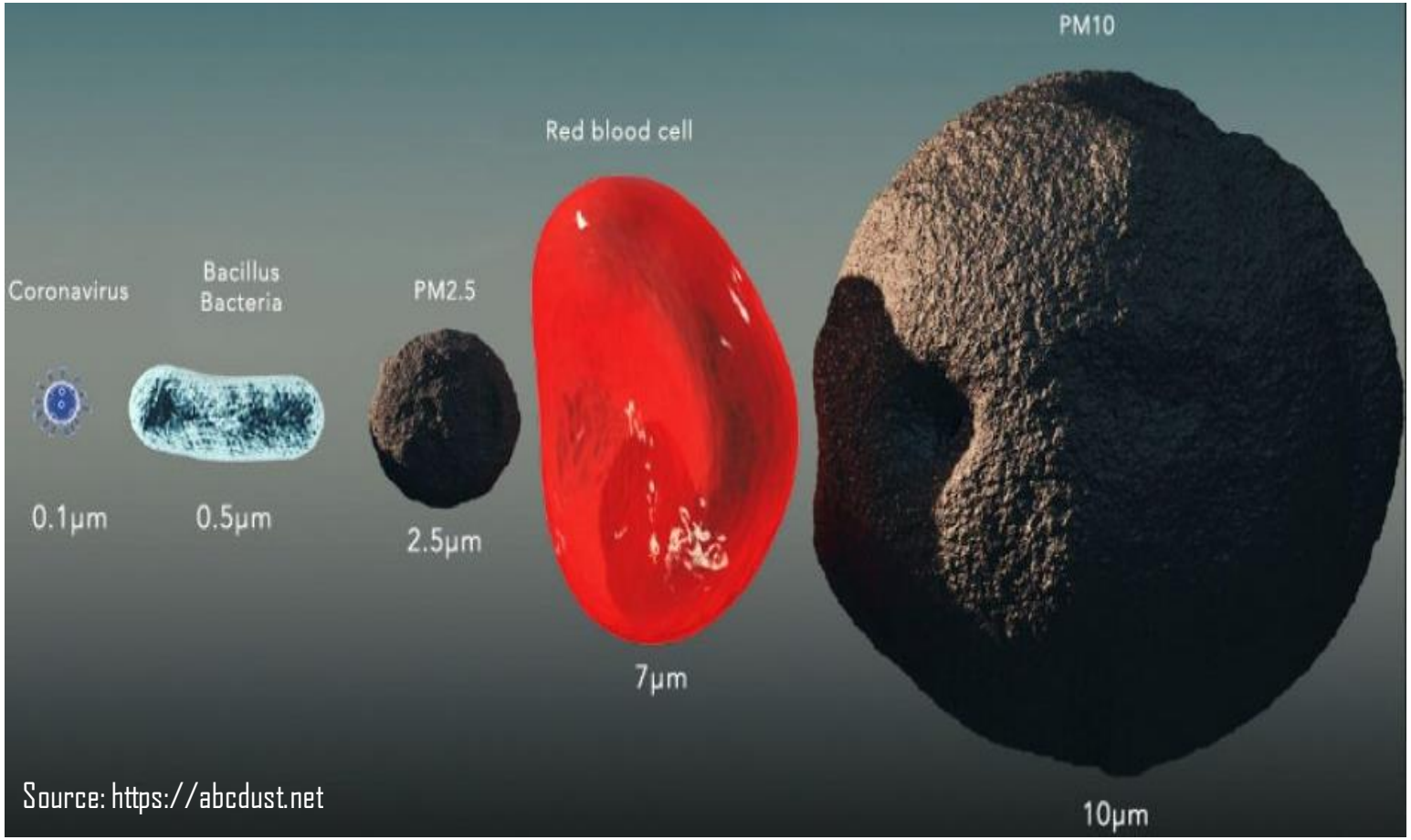
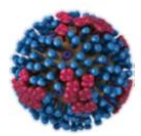
The history of transmission of respiratory pathogens: from the miasma theory to the WHO paradigm shift

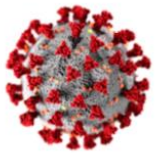

THROUGHOUT HISTORY, as humans spread across the world, infectious diseases have been a constant companion. Even in this modern era, outbreaks are nearly constant.
Here are some of history's most deadly pandemics, from the Antonine Plague to COVID-19.
Antonine Plague
Plague of Justinian 541-542 30-50M
Japanese Smallpox Epidemic
Black Death (Bubonic Plague) 200M 1347-1351
Smallpox 56M
17th Century Great Plagues 2M
18th Century Great Plagues 600K
Cholera 6 outbreak 1M
The Third Plague 12M
Yellow Fever 100-150K
Spanish Flu
Russian Flu 1M
HIV/AIDS 25-35M
Asian Flu 1.1M 1957-1958
Hong Kong Flu 1M 1968-1970
SARS 770
MERS 850
Ebola 11.3K
Swine Flu 200K
COVID-19 5.4M*


DEATH TOLL
[HIGHEST TO LOWEST]
the impact of COVID-19 because the disease is new to medicine, and data is still coming in.
*Johns Hopkins University estimates
200M
Black Death (Bubonic Plague)
1347-1351
56M
Smallpox
1520
40-50M
Spanish Flu
1918-1919
30-50M
Plague of Justinian
541-542
The plague originated in rats and spread to humans via infected fleas.
The outbreak wiped out 30-50% of Europe's population. It took more than 200 years for the continent's population to recover.
Smallpox killed an estimated 90% of Native Americans. In Europe during the 1800s, an estimated 400,000 people were being killed by smallpox annually. The first ever vaccine was created to ward off smallpox.
The death toll of this plague is still under debate as new evidence is uncovered, but many think it may have helped hasten the fall of the Roman Empire.
25-35M
HIV/AIDS
1981-PRESENT
12M
The Third Plague
1855
5.4M*
COVID-19
2019-8:00AM PT, DEC 28, 2021
[ONGOING]
5M
Antonine Plague
165-180
3M
17th Century Great Plagues
1600
1.1M
Asian Flu
1957-1958
1M
Russian Flu
1889-1890
1M
Hong Kong Flu
1968-1970
1M
Cholera 6 outbreak
1817-1923
1M
Japanese Smallpox Epidemic
735-737
600K
18th Century Great Plagues
1700
200K
Swine Flu
2009-2010
100-150K
Yellow Fever
LATE 1800s
11.3K
Ebola
2014-2016
850
MERS
2012-PRESENT
770
SARS
2002-2003



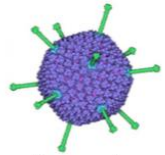


influenza
0.1 μm

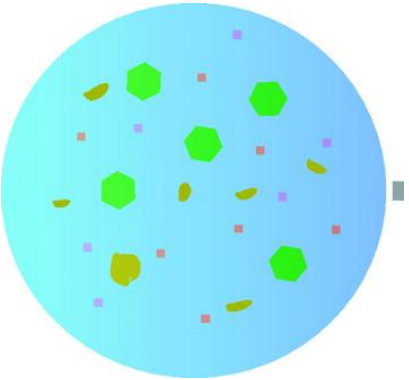


SARS-CoV-2
0.12 μm

rhinovirus
0.03 μm



adenovirus
0.1 μm



World Health Organization. Infection prevention and control of epidemic and pandemic prone acute respiratory infections in health care, 2014. Online at: https://www.who.int/publications/i/item/infection-prevention-and-control-of-epidemic-and-pandemic-prone-acute-respiratory-infections-in-health-care

Infection prevention and control of epidemic- and pandemic-prone acute respiratory infections in health care

WHO Guidelines

World Health Organization

Droplet transmission

The spread of an infectious agent caused by the dissemination of droplets. Droplets are primarily generated from an infected (source) person during coughing, sneezing and talking. Transmission occurs when these droplets that contain microorganisms are propelled (usually < 1 m) through the air and deposited on the conjunctivae, mouth, nasal, throat or pharynx mucosa of another person. Most of the volume (> 99%) comprises large droplets that travel short distances (< 1 m) and do not remain suspended in the air. Thus, special air handling and ventilation are not required to prevent droplet transmission (*5*).

Infectious respiratory aerosols

Respiratory aerosols that contain infectious particles. Aerosol size is determined by the force and pressure involved in the generation of the particles. The final size depends on the nature of the fluid containing the organisms, the force and pressure at emission, the initial size of the aerosol, environmental conditions (e.g. temperature, relative humidity and airflow), the time spent airborne, and the size of the organisms within a droplet. The distance travelled and the length of time particles remain suspended in the air is determined by the types of organism, particle size, settling velocity, relative humidity and airflow. Large particles typically remain suspended in the air for a limited period of time and settle within 1 m (3 feet) of the source. Smaller particles evaporate quickly; the resulting dried residues settle from the air slowly, and remain suspended in the air for variable lengths of time. The definitions and classification of the different types of infectious respiratory aerosols are evolving, and the implications for IPC measures are not yet clear. However, for the purpose of this document, infectious respiratory aerosols are classified into:

- *droplets* – respiratory aerosols > 5 μm in diameter; and
- *droplet nuclei* – the residue of dried respiratory aerosols (≤ 5 μm in diameter) that results from evaporation of droplets coughed or sneezed into the atmosphere or by aerosolization of infective material.

