Comparing the airborne survival of enveloped and non-enveloped viruses

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1. Background

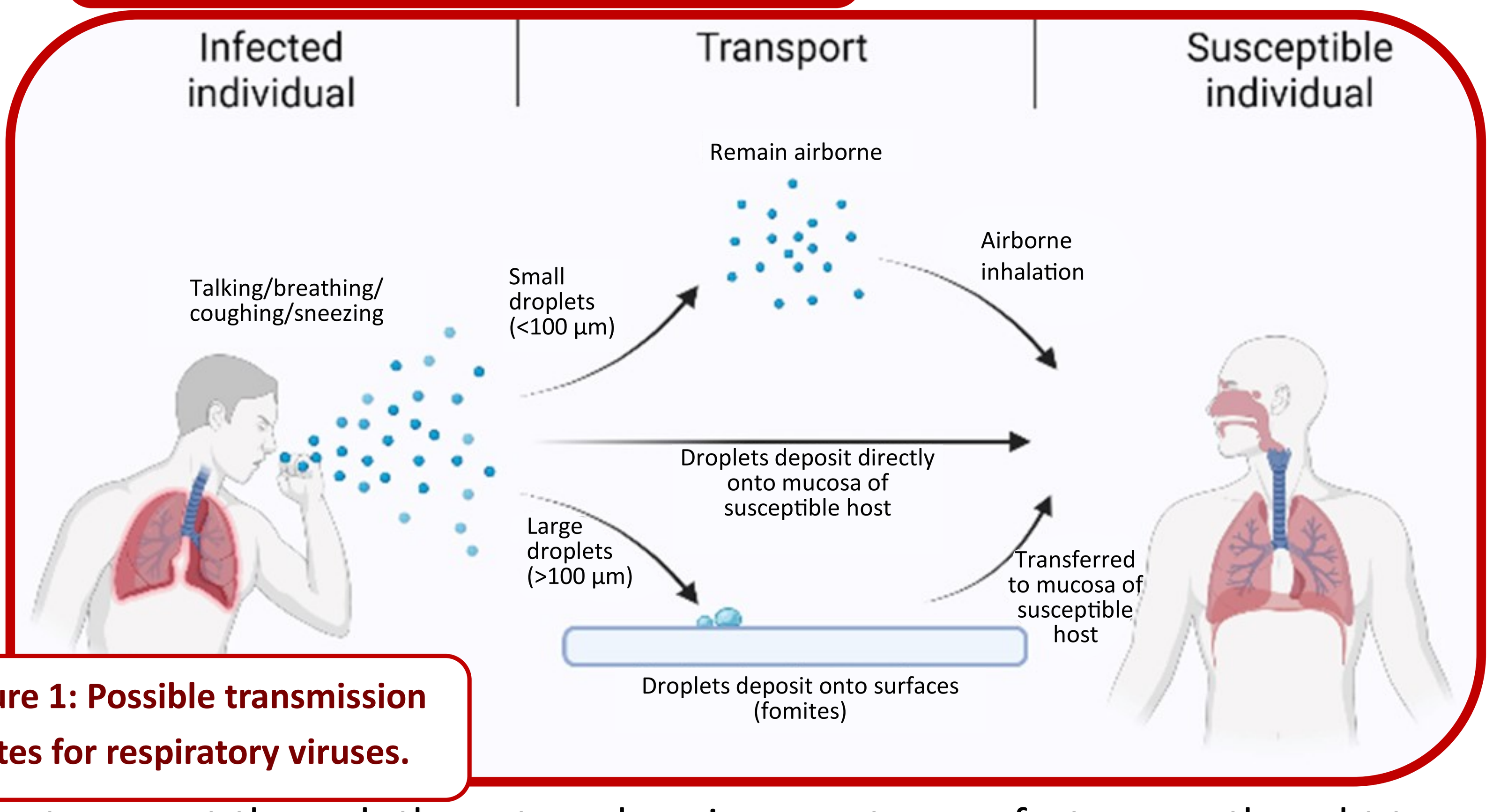


Figure 1: Possible transmission routes for respiratory viruses.

