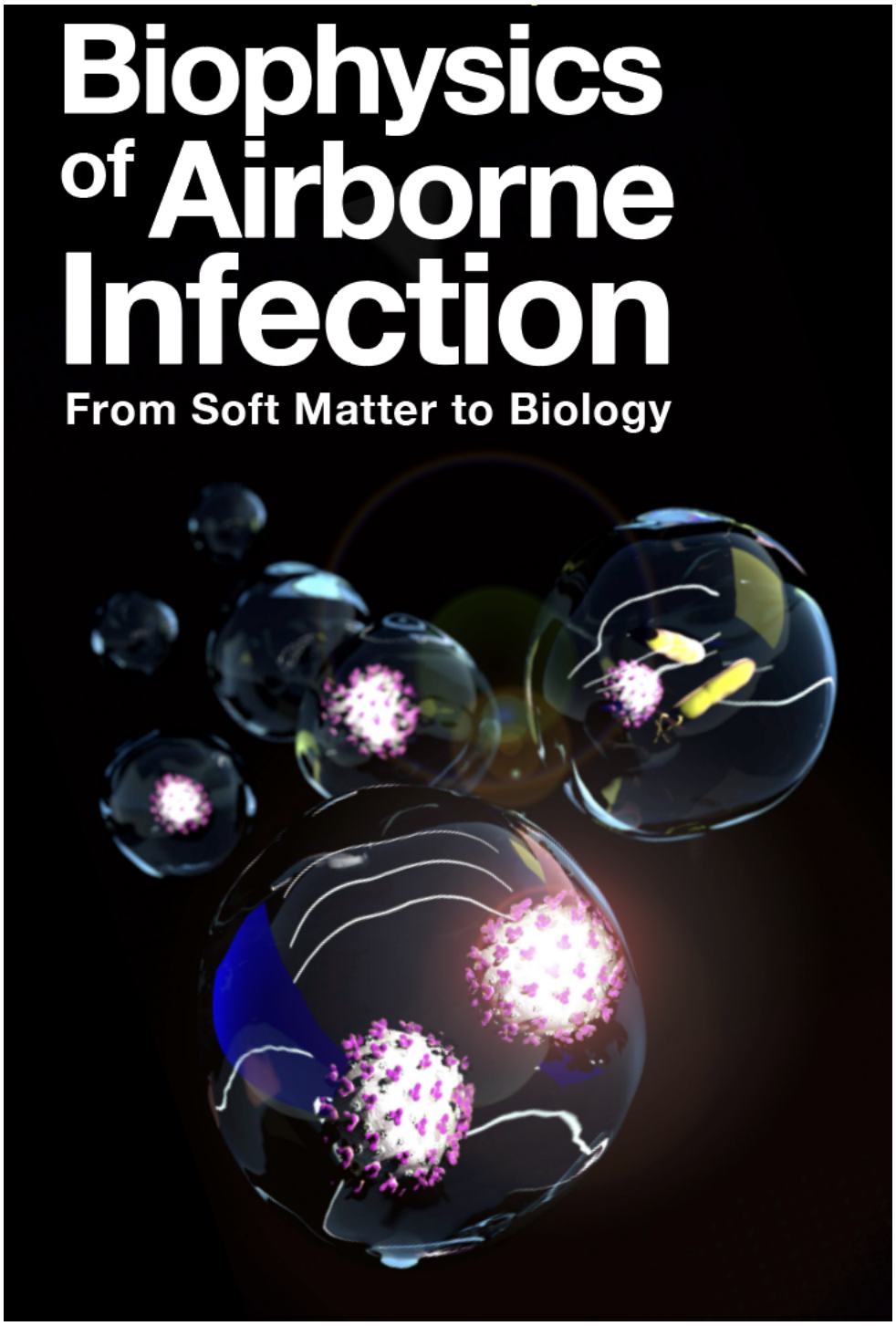

Book of Abstracts

Montpellier

4th-6th of June 2025

Invited Speakers

Airborne Disease Transmission: Respiratory Particles, Face Masks and Indoor Air

Mohsen Bagheri*[1]

[1]Max Planck Institute for Dynamics and Self-Organization – Germany

Abstract

Respiratory particles play a central role in the airborne transmission of infections during pandemics, yet the rate at which individuals generate them varies widely. To quantify this variability, we measured the full particle-size spectrum exhaled by 132 healthy volunteers (ages 5–80) during breathing, speaking, singing, and shouting under tightly controlled conditions. Age emerged as the dominant factor influencing the emission of fine particles ($< 5\mu$m), which remain airborne the longest, while other factors, such as gender, body mass index, smoking, or exercise, had negligible effect. Distinct particle sizes were associated with specific regions of the respiratory tract, and we found that individuals can differ by up to two orders of magnitude in their potential to emit infectious aerosols. I will show how these source-strength data refine estimates of face mask performance and help quantify their effectiveness in reducing the risk of airborne infection transmission. In particular, I will present evidence that appropriate mask use in the community offers strong protection for both the wearer and others, substantially reducing the importance of physical distancing. Finally, I will compare the widely used idealised model of a "well-mixed" room with measurements from a classroom model, illustrating how real airflow patterns and human presence influence indoor aerosol dispersion.

*Speaker

Fluid/bio-physics of disease transmission

Prof. Lydia Bourouiba[1]

The Fluid Dynamics of Disease Transmission Laboratory, Fluids and Health Network, Massachusetts Institute of Technology

ABSTRACT :

Infectious disease transmission involves interactions of pathogens with complex fluids such as in respiratory mucous, isolated droplets, or multiphase turbulent clouds. This is true for products of human exhalations, bursting bubbles, or impacting raindrops, all having potential to be efficient sources of pathogen-laden microdroplets. Our mechanistic understanding of how such pathogens successfully and sustainably transfer from one host or ecological reservoir to the next, despite sharp shifts in environmental and climate conditions, remains limited. We will highlight how studying such challenging health questions can lead to fundamentally new insights, and emergence of a broad class of relevant open fluid/bio-physics and mechanics problems, including those in which the unsteadiness of fragmentation, mixing, rheology, and phase change are at the core. And how in turn these fundamental processes begin to shed light on the entangled interactions of physics and biology in shaping adaptation and evolution of the pathogens. This will be illustrated in the context of Mycobacterium tuberculosis (Mtb) transmission.

Understanding how SARS-CoV-2 variants spread in the airways: insights from reconstructed human epithelial models

Lisa A. Chakrabarti*[1]

[1]Control of Chronic Viral Infections Group, Virus Immunity Unit, Institut Pasteur, Université Paris Cité – Institut Pasteur [Paris] – France

Abstract

There is a critical need of relevant model systems to understand how viruses spread in the human respiratory tract. We will discuss how 3D tissue models can be harnessed to analyze the early steps of SARS-CoV-2 replication in the airways. We will analyze how SARS-CoV-2 replication perturbs the clearance function of the motile cilia layer in a reconstructed airway epithelium model. We will also explore how temperature controls the induction of the innate antiviral response to different SARS-CoV-2 variants. Last, we will discuss how advances in organ-on-chip technologies can lead to the development of 3D airway and alveolar models with increased physiological relevance.

*Speaker

Vaporised glycols inactivate respiratory viruses and prevent airborne transmission.

Rachel Edgar*[1,2]

[1]Department of Infectious Diseaase, Imperial College London – United Kingdom
[2]The Francis Crick Institute [London] – United Kingdom

Abstract

Pandemic prevention and management requires multiple strategies to limit the spread of infection. An ideal transmission-blocking intervention would be safe, cost-effective, minimally disruptive and easy to deploy across the globe or use prophylactically to prevent zoonosis. Non-toxic glycol vapour can inactivate respiratory viruses within airborne and surface droplets, directly reducing the environmental infectious burden and onward transmission of SARS-CoV-2 and influenza A to susceptible cells using an *in vitro* experimental platform. Vaporised glycols work by biophysical disruption of viral proteins and particles, presenting a substantial barrier to evolutionary escape. Use of this broad-spectrum virucide could therefore protect populations against existing and emerging infectious threats. Testing glycol vapour efficacy within clinical, agricultural, transport and commercial settings is now paramount. Across academia, industry, public health and governmental regulatory bodies there is little clarity or consensus about how to assess transmission blockade for viral infections. More broadly, I will discuss the future steps required to rapidly test whether interventions prevent disease transmission and move them from the laboratory to the real world.