1 April 2020

Dr. Tedros Adhanom Ghebreyesus
Director General
World Health Organization
Avenue Appia 20
1211 Geneva, Switzerland

Dear Dr. Tedros Adhanom Ghebreyesus,

We, scientists from around the world, who have worked for many years on the characteristics and mechanisms behind the transport of droplets expired by humans, and on airflow patterns in buildings, appeal to you to recognize the significance of the airborne spread of SARS-CoV-2 (COVID-19) and advocate for preventive measures to mitigate this.

The current advice from the WHO is to wash your hands and maintain a social distance of about 1.0 m. However, these measures do not adequately protect the population from the small virus-carrying particles exhaled by infected people, and inhaled by others who share the same not-well-ventilated environments. These particles can travel tens of meters and remain airborne for prolonged periods.

Health care workers are among those who best adhere to the recommendations and are well

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.

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

World Health Organization

March 28 2020

#Coronavirus #COVID19

239 Experts With One Big Claim: The Coronavirus Is Airborne

The W.H.O. has resisted mounting evidence that viral particles floating indoors are infectious, some scientists say. The agency maintains the research is still inconclusive.

Journal of Hospital Infection 110 (2021) 89–96

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Review

Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2)

J.W. Tang [a], W.P. Bahnfleth [b], P.M. Bluyssen [c], G. Buonanno [d], J.L. Jimenez [e], J. Kurnitski [f], Y. Li [g], S. Miller [h], C. Sekhar [i], L. Morawska [j], L.C. Marr [k], A.K. Melikov [l], W.W. Nazaroff [m], P.V. Nielsen [n], R. Tellier [o], P. Wargocki [l], S.J. Dancer [p,q,*]

Differences between clinicians, aerosol scientists and the general public in understanding of airborne terminology

Term	Clinicians	Aerosol scientists	General public
Airborne	Long-distance transmission, such as measles; requires an N95/FFP2/FFP3 respirator (or equivalent) for infection control	Anything in the air	Anything in the air
Aerosol	Particle <5 μm that mediates airborne transmission; produced during aerosol-generating procedures and also requires an N95 respirator	Collection of solid or liquid particles of any size suspended in a gas	Hair spray and other personal/cleaning products
Droplet	Particle >5 μm that falls rapidly to the ground within a distance of 1—2 m from source; requires a surgical mask for infection control	Liquid particle	What comes out of an eyedropper
Droplet nuclei	Residue of a droplet that has evaporated to <5 μm; synonymous with 'aerosol'	A related term, 'cloud condensation nuclei', refers to small particles on to which water condenses to form cloud droplets	Never heard of!
Particle	Virion	Tiny solid or liquid 'blob' in the air	Like soot or ash

Myth 1: ‘aerosols are droplets with a diameter of 5 μm or less’

Myth 2: ‘all particles larger than 5 μm fall within 1–2 m of the source’

Myth 3: ‘if it is short range, it cannot be airborne’

Myth 4: ‘if the basic reproductive number, R0, is not as large as for measles, then it cannot be airborne’

Myth 5a. ‘If it is airborne, surgical masks (or cloth face coverings) will not work’

Myth 5b: ‘the virus is only 100 nm (0.1 μm) in size so filters and masks will not work’

Myth 6: ‘unless it grows in tissue culture, it is not infectious’

9 July 2020 – https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precaution

30 April 2021 – Scientific brief, WHO – Airborne transmission is one of the modes of transmission COVID19

23 December 2021- Airborne transmission is an important mode of transmission - https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-how-is-it-transmitted

Airborne transmission of SARS-CoV-2 **can occur during medical procedures** that generate aerosols ("aerosol generating procedures").(12) **WHO**, together with the scientific community, **has been actively discussing and evaluating whether SARS-CoV-2 may also spread through aerosols** in the absence of aerosol generating procedures, particularly in indoor settings with poor ventilation.

Outside of medical facilities, … short-range aerosol transmission, particularly in specific indoor locations, such as crowded and inadequately ventilated spaces over a prolonged period of time with infected persons cannot be ruled out. However, **the detailed investigations of these clusters suggest that droplet and fomite transmission could also explain human-to-human transmission within these clusters**. Further, the close contact environments of these clusters may have facilitated transmission from a small number of cases to many other people (e.g., superspreading event), **especially if hand hygiene was not performed** and masks were not used when physical distancing was not maintained.

We know that the disease is caused by the SARS-CoV-2 virus, which spreads between people in several different ways.

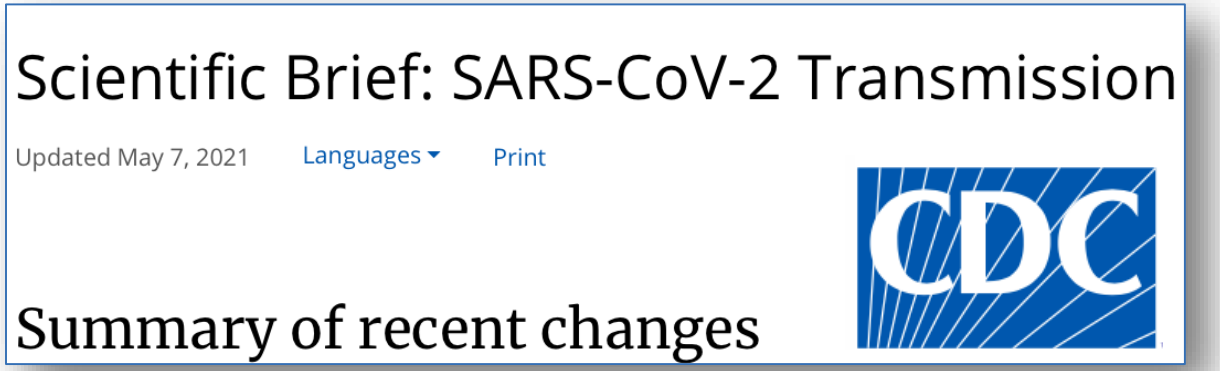
•Current evidence suggests that the virus spreads mainly between people who are in close contact with each other, for example at a conversational distance. The virus can spread from an infected person's mouth or nose in small liquid particles when they cough, sneeze, speak, sing or breathe. Another person can then contract the virus when infectious particles that pass through the air are inhaled at short range (this is often called **short-range aerosol** or **short-range airborne transmission**) or if infectious particles come into direct contact with the eyes, nose, or mouth (droplet transmission).

•The virus can also spread in poorly ventilated and/or crowded indoor settings, where people tend to spend longer periods of time. This is because aerosols can remain suspended in the air or travel farther than conversational distance (this is often called **long-range aerosol** or **long-range airborne transmission**).

•People may also become infected when touching their eyes, nose or mouth after touching surfaces or objects that have been contaminated by the virus.

On **Friday 18 September 2020** the CDC posted information on its website that for the first time said covid-19 could be spread through "respiratory droplets or small particles, such as those in aerosols, produced when an infected person coughs, sneezes, sings, talks, or breathes. These particles can be inhaled into the nose, mouth, airways, and lungs and cause infection. This is thought to be the main way the virus spreads."
It added, "There is growing evidence that droplets and airborne particles can remain suspended in the air and be breathed in by others and travel distances beyond 6 feet (for example, during choir practice, in restaurants, or in fitness classes). In general, indoor environments without good ventilation increase this risk."
On Monday 21 September the CDC removed the information about aerosols and distances greater than 6 feet (1.8 m) and replaced it with previous information that warned only about droplets and advised people to stay 6 feet apart.

... the risk of SARS-CoV-2 infection via the fomite transmission route is low, and generally less than 1 in 10,000, which means that each contact with a contaminated surface has less than a 1 in 10,000 chance of causing an infection. **5 April 2021**, https://www.cdc.gov/coronavirus/2019-ncov/more/science-and-research/surface-transmission.html



Infectious exposures to respiratory fluids carrying SARS-CoV-2 occur in three principal ways (not mutually exclusive):
1.Inhalation of air carrying very small fine droplets and aerosol particles that contain infectious virus. Risk of transmission is greatest within three to six feet of an infectious source where the concentration of these very fine droplets and particles is greatest.
2.Deposition of virus carried in exhaled droplets and particles onto exposed mucous membranes (i.e., "splashes and sprays", such as being coughed on). Risk of transmission is likewise greatest close to an infectious source where the concentration of these exhaled droplets and particles is greatest.
3.Touching mucous membranes with hands soiled by exhaled respiratory fluids containing virus or from touching inanimate surfaces contaminated with virus.

Clinical Infectious Diseases

VIEWPOINTS

Coronavirus Disease 2019 and Airborne Transmission: Science Rejected, Lives Lost. Can Society Do Better?

Lidia Morawska,[1] William Bahnfleth,[2] Philomena M. Bluyssen,[3] Atze Boerstra,[4] Giorgio Buonanno,[5] Stephanie J. Dancer,[6] Andres Floto,[7] Francesco Franchimon,[8] Charles Haworth,[9] Jaap Hogeling,[10] Christina Isaxon,[11] Jose L. Jimenez,[12] Jarek Kurnitski,[13] Yuguo Li,[14] Marcel Loomans,[15] Guy Marks,[16] Linsey C. Marr,[17] Livio Mazzarella,[18] Arsen Krikor Melikov,[19] Shelly Miller,[20] Donald K. Milton,[21] William Nazaroff,[22] Peter V. Nielsen,[23] Catherine Noakes,[24] Jordan Peccia,[25] Xavier Querol,[26] Chandra Sekhar,[27] Olli Seppänen,[28] Shin-ichi Tanabe,[29] Raymond Tellier,[30] Tham Kwok Wai,[27] Pawel Wargocki,[19] and Aneta Wierzbicka[31]

This is an account that should be heard of an important struggle: the struggle of a large group of experts who came together at the beginning of the COVID-19 pandemic to warn the world about the risk of airborne transmission and the consequences of ignoring it. We alerted the World Health Organization about the potential significance of the airborne transmission of SARS-CoV-2 and the urgent need to control it, but our concerns were dismissed. Here we describe how this happened and the consequences. We hope that by reporting this story we can raise awareness of the importance of interdisciplinary collaboration and the need to be open to new evidence, and to prevent it from happening again. Acknowledgement of an issue, and the emergence of new evidence related to it, is the first necessary step towards finding effective mitigation solutions.

