Bioaerosol Sampling

High efficiency detection of airborne virus using a condensation growth sampling method

Evidence for airborne transmission of SARS-CoV-2

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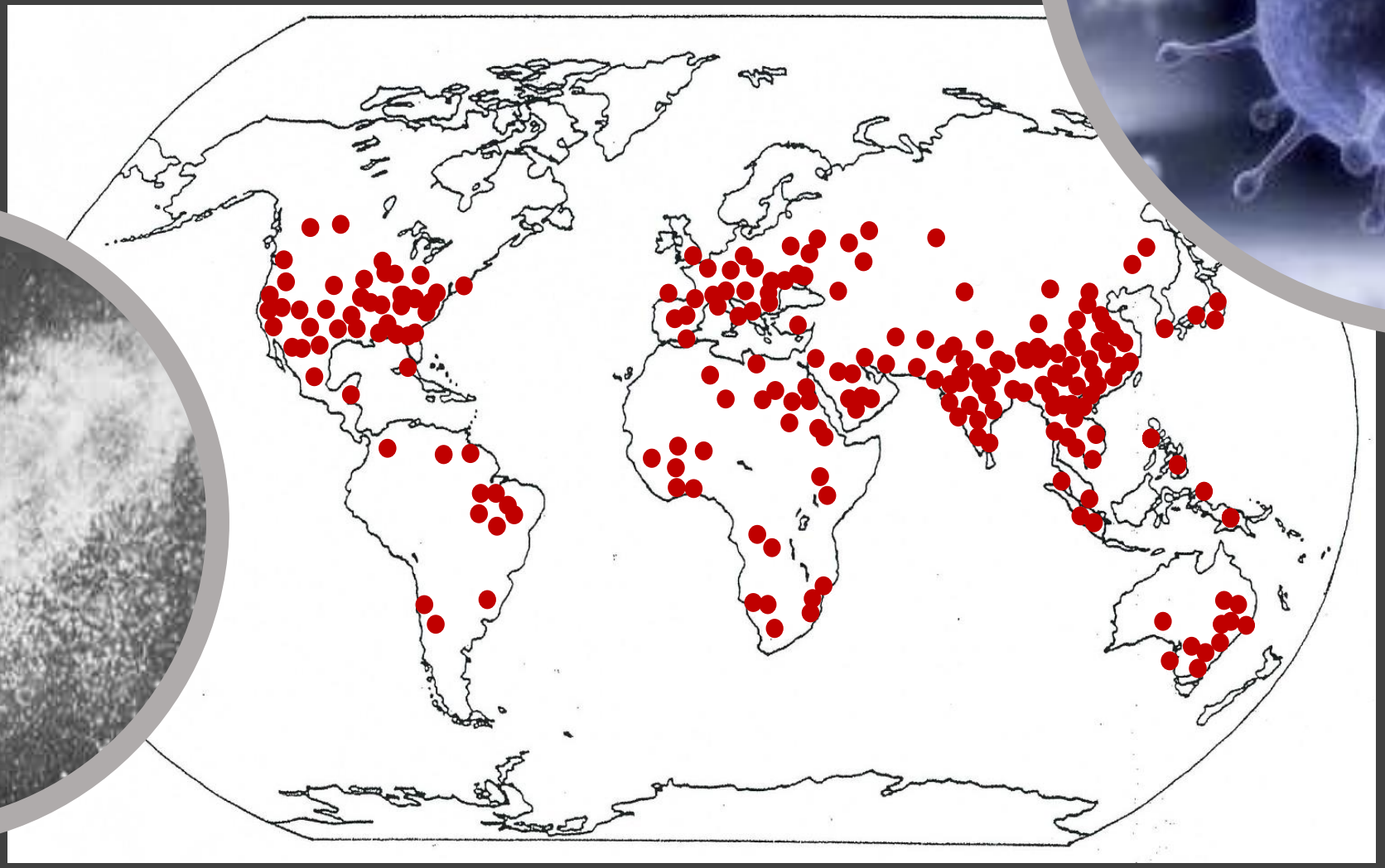
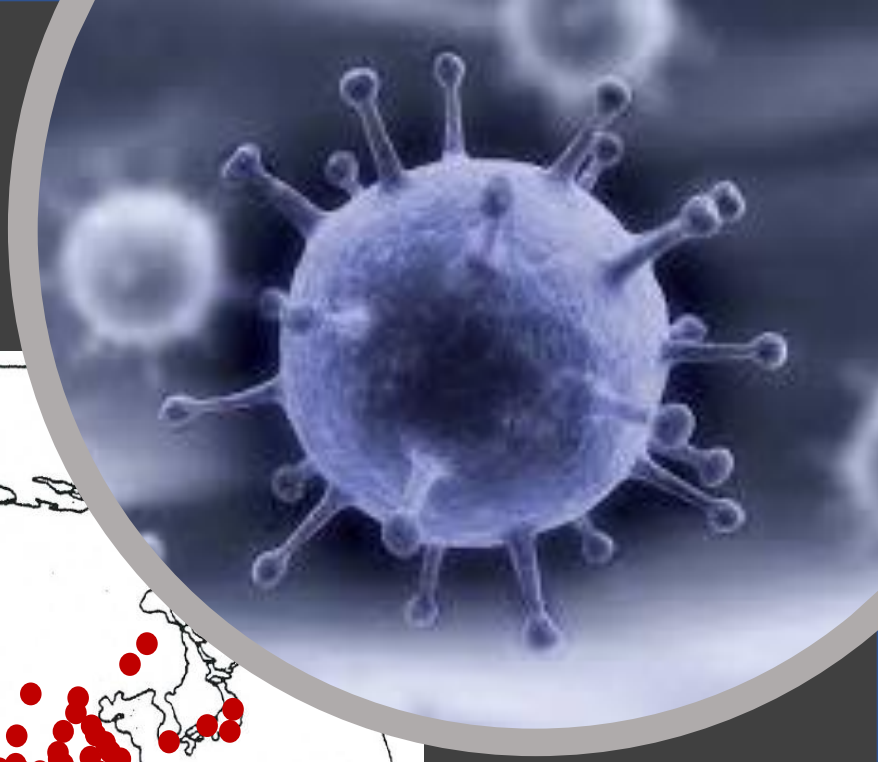
The Problem





Highly Mobile Society

“There is no evidence of aerosol transmission”

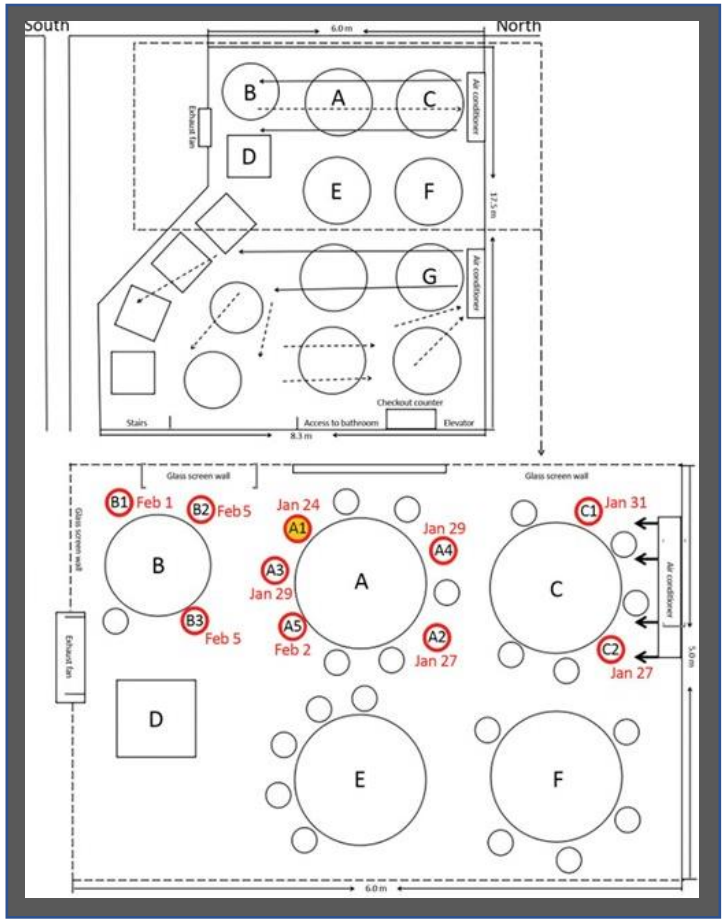
WHO still will not recognize aerosols as a significant route of the SARS-CoV-2 virus transmission

When scientists say “there is no evidence”, sometimes it’s because that evidence is genuinely hard to collect.

