

# Bioaerosol Sampling

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

# Evidence for airborne transmission of SARS-CoV-2

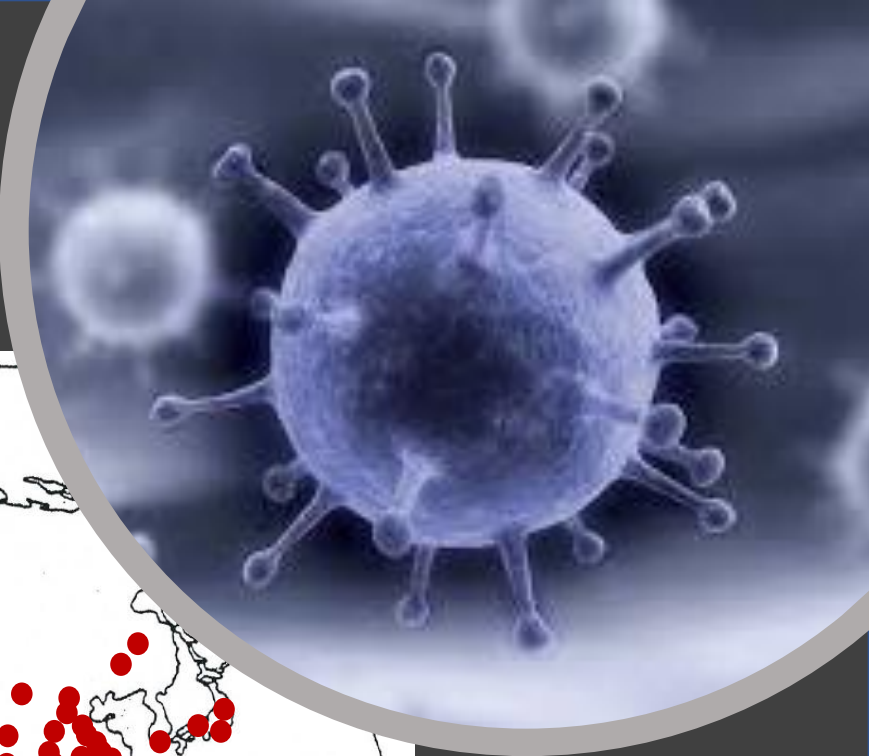
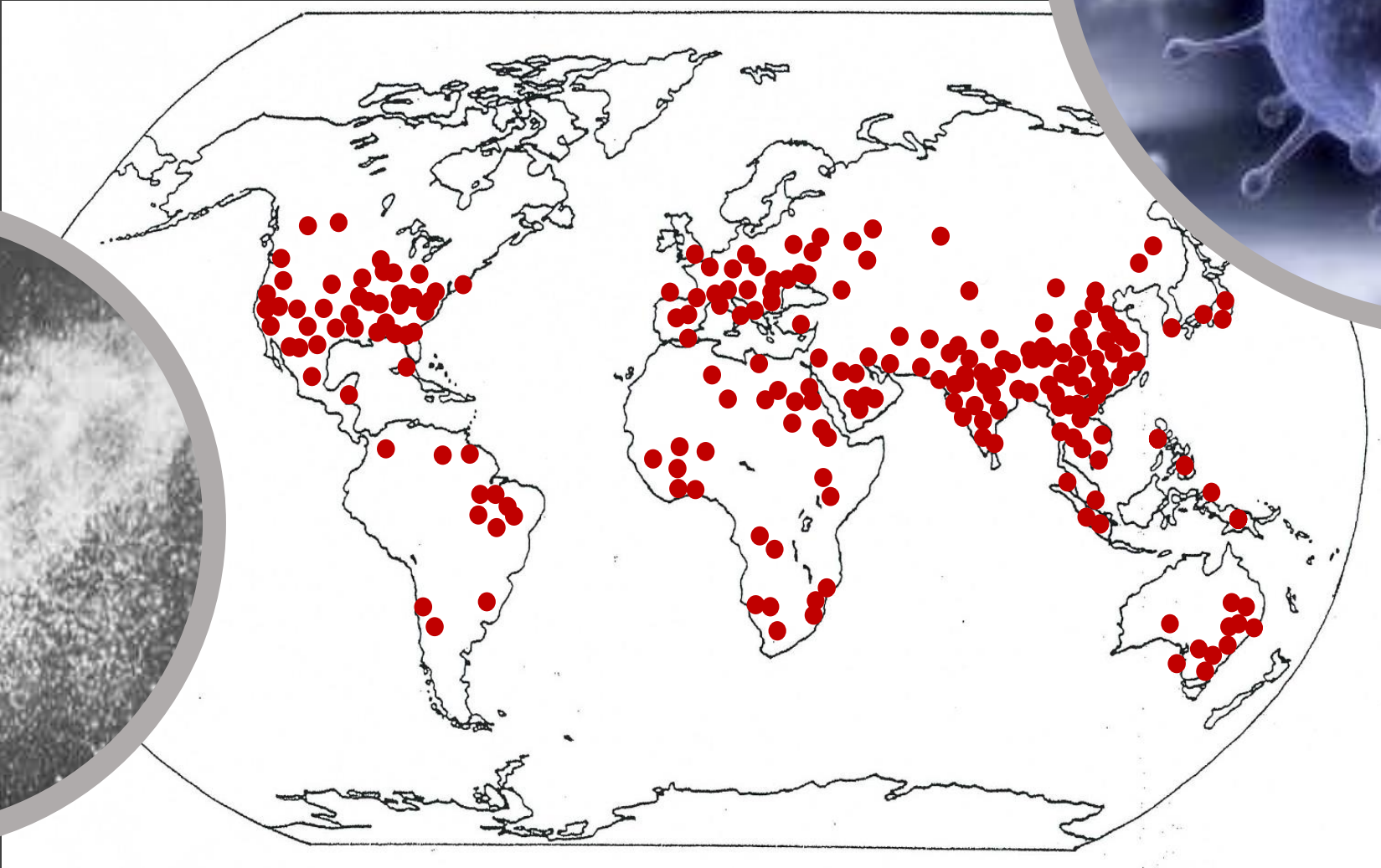
Pat Keady, President