Keywords. airborne transmission; airborne infection spread; coronavirus; COVID-19; SARS-CoV-2 virus.

It is a tragic situation for our society that scientific fact is not timely adopted in public health decision making. We recognize that, when setting policy, decision-makers must weigh numerous considerations: scientific, economic, social, ethical, and others. However, science must not be sidelined in the process, which unfortunately is the case in many other decisions critical to the well-being of our society. We believe that, as a society, we can and should do much better and we recommend how to do it.

Airborne transmission of SARS-CoV-1

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Evidence of Airborne Transmission of the Severe Acute Respiratory Syndrome Virus

Ignatius T.S. Yu, M.B., B.S., M.P.H., Yuguo Li, Ph.D., Tze Wai Wong, M.B., B.S., Wilson Tam, M.Phil., Andy T. Chan, Ph.D., Joseph H.W. Lee, Ph.D., Dennis Y.C. Leung, Ph.D., and Tommy Ho, B.Sc.

ABSTRACT

BACKGROUND

There is uncertainty about the mode of transmission of the severe acute respiratory syndrome (SARS) virus. We analyzed the temporal and spatial distributions of cases in a large community outbreak of SARS in Hong Kong and examined the correlation of these data with the three-dimensional spread of a virus-laden aerosol plume that was modeled using studies of airflow dynamics.

CONCLUSIONS

Airborne spread of the virus appears to explain this large community outbreak of SARS, and future efforts at prevention and control must take into consideration the potential for airborne spread of this virus.

Why were papers like this forgotten?

The main reason is that because they were based on retrospective cases, they were published some time after the end of the epidemic.

Received: 12 November 2021 | Revised: 25 May 2022 | Accepted: 30 May 2022
DOI: 10.1111/ina.13070

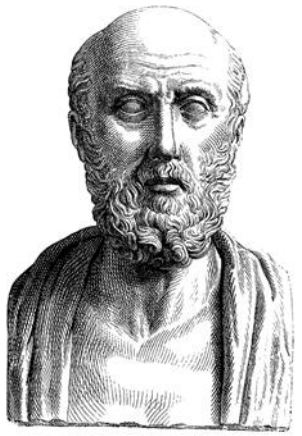
REVIEW

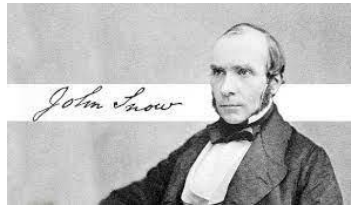
WILEY

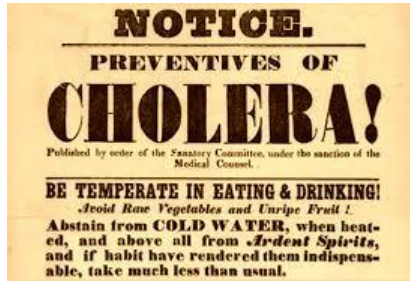
What were the historical reasons for the resistance to recognizing airborne transmission during the COVID-19 pandemic?

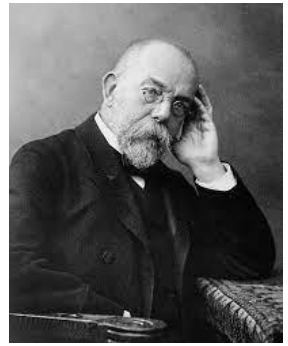
Jose L. Jimenez[1] | Linsey C. Marr[2] | Katherine Randall[3] | Edward Thomas Ewing[4] | Zeynep Tufekci[5] | Trish Greenhalgh[6] | Raymond Tellier[7] | Julian W. Tang[8] | Yuguo Li[9] | Lidia Morawska[10] | Jonathan Mesiano-Crookston[11] | David Fisman[12] | Orla Hegarty[13] | Stephanie J. Dancer[14] | Philomena M. Bluyssen[15] | Giorgio Buonanno[16] | Marcel G. L. C. Loomans[17] | William P. Bahnfleth[18] | Maosheng Yao[19] | Chandra Sekhar[20] | Pawel Wargocki[21] | Arsen K. Melikov[21] | Kimberly A. Prather[22]

[1]Department of Chemistry and Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado, USA
[2]Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, Virginia, USA
[3]Department of English, Virginia Tech, Blacksburg, Virginia, USA
[4]Department of History, Virginia Tech, Blacksburg, Virginia, USA
[5]School of Journalism, Columbia University, New York, New York, USA
[6]Department of Primary Care Health Sciences, Medical Sciences Division, University of Oxford, Oxford, UK
[7]Department of Medicine, McGill University, Montreal, Québec, Canada
[8]Department of Respiratory Sciences, University of Leicester, Leicester, UK
[9]Department of Mechanical Engineering, University of Hong Kong, Hong Kong, China
[10]International Laboratory for Air Quality and Heath, Queensland University of Technology, Brisbane, Queensland, Australia
[11]Goldman Hine LLP, Toronto, Ontario, Canada
[12]Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada
[13]School of Architecture, Planning & Environmental Policy, University College Dublin, Dublin, Ireland
[14]Department of Microbiology, Hairmyres Hospital, Glasgow, and Edinburgh Napier University, Glasgow, UK
[15]Faculty of Architecture and the Built Environment, Delft University of Technology, Delft, The Netherlands
[16]Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino, Italy
[17]Department of the Built Environment, Eindhoven University of Technology (TU/e), Eindhoven, The Netherlands
[18]Department of Architectural Engineering, The Pennsylvania State University, University Park, Pennsylvania, USA
[19]College of Environmental Sciences and Engineering, Peking University, Beijing, China
[20]Department of the Built Environment, National University of Singapore, Singapore, Singapore
[21]Department of Civil Engineering, Technical University of Denmark, Lyngby, Denmark
[22]Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, USA