Anecdotal evidence: rapid disease spread

Diamond-Princess cruise ship

Church choir practice



Guangzhou China restaurant

San Quentin Prison

Minnesota bars

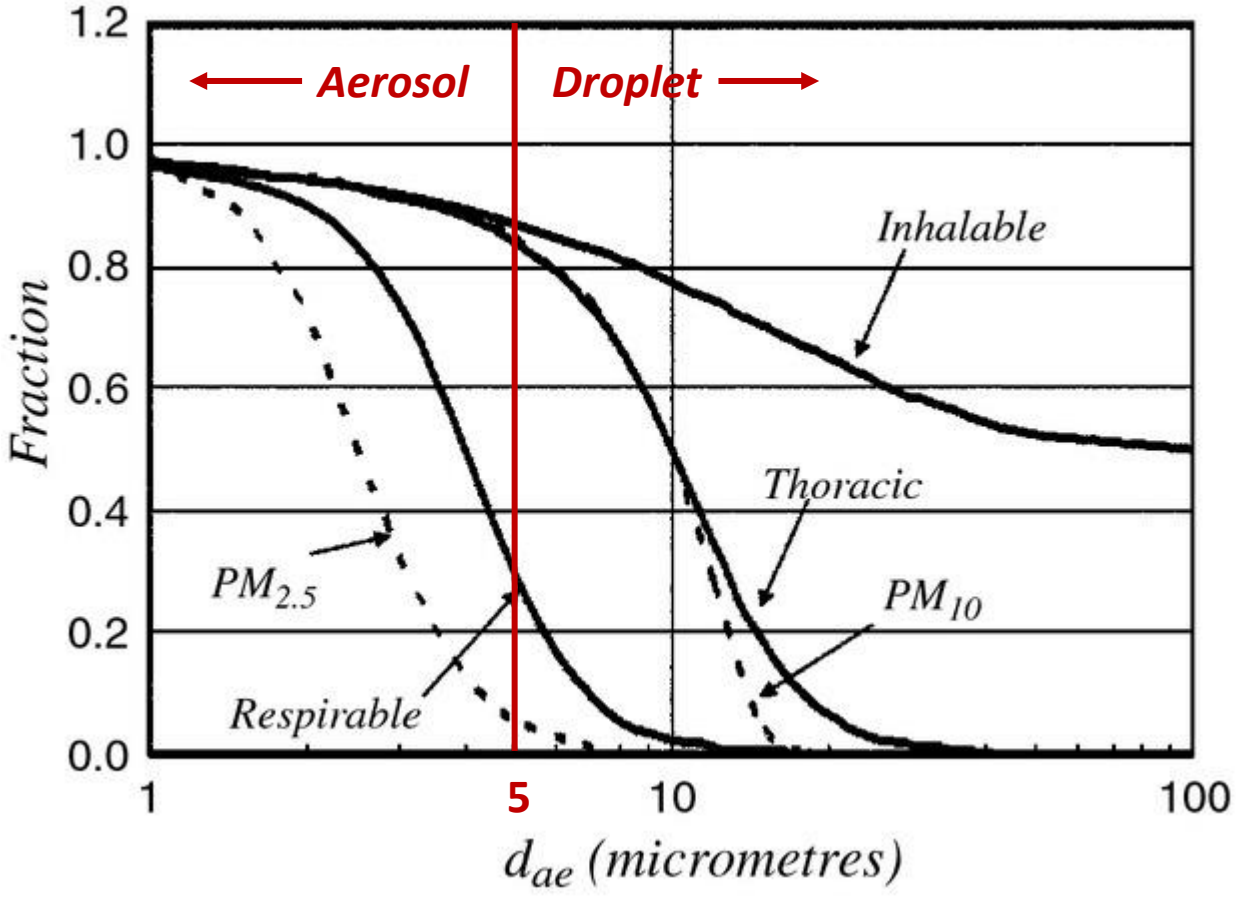
Anecdotal evidence: virus found on air vents, in nurse changing rooms, and in hallways outside of infected patient rooms.

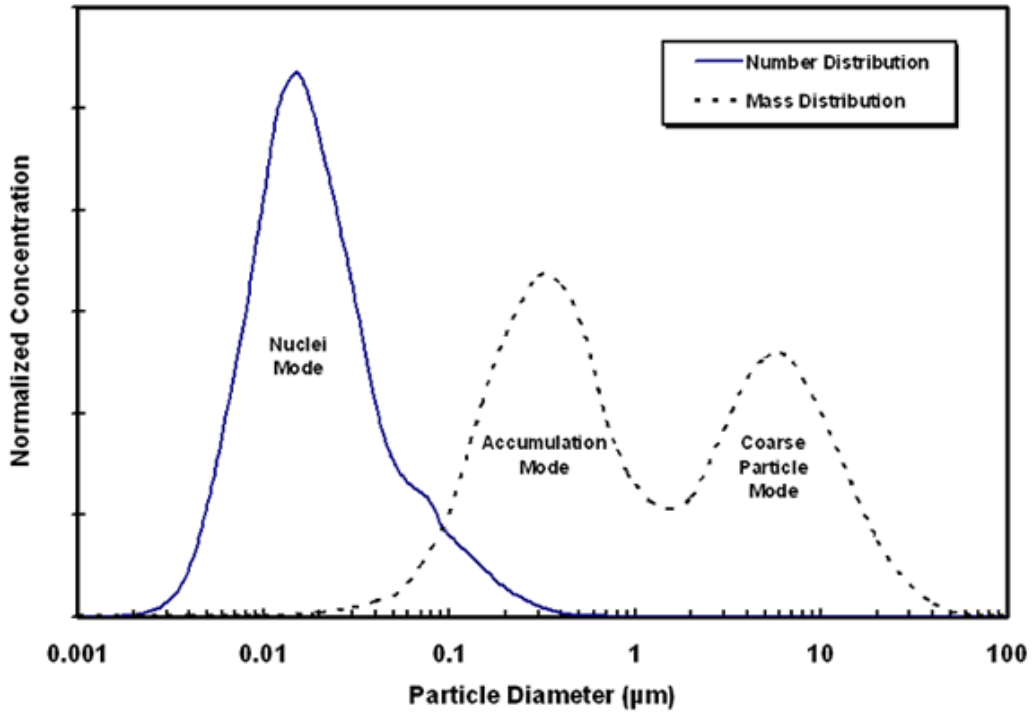
Added to the WHO website just yesterday, July 9th !

There have been reported outbreaks of COVID-19 reported in some closed settings, such as restaurants, nightclubs, places of worship or places of work where people may be shouting, talking, or singing. In these outbreaks, **aerosol transmission**, particularly in these indoor locations where there are crowded and inadequately ventilated spaces where infected persons spend long periods of time with others, **cannot be ruled out.** ***More studies are urgently needed*** to investigate such instances and assess their significance for transmission of COVID-19.

https://www.who.int/news-room/q-a-detail/q-a-how-is-covid-19-transmitted

What is an aerosol?





Vincent, J.H. J Env Monitoring, https://doi.org/10.1039/B509617K

Do we have a common language?