*Speaker

Active bacterial pattern formation inside evaporating droplets

Hanneke Gelderblom*[1,2,3], Twan Wilting[4,5], Myrthe Reijnier[4], Michiel Brebels[4], Alexandre Villie[6], and Remy Colin[7]

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[6]Department of Applied Physics Science Education, Eindhoven University of Technology – Netherlands

[7]Max Planck Institute for Terrestrial Microbiology and Center for Synthetic Microbiology (SYNMIKRO) – Germany

Abstract

Bacteria living on surfaces are often confined to droplets. When these droplets evaporate, the motion of the liquid-air interface and the associated internal capillary flow confine the bacteria. Here we study how *E. coli* bacteria interact with this capillary confinement and agglomerate at the droplet's contact line. Counter-intuitively, the bacterial activity does not cause the bacterial patterns to homogenize. Instead, a non-trivial self-organization of bacteria arises that causes a persistent local stirring of the liquid. We demonstrate that, depending on the droplet's ambient conditions, this bacterial collective motion gives rise to an instability in bacterial number density that leads to the formation of a fingering pattern. By a combination of experiments and theoretical modelling, we investigate how the bacterial motility, number density and droplet evaporation rate control the pattern dynamics. Ultimately, our aim is to understand how the interplay between the bacteria and their surrounding liquid governs their dispersal.

*Speaker

Relating Respiratory Aerosol Emission Rates, the Exhaled Carbon Dioxide Flux and the Airborne Survival of Pathogens to Assess Transmission Risk in Indoor Environments

Allen Haddrell*[1]

[1]University of Bristol [Bristol] – United Kingdom

Abstract

Assessing the risk of airborne transmission of respiratory pathogens indoors often relies on estimating the volume of aerosol emitted during respiratory and vocal activities, especially in the absence of direct measurements of infectious virus concentrations. At the University of Bristol Aerosol Research Centre, we have conducted two major studies-**PERFORM** and **AERATOR**-collecting data from nearly 400 participants. These studies uniquely quantify the absolute aerosol output from a range of respiratory and vocal activities, such as speaking and singing, and explore how this correlates with exhaled carbon dioxide (CO) and the presence of pre-existing lung conditions.
By simultaneously measuring exhaled aerosol and key respiratory metrics (e.g., minute ventilation), we examine how aerosol and CO emissions vary during breathing, exercising, speaking, and singing, in both healthy individuals and those with respiratory illness. Although CO is widely used as a proxy for indoor ventilation and transmission risk, our findings suggest it is a **poor indicator** of aerosol emission and, by extension, airborne pathogen load. For example, certain vocal activities can increase aerosol emissions by **1–3 orders of magnitude** without a corresponding rise in CO levels.

To complement the human data, we also present measurements of airborne virus survival using the **Controlled Electrodynamic Levitation and Extraction of Bioaerosol onto a Substrate (CELEBS)** method. These experiments reveal that **gas-phase CO plays a critical role** in maintaining the infectivity of airborne viruses like SARS-CoV-2. Elevated CO levels influence the pH of aerosol particles by affecting the dissolved CO content, mitigating alkaline conditions that would otherwise degrade viral infectivity. Therefore, in poorly ventilated indoor spaces with high CO levels, both **viral longevity** and **transmission potential** may be increased.
In summary, CO concentration alone is insufficient to gauge airborne transmission risk. It may underestimate aerosol and pathogen levels during high-emission activities and, paradoxically, support longer pathogen survival under certain conditions. These findings underscore the need for more sophisticated risk assessment strategies that go beyond CO as a standalone metric.

*Speaker

Respiratory and Salivary Viral Shedding: Insights and Correlations with Airborne Transmission

Jérôme Le Goff*[1]

[1]Virology, Hôpital Saint-Louis, GHU APHP-NORD, APHP, Université Paris Cité – Hôpital Saint-Louis, Assistance publique - Hôpitaux de Paris (AP-HP), Université Paris Cité – France

Abstract

Understanding the dynamics of viral shedding via respiratory and salivary secretions is essential for accurately assessing the risk of airborne transmission, especially for respiratory pathogens such as SARS-CoV-2 and influenza viruses. Current evidence highlights the complex interplay between viral load, anatomical shedding sites, host factors, and environmental conditions that influence the potential for aerosol generation and transmission. Saliva has emerged as a valuable, non-invasive diagnostic matrix, often correlating well with nasopharyngeal viral loads, while also providing insight into early infection and transmissibility.
Quantitative and qualitative analyses of exhaled breath, aerosols, and surface contamination further elucidate the conditions under which infectious virus particles can remain airborne and contribute to transmission, especially in poorly ventilated or crowded indoor environments. In parallel, computational airflow modeling and environmental sampling have improved our understanding of virus dispersion in real-world settings.
This presentation will highlight the importance of integrating respiratory and salivary detection with environmental air sampling and airflow measurements to better characterize transmission risks. Combining these complementary approaches offers a more comprehensive framework for monitoring respiratory virus spread, optimizing mitigation strategies, and guiding public health preparedness.

*Speaker

Implementation of Atomic Force Microscopy Coupled with STED Microscopy in a Class 3 Biosafety Laboratory for the Mechanobiology of Single Viruses

Sébastien Lyonnais

CEMIPAI UAR3725 CNRS Montpellier University, 1919 Route de Mende, 34000 Montpellier

Atomic force microscopy (AFM) is a scanning imaging technique able to work at the nanoscale. It uses a cantilever with a tip to move across samples' surface and a laser to measure the cantilever bending, enabling the assessment of interaction forces between tip and sample, and creating a three-dimensional visual representation of its surface. AFM has gone through many technological advancements for its adaptation to biology, resulting today in a highly sensitive, label-free technique that measures forces with exceptional spatial and temporal resolution, in near-physiological conditions. This new generation of Bio-AFM has become a prominent tool in physical virology and enables imaging, force spectroscopy and nanomechanical analysis of cells and viruses, making it a powerful swiss-knife in virology research for applications such as virus imaging, nanoindentation, mechanical property characterization and interaction mechanisms with host cells.

We recently introduced the latest generation of bioAFM in the level 3 containment laboratory at CEMIPAI in Montpellier, so that this technology can be applied to pathogenic viruses, including those responsible for respiratory diseases such as SARS-CoV-2 or Influenza virus. I will present here this unique instrument, as well as its coupling with a super-resolution STED fluorescence microscope, enabling AFM analysis to be correlated with fluorescence specificity at the required resolution for single particle imaging.

Airborne transmission of infectious diseases

Peter Nielsen*[1]

[1]Aalborg University – Denmark

Abstract

The spreading of a disease largely occurs in buildings or in collective transport. The microenvironment flow processes around people contribute to the cross-infection risk, for example when two people are standing close to each other. The cross-infection risk is also dependent on the macro-environment e.g. distribution of velocity and turbulence in the room.
There are several relations and parameters which will influence the processes in the microenvironment. The position and the direction of exhalation from the index person in relation to the surrounding persons is important. The facial geometry of involved people varies significantly in a family and all over the world, so expiration direction and mouth opening area are important. Another parameter is the activity level of the index person, which will influence both exhalation flow and his/her body thermal boundary layer. The activity level of the susceptible individual also plays a role, and his/her high activity level will increase the risk. The exposure duration is obviously an important parameter.

Flow for aerosol distribution in exhalation and eventually in the persons' boundary layer are established and the cross-infection risk is evaluated expressed as concentration in the susceptible individual's breathing zone normalized by the concentration in the room (fully mixed concentration). The surrounding temperature and the presence of a vertical temperature gradient can also modify airflows in the microenvironment and subsequently influence the cross-infection risk.

This study is supported by the Independent Research Fund Denmark (No. 3105–00106B).

*Speaker

The effect of polymeric solutes on evaporation

Max Huisman[1], Paul Digard[2], Wilson Poon*[1], and Simon Titmuss[1]

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[2]Department of Infection and Immunity, The Roslin Institute, The University of Edinburgh – United Kingdom

Abstract

Long ago in a classic 1934 paper, Wells explained why the transmission of pathogens via airborne droplets depends on a balance between the rate of evaporation and the rate of gravitational sedimentation. A key factor affecting the rate of droplet evaporation is the relative humidity (RH) of the environment. Common sense suggests that the more humid the environment, the slower droplets will evaporate. We show experimentally that the presence of polymeric solutes may fundamentally change this common-sense picture and give rise to evaporative kinetics that is relatively independent of RH up to around 80% (Huisman et al., Phys. Rev. Lett 131, 248102 (2023)). We will explain why polymers could have this effect, and, time permitting, explore how this effect may depend on polymeric propeerties (e.g. charge).