During transport through the external environment many factors are thought to control virus viability, including ambient **relative humidity** (RH), **ambient temperature**, **UV exposure** and **air pollution** [1]. The influence of RH on virus viability is of particular interest as it determines many microphysical properties of respiratory droplets.

Respiratory fluid has a complex composition of water and non-volatile solutes (e.g. salts, proteins and surfactants). When transitioning from the high humidity environment of the lungs (99.5% RH) into the ambient environment (<70% RH, typically) respiratory droplets undergo evaporation resulting in **supersaturated salt concentrations** and **phase changes** [2].

Additionally, rapid flux of CO_2 (originally in the form of HCO_3^-) from the respiratory droplet upon exhalation causes the respiratory droplet to become **highly alkaline** (~pH 11) [3].

These physicochemical changes may harm suspended viruses limiting disease transmission.

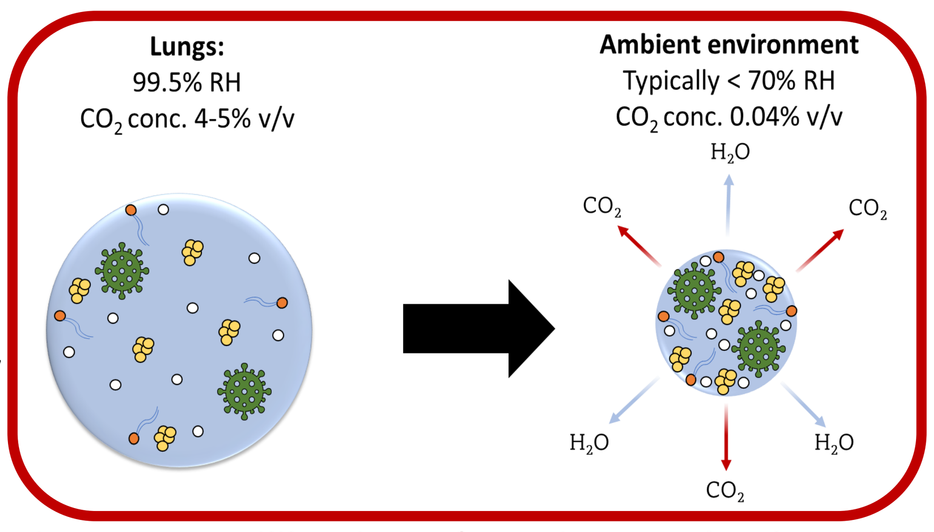


Figure 2: Equilibration of respiratory droplet with ambient environment. Depicts flux of CO_2 and water from respiratory droplet.

2. Statement of problem

- The mechanisms by which environmental factors control virus viability are not fully understood.
- The relationship between virus viability and environmental conditions is unclear. Reported levels of virus inactivation under different RH conditions are inconsistent between studies (Figure 3).
- These uncertainties hinder the development of appropriate public health interventions to mitigate virus transmission.