Seeing a bright side to the COVID-19 pandemic, one aerosol scientist said to another:

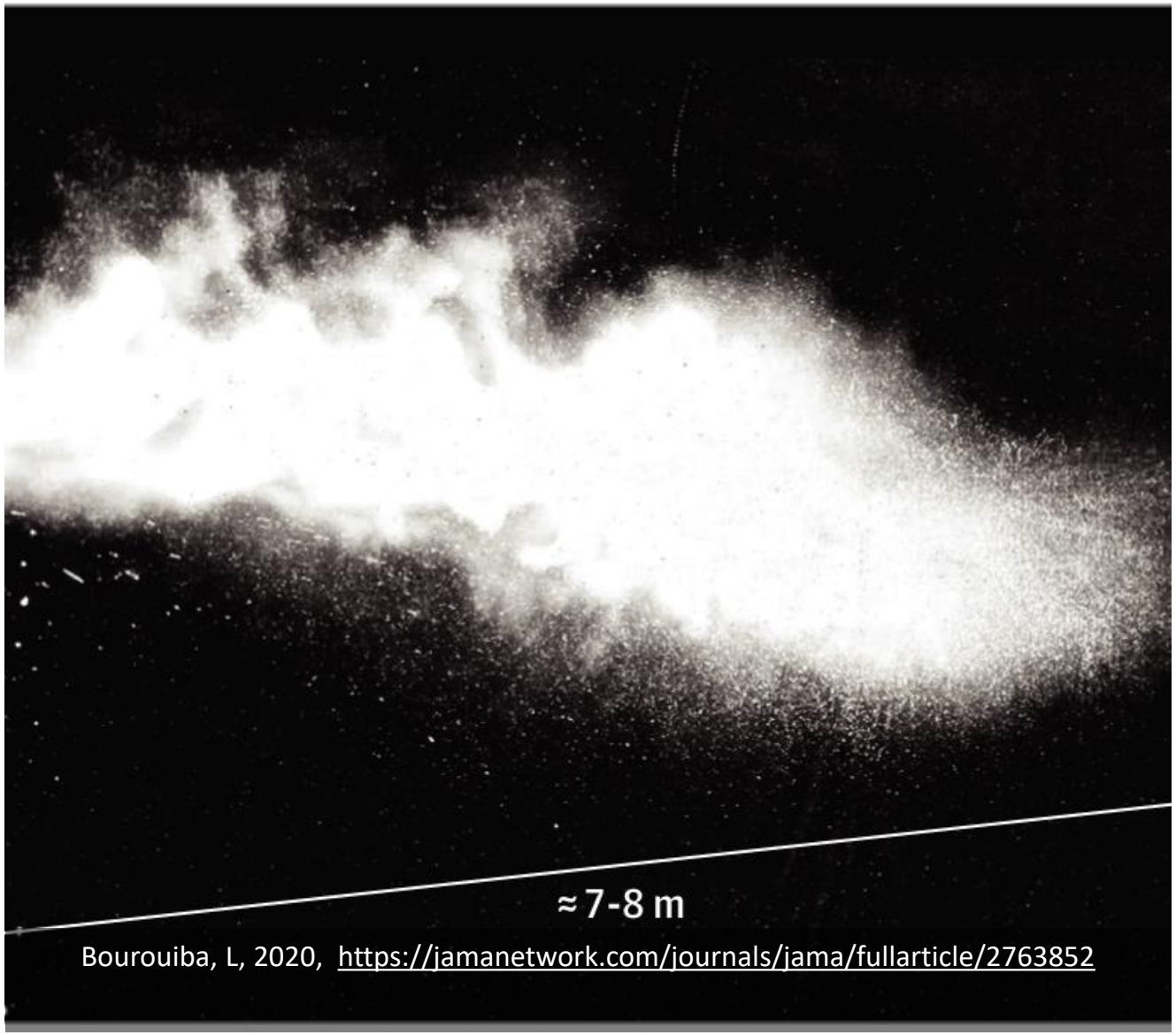
“At least now people won’t think ***aerosols*** are just spray cans and graffiti.”

“Yeah, now they think aerosols are ***viruses***!”

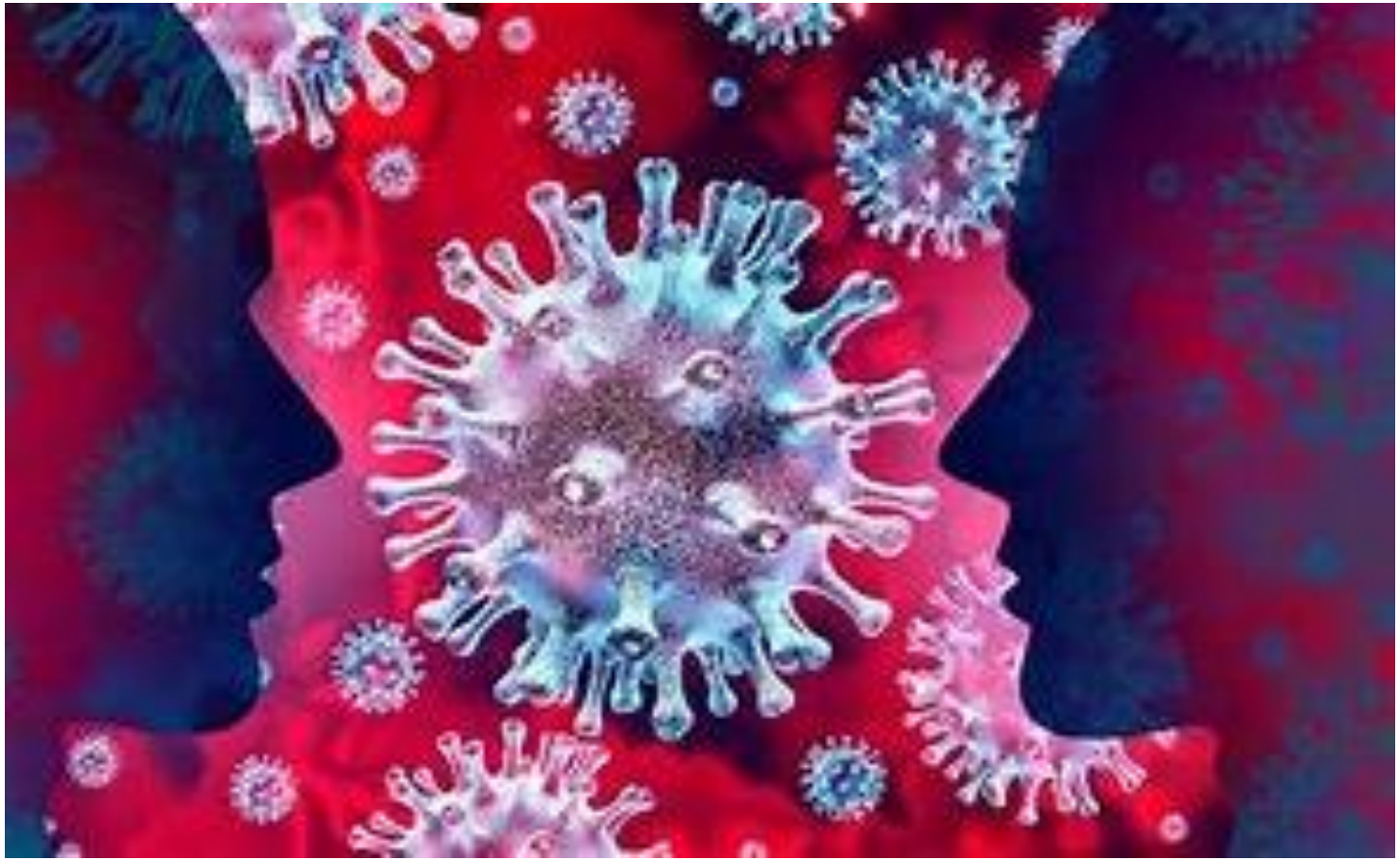
Pathogen emissions expelled from human respiratory tract