*Speaker

To Exhale or Not to Exhale: Host Barriers to Virus Aerosolization

Patricia Romanos Martinez[1], Filipa Vermelho[1], Trent Bushmaker[2], Kwe Claude Yinda[2], Vincent J. Munster[2], and Julia R. Port*[1,2]

[1]Laboratory of Transmission Immunology, Helmholtz Center for Infection Research (HZI), Brunswick – Germany

[2]Laboratory of Virology, Division of Intramural Research, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Hamilton, MT – United States

Abstract

Coronaviruses continue to represent a substantial public health challenge and carry a heightened potential to trigger a new pandemic. How SARS-CoV-2 influences the physiological host factors that are essential for aerosol transmission remains poorly understood. The present study investigated the potential for SARS-CoV-2 transmission via fine aerosols and the host and viral factors that determine this process. Syrian hamsters intranasally inoculated were positive for viral RNA in respiratory swabs for up to seven days and for infectious virus for up to five days. Fine aerosol transmission occurred within one hour of exposure on the first day of infection. However, this was not the case on the third day, despite the presence of the infectious virus in oral swabs. An assessment was conducted of breathing patterns, exhaled droplets, and infectious viruses post-infection. The development of technology for the sampling of cage air for the purpose of detecting exhaled viruses was a key achievement. Lineage A, Alpha and Delta exhibited a restricted period of detectability for infectious airborne virus (24-48 hours), which was more brief than that observed with oropharyngeal swabs. The loss of airborne shedding was linked to airway constriction, measured by whole-body plethysmography, resulting in a decrease of fine aerosols (1-10 μm) exhaled by infected animals. In the subsequent phase of the study, the investigation focused on the specific exhalation of virus variants as a function of exposure route. The findings indicated delayed shedding into the air (days 4-6) following fomite and intra-tracheal exposure, as well as in sentinels exposed via the air. These observations suggest that a specific region within the upper respiratory tract must be actively infected to enable exhalation. No infectious viral particles were detected in the air for variants that were unable to transmit in vivo. Evidence was provided that in vaccinated and previously exposed hamsters, pre-existing humoral immunity robustly limited transmission and affected the selective pressure within each host and during transmission. As demonstrated in the proof-of-concept study, even three months following exposure, protective mucosal antibody levels were detected. These levels were found to be capable of neutralizing the virus in secretions and protecting naive animals from aerosolized virus. This work underscores the significance of ongoing evaluation of SARS-CoV-2 variants and their capacity to transmit, contingent on both host and virus-related factors, culminating in a distinct exhaled particle profile. Such assessment is imperative for comprehending the mechanisms of airborne transmission. This work was supported by the Intramural Research Program of the National Institute of Allergy and Infectious Diseases, National Institutes of Health and the Initiative and Networking Fund of the Helmholtz Association.

*Speaker

Oral Tropism: The Mouth, the Glands, and Transmission Biology

Blake Warner*[1]

[1]National Institutes of Health [Bethesda, MD, USA] – United States

Abstract

Uncovering Viral Reservoirs, Salivary Routes in Infection, and Consequences of Viral Peristence
Saliva is more than a harmless bodily fluid; it is also a powerful vehicle for viral transmission. From respiratory to systemic infections, recent research has uncovered that the salivary glands are not passive bystanders but active sites of viral infection, replication, and shedding. During the COVID-19 pandemic, studies revealed that SARS-CoV-2 directly infects cells within the salivary glands, which express high levels of viral entry factors. Even individuals without symptoms can carry and shed virus in their saliva, suggesting that these glands are a hidden reservoir contributing to ongoing transmission.

Importantly, this isn't unique to COVID-19. Other viruses such as Epstein-Barr (EBV), cytomegalovirus (CMV), measles virus (MeV), and others, also target the salivary glands. These pathogens can evade immune responses within glandular tissue, allowing them to persist and possibly spread through droplets and saliva, often before systemic infection is detectable.

Beyond the immediate dynamics of infection and transmission, recent research on post-acute COVID-19 syndrome (PACS) has revealed a deeper, long-term consequence of viral infection: the potential to trigger chronic immune dysregulation and autoimmunity. Notably, SARS-CoV-2 infection of the salivary glands has been shown to impair the production of key secreted antimicrobial peptides, including antifungal factors, which may contribute to secondary complications such as oral candidiasis. This disruption of the gland's protective functions occurs alongside persistent viral presence, driving local inflammation and immune activation that mirrors the pathology of Sjögren's Disease-a systemic autoimmune disorder characterized by dry mouth, salivary gland dysfunction, and widespread immune involvement. Animal models have demonstrated that chronic viral infection of glandular tissues can initiate epithelial injury, immune cell infiltration, and autoantibody production. These findings raise an urgent question: could early or persistent viral infection of the salivary glands serve as a trigger for lifelong autoimmune disease in susceptible individuals?
Understanding how viruses colonize and persist in the oral cavity opens new frontiers for diagnostics, vaccines, and therapies. These avenues of research are not just to stop transmission, but may also be leveraged to prevent downstream diseases. Thus, the mouth may be one of the first sites of infection-and possibly the first place to intervene.

*Speaker

Short Talks

Viral inactivation, aggregation and DNA ejection induced by inert gas bubbling

Ryan Morris[1], Jana Schwarz-Linek[1], Aidan Brown*[1], Wilson Poon[1], and Paul Digard[1]

[1]The University of Edinburgh – United Kingdom

Abstract

The observation that simply bubbling an inert gas through a suspension of viral particles reduces the apparent titre is an old one. We revisit this phenomenon and verify that bubbling inert nitrogen gas through a suspension of bacteriophages can reduce the apparent titre by four orders of magnitude. Using dynamic light scattering and electron microscopy, we find that the bubble-treated phage form aggregates and that some have released their genomic DNA. Our results indicate that phage deactivation by gas bubbling is due to a combination of genome ejection and aggregation. These results are likely to be applicable to some pathogenic viruses, and open up potential new routes to viral disinfection.

*Speaker

Characterization of Viral Particles by Nanopores

Léa Chazot-Franguiadakis*[1] and Fabien Montel[2]

[1]Laboratoire de Physique ENS Lyon – Laboratoire de Physique de l'ENS de Lyon – France
[2]Laboratoire Physique ENS Lyon – Laboratoire de Physique de l'ENS de Lyon – France

Abstract

Nanopore-based technologies have proven highly effective in DNA sequencing and are now emerging as powerful tools to study viruses. Indeed, their ability to probe viral properties with high precision opens new avenues to develop alternative methods for virus detection and characterization that are simpler, faster, and more compact. Our research focuses on developing a nanopore-based device for real-time virus detection and characterization at the single-particle level. To do so, we rely on a highly sensitive optical system, developed within our team, which allows us to detect fluorescently labeled viruses transported through nanopores under flow (1). This system enables both the detection and quantification of virus concentration, as well as the identification of the viral types in complex samples.
Regarding concentration quantification, we have developed a rapid and robust method that requires only fluorescent labeling, therefore allowing a tunable specificity. For example, by selecting appropriate fluorescent labels, we can target entire viral particles and/or their genome. Unlike conventional techniques such as PCR or antigenic assays, which analyze genetic material or proteins separately, our system detects intact viral particles. Moreover, it offers a significant advantage for concentration quantification in low-concentration samples, as its detection limit is less than 105 particles/mL (for an acquisition time of 60 seconds) (2), which is 100 times lower than current whole-virus detection techniques like Nanoparticle Tracking Analysis or interferometric microscopy.

For viral type identification, we combine fluorescent labeling with nanopore transport analysis to determine the dominant viral type in a sample. Indeed, by measuring translocation frequency as a function of control parameters (e.g., pressure, concentration), we reveal a jamming phenomenon caused by viral confinement under flow. We investigate the physical and chemical determinants of this effect and model it as a phase transition under flow (2). The extracted parameters provide insights into virus-pore interactions, enabling viral type identification (3) but also the study of structural modifications induced by topological defect modulators.
(1)Chazot-Franguiadakis L., et al., *Nano Letters*, 22, 9, 3651–3658 (2022).
(2)Chazot-Franguiadakis L., et al., *Nat. Communications*,15, 6180 (2024).
(3)Montel F., et al., *French Patent Application* 2309837 (2023).