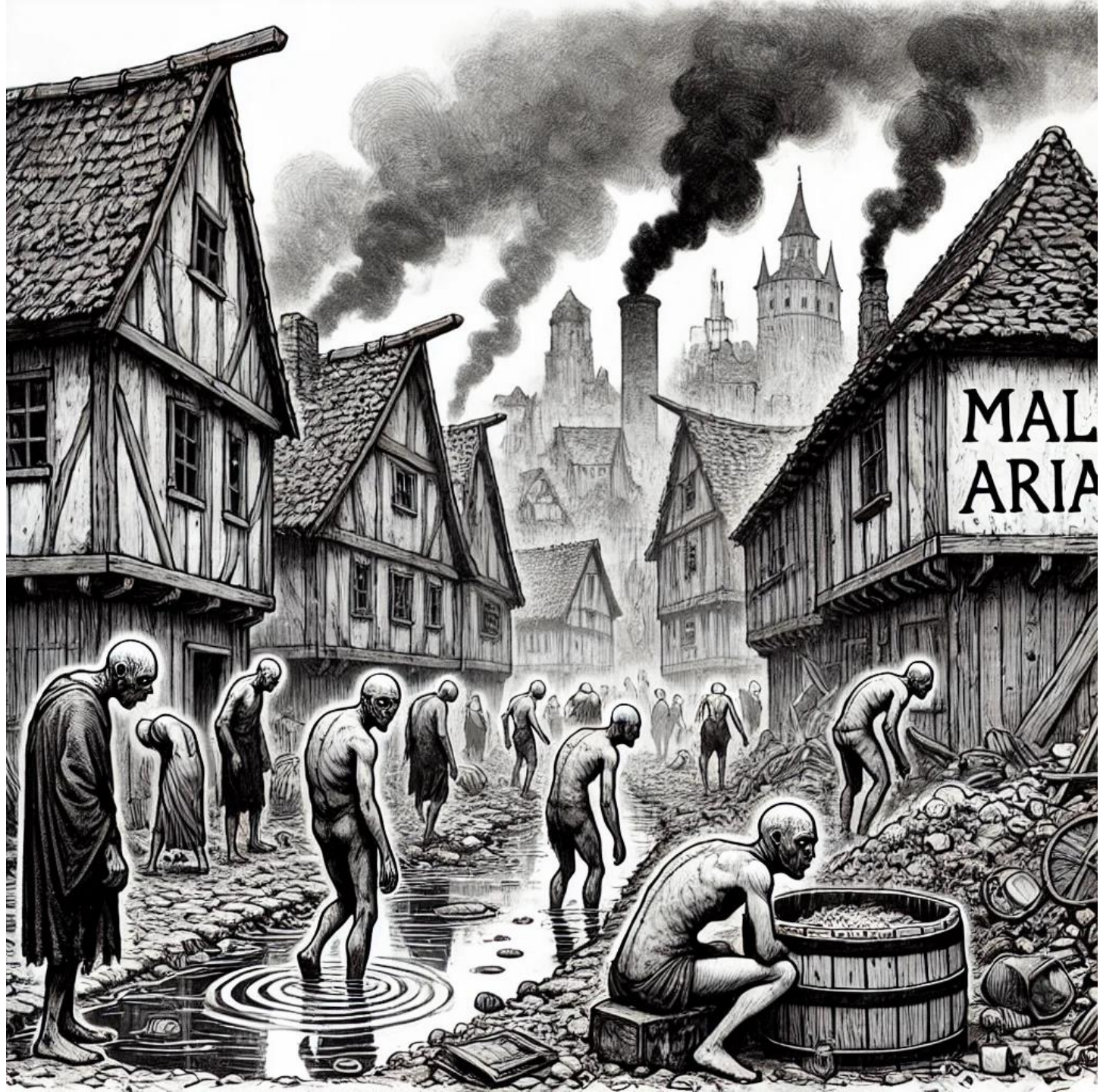






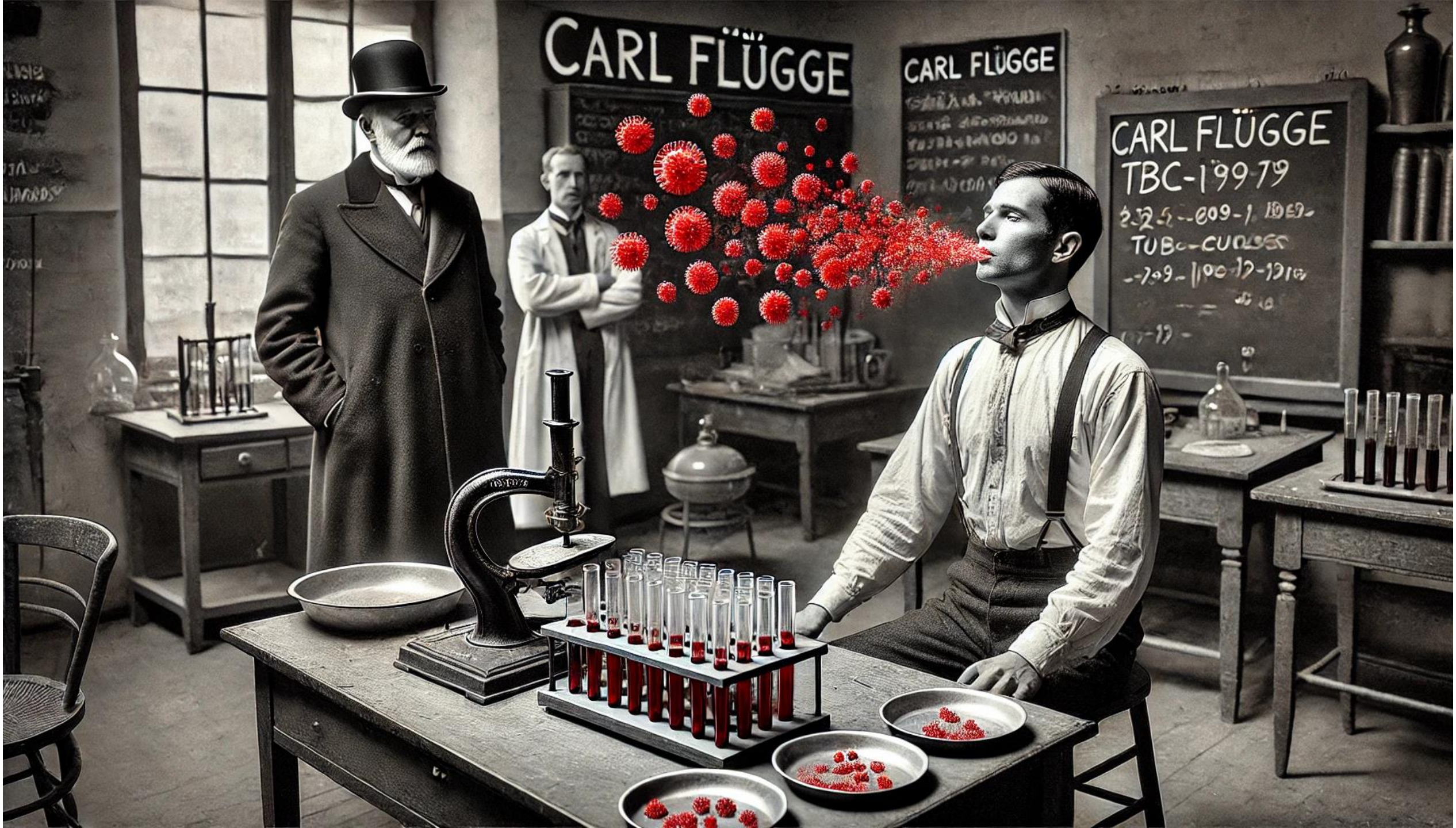


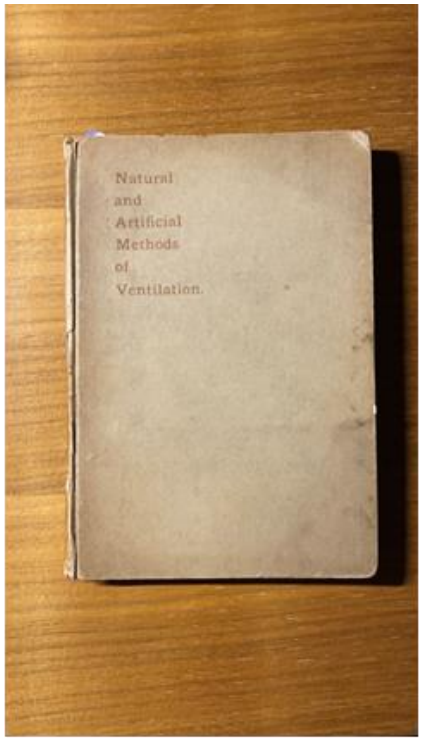
- For most of human history, the dominant paradigm was that many diseases were carried by the air, often over long distances and in a phantasmagorical way. This miasmatic paradigm was challenged in the mid to late 19th century with the rise of germ theory, and as diseases such as cholera, puerperal fever, and malaria were found to actually transmit in other ways.
- Motivated by his views on the importance of contact/droplet infection, and the resistance he encountered from the remaining influence of miasma theory, prominent public health official Charles Chapin in 1910 helped initiate a successful paradigm shift, deeming airborne transmission most unlikely. This new paradigm became dominant.


MAL
ARIA

Florence Nightingale in a 19th-century hospital


JOHN SNOW
SNIDER
WATER PUM


CARL FLÜGGE
CARL FLÜGGE
CARL FLÜGGE
TBC-1979



Natural and Artificial Methods of Ventilation.

"A People's Health's a Nation's Wealth."—FRANKLIN.

LONDON:
ROBERT BOYLE & SON, LIMITED,
64, HOLBORN VIADUCT.
AND AT
GLASGOW, PARIS, BERLIN, AND NEW YORK.
1899.

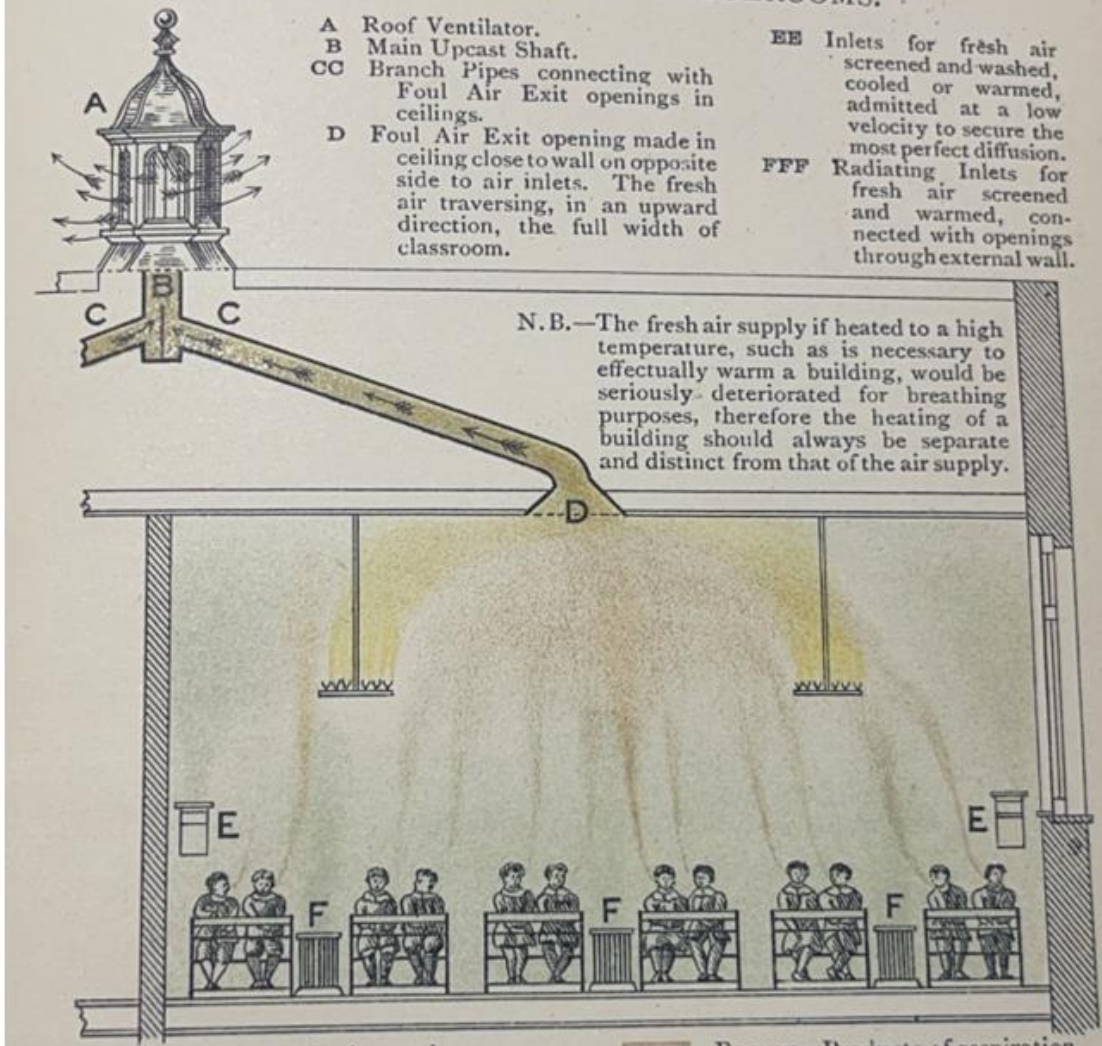
"Air is the prime supporter of life; health; even life itself is dependent upon its purity.