- Coughing and Sneezing
- Singing
- Loud talking
- Laughing
- Just breathing

- Particles expelled are a continuum of sizes



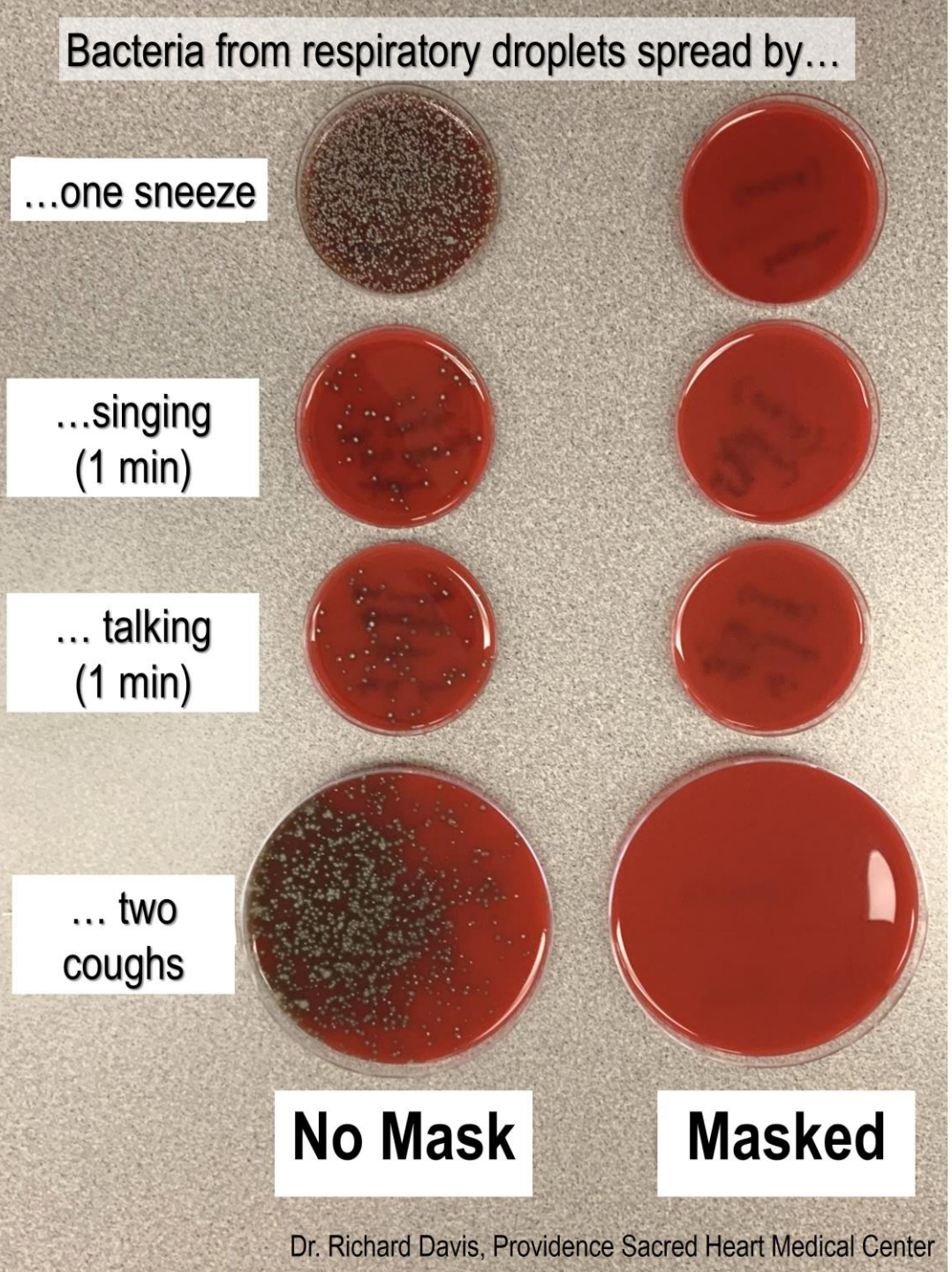
Bourouiba, L, 2020, https://jamanetwork.com/journals/jama/fullarticle/2763852



Super spreaders

Some people, known as “super spreaders”, happen to be especially good at exhaling fine material, producing 1,000 times more than others.

Pre-symptomatic and asymptomatic cases can be considered “stealth” spreaders.



Note: In this demonstration presence of bacteria (not viruses) on plates is only meant to be a proxy for microbes present in respiratory droplets.

Likely, smaller aerosolized droplets (that could carry viruses like SARS-CoV-2) are also produced by coughing, sneezing etc. and that these would travel further and stay in the air longer than larger respiratory droplets.

Masks Work

Which masks work best?

- **Best:** Powered air purifying respirator (PAPR) - what fire fighters use
- **Better:** Elastomeric face masks with cartridge filters – high efficiency and great face seal, fit tested - for dangerous occupational exposures
- **Good:** N95 (FFP2) Filtering face pieces, fit tested – what medical doctors/nurses use
- **Fair:** Surgical masks and home-made cloth masks – remove large expelled droplets and are most protective of others, but can still offer some protection to the wearer if worn correctly
- **Poor**: NO MASK

Arguably the best description for how a N95 (or FFP2) mask works – accurate AND understandable: https://youtu.be/eAdanPfQdCA

COVID-19 Airborne Transmission Tool Available
New model estimates COVID-19 transmission in classrooms, buses, protests, more

Developed by J Jimenez, Univ Colorado Boulder, with input from many aerosol scientists

https://cires.colorado.edu/news/covid-19-airborne-transmission-tool-available

https://docs.google.com/spreadsheets/d/16K1OQkLD4BjgBdO8ePj6ytf-RpPMlJ6aXFg3PrIQBbQ/edit#gid=519189277

Missing evidence: what we still don't know about airborne SARS-CoV-2

- Particle size distribution and viral content from exhaled breath
- Viability of airborne viruses
- Airborne transportation and exposure
- Dose response – how many viable virions cause infection?
- Viral shedding load at various stages of infection

Knowledge will lead to more effective non-pharmaceutical interventions

Engineering Controls

- Ventilation
- Physical barriers
- Filtration
- UV light
- Germicidal sprays

Social distancing

- Is 2m distance far enough? Is 1m sufficient?

Face Masks

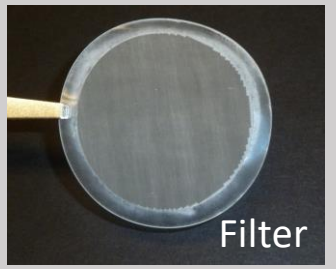
- N95 vs surgical masks
- Homemade cloth coverings
- Fit Testing

We are blind to the biohazards
in the air we breathe

Bioaerosols are Difficult to Sample

- Size-dependent collection efficiency
- Reduced collection into liquids for hydrophobic organisms
- Dilute liquid samples
- Prone to contamination
- No regulatory standard method

Common Sampling Methods

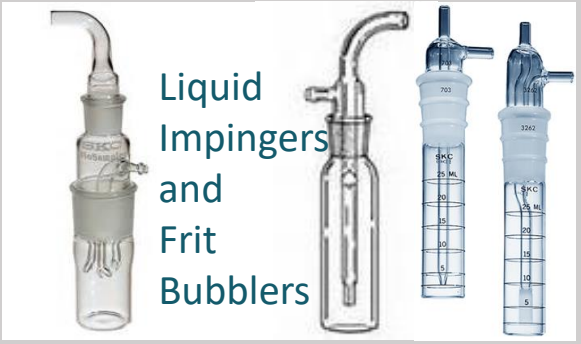

Filter


Slit Impactor with culture plate


Wet-walled cyclone


Filter Sampling System


Impactor


Liquid Impingers and Frit Bubblers

Sampling Viable Bioaerosols

Viable organisms inactivated by the sampling method

- Dessication
- Mechanical stress
- Thermal shock

A New Approach for Sampling Aerosols for Biological Analysis

SPOT SAMPLER™
Aerosol Particle Collector

- ✓ High collection efficiency
- ✓ Concentrated sample
- ✓ Time-resolved sampling
- ✓ Maintains viability
- ✓ Instant genomic-DNA/RNA preservation

BioSpot-VIVAS™
Bioaerosol Sampler

Patented technology with exclusive license from Aerosol Dynamics Inc.

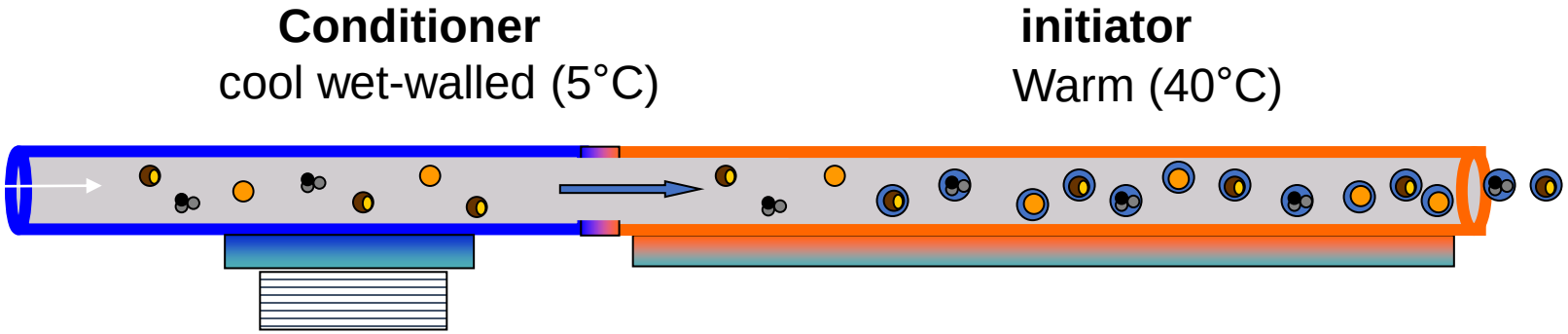
Brief History of Water-based Condensation Particle Growth