Aerosol Devices Inc

[pkeady@aerosoldevices.com](mailto:pkeady@aerosoldevices.com)

# 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



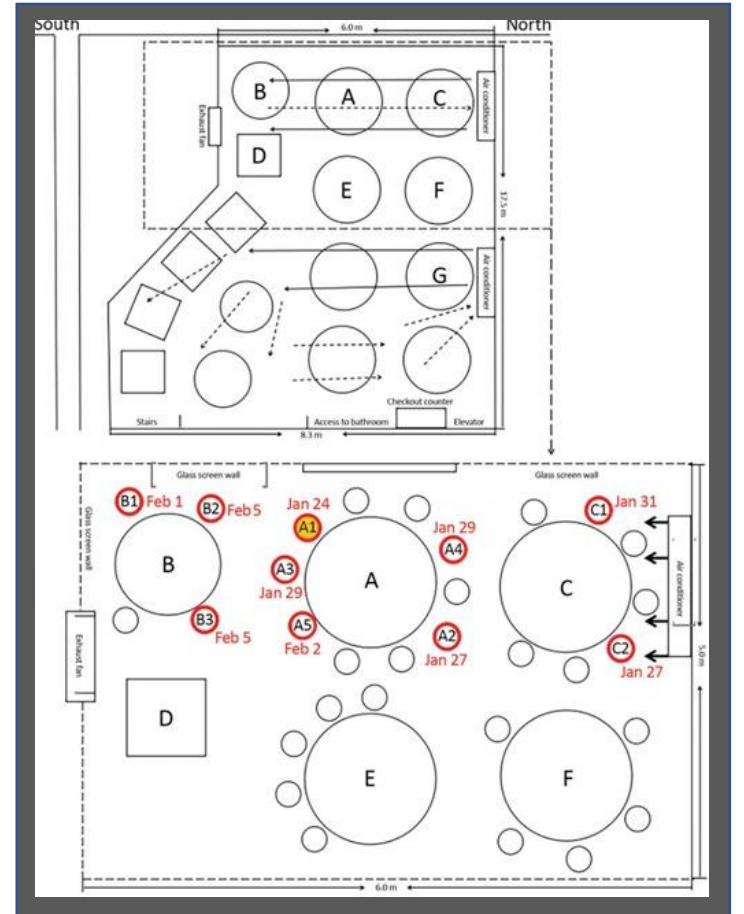