"Statistical inquiries on mortality prove beyond a doubt that of the causes of death which are usually in action, impurity of the air is the most important."

—PARKES.

"NATURAL SYSTEM OF VENTILATION BY EXTRACTION AND DIFFUSION, APPLIED TO SCHOOLROOMS.

A Roof Ventilator.
B Main Upcast Shaft.
CC Branch Pipes connecting with Foul Air Exit openings in ceilings.
D Foul Air Exit opening made in ceiling close to wall on opposite side to air inlets. The fresh air traversing, in an upward direction, the full width of classroom.
EE Inlets for fresh air screened and washed, cooled or warmed, admitted at a low velocity to secure the most perfect diffusion.
FFF Radiating Inlets for fresh air screened and warmed, connected with openings through external wall.



N.B.—The fresh air supply if heated to a high temperature, such as is necessary to effectually warm a building, would be seriously deteriorated for breathing purposes, therefore the heating of a building should always be separate and distinct from that of the air supply.

BLUE—Fresh air supply.
YELLOW—Products of combustion.
BROWN—Products of respiration.
RED—Products of respiration from infected scholars.

" Science proves that there is not a moment of time but when there is a movement of the air,


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.

- The lack of understanding of aerosols led to systematic errors in the interpretation of research evidence on transmission pathways. For the first five decades, airborne transmission was considered of negligible or minor importance for all major respiratory diseases, until a demonstration of airborne transmission of tuberculosis (which had been mistakenly thought to be transmitted by droplets) in 1962.
- The contact/droplet paradigm remained dominant, and only a few diseases were widely accepted as airborne before COVID-19: those that were clearly transmitted to people not in the same room. The acceleration of interdisciplinary research inspired by the COVID-19 pandemic has shown that airborne transmission is a major mode of transmission for this disease, and is likely to be significant for many respiratory infectious diseases.

William Wells
(1887–1963)

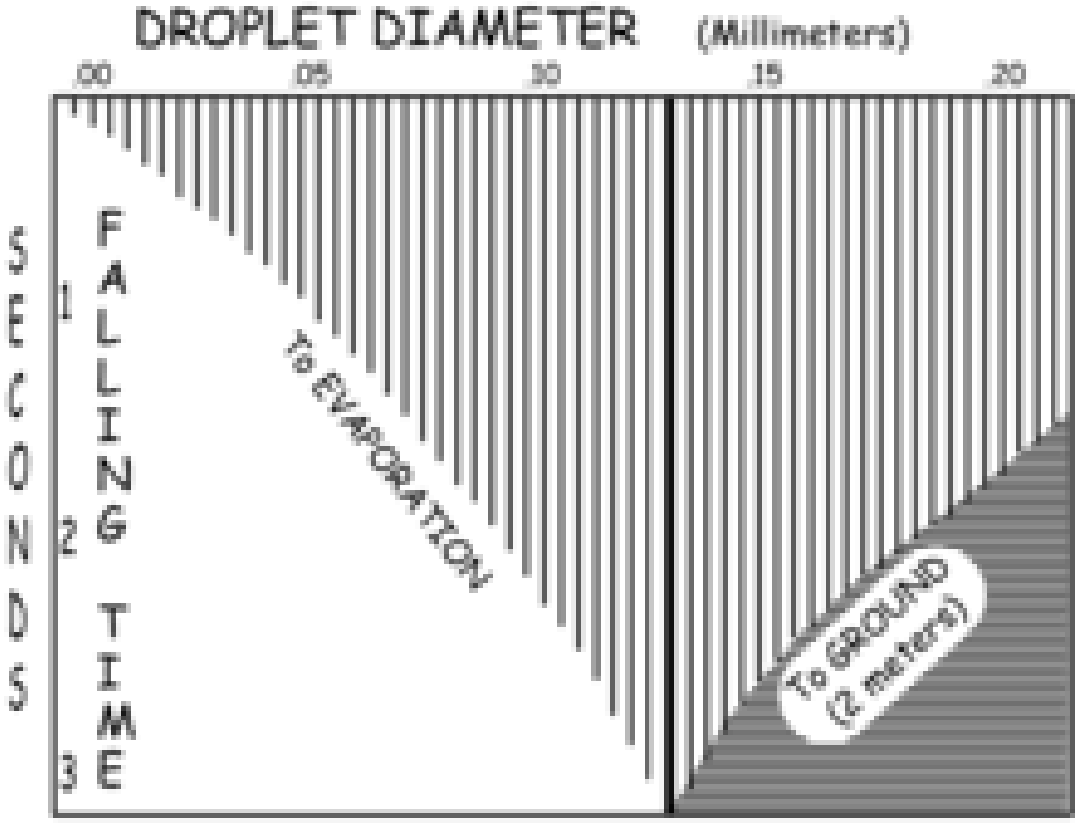
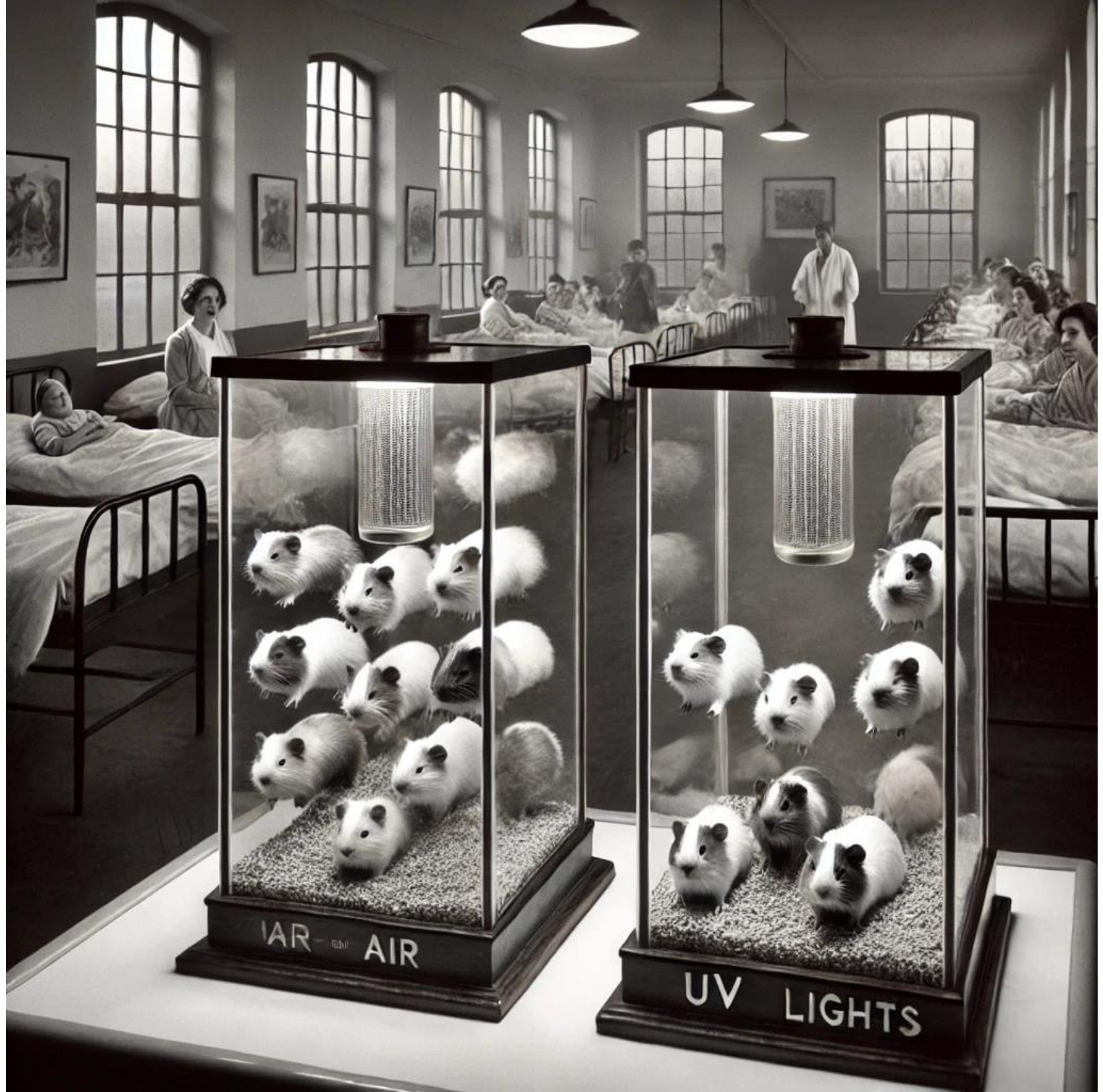
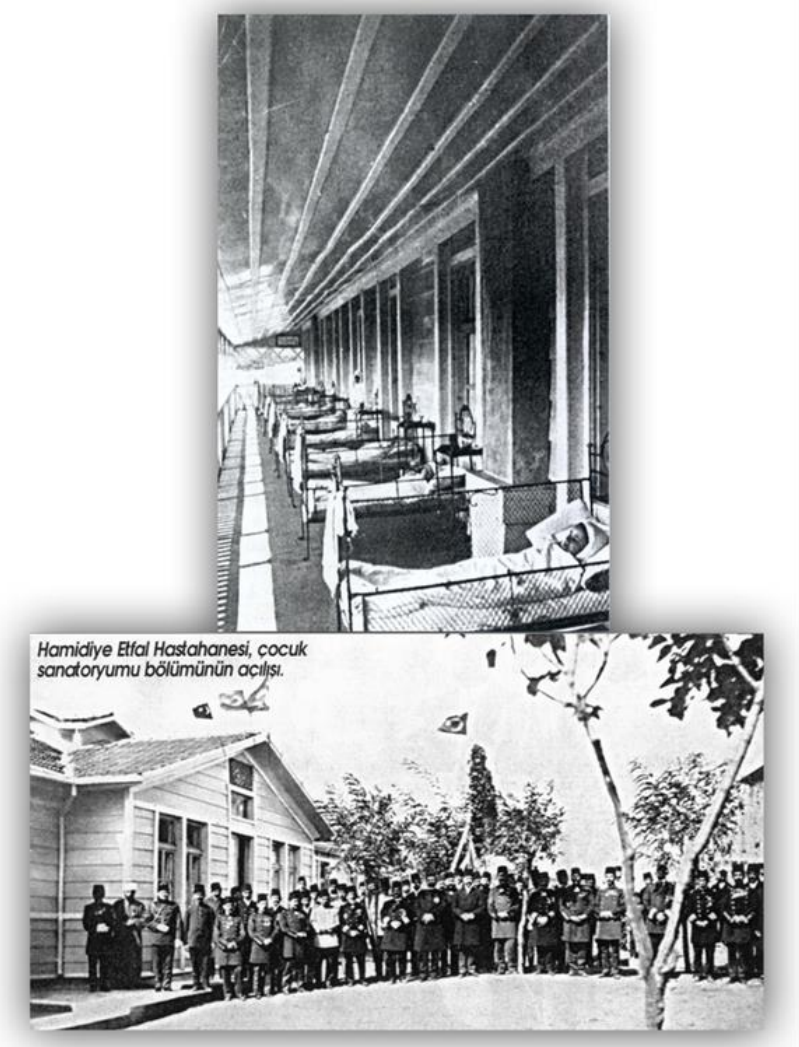