First systems: mix steam into airstream, then cool

Maze Collector (Simon and Dasgupta, 1995)
Steam-jet Collector (Khlystov et al, 1995)
Particle-in-Liquid Sampler (Weber et al, 2001)

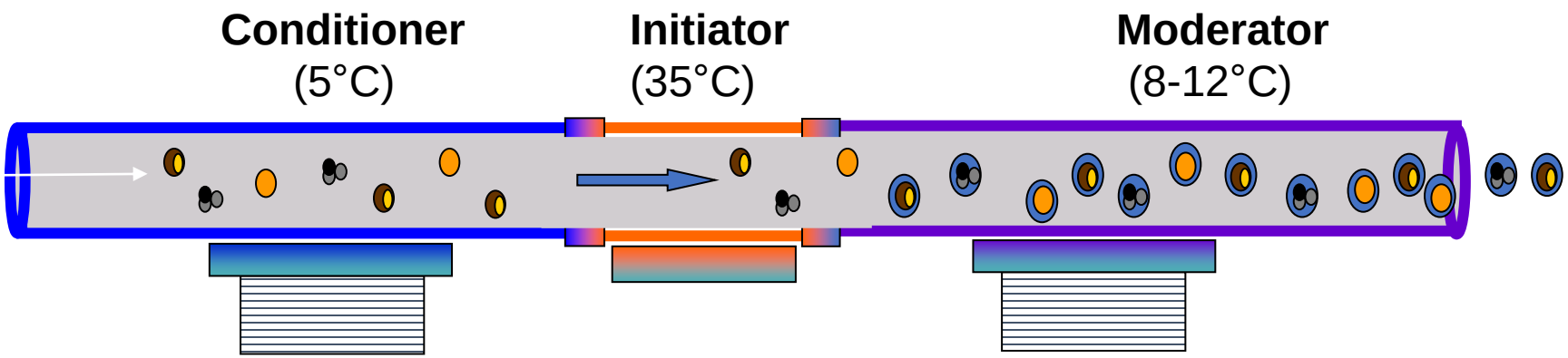
These methods subject the sample to high temperatures

2003, S. Hering (Aerosol Dynamics Inc.) introduced technology that allows particle growth through laminar flow water condensation



Eiguren-Fernandez et al., presented at RICTA 2015, the 3rd Iberian Meeting on Aerosol Science and Technology in Elche, Spain, June 29-July 1, 2015.

New Design

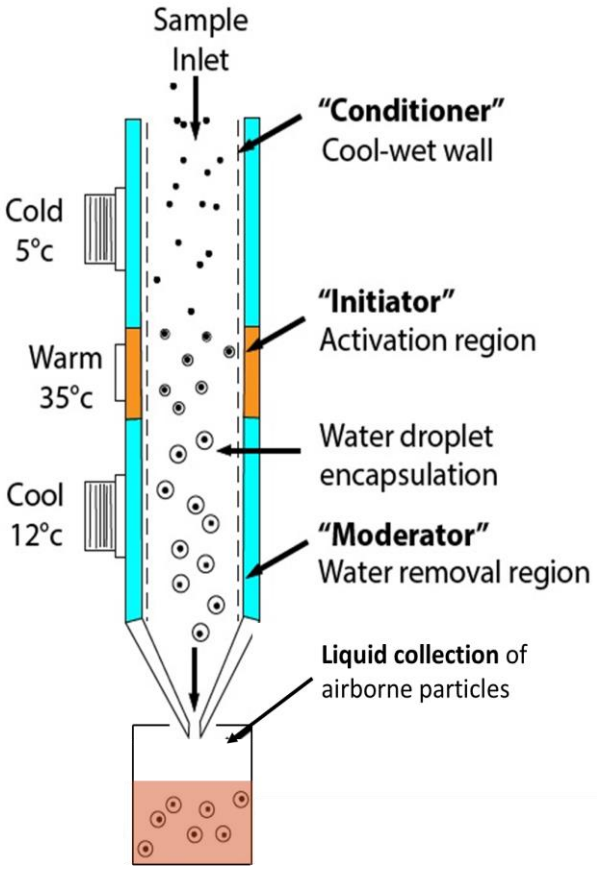


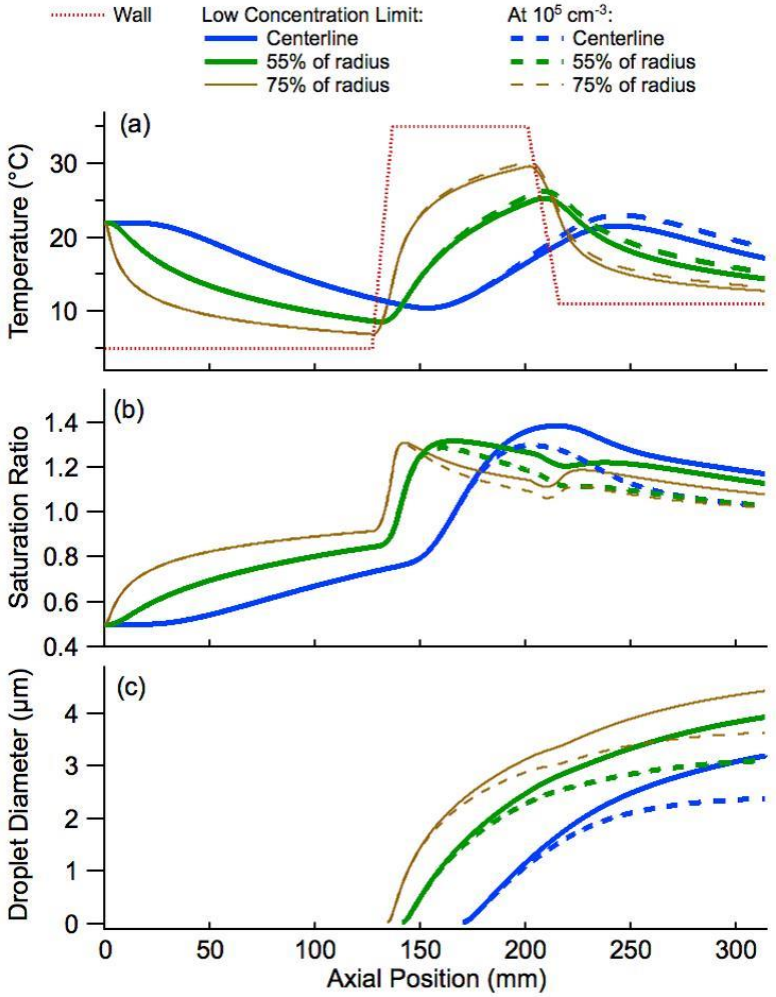
Condensation Growth Tube = CGT

A. Eiguren-Fernandez et al., presented at RICTA 2015, the 3rd Iberian Meeting on Aerosol Science and Technology in Elche, Spain, June 29-July 1, 2015.

Susanne V. Hering , Steven R. Spielman & Gregory S. Lewis, Aerosol Science and Technology, 48:4, 401-408: 2014.