Church choir practice



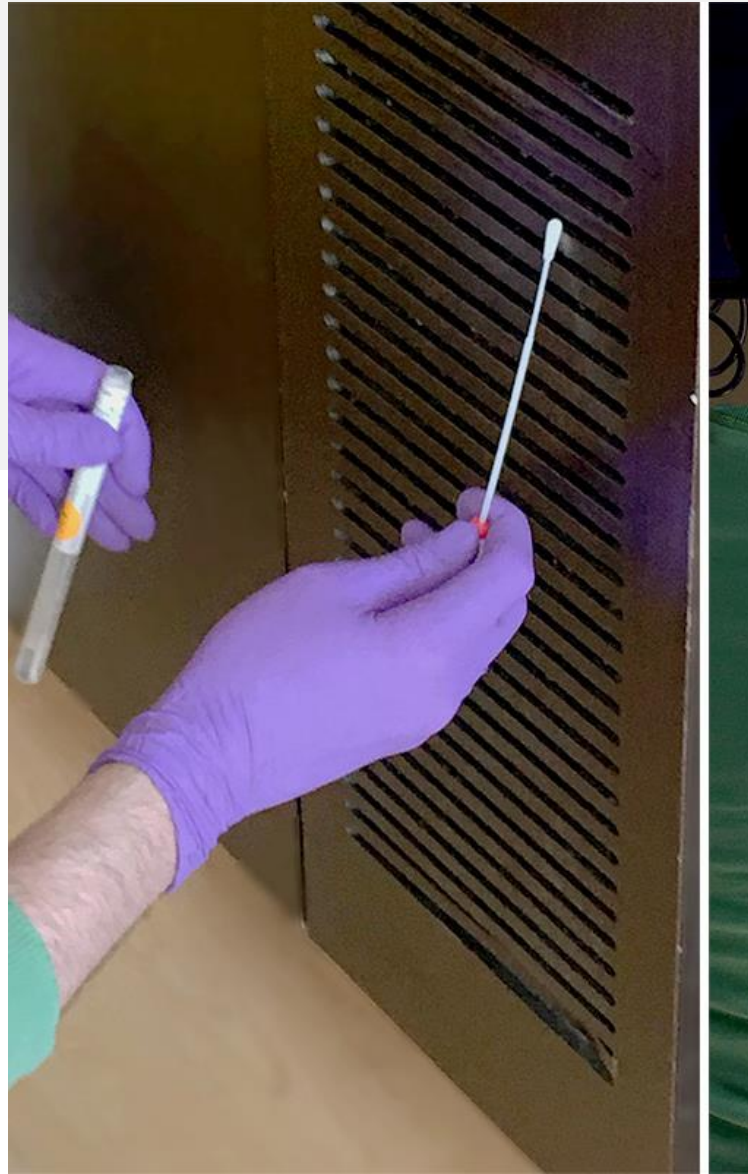
San Quentin Prison



Minnesota bars



Guangzhou China restaurant



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