*Speaker

Impact of Charged Particles on Pulmonary Surfactant: Mechanistic Insights into Respiratory Disruption

Bogdan Munteanu , Frederic Harb*[1], Jean-Paul Rieu[2], Yves Berthier[3], Bernard Tinland[4], and Anna-Maria Trunfio-Sfarghiu[5]

[1]University of Balamand [Liban] – Lebanon
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[5]Laboratoire de Mécanique des Contacts et des Structures [Villeurbanne] – Institut National des Sciences Appliquées de Lyon, Centre National de la Recherche Scientifique - CNRS – France

Abstract

Airborne particulate matter (PM) is a major environmental concern due to its detrimental impact on respiratory health. The pulmonary surfactant, a lipid-protein complex crucial for lung function, is particularly vulnerable to interactions with charged particles, which may contribute to surfactant inhibition and respiratory distress. This study investigates the biophysical interactions between charged particles and a biomimetic pulmonary surfactant model composed of mixed supported lipid bilayers (SLB). Using fluorescence microscopy and Fluorescence Recovery After Patterned Photobleaching (FRAPP), we quantified particle adsorption and lipid diffusion coefficients as indicators of interaction strength. Our findings reveal that positively charged particles exhibit minimal interaction with the bilayer, likely due to electrostatic repulsion. In contrast, negatively charged particles strongly adsorb onto the bilayer, significantly reducing lipid mobility, a phenomenon correlated with particle zeta potential. These results provide critical insights into the mechanistic pathways through which PM may disrupt pulmonary surfactant function, potentially exacerbating respiratory pathologies. This study underscores the necessity of understanding particle-surfactant interactions to develop strategies mitigating air pollution-induced lung damage.

*Speaker

Dynamics of Indoor Airborne Infection Transmission

Hossein Khodamoradi*[1], Oliver Schlenczek[1], Eberhard Bodenschatz[1,2,3], and Gholamhossein Bagheri[1]

[1]Laboratory for Fluid Physics, Pattern Formation and Biocomplexity, Max Planck Institute for Dynamics and Self-Organisation – Germany
[2]Institute for the Dynamics of Complex Systems, University of Goettingen, – Germany
[3]Physics Department, Cornell University – United States

Abstract

Understanding airborne infection transmission in indoor spaces is crucial for public health, particularly in light of recent pandemics. The well-mixed room (WMR) model, commonly used to estimate infection risk, assumes uniform aerosol distribution. However, real-world conditions challenge this assumption, as aerosol concentrations can vary significantly within a room, impacting local transmission risks. To investigate these dynamics, we developed the Bovenden Aerosol Room (BAR), a controlled environment resembling German classrooms, equipped with 125 aerosol sensors measuring particle concentrations (0.3–40 μm), CO, volatile organic compounds, temperature, and humidity. The BAR allows for the study of spatial and temporal variations in aerosol dispersion under different ventilation strategies and occupancy conditions. Our experiments reveal that aerosol concentrations can vary by over three orders of magnitude across different regions within minutes, indicating that local hotspots of high transmission risk persist even in mechanically ventilated spaces. The presence of people further influences aerosol transport, creating dynamic conditions that deviate from WMR predictions. We introduce a novel method using the SensoRod system to quantify mixing efficiency and infection risk across diverse ventilation and dispersion scenarios. Results from both pulse and continuous particle release experiments show that ventilation efficacy varies significantly depending on configuration, with continuous releases exhibiting much higher variability.

*Speaker

Modeling the nosocomial transmission of respiratory infections by coupling close-proximity interactions and aerosol-mediated long-distance transmission routes

Maylis Layan*[1,2], Olivier Gaufrès[3], Lulla Opatowski[1], and Laura Temime[4]

[1]Epidemiology and Modelling of Antibacterial Evasion Unit – Université Paris-Saclay, UVSQ, Inserm, CESP, Villejuif, Institut Pasteur de Paris – France

[2]Modelling, epidemiology, and surveillance of health risks laboratory – Institut Pasteur de Paris, Conservatoire National des Arts et Métiers (CNAM) – France

[3]Modelling, epidemiology, and surveillance of health risks laboratory – Conservatoire National des Arts et Métiers - CNAM (FRANCE), Institut Pasteur Paris – France

[4]Modelling, epidemiology, and surveillance of health risks laboratory – Conservatoire National des Arts et Métiers (CNAM), Institut Pasteur Paris – France

Abstract

Nosocomial transmission of respiratory infections represent an important public health issue for hospitals, with a high risk of transmission affecting both patients and healthcare workers. It is commonly admitted that respiratory pathogens are transmitted through large droplets, emitted while speaking or coughing, which can lead to short-range transmission during close-proximity interactions, but also through small size aerosols that remain suspended in the air and may cause long-range transmission. Better characterizing the respective roles of close contact and long-distance aerosol transmissions in epidemic dynamics is essential to design effective control strategies. Yet, few attempts have been made to combine both transmission routes on periods longer than a few days. We developed an agent-based stochastic model of respiratory pathogen transmission in a hospital ward accounting simultaneously for close-contact and aerosol-mediated transmission. We informed our model with real close-proximity interaction data collected in an intensive care unit during the first wave of the SARS-CoV-2 pandemic. Using simulations, we explored five scenarios illustrating a range of respiratory pathogens with different person-to-person transmission rates and individual shedding rates of pathogen-laden aerosols. Parameter values were chosen so that the overall average secondary attack rate (SAR, proportion of susceptible individuals infected after the introduction of the index case) remained between 20% and 30% in the three months following the introduction of the index case. We found that epidemic dynamics (epidemic duration, peak timing, epidemic curves) were overall comparable, with no effect of the transmission scenario. However, when the contact rate increased from 0.25 to 1.5 per day while the shedding rate decreased from 20 to 5 per day, the relative contribution of the contact transmission route increased from 10 to 50%, the SAR among patients increased by 50%, and the SAR among paramedical staff decreased by 13%. In scenarios with higher transmission through contacts, patients were more represented among secondary cases. Our results suggest that

*Speaker

considering more precisely physical mechanisms involved in transmission could allow us to adapt intervention measures depending on transmission route relative contributions.

Active Mucus-Cilia Hydrodynamic Coupling Drives Self-Organization and Efficient Transport in Human Bronchial Epithelium

Etienne Loiseau*[1], Simon Gsell[2], Alice Briole[1], Umberto D'ortona[3], Julien Favier[3], and Annie Viallat[1]

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[3]m2p2 – $\mathrm{Aix}_{M}arseilleUniv, CNRS, CentraleMarseille, M2P2, Marseille, France - -France$

Abstract

Effective clearance of inhaled pathogens requires the coordinated transport of mucus at the surface of the bronchial epithelium, driven by millions of cilia. Impaired coordination, and consequently reduced clearance, underlies several respiratory diseases. In this presentation I will address the fundamental question: What key biophysical parameters drive efficient, large-scale mucus transport?
Using human bronchial epithelia, reconstituted in vitro, and computational fluid dynamics, we studied the emergence of mucus flow patterns during ciliogenesis. We observed a clear transition: initially localized mucus motion evolves into distinct, growing swirls, and finally, at physiological ciliary densities, into macroscopic, coordinated transport spanning the epithelium. This large-scale flow regime is strongly correlated with the emergence of long-range circular orientational order in the underlying ciliary beat directions.

To isolate the role of the mucus itself, we performed simple experiments: removing the mucus layer caused a loss of the large-scale ciliary orientational order, while the global order was restored upon re-adding mucus. This provides direct evidence that hydrodynamic coupling between the flowing mucus and the cilia is an essential mechanism underlying the collective coordination required for efficient, large-scale transport.

Our findings, supported by a hydrodynamics model, identify two critical biophysical parameters for transport efficiency :

Ciliary Density : Sufficient density is required for propulsion and to enable long-range order via hydrodynamic interactions. Below a threshold, transport is localized.

Mucus Viscosity : This determines the hydrodynamic interaction length scale. Higher viscosity facilitates longer-range coupling, promoting global coordination for large-scale flow.
In summary, efficient mucociliary transport is an emergent property driven by active hydrodynamic feedback between mucus and cilia. It critically depends on achieving sufficient ciliary density and appropriate mucus rheology to enable long-range coordination, offering insights into airway defense.