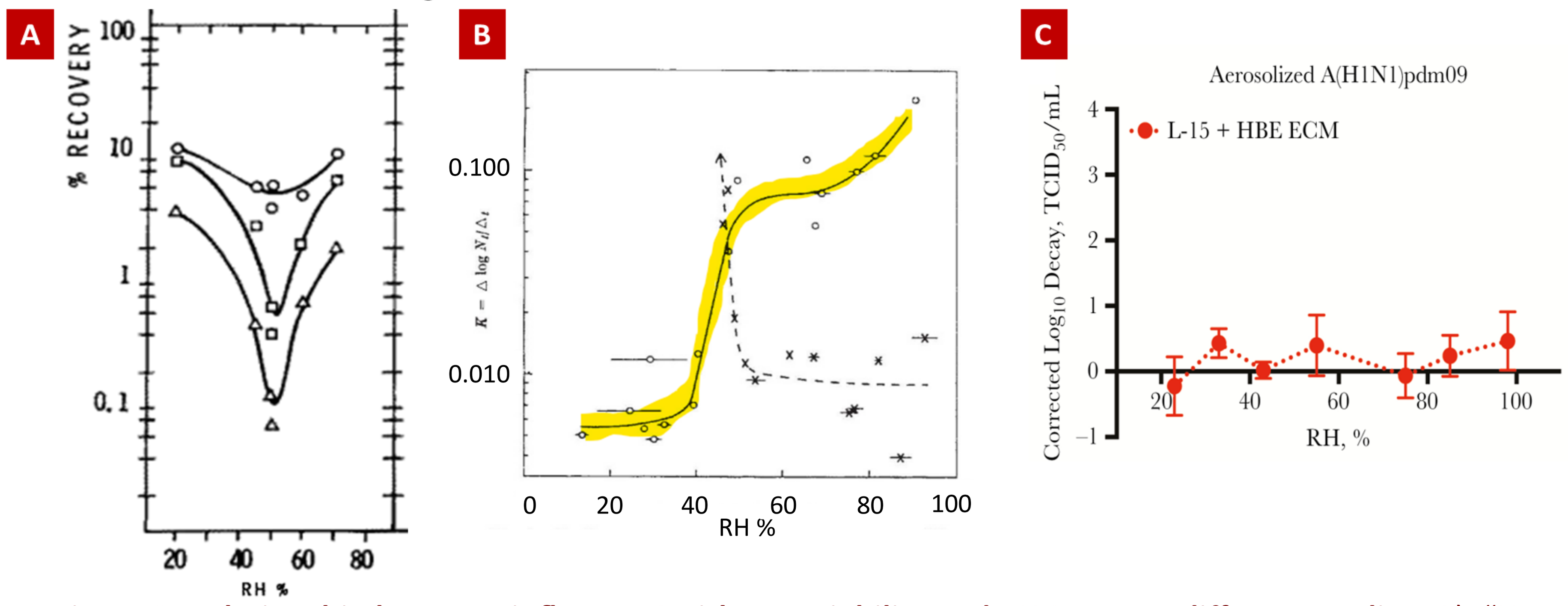


Figure 3: Relationship between influenza A airborne viability and RH % across different studies. A) "U-shaped" relationship between virus viability and RH [4] B) Highest virus inactivation rate at high RH [5] C) No relationship between RH and virus inactivation [6].

3. Research Objectives

Objective 1 - Assess the influence of RH, absolute humidity and temperature on the enveloped viruses, **human coronavirus 229E** (HCoV-229E) and **influenza A**, and the non-enveloped virus, **human adenovirus type 5,** in suspended aerosol droplets

Objective 2 - Assess the **impact of different suspension medium compositions** on the airborne viability of the above mentioned virus species

Objective 3 - Assess the **impact of droplet size, pH, and mucin content** on the viability of the above-mentioned virus species

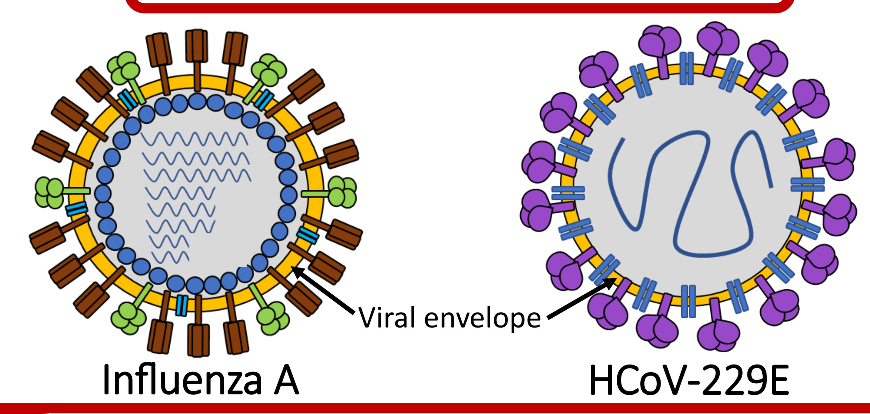
Objective 4 - Identify biological features that determine the aero-stability of severe acute respiratory coronavirus 2 (SARS-CoV-2) strains using reverse genetics