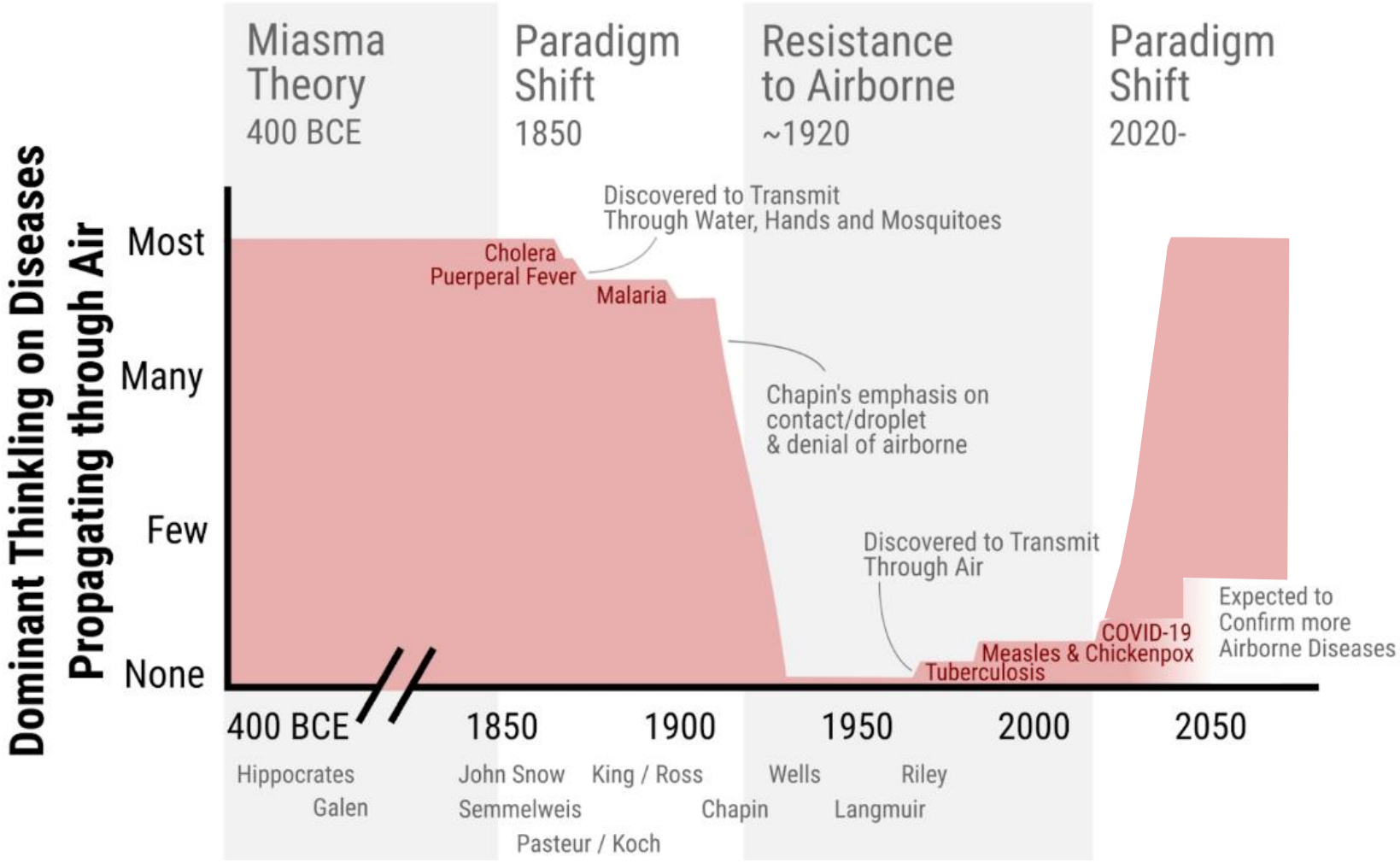
CHART I. Falling and evaporation times for droplets of varying diameter.

Redrawn from Wells, W. F. 1934.


AIR
UV LIGHTS



First children's TB sanatorium in Turkey during the Ottoman times (1898) and from the Republic era in Turkey in 1950s. Note how the children are put in the balcony in beds


Miasma Theory
400 BCE
Paradigm Shift
1850
Resistance to Airborne
~1920
Paradigm Shift
2020-
Dominant Thinkling on Diseases Propagating through Air
Most
Many
Few
None
Discovered to Transmit Through Water, Hands and Mosquitoes
Cholera
Puerperal Fever
Malaria
Chapin's emphasis on contact/droplet & denial of airborne
Discovered to Transmit Through Air
Tuberculosis
Measles & Chickenpox
COVID-19
Expected to Confirm more Airborne Diseases
400 BCE
1850
1900
1950
2000
2050
Hippocrates
Galen
John Snow
Semmelweis
Pasteur / Koch
King / Ross
Chapin
Wells
Langmuir
Riley

POLICY FORUM

Science

INFECTIOUS DISEASE

A paradigm shift to combat indoor respiratory infection

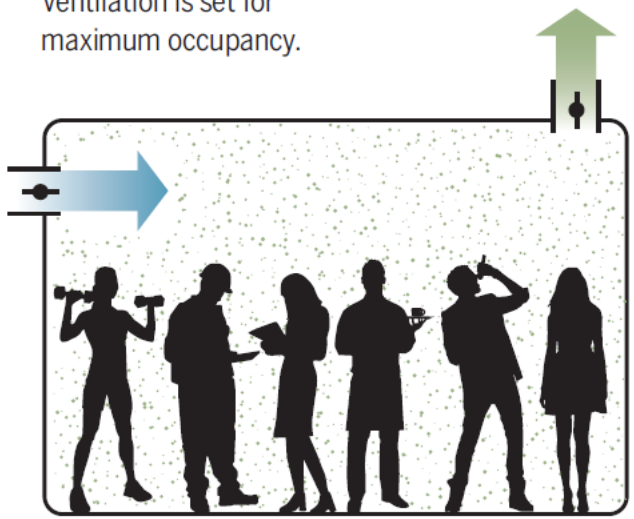
Building ventilation systems must get much better

By **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**

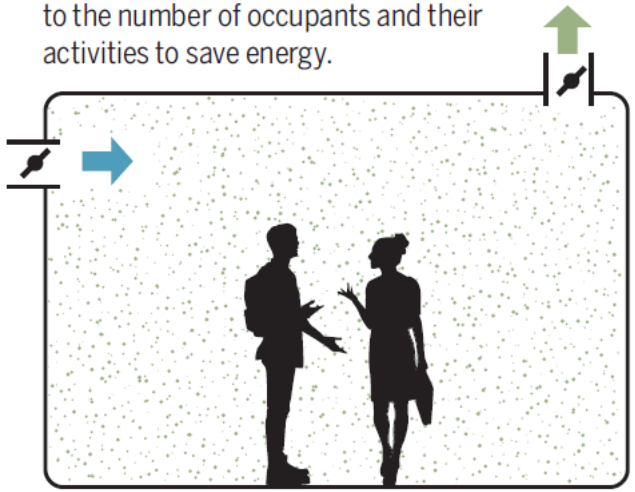
Flexible ventilation systems, dependent on the building's purpose

Ventilation airflow rates must be controlled by the number of occupants in the space and their activity.