*Speaker

Respiratory flows through face masks

Camille Duprat*[1], Christophe Josserand[1], and Olivier Marchand[1]

[1]Laboratoire d'hydrodynamique – Ecole Polytechnique, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UMR7646 – France

Abstract

The efficiency of a face mask to collect respiratory droplets relies not only on the drop capture efficiency, but also on the proportion of exhaled flow that goes through the mask. Indeed, most of the time the mask is not perfectly fitted to the head, and large leaks are present above the nose or near the ears. Depending on the flow and on the permeability of the mask, a large proportion of the flow may be deviated through the leaks, and thus not filtrated. We study these effects quantitatively with laboratory experiments and theoretical modelling. First, we build a machine capable of reproducing respiratory flows (breathing or coughing), with a control on the transient dynamics of the flow as well as the exhaled volume, using measured respiratory flows as an input. This machine is then used to produce flows through porous fibrous materials, from model meshes to nonwoven surgical masks. We tune the studied geometry from a flat plate, with leaks of constant thickness, to a head-shape with a regularly worn mask. We study both expiration and inspiration. The proportion of the flow that goes through the mask or through the leaks highly depends on the permeability of the mask and on the flow rate, as well as the geometry, and exhibits a strong difference in inspiration or expiration.

*Speaker

Atomization of viscoelastic respiratory-like fluids in a cough machine

Alvaro Marin*[1], Tommie Verouden[1], Abe Sikkema[1], and Detlef Lohse[1,2]

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Abstract

Many unresolved questions about the spread of airborne respiratory diseases are rooted in fluid dynamics, including the mechanisms of aerosol generation. While respiratory droplets can originate at different levels within the respiratory tract (1,2), the aerosols formed during events such as coughing or sneezing typically involve the largest volume of atomised fluid in the shortest time. This process occurs when a turbulent airflow from the lungs interacts with the mucosal liquid film lining the trachea, leading to its fragmentation into droplets. Traditionally, this breakup mechanism has been assumed to be a classical shear-induced surface wave instability. However, recent studies (3) using an experimental model system designed to mimic a human trachea ("cough machine"), have revealed a more intricate mechanism. Their findings, based on glycerol/water samples, indicate that atomisation primarily occurs through the formation of thin liquid films or "bags" that inflate under airflow stress before breaking up into droplets.

Preliminary results have shown that liquid films featuring viscoelasticity - as most mucosal fluids do - also atomize following a bag-mediated process. However, it does significantly affect the later stages of fragmentation, influencing the resulting droplet size distribution, which is critical for understanding airborne disease transmission.

Here, we extend the work of Li et al. (4) to liquid films that closely replicate the rheology of respiratory fluids. As done before, we investigate the breakup of thin viscoelastic liquid films but we here put our focus on individual millimetric droplets exposed to the same airflow from a cough machine. By analyzing individual bag formation and fragmentation events, we offer a more detailed insight into the influence of viscoelasticity on respiratory fluid atomization.

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Hydrodynamics of viral transport in evaporating sessile model respiratory droplets

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Abstract

Viral particles, or virions, remain infective in the dry residue of respiratory droplets for times as long as hours (1–3). This is surprising, since when the drop's water fully evaporates the salt concentration becomes large, making the drop a harsh environment for virions (4). A possible explanation for the slow decay of viral infectivity is that the drop components (mainly salt and protein (5)) segregate during the evaporation. A hypothesis that has not yet been confirmed is that virions are transported away from salt deposits, preserving them from the salt's damaging effects (1). Knowing where virions reside in a drop residue is essential to disentangle the physico-chemical mechanisms that drive their inactivation (6), but experimentally it is challenging to determine the presence of virions in an environment as heterogeneous and complex as a respiratory drop. Here we use electron microscopy to show that virions are found mainly forming aggregates in protein-rich regions of the residue, segregated from salt crystals. Although previous works have aimed at detecting the presence of virions in drop residues, their results are not conclusive due to experimental limitations (5, 7, 8). Also, the physical mechanism behind the observed viral distributions were not properly described. We complement our experimental observations with a theoretical description of the flow inside the drop, which allows us to elucidate the transport mechanisms behind the viral spatial distribution. The theoretical transport model, supported by experiments, allows us to rationalize the spatial distribution of salt, protein, and virions inside evaporating respiratory drops. We anticipate our results to be an essential ingredient to explain the discrepancies between the infectivity decay rates measured in respiratory drops, which nowadays exhibit important discrepancies (9).

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The way we speak and the way we disperse: effect of aspirated plosives on aerosol transport

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Abstract

The COVID-19 pandemic has underscored the significance of asymptomatic transmission and the importance of understanding aerosol generation and transport through speech and breathing. While coughing and sneezing have been extensively studied, speech-generated aerosols have received less attention, particularly regarding their transport and potential for infection spread. Although direct transport of speech aerosols is generally considered limited, certain phonemes produce airflow patterns akin to micro-coughs, enabling aerosols to reach distances up to 1 meter in less than a second.
In particular, plosives-consonants produced by a sudden release of air (e.g., /p/, /t/, /k/)- have the potential to aerosolize saliva and transport the aerosols in the resulting puff. Aspirated plosives, which involve additional airflow through the glottis, may further enhance aerosol production and transport. In this study, we investigated the similarities and differences between aspirated and non-aspirated plosives in terms of droplet production and aerosol transport. Experimental data from a dozen volunteers were collected using particle image velocimetry (PIV), Schlieren imaging, sound recording, and mouth movement tracking, and were combined with computational fluid dynamics (CFD) simulations for further analysis.

Our results demonstrate that aspirated plosives indeed generate greater airflow velocities and turbulence, leading to enhanced forward transport. We show that this enhanced transport is associated with the prolonged injection time of aspiration and, in some cases, a more intense plosion by certain participants.
Our measurements allow us to propose a detailed sequence of flow and atomization events for aspirated and non-aspirated plosives that clarifies the underlying mechanisms. Specifically, we show that the initial plosion is responsible for an intense but small jet that atomizes saliva. The aspiration jet that follows is strong enough to entrain the first jet created,

*Speaker

forming a main puff that collects the generated droplets and transports them over longer distances. Our findings represent a clear demonstration of how small differences in linguistics can significantly affect aerosol transport relevant to disease transmission.

A Blueprint for Far-UVC Use in Airborne Pathogen Control

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Abstract

Background: Protecting people from infectious aerosols in their indoor air is a remarkable opportunity for improving public health, but comes with significant challenges. Recent standards, such as ASHRAE 241, set equivalent clean air delivery rate targets to reduce airborne transmission risk. While increased ventilation and added filtration can meet these targets in some settings, many environments-such as classrooms, gyms, and restaurants-require impractically high ventilation rates to achieve sufficient infection risk mitigation. This gap highlights the need for additional strategies to supplement traditional air quality interventions. Far-UVC – an emerging type of germicidal UV light – could be one of these strategies.
Methods: To develop an actionable roadmap for far-UVC disinfection, we conducted extensive literature reviews, semi-structured interviews with over 100 experts from academia, industry, government, healthcare, and the non-profit sector, and performed parametric modeling using the Wells-Riley infection risk framework. This multidisciplinary effort evaluated far-UVC's potential to inactivate pathogens in diverse settings, focusing on technical domains such as disinfection efficacy, photobiological safety, materials compatibility, and indoor air chemistry.

Key Findings: Far-UVC can be both safe and effective when properly implemented. That safety and effectiveness depends on the physical interactions between UV photons and biological materials (both pathogens in aerosols and human tissues). Current evidence supports its safety below existing exposure guidelines, with studies showing minimal DNA damage in skin and eyes due to limited tissue penetration. When integrated with other air cleaning technologies like ventilation and filtration, far-UVC offers a cost-effective and energy-efficient way to achieve equivalent clean air delivery rate targets, particularly in spaces where increased ventilation is impractical.
Our presentation will focus on recommendations for developing standardized biophysical measurement techniques essential for advancing far-UVC research. We will highlight the need for rigorous protocols to characterize the physical and biological properties of respiratory aerosols, quantify pathogen susceptibility across varying environmental conditions, and measure UV dose distribution in complex airflows. These recommendations emphasize how integrating approaches from physics, fluid mechanics, virology, and microbiology can establish the foundation for effective airborne pathogen control technologies.