4. Methodology

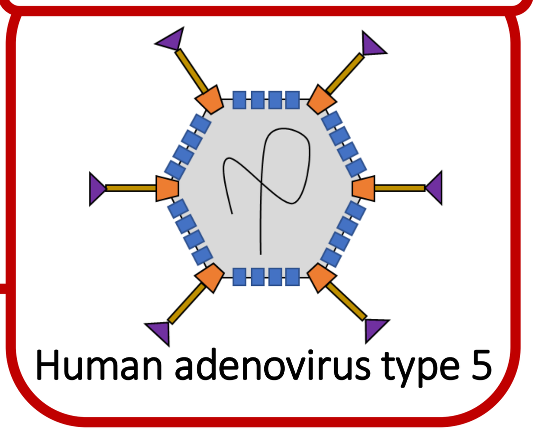
Controlled Electrodynamic Levitations and Extraction of Bioaerosols onto a Substrate (CELEBS)

- CELEBS allows the relationship between environmental factors (e.g. temperature, absolute humidity and RH) and virus viability in aerosolised droplets to be investigated [1].
- Generates monodispersed populations of aerosols with known chemical and biological composition.
- It accurately simulates aerosol phase by levitating aerosol droplets in an electromagnetic field produced by two ring electrodes [3]
- Atmospheric conditions experienced by the pathogen is controlled by a laminar airflow which is passed over levitated droplets
- Accessible atmospheric conditions:
  Temperature: ~5-40 °C ; RH: 10-90%
- After exposure to a desired atmospheric condition droplets are deposited into cell tissue growth media and the impact on virus viability is assessed using an infectivity assay.