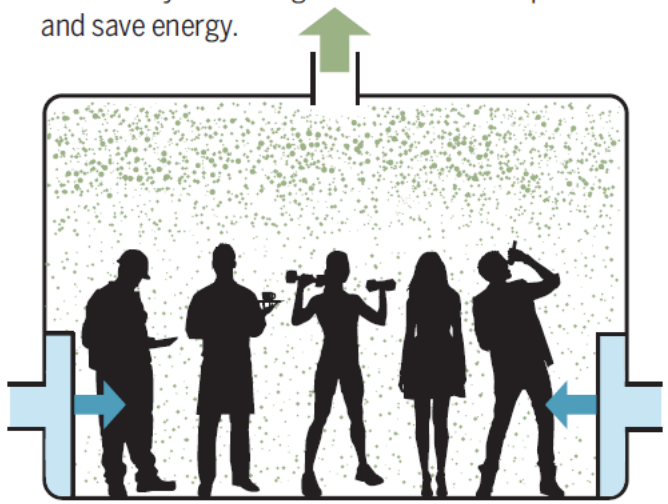
Design occupancy
Ventilation is set for maximum occupancy.



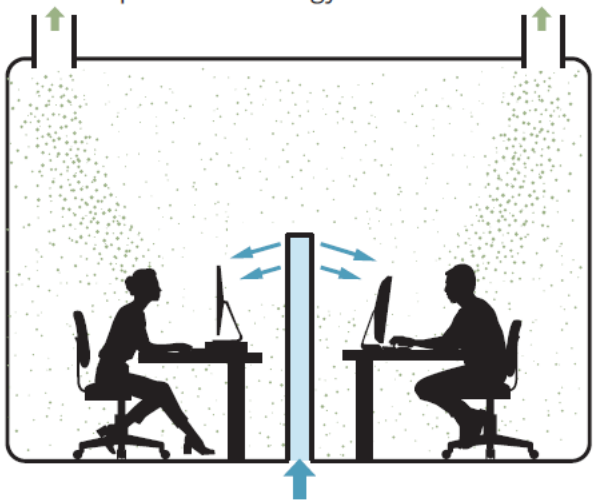
Demand controlled
Ventilation is adjusted according to the number of occupants and their activities to save energy.



Improved air distribution
Different system designs can decrease exposure and save energy.

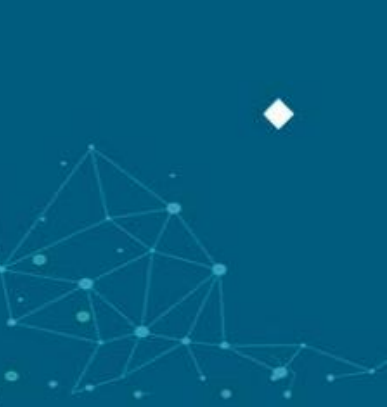


Personalized ventilation
Clean air is supplied where needed to further reduce exposure and energy use.



The COVID-19 pandemic has revealed how unprepared the world was to respond to it, despite the knowledge gained from past pandemics. A paradigm shift is needed on the scale that occurred when Chadwick's *Sanitary Report* in 1842 led the British government to encourage cities to organize clean water supplies and centralized sewage systems. In the 21st century, we need to establish the foundations to ensure that the air in our buildings is clean with a substantially reduced pathogen count, contributing to the building occupants' health, just as we expect for the water coming out of our taps. ■

Global technical consultation report on proposed terminology for pathogens that transmit through the air

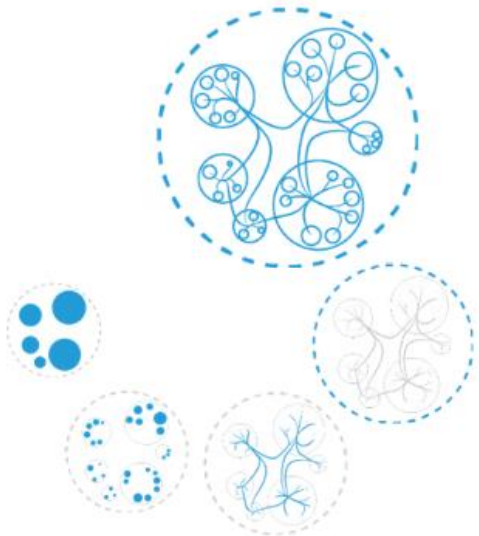


World Health Organization

Airborne Risk Indoor Assessment

in the context of SARS-CoV-2

Method and application



ARIA (DEMO)

Airborne Risk Indoor Assessment

Home | Inhalation mechanism | Systematic review results

1 Context - Geographical location and date

Context - Geographical location and date

Please provide the date and location of the event/activity

If these information are not available, Geneva specific data will be used

Date: 09/11/2022

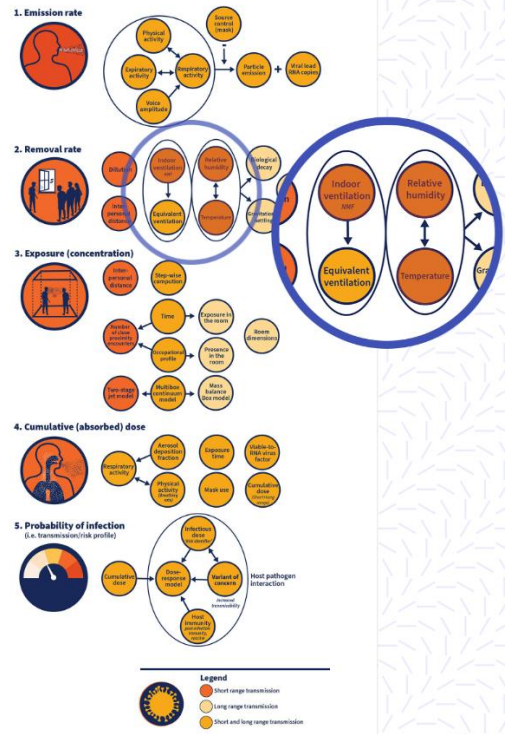
Location

Country: No country selected

City: No city selected

I don't know... | Next

The location and time enable to estimate outdoor temperature and humidity which can affect the natural indoor ventilation.



During the infectious stage of the disease, an infected person can generate particles containing the pathogen, along with water, and respiratory secretions. Such particles are here described as ‘infectious respiratory particles’.

These infectious particles are then carried by expired airflow, exit the infectious person’s mouth and/or nose when they breathe, talk, sing, spit, cough or sneeze and are released into the surrounding air.

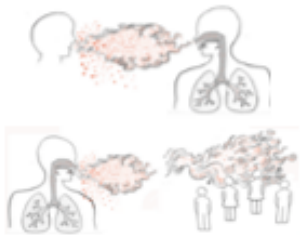
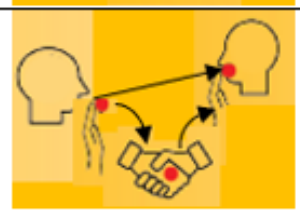
The IRPs exist in a wide range of sizes (from sub-microns to millimetres in diameter) and travel in the air in a turbulent puff cloud (exhaled mixture of gases from the lungs and respiratory particles). The IRPs are carried by the puff cloud and remain concentrated until the cloud reduces sufficiently in momentum to enable the IRP dispersal by the background indoor air turbulence.

After IRPs are emitted from an infectious person, they progressively diminish in infectivity over a time frame specific to the pathogen. The modes in which viable IRPs then travel to, enter, and can potentially infect another individual can broadly be described as occurring in the following three ways:

i) Airborne transmission/ inhalation: Occurs when IRPs expelled into the air as described above and enter, through inhalation, the respiratory tract of another person. This form of transmission can occur when the IRPs have travelled either short or long distances from the infectious person. The portal of entry of an IRP with respiratory tract tissue during airborne transmission can theoretically occur at any point along the human respiratory tract, but preferred sites of entry may be pathogen-specific. It should be noted that the distance traveled depends on multiple factors including pathogen, particle size, mode of expulsion and environmental conditions (such as setting, ventilation, etc.).