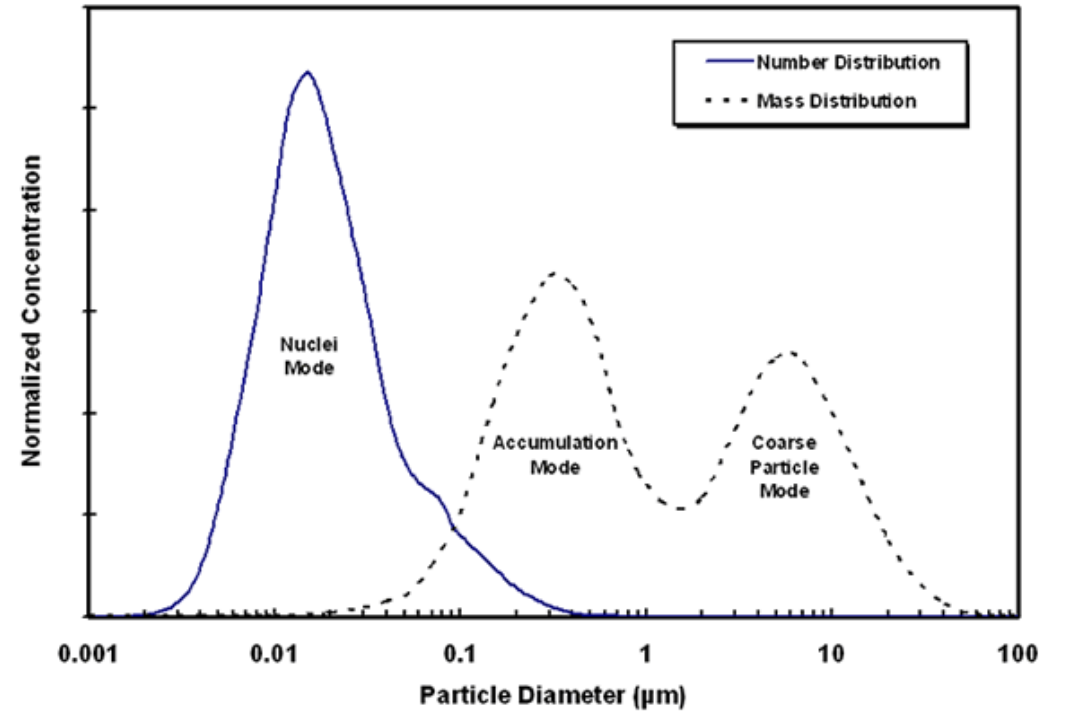
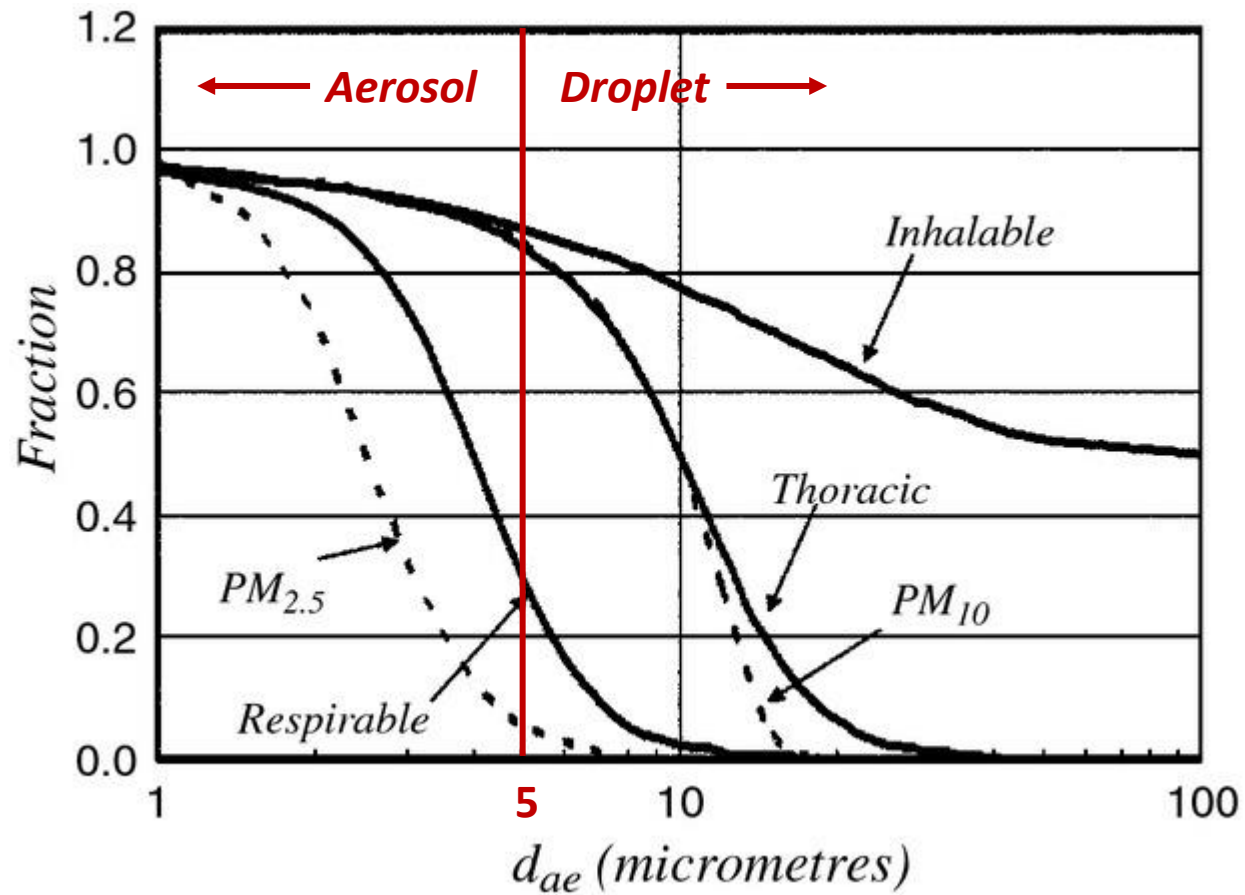
Added to the  
WHO website  
just yesterday,  
July 9<sup>th</sup> !