Enveloped viruses



Non-enveloped virus



CELEBS

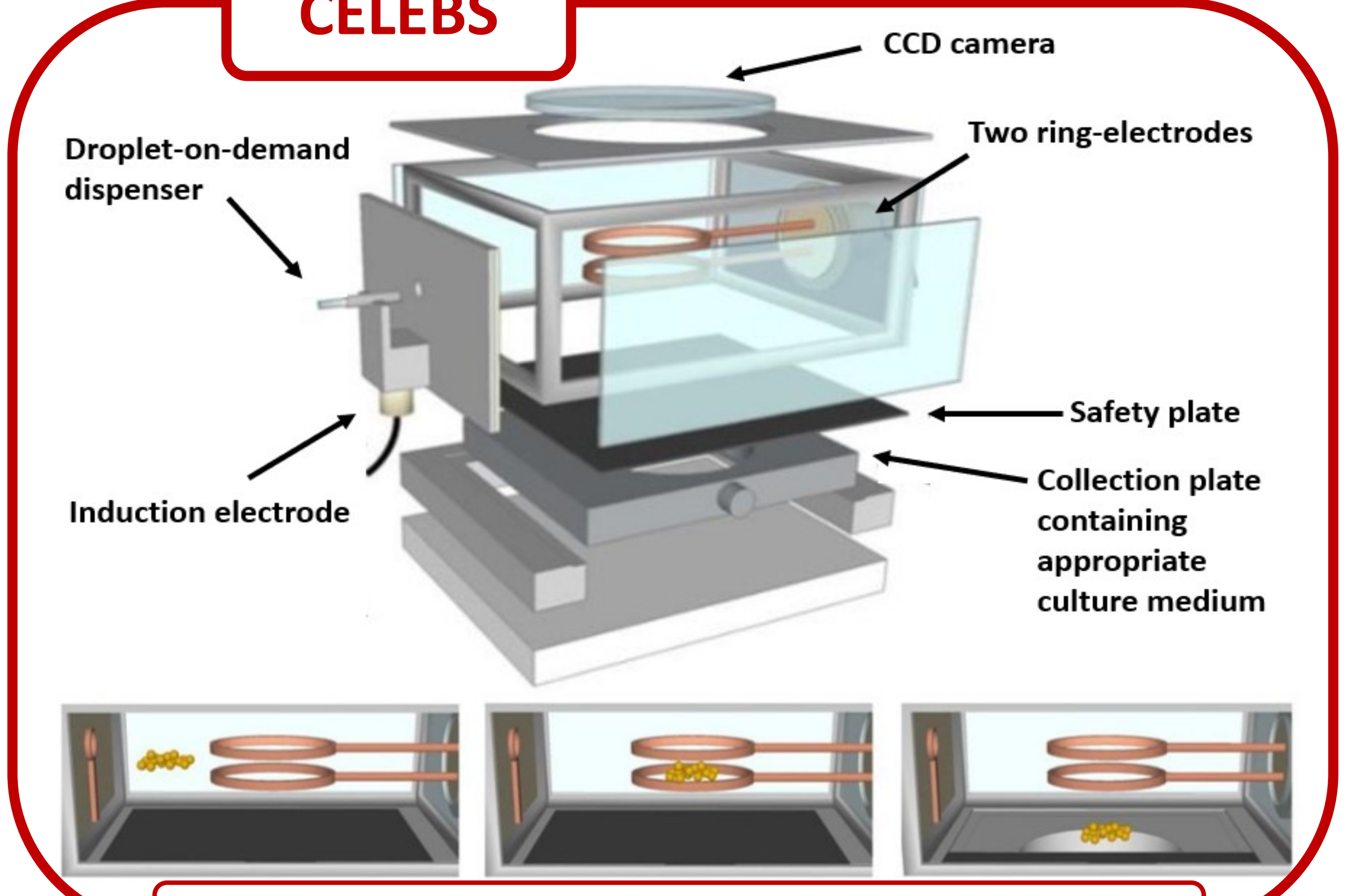


Figure 4: General configuration of the CELEBS apparatus [1].

SARS-CoV-2: Viral reverse genetics

- Identify genes and mutations that promote airborne viability in SARS-CoV-2
- Mutations in SARS-CoV-2 strains that present lower airborne viability will be engineered into strains that present higher airborne viability.
- If the airborne viability of the engineered strain decreases compared to the original strain it will confirm the relevance of that mutation for aero-stability of SARS-CoV-2

5. Challenges

Challenge 1 - Generating a **suspension medium** that is representative of respiratory fluid

Challenge 2 - Obtaining **high virus titers** for use in CELEBs

6. Responsible innovation

Dual-use concern - Understanding environmental and biological factors that control virus transmission could help **develop mitigation strategies** to minimize the spread of disease; **BUT** could also be misused to **enhance dissemination** of infectious agents

7. Policy

A greater understanding of factors controlling respiratory virus inactivation could:

- **Improve building codes and standards:** Ensure indoor environments are designed to minimize the risk of virus transmission.
- **Inform vaccination distribution:** Prioritize individuals that spend time in high risk environments.
- **Aid public health officials** to develop more effective response plans to prevent or mitigate the spread of disease.

8. References

[1] M. O. Fernandez, R. J. Thomas, N. J. Garton, A. Hudson, A. Haddrell, and J. P. Reid, 'Assessing the airborne survival of bacteria in populations of aerosol droplets with a novel technology', *J. R. Soc. Interface*, vol. 16, no. 150, p. 20180779, Jan. 2019.
[2] E. Huynh *et al.*, 'Evidence for a semisolid phase state of aerosols and droplets relevant to the airborne and surface survival of pathogens', *Proc. Natl. Acad. Sci.*, vol. 119, no. 4, p. e2109750119, Jan. 2022.
[3] H. P. Oswin *et al.*, 'The dynamics of SARS-CoV-2 infectivity with changes in aerosol microenvironment', *Proc. Natl. Acad. Sci.*, vol. 119, no. 27, p. e2200109119, Jul. 2022.
[4] F. L. Schaffer, M. E. Soergel, and D. C. Straube, 'Survival of airborne influenza virus: Effects of propagating host, relative humidity, and composition of spray fluids', *Arch. Virol.*, vol. 51, no. 4, pp. 263–273, Dec. 1976.
[5] J. H. Hemmes, K. C. Winkler, and S. M. Kool, 'Virus survival as a seasonal factor in influenza and poliomyelitis', *Nature*, vol. 188, no. 4748, pp. 430–431, Oct. 1960.
[6] K. A. Kormuth *et al.*, 'Influenza virus infectivity Is retained in aerosols and droplets independent of relative humidity', *J. Infect. Dis.*, vol. 218, no. 5, pp. 739–747, Jul. 2018.