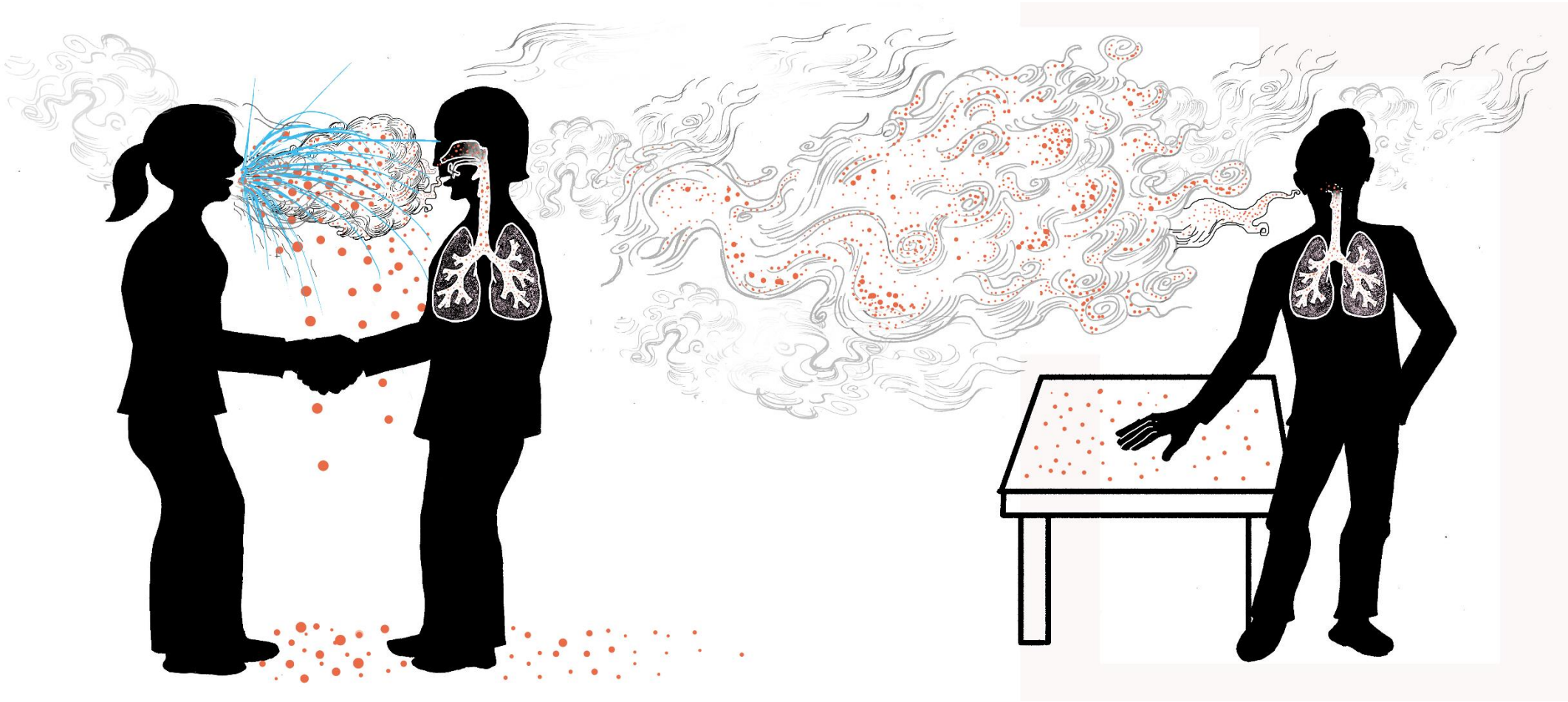
ii) Direct deposition: Occurs when IRPs expelled into the air following a short-range semi-ballistic trajectory, then directly deposited on the exposed facial mucosal surfaces (mouth, nose or eyes) of another person, thus, enter the human respiratory tract via these portals and potentially cause infection.

iii) Contact transmission (added for completeness): Contaminated surfaces are created when IRPs expelled into the air are settled on a surface, or when an infected person transfers infectious respiratory secretions by touching their own mouth, nose or eyes and then the surface or shaking hands. Infectious pathogens on the contaminated surfaces are then transferred to another person who touches that contaminated surface and then their own mouth, nose or eyes. This is commonly known as *indirect contact transmission*. In addition, *direct contact transmission* can occur when an infectious person directly transfers infectious pathogens from their own respiratory tract, not via IRPs, to another person by being in direct contact with that person (e.g. via a handshake), who then directly transfers the IRPs into their own mouth, nose or eyes. Other preferred labels for this mode of transmission are *indirect* and *direct deposition*. This form of transmission does not directly involve the transmission of pathogens to humans through the air, so is not considered part of the 'through the air' descriptors covered by this document, but is included for completeness.

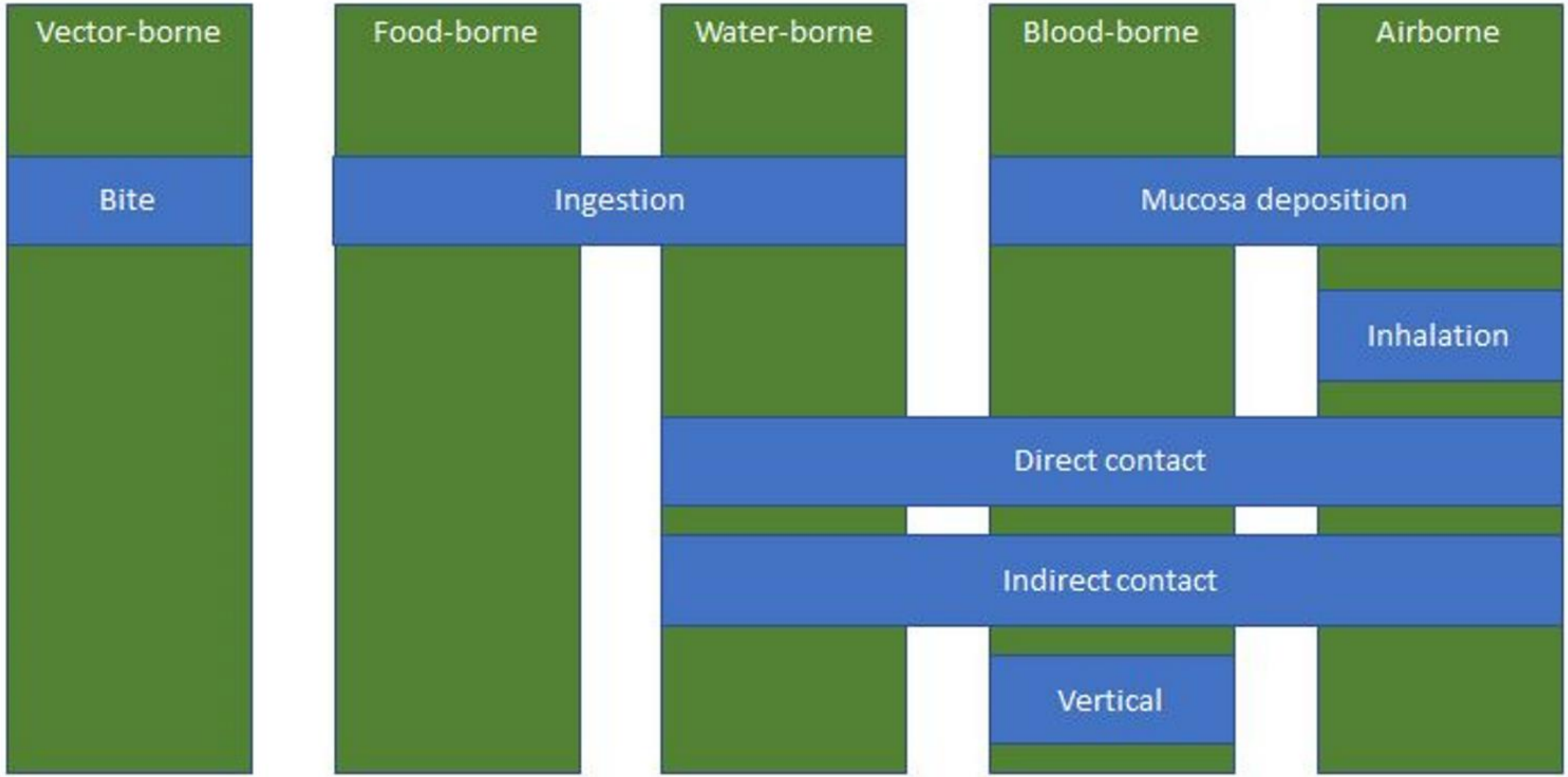
Mode of transmission	Typical distance from the source	Route of transfer to another human	Respiratory tract entry mechanism	Respiratory tract entry portal	Schematic depiction
THROUGH THE AIR					
Airborne transmission/ inhalation	Any distance	Through the air (suspended in air or moving via air flows)	Inhalation	Anywhere along the respiratory tract	
Direct deposition	Short	Through the air (semi-ballistic trajectory)	Deposition on the mucosa	Mouth, nose or eyes*	
CONTACT#					
Indirect contact	*Any distance*	*Not through the air, although IRPs may reach an intermediate object through the air*	*Indirect transfer (via touching on intermediate object)*	*Mouth, nose or eyes**	
Direct contact	*Short*	*Not through the air*	*Direct transfer (via touch, usually with hands)*	*Mouth, nose or eyes**	

* Note that the mucosa of the eyes are not part of the human respiratory tract but are a portal of entry to the respiratory system

Note that this mode of transmission to another human does not involve a 'through the air' route but is included here for completeness
Depictions above assume the human(s) on the left is/are the infectious person(s) and the human on the right is the recipient of the IRP



Source: Developed by A. Mana and L. Bourouiba, adapted from LC, Tang JW (2021); Bourouiba L (2016,2020,2021).



Green: epidemiologic classification of diseases (describe where pathogens can be found)
Blue: mode of transmission (how pathogens are transmitted to a new host)

Pathogens transmission routes

	Waterborne	Foodborne	Airborne
Legislation			
Monitoring			
Standards			
Industry priority