*Speaker

Modelling enveloped viruses with flexible spikes

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Abstract

Since 2019, the SARS-CoV-2 virus has been a critical global issue due to its significant health impact. This study proposes a model for enveloped viruses, such as SARS-CoV-2, based on their morphological features. Enveloped viruses can be modeled as decorated spherical nanoparticles and characterized by their translational and rotational diffusivity. To simulate the transport of virions and spike proteins, we employ the Rigid Multi-Blob (RMB) methodology (1) and Smoothed Dissipative Particle Dynamics (SDPD) (2). We construct virion models using RMB by discretizing their structures into rigidly connected spherical beads. We then compute their mobility tensor to determine diffusion coefficients. Our results reveal the impact of spike arrangement, number, density, and morphology on virion transport
(3).
Furthermore, using RMB's blob discretization approach, we conduct SDPD simulations by treating the envelope and spikes as separate rigid bodies, allowing for spike flexibility. This method enables us to characterize the effects of flexible spikes and compare diffusivity coefficients in cases where spikes exhibit mobility. Our findings highlight the role of passive diffusion when flexibility is included and provide valuable insights into viral behavior.
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*Speaker

Evaluating technologies for suppressing airborne pathogen transmission

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Abstract

Researchers are continually generating more insights into the mechanisms of pathogen aerosolization, decay, and host entry, and these insights can be applied to help engineer systems that reduce indoor airborne transmission.
We first summarize historical attempts at developing technologies to decontaminate occupied indoor spaces, including early research done in the 1930s-50s by the U.S. Armed Forces Epidemiology Board and the U.K. National Institute for Medical Research on ultraviolet irradiation and air disinfection via germicidal vapors. We then offer a mechanism-of-action-based framework for both existing and nascent occupied-space air decontamination technologies (physical, electromagnetic, and chemical; recirculating vs. whole-room systems) and how they might layer together to achieve indoor air decontamination targets. We present known tradeoffs between these technologies for both a crisis and routine use case, including price, disruptiveness, robustness of efficacy to different environments, and energy requirements. We finally 1) offer a catechism of questions that must be answered in order to evaluate the potential risks, costs, and benefits of each technology, 2) track the scientific community's progress to date at answering these questions for each technology, and 3) share our plans for commissioning research on some of the remaining questions.
By presenting a brief history, framework, and status of technologies to decontaminate air in occupied spaces, we hope to help the bioaerosol research community identify important opportunities for applying basic research.

*Speaker

Chemical Inactivation of Airborne Pathogen Surrogates by Triethylene Glycol

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Abstract

Airborne transmission plays a critical role in the spread of many human infectious diseases. triethylene glycol (TEG) has emerged as a viable contender for mitigating this risk. When TEG is aerosolized, it exhibits strong antimicrobial effects against airborne microorganisms, especially as vapor molecules attach to microbe-bearing particles. Aerosolized TEG achieves significant reductions of 2 to 5 log in microbial counts, including bacteria, viruses, molds, and TB, at aerosol concentrations ranging from 0.04 to 0.5 mg/m3. This is achieved in a a matter of a few minutes as opposed to 1.5-3 hours using room ventilation. The US EPA has not identified toxicological endpoints of concern for the active and inert uses of triethylene glycol and has no risk concerns for TEG with respect to human exposure at these concentrations. The US EPA and other international standard-setting organizations have concluded that TEG is of very low toxicity by the oral, dermal, and inhalation routes of exposure. Grignard Pure™ Technology, a formulation with TEG as the active ingredient, was developed to safely aerosolize TEG for air decontamination. It is crucial to precisely evaluate the safety and effectiveness of products designed to deactivate or manage airborne pathogens that pose a public health risk. Development and implementation of testing protocols that match the product's intended use will ensure a more accurate measure of its ability to eradicate microbial pathogens such as bacteria, viruses, and fungi. Our study demonstrates that aerosolizing both the test organisms and the antimicrobial agent offers a more reliable measure of an antimicrobial product's efficacy compared to testing such a product in traditional surface-based assays, which involve exposing microbial samples on surfaces to the agent. Using these testing protocols. the TEG-based antimicrobial air treatment product Grignard Pure™ Technology shows high efficacy of viral inactivation and a favorable safety profile. As a result, it can be used to reduce exposure to a range of infectious microorganisms in indoor public spaces. This treatment can be an important weapon against future pandemics, especially in the face of vaccine hesitancy and public resistance to personal use of masks and other behavioral changes.

*Speaker

Turning up the heat; mechanistic insights from thermal inactivation of influenza A virus.

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Abstract

Thermal inactivation is an age-old method (1) of sterilisation, but the molecular mechanisms through which this occurs remain elusive. We experimentally studied the dynamics of influenza A virus (IAV) heat inactivation, finding a simple exponential decay of infectivity over all tested temperatures. The decay rate shows an Arrhenius-like temperature dependence indicating a transition between two distinct inactivation mechanisms at approximately 40℃. Within the 40-50℃ range, a measured activation enthalpy of 99 ± 3 kBT was similar to that found in simulations of conformational change of the IAV membrane protein haemagglutinin-2 (HA2) (2), and the activation entropy of 66 ± 3 kB, was consistent with such a protein unfolding process. Normally, this conformational change is triggered by progressive acidification inside a host cell's endosome. It exposes a hydrophobic peptide that fuses the viral and endosomal membranes, allowing viral entry once the genome is released by the acidic environment.
We confirmed the involvement of HA in viral failure by testing IAVs with mutant HA, and by lowering the pH. At low pH, virus inactivation exhibited a time-dependent (non-exponential) decay rate. We were able to reproduce both the neutral and low-pH data by using a 3-state model for HA conformation. A necessary condition of our model is that a single triggered HA can cause viral failure, perhaps by binding to the wrong cellular membrane, or interfering with genome release. This suggests a general principle; which is that the sensitive molecular triggers for viral genome release are by necessity likely points of viral failure.

Considering the ubiquity of fusion proteins such as HA across enveloped viral species (3), mechanistic insights in this area will have broader implications for understanding viral stability and disinfection.

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*Speaker

On the Influence of Haddrell et al.'s new Inactivation Data on airborne SARS-CoV-2 Infection Risk Prediction

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Abstract

Haddrell et al. (10.1038/s41467-024-47777-5) - co-authored by invited keynote speaker Jonathan P. Reid - recently used their controlled electrodynamic levitation and extraction of bioaerosol onto a substrate (CELEBS) method to observe the rapid inactivation of SARS-CoV-2 in aerosol with high temporal resolution. They recommend using computational fluid dynamics (CFD) to predict the transport of virus-laden particles and the risk of infection taking into account their new findings.
Following their suggestion, we plan to present published results (https://doi.org/10.1007/s13272-025-00822-5) of our CFD-based infection risk model (https://doi.org/10.1155/2024/9927275) with SARS-CoV-2 inactivation rates from Haddrell et al. We estimate the fraction of particles that reach other passengers and their age using CFD simulations. Particle age and inactivation rates, are used to estimate airborne inactivation and the remaining infectious dose. The dose-response is modeled by the Wells-Riley exponential approach fitted to SARS-CoV-2 human challenge data.

We simulate an aircraft cabin with 70 passengers, where the infectious person (IP) is the particle source and iterates through all 70 seats running 70 CFD simulations. This results in 4831 (70×69) seat combinations between the IP and the susceptible person, and predicts the average risk of infection for each seat when the position of the IP is unknown. We repeat this for different SARS-CoV-2 inactivation rates measured by Haddrell et al. under different conditions: 40% and 90% RH, 500 ppm and 3000 ppm CO.
Our results show that in the considered aircraft cabin, high RH increases the risk of infection mainly for non-window seats. Large-scale circulations transport air and particles from the windows to the aisle at face level and back to the sidewalls near the floor. Passengers in window seats inhale less of the recently exhaled air, so they are less affected by the brief inactivation caused by high RH. In addition, high CO (3000 ppm) increases the risk of infection by _˜50% in a typical event or adds three expected infections in a superspreader event.

*Speaker

From saliva aerosolization to spit production during speech

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Abstract

Phonation produces aerosols, and speech has proven to be a pernicious, invisible, yet potent viral transmission route among asymptomatic individuals in the COVID-19 pandemic. To develop comprehensive mitigation strategies and mechanisms to control transmission, it is crucial to understand the atomization processes during speech.
Here we present a preliminary study on the destabilization of saliva filaments produced artificially by the fast and controlled displacement of two surfaces in a few milliseconds mimicking the opening of the lips observed during bilabial stop consonant phonation.

We describe the process by which these filaments are deformed and destabilize under rapid air flow conditions of tens of meters per seconds analogous to the conditions representative of consonant plosion.
We finally propose a model to describe the shape of the filaments and discuss their destabilization into droplets in relationship to the rheology of the solution.