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?

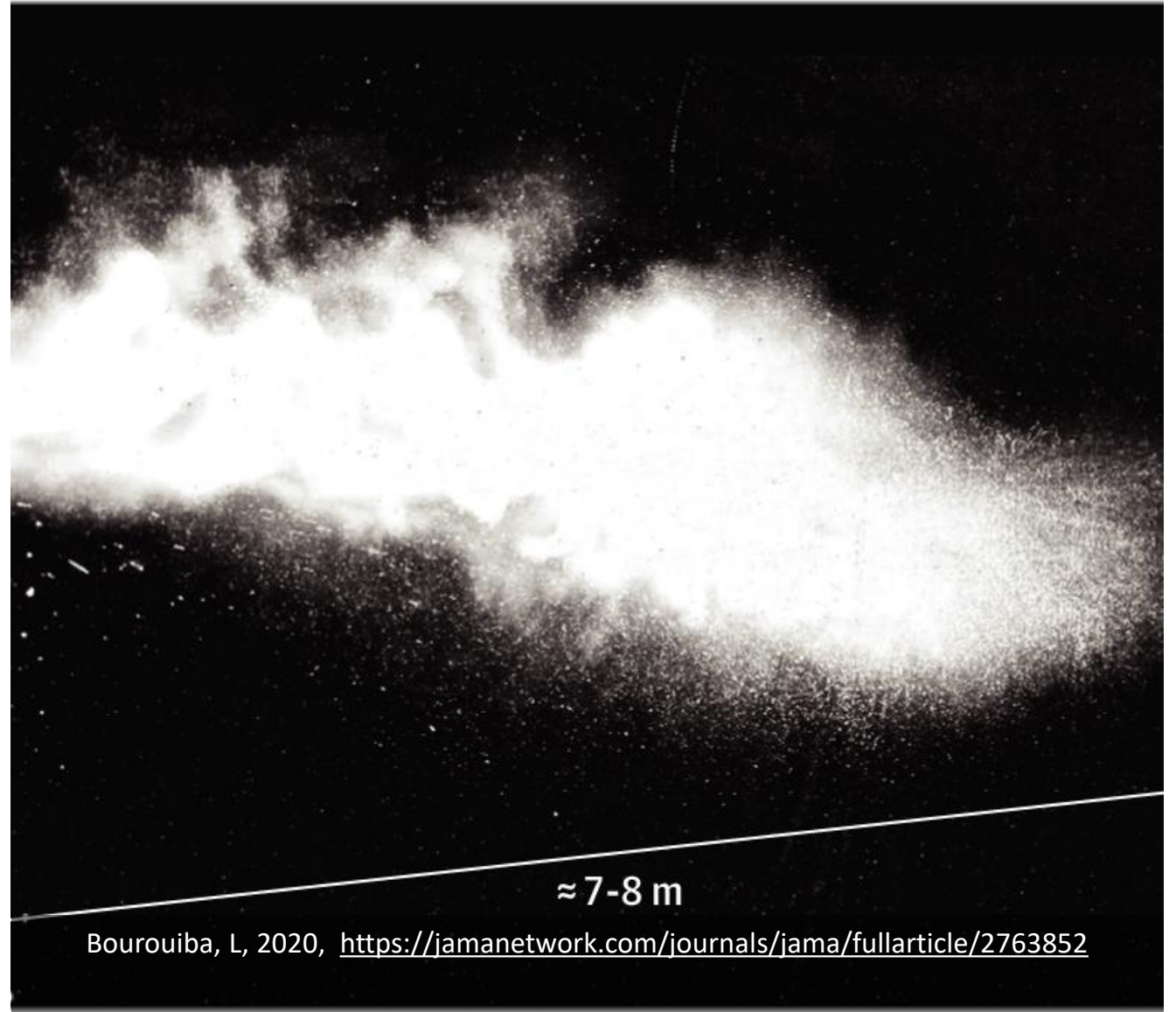
Seeing a bright side to the COVID-19 pandemic,  
one aerosol scientist said to another:

“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





# Super spreaders

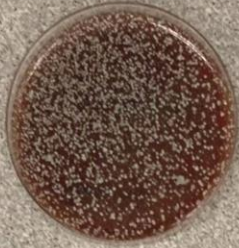
Some people, known as “super spreaders”, happen to be especially good at exhaling fine material, producing 1,000 times more than others.

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

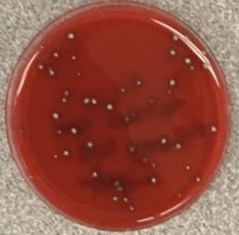


## Bacteria from respiratory droplets spread by...

...one sneeze



...singing  
(1 min)



... talking  
(1 min)



... two  
coughs



**No Mask**

**Masked**

Dr. Richard Davis, Providence Sacred Heart Medical Center



# Masks Work

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.



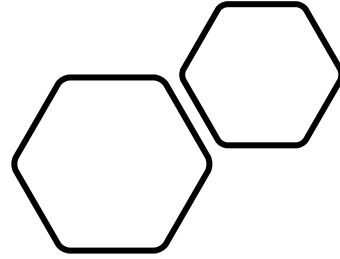
# Which masks work best?



- **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-RpPMIJ6aXFg3PrIQBbQ/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

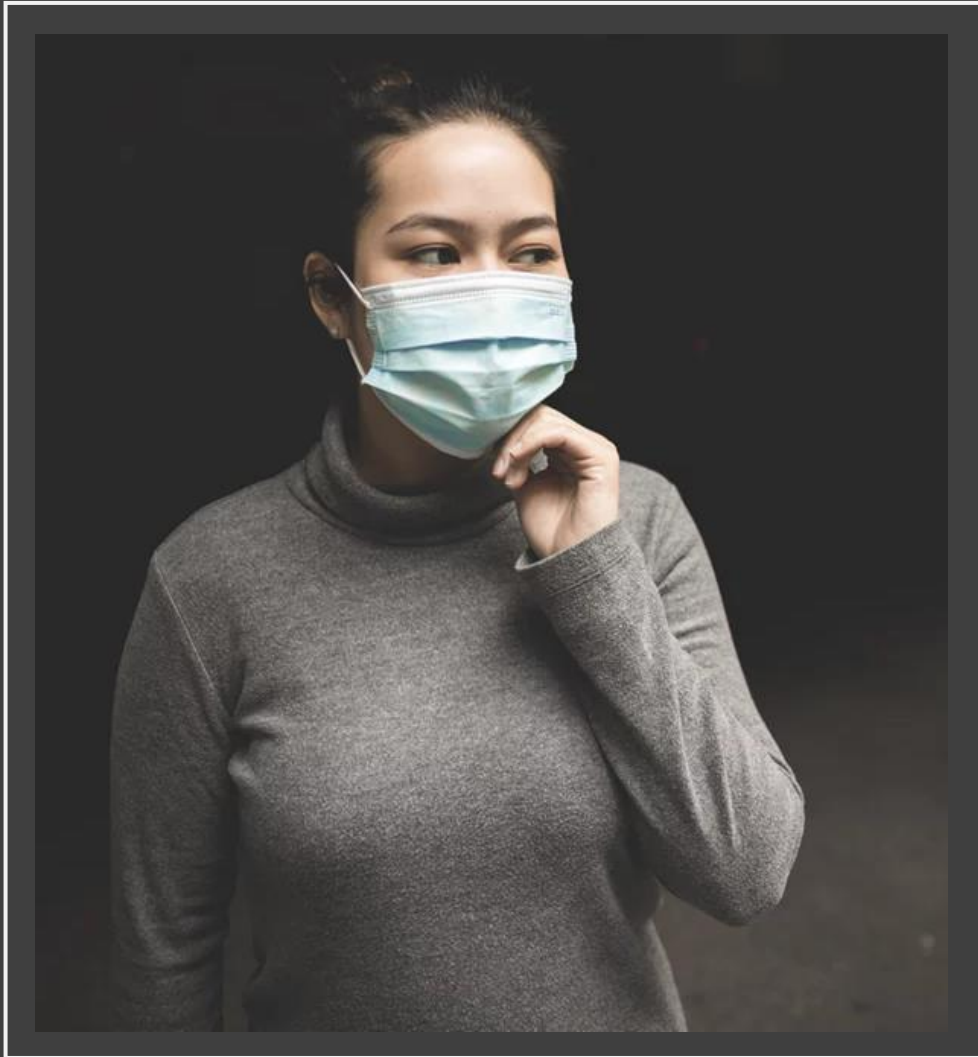
### **Social distancing**

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

### **Face Masks**

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



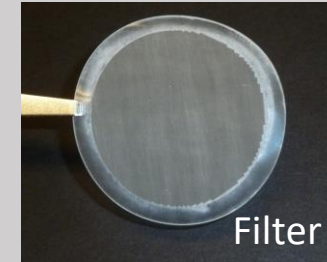


We are blind to the  
biohazards  
in the air we breathe

# 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



Wet-walled  
cyclone



Filter  
Sampling  
System



Impactor



Liquid  
Impingers  
and  
Frit  
Bubblers



# Sampling Viable Bioaerosols

Viable organisms inactivated by  
the sampling method

- Dessiccation
- 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

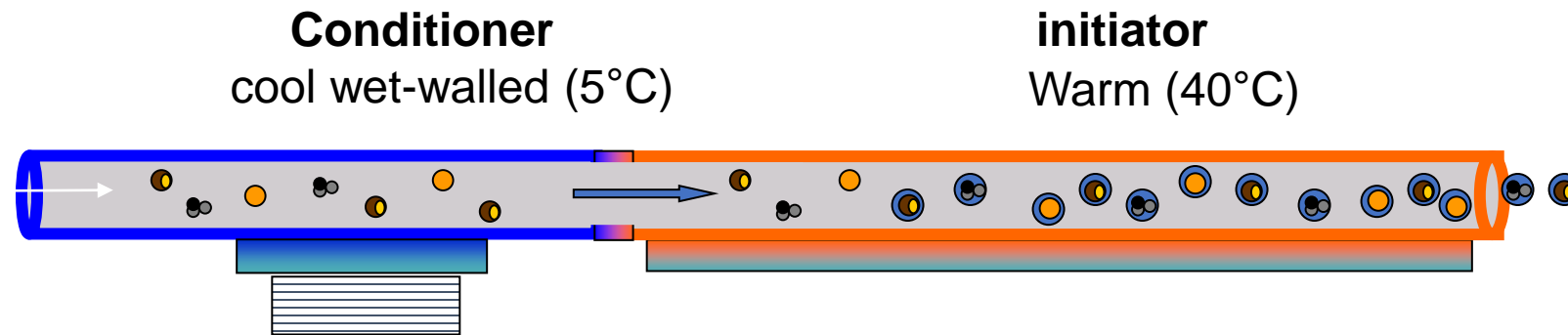
Maze Collector (Simon and Dasgupta, 1995)

Steam-jet Collector (Khlystov et al, 1995)

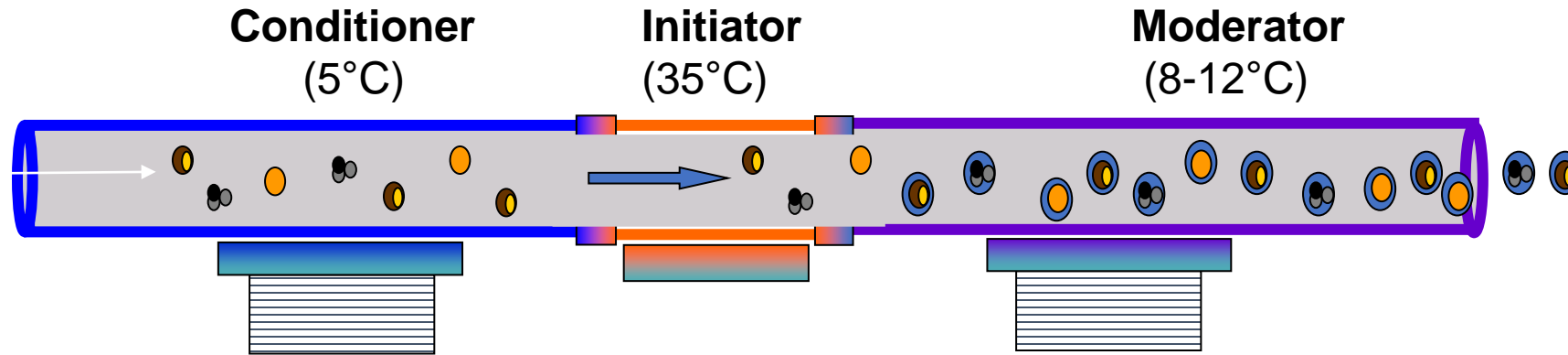
Particle-in-Liquid Sampler (Weber et al, 2001)

*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



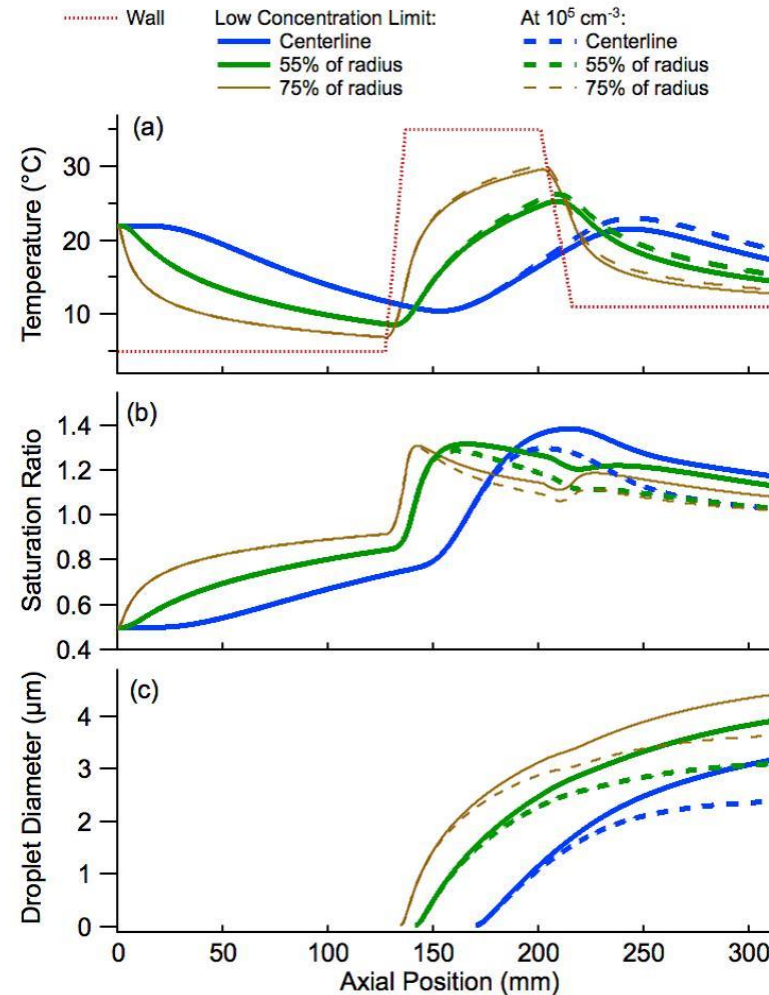