Condensation Growth Tube (CGT) Capture





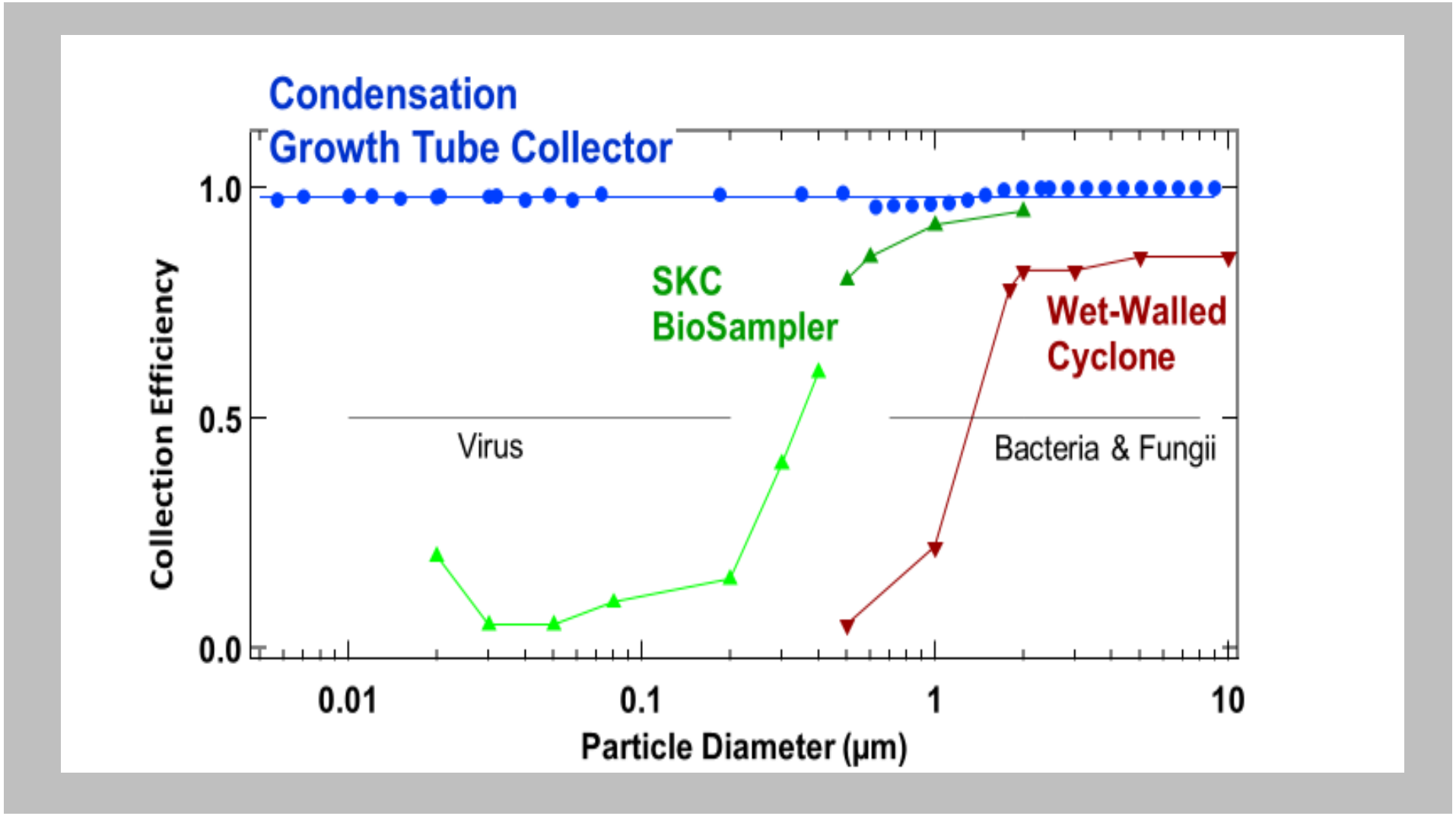
Moderate sample flow temperatures never exceed 30˚C. Exit flow temperature <18˚C; dewpoint < 20˚C.

Supersaturation levels of 120-140% activate condensation growth on particles as small as 5 nm.

Droplets grown to nominal 3µm diameter are easily captured by bounce-free, soft inertial impaction on to a solid surface or into liquid

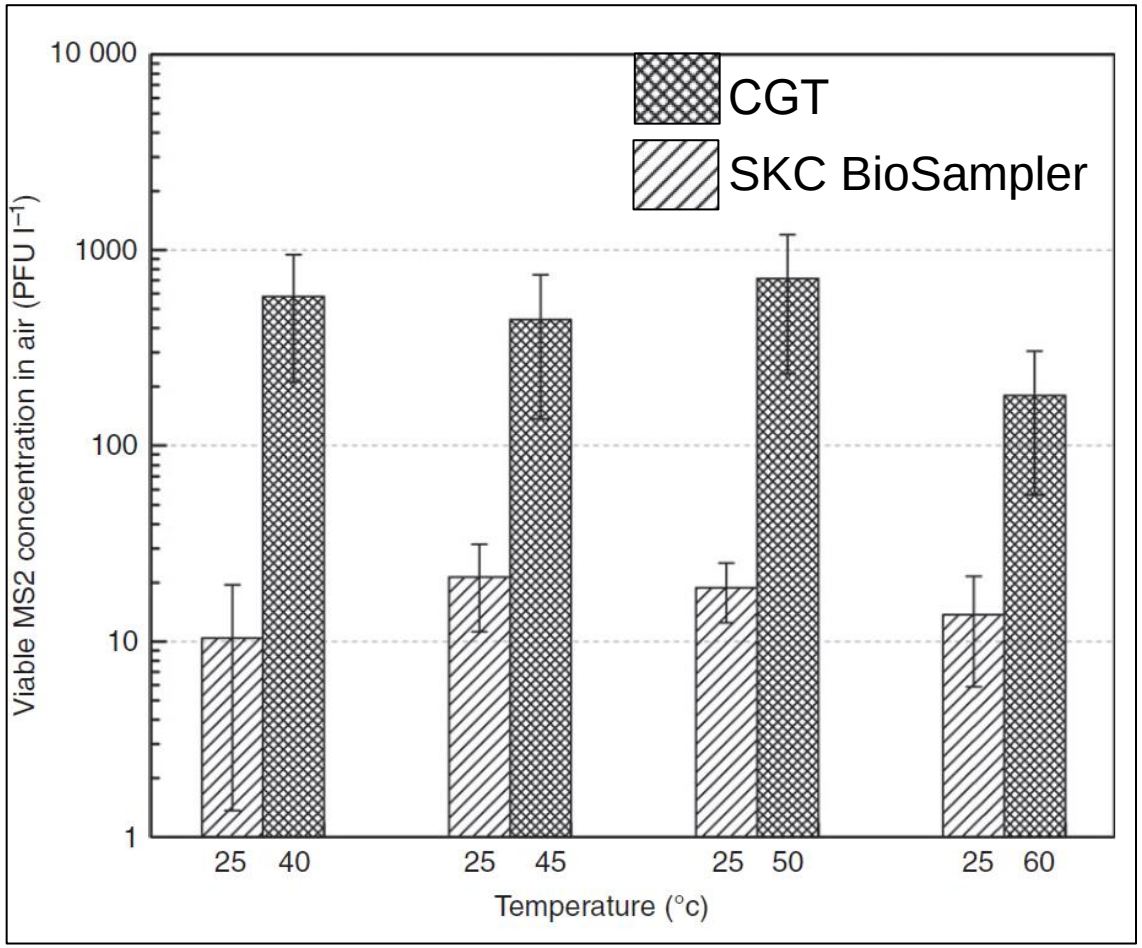
Hering, et. al. (2014) *Aerosol Science & Technology* 48:401-408.

Growth Tube - Efficient over all Particle Sizes



Data for wet-walled cyclone from McFarland et al (2010); BioSampler data from Hogan et al (2005) and Willeke et al. (1998).