*Speaker

Posters

The Role of Evaporation History in Bacterial Pathogenesis: Insights from Levitated Respiratory Droplets

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Abstract

Aerosols are the principal cause of airborne infections and respiratory diseases. A droplet is an integral part of aerosol spray and exhalations from the host. Droplets ejected from the host can evaporate and form a precipitate in the air (aerosol mode), evaporate for some time, and fall on the ground (mixed mode), or directly fall on the ground and evaporate as sessile mode. Therefore, it is a holistic study to understand the desiccation dynamics of infected droplets coupled with the infection study of the crystal/settled droplet. Given the complexity of the experiment with actual bacteria/viruses in respiratory fluid, such studies have been rarely attempted. Different evaporation modes, stages of evaporation, and relative humidity (RH) conditions affect the survival and infectivity of the bacteria in the precipitate. With this pretext, we have investigated three droplet diameter reduction ratio-based stages of evaporation of a bacteria-laden levitated droplet at two RH settings and evaporation modes (aerosol and mixed), mimicking real-life scenarios. The low RH condition mimics evaporation in arid regions. e.g., Delhi and the high RH conditions imitate cold areas like London. The study analyses the mass transport, micro-characterizes the samples, and investigates the survival and infectivity of bacteria in the sample. The bacteria survive more in the high RH condition than in the low RH condition for all diameter reduction ratio-based stages and modes of evaporation. For the aerosol mode, at a fixed RH condition, the evaporation time plays a vital role as the bacteria in early-stage partially dried samples are more viable than the full precipitate. The evaporation rate and the generation of reactive oxygen species (ROS) cause a remarkable difference in the viability and infectivity of the bacterial samples. Therefore, our findings report that the evaporation history of an infected droplet is an indispensable factor in determining bacterial viability and subsequent infectivity.

*Speaker

Efflorescence of Sodium Chloride with organic impurities: A step towards understanding crystallization in respiratory aerosols

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Abstract

Airborne transmission is one of the major routes of spread of respiratory diseases. Exhaled droplets and aerosols are emitted in wide size range and with variable composition, which is thought to be dependent on respiratory activity and site of origin in the respiratory tract. These aerosols can suspend in the ambient environment from hours to days. Despite the prevalence and importance of these sub-100 micron particles of exhaled saliva and lung fluid, detailed understanding of their structure and composition is lacking and characterization is limited.
The drying dynamics of exhaled aerosols and consequent phase changes from multi-component solution/suspension to solid particles can lead to particles with internally heterogenous structures. This may affect the viability of the pathogens (virus and bacteria) present inside them and thus may affect the efficiency of transmission of infections by droplets and aerosols.

Among the major components of exhaled aerosols are sodium chloride and mucin (protein). Here we studied the influence of composition on the efflorescence (precipitation of crystalline phase) behaviour of exhaled aerosols in simplified synthetic system containing mucin and NaCl. Droplets dispersed on glass slides were placed in a relative humidity (RH) and temperature-controlled chamber under a light microscope and were subject to gradually decreasing RH. Videos were recorded from experiments and were used to quantify the crystallization and nucleation rates of droplets.

It was observed that the addition of mucin impedes the crystallization of NaCl, reducing the range of RH at which efflorescence occurs by a few percent, from 52-47% to 49-44%. The effect was of a similar magnitude across the range for mass ratios of mucin:NaCL tested, from 1:10 to 1:2. However, changes in the crystal morphology were noted where thin dendritic structures with fine branches were observed for higher ratios of mucin to NaCl while relatively thicker dendritic structures with indefinite branches for lower concentration of mucin were reported in SEM images. The delay in the efflorescence may provide better survival conditions for the pathogens, as crystallization of the droplet components may eliminate the harmful impacts of the viruses.
Next step to the project is to collect exhaled aerosols from human subjects, so structure and composition of the formed particles can be investigated and compared within people and with synthetic lung fluids.

*Speaker

How does mucus rheology affect mucociliary clearance?

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Abstract

The airways are protected by mucus, a complex fluid transported along the epithelial surface, from the lungs to the throat, by the coordinated beating of millions of microscopic cilia. This process is known as mucociliary clearance. Efficient elimination of inhaled particles, including infectious agents, relies on effective mucus transport-a process that may be influenced by ciliary activity and the rheological properties of the mucus itself. In this study, we investigate how mucus rheology affects its transport efficiency.
In vitro experiments are carried out on air-liquid interface (ALI) cultures of bronchial epithelium. While mucus swirls are observed, transport efficiency and microrheology measurements are performed using traceable fluorescent beads. The transport properties of healthy native mucus are compared to those of an artificial mucus of controlled rheology.
We show that native mucus displays elastic behaviour up to a critical flow rate, which is reached through hydration. At this point, viscoelastic behaviour emerges. The comparison between native and artificial mucus shows that native mucus stops flowing for lower elastic modulus than the artificial one. We conclude that rheology alone cannot account for transport efficiency and discuss other parameters that should be considered. Our findings provide new insights into the biophysical parameters that govern mucociliary clearance, an essential mechanism in the defense against pathogens in the ariway.

*Speaker

Investigating how saliva composition affects respiratory virus infectivity

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Abstract

Respiratory viruses, including SARS-CoV-2, are primarily transmitted through microdroplets of saliva released during sneezing, coughing, and speech. Saliva is a complex fluid containing mucins, immunoglobulins, lactoferrin, peptides, and cellular debris, all of which influence the viral microenvironment within droplets. As such, saliva composition is an essential factor for understanding viral transmission. During the COVID-19 pandemic, certain individuals, termed superspreaders, transmitted the virus to numerous hosts, while others exhibited no transmission. This variability cannot be fully explained by behavioral or environmental factors, nor by the viral load contained in the saliva. Here, we aimed to explore the relationship between saliva composition, viral load, and infectivity. To this end, we developed and optimized a cell-based assay to measure SARS-CoV-2 infectivity upon incubation with salivas from healthy donors. In parallel, the composition of these same salivas was evaluated by liquid chromatography tandem mass spectrometry (LC-MS/MS). Our preliminary data revealed that saliva from various donors significantly modulated SARS-CoV-2 infection, suggesting that indeed, the composition of saliva governs the infectiveness of the virus. Mass spectrometry analysis of the 10 first donors highlighted the wide intra-donor divergence of saliva composition. Correlative analyses between infectiveness and saliva composition are ongoing to identify the main determinants driving efficient virus infection. Identifying key components of saliva that influence infectivity could guide the development of targeted interventions to reduce viral transmission.

*Speaker

Exploring the Impact of Environmental Conditions on Aerosolised Streptococcus pyogenes Viability Using CELEBS

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Abstract

Over the past decade, there has been a significant increase in both superficial and invasive infections of *Streptococcus pyogenes* within the UK. Scarlet fever is a superficial infection caused by *S. pyogenes* that predominantly affects young children and, at the end of February 2014, the number of reported cases of significantly increased in the UK. Incidence rates of scarlet fever have been elevated since then, with regular peaks in springtime. Many UK cases are currently caused by an emergent strain of *S. pyogenes*, designated M1UK. This strain is a concern as not only is it resulting in an increased incidence rate of scarlet fever, but also invasive infections. This was illustrated during the 2022/2023 season, where increased incidence rates of both scarlet fever and invasive streptococcal infections were seen. While many may consider direct contact a primary mode of scarlet fever transmission, growing evidence highlights the aerosol route as a significant pathway for *S. pyogenes* dispersal. However, the airborne behaviour of *S. pyogenes* remains poorly understood. This research aims to gain an understanding of how environmental conditions affect the viability of aerosolised *S. pyogenes* via the use of a custom-built Controlled Electrodynamic Levitation and Extraction of Bioaerosols (CELEBS) instrument. CELEBS is a relatively new approach to studying bioaerosols and allows for the study of monodisperse droplet populations within a controlled environment while maintaining a high sampling efficiency. The use of this instrument will allow us to further explore the impact of relative humidity, ranging from 95% to 7%, has on the viability of aerosolised *S. pyogenes*, beginning with M1UK. Additionally, this CELEBS instrument can regulate temperature between 10°C and 35°C, which will give us a new insight how temperature impacts *S. pyogenes* survival. Future research aims to investigate how pH and ambient concentrations of gaseous pollutants influence airborne *S. pyogenes* viability, as pH has been increasingly recognised as a key factor in bioaerosol survival.

*Speaker

Diffusivity analysis of E. coli biofilm formation using Differential Dynamic Microscopy

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Bacterial biofilms, structured communities of cells embedded in self-produced extracellular matrix, are ubiquitous in natural and clinical environments1, yet the collective dynamics governing the transition from swimming to surface-attached communities remain poorly understood. We employ Differential Dynamic Microscopy (DDM)2 to characterize Escherichia coli population dynamics during biofilm formation in 96-well plates, at room temperature. DDM provides ensemble-averaged transport measurements without single-cell resolution, proving advantageous in dense suspensions where optical crowding limits conventional tracking. Our analysis extracts intermediate scattering functions (ISF) across multiple scales, revealing distinct phases as bacteria transition from free swimming to crowded and surface-attached states. These morphological changes in the ISF reveal fundamental shifts in the underlying transport mechanisms as bacterial communities reorganize.