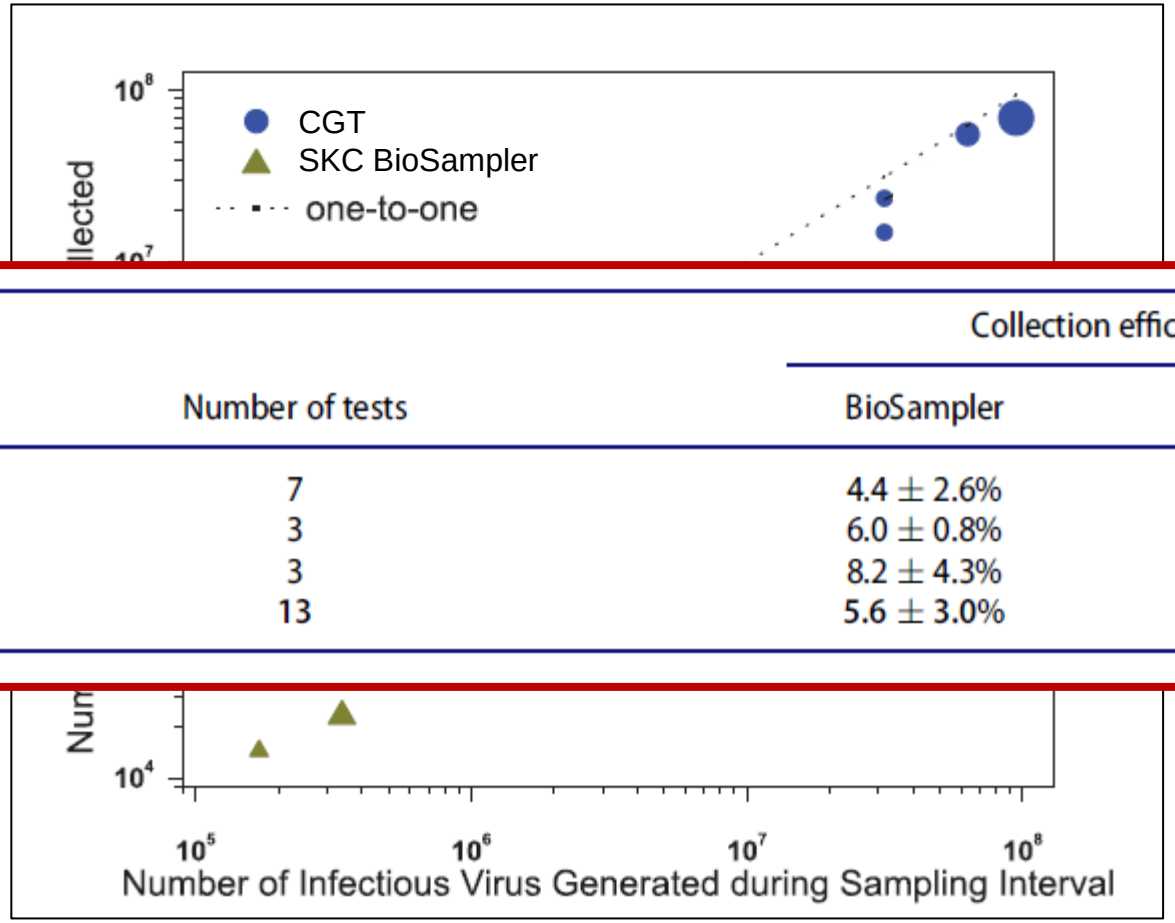
Collection of MS2 virus aerosol



Condensation Growth Tube = CGT

M. Pan et al., Journal of Applied Microbiology; 120, 805-815: 2016.

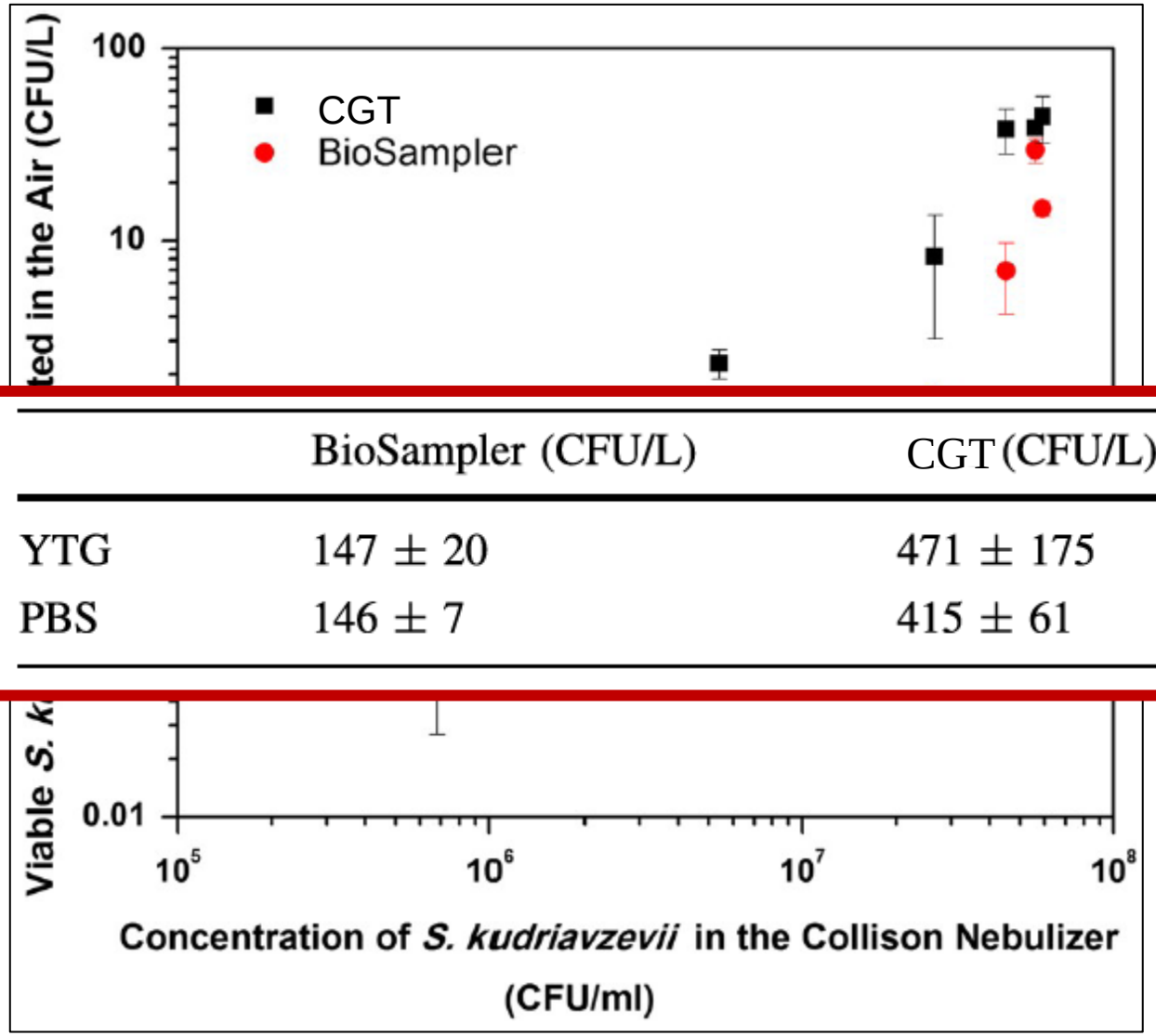
Collection of infectious *viable* influenza H1N1 virus aerosol



Sampling period (min)	Number of tests	Collection efficiency of infectious H1N1	
		BioSampler	CGT
5	7	4.4 ± 2.6%	67 ± 10%
10	3	6.0 ± 0.8%	83 ± 12%
15	3	8.2 ± 4.3%	80 ± 07%
All Runs	13	5.6 ± 3.0%	74 ± 12%

J. Lednicky et al., Aerosol Science and Technology, 50:7: 2016.

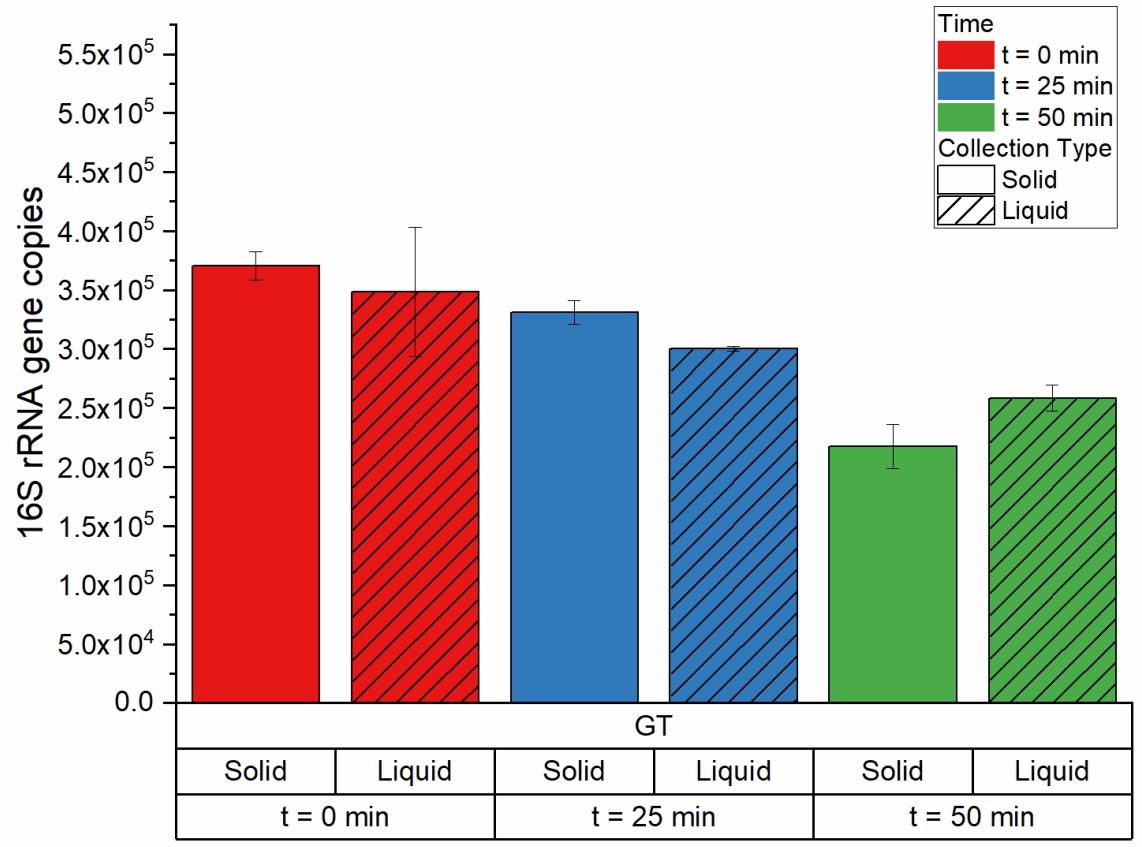
Collection of airborne viable bacteria and yeast

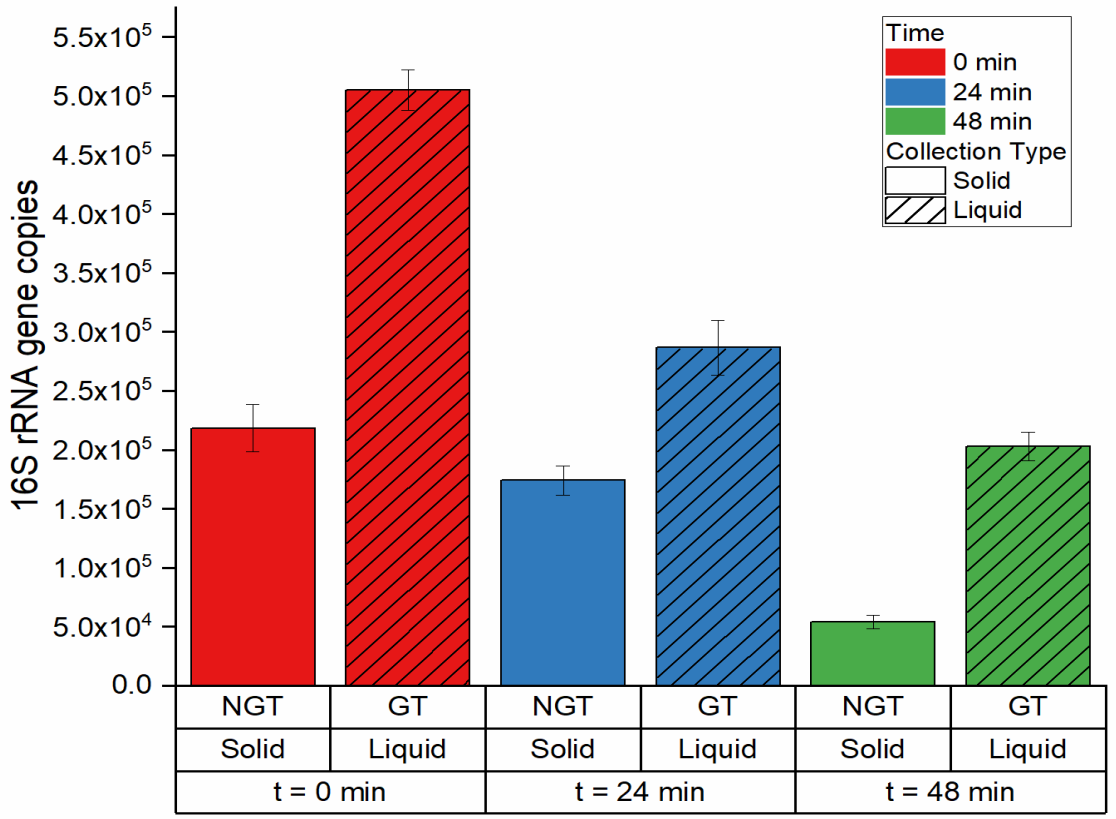


	BioSampler (CFU/L)	CGT (CFU/L)
YTG	147 ± 20	471 ± 175
PBS	146 ± 7	415 ± 61

. Pan. et al., Aerobiologia (2018) 34: 337.

Condensation Capture into Genomic Preservative



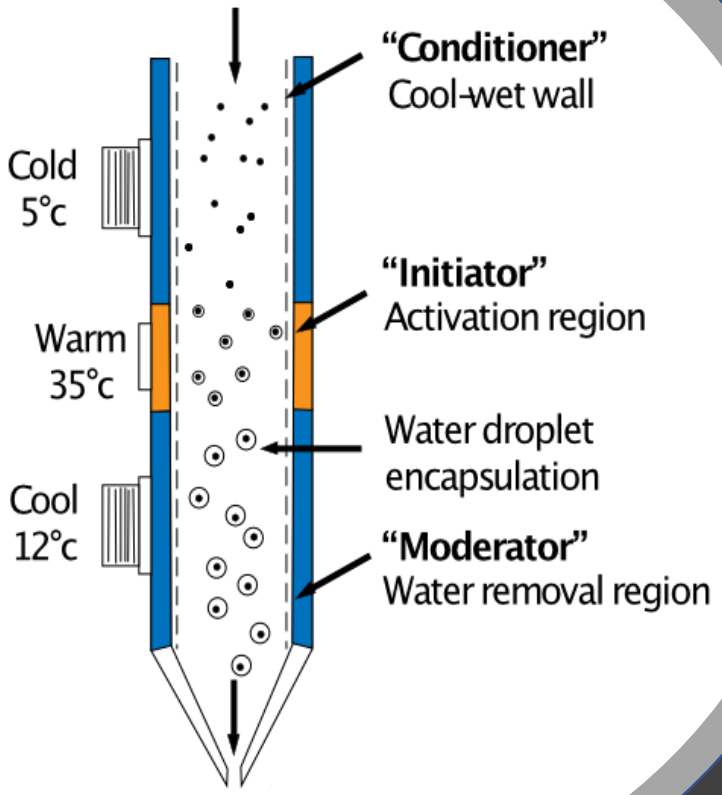


Condensation Growth Tube = CGT

No Condensation Growth Tube = NCGT

M. Nieto Caballero et al., 2019, High Fidelity Recovery of Airborne Microbial Genetic Materials by Direct Condensation Capture into Genomic Preservatives.

Bioaerosol Sampling and Analysis



- Biological Assays
- Fluorescence spectroscopy
- Microscopy techniques
- qPCR, DNA/RNA Sequencing
- Culture
- Microfluidic Sensing
- MALDI-TOF spectrometry
- Raman spectroscopy

Mount
Sinai

Early Adopters


FDA
U.S Food and Drug Administration

Future Developments

IH/IAQ Consult
Health care
Public health
Agribusiness
Eldercare Homes
Transportation
Restaurants/Bars

Low cost, simple sampler for genomic analysis – qPCR, RNA/DNA sequencing

Sampler integrated with an electrochemical biosensor targeted for a specific virus or bacteria; focus is initially on SARS-CoV-2

https://www.youtube.com/watch?v=ujFhI42R2-8

Condensation Growth Tube Capture – Advantages for Bioaerosols

- Gentle capture into liquid maintains viability
- Capture into a genomic stabilizer instantly preserves DNA/RNA
- Choice of collection terminus – liquid or solid substrate
- High, uniform collection efficiency independent of particle size, shape, composition, or hydrophobicity
- Wide particle size range from 5nm to 10µm
- Concentrated sample
- No temperature extremes – mimics the environmental conditions in the human lung
- No particle bounce or re-aerosolization
- Minimal sample handling → low contamination potential

For a healthier future, together.

Thank you!

Aerosol Devices Inc

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