Understanding the relationship between SARS-CoV-2 and climate

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Abstract

SARS-CoV-2 appeared in China in 2019 and has produced a global pandemic-the COVID-19 pandemics-as of
March 2020. To cope with the disease, unprecedented mobility reduction measures such as lockdowns or curfews
were implemented in many countries around the world, causing a major financial impact. These measures were
justified by the fact that population mobility is a key factor for the virus circulation, together with population
density, associated with a higher likelihood of infectious contacts between people. Among other causes, we studied the link between the spread of respiratory viruses and climatic conditions. This research led to the creation of an index, IPTCC, characterizing the impact of temperature and humidity on aerosol disease spread. COVID-19 is transmitted through three modes: by hand contact, by close-range droplets, and through aerosols. The latter are weather-dependent.
IPTCC is an index characterizing the potential transmission of COVID-19 through aerosols based on
three meteorological parameters: temperature, relative humidity and absolute humidity.

Climate data from 63 weather stations of the Météo-France network, spread across the entire metropolitan territory, allowed for the calculation of IPTCC during spring 2020. The number of deaths per million inhabitants and per region
was also highlighted. A correlation was observed between the average IPTCC in France in March 2020 and the number of COVID-19 deaths by April 10, 2020. The regions with the highest mortality are those where IPTCC is the highest (Grand Est, Île-de-France). Conversely, the Atlantic coast, which was less affected during this period, presents a lower index.

The epidemic follow-up curve allows to highlight successive waves which affected France as well as the average IPTCC calculated on stations representative of territory. The periods of IPTCC rise, corresponding to climatic conditions conducive to
spread of the virus, are associated with increases in cases. Conversely, summer represented by a low IPTCC are associated with a slowdown in epidemic activity. The correlation between IPTCC and epidemic indicators is clear. The weather is one factor among others: government measures (curfew, containment, wearing a mask), the contagiousness of the circulating variant and vaccination have a strong impact on the evolution of the pandemic.

*Speaker

During the pandemic, Predict exchanged with numerous scientic and institutional actors to better understand and leverage the weight of the meteorological factor on COVID-19: Météo-France, Institut Pasteur, Santé Publique France, the Scientic Council, the Directorate General for Health, and the Articial Intelligence in Health department of Université de Paris.
Finally, during the pandemic, we mapped to highligh risk areas, as well as a visual and immediate follow-up of the situation and we communicated information to citizens.

Extension and Retraction of impulsively induced viscoelastic jets

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Abstract

The extensional behavior of saliva plays a key role in aerosol formation during speech, influencing the airborne transmission of viruses like SARS-CoV-2 (1). To understand these dynamics, we investigate the extension and retraction dynamics of impulsively generated jets with a Dropon-Demand system, as seen in figure 1a), using the viscoelastic model fluid of bridged microemulsions. While the retraction dynamics of Newtonian fluids are primarily driven by capillary effects, the retraction of viscoelastic filaments is accompanied by additional polymeric stresses that arise due to the flow deformation prior to the pinch-off (2). This can be seen in figure 1b) as the terminal slope of the jet length. By quantifying these stresses one can extract the relaxation time of the model fluid, to establish a framework which allows to characterize the extensional properties of saliva and other viscoelastic fluids. This approach provides new insight into the mechanical response of viscoelastic fluids at high strain rates, with possible implications for disease transmission.
(1) M. Abkarian, and H. A. Stone Physical Review Fluids 2020, 5, 102301. DOI:10.1103/PhysRevFluids.5.102301
(2) Uddalok Sen, Charu Datt, Tim Segers, Herman Wijshoff, Jacco H. Snoeijer, Michel Versluis and Detlef Lohse J. Fluid Mech. 2021, 929, A25. DOI:10.1017/jfm.2021.855

*Speaker

The Twente Cough Machine

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Abstract

The generation of respiratory aerosols in human beings involves the atomisation of films of respiratory fluid in different parts of the respiratory tract. Most of the expelled volume of fluid originates in the upper part, primarily through violent events like sneezing or coughing. Understanding the atomisation process and factors influencing the droplet size distribution is of prime interest for predicting e.g. safety distances, prevention measures, and viral load in bioaerosols.
Nevertheless, little is known about this common process that we all experience yearly. This lack of understanding is partly due to the difficulty of observing the process *in vivo*, as we typically only see the droplets once they have been expelled into the air.

On this poster, we present an *in vitro* approach to study the formation of droplets in upper airways: a so-called "cough machine", i.e. a device that mimics a human cough. This approach was popularised by, among others, King et al. (Clearance of mucus by simulated cough, J. Appl. Physiol. 58, 1776 (1985)), and has mostly been employed to study film stability in the human trachea. However, our system is designed to allow for high-speed imaging of the film atomisation process, as well as to assess the droplet size distribution of the expelled spray using laser diffraction.

The experimental configuration of the Twente Cough Machine consists of a 30 cm long, horizontal transparent channel made of polymethyl methacrylate (Plexiglas), with a 2×1 cm^2 (w×h) cross-section. The fluid is deposited at the bottom of this rectangular channel, mimicking the film of mucosalivary fluid in the trachea, away from the oral cavity. The channel is then connected to a pressurised tank via a fast valve which operates on the millisecond time scale characteristic of a cough. To match the physical properties of the mucosalivary fluid, we use polyethylene-oxide solutions (in water) with varying molecular weights and concentrations.
In a typical experiment, the valve opens for 50 ms and the flow rate quickly reaches a maximum of about 10 L/s, matching the cough model described by Gupta et al. (Flow dynamics and characterization of a cough, Indoor Air 19, 6 (2009)). This results in maximum velocities greater than 50 m/s and Reynolds numbers on the order of 10,000. This poster will discuss the fluid-mechanical aspects of the cough machine and their connection to the atomisation process.

*Speaker

AIRMAP: A Longitudinal Respiratory Aerosol Monitoring Study

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Abstract

Summary
We developed a method that enables reliable measurement of respiratory aerosol emissions outside ultra-clean environments, through effective background particle filtration. Measurements of different respiratory activities were reproducible between participants across multiple recording days. Individuals identified as high emitters consistently remain high emitters over a 28-day period.

Background
Respiratory aerosols, including mucosalivary droplets and particles from small airways, are expelled during breathing, coughing, and vocalisation, and can carry airborne pathogens. Some individuals act as *super-emitters*, generating unusually high concentrations of aerosols and potentially contributing to *super-spreading* events. However, it remains unclear why certain individuals emit more aerosols than others, and whether this is a stable trait or a transient state.

Challenges

Most environments contain high concentrations of background particles (e.g., pollen, skin squames, dust) that vary over time and obscure respiratory aerosol signals. Excluding these background particles is essential for accurate measurement. Also, there is substantial inter-individual variation in aerosol generation, spanning up to three orders of magnitude.

Aims

Monitor intra-individual trends in respiratory aerosol emissions over time

Identify factors affecting particle number concentration and size distribution

*Speaker

Determine whether high emitters remain high emitters over a prolonged period or is it a transient phenomenon

Methods
Participants wore a tightly sealed facemask through which inhaled air passed via five low-resistance filters to eliminate background aerosol contamination. A 30-second breath hold ensured the integrity of the mask seal.

Respiratory particles were measured using an Aerodynamic Particle Sizer (APS; model 3321, TSI), which detects particles 0.5–20 μm in diameter at a sampling frequency of 1 Hz.

Each participant completed a standardized sequence of activities: tidal breathing, deep breathing, conversational vocalisation, and loud vocalisation-with three repetitions per activity.

Recruits

Pilot cohort: 5 healthy, non-smoking males (ages 21–51; BMI 22–24) with normal lung function (FVC, FEV1, FEV1/FVC)

Planned full cohort: 50 participants (balanced by sex), followed over 6 or 12 months (optional)

Results
Respiratory aerosol emissions can be reliably and reproducibly measured in standard laboratory environments when appropriate controls are in place. Loud vocalisation produced a **136-fold** increase in aerosol concentration compared to tidal breathing (median (IQR): 1.26 (0.83–1.54) vs. 0.0092 (0.006–0.0272) particles/cm^3; $p <$ 0.00001, Wilcoxon). Inter-individual variation in aerosol output exceeded intra-individual variation. High emitters maintained elevated emission levels throughout the 28-day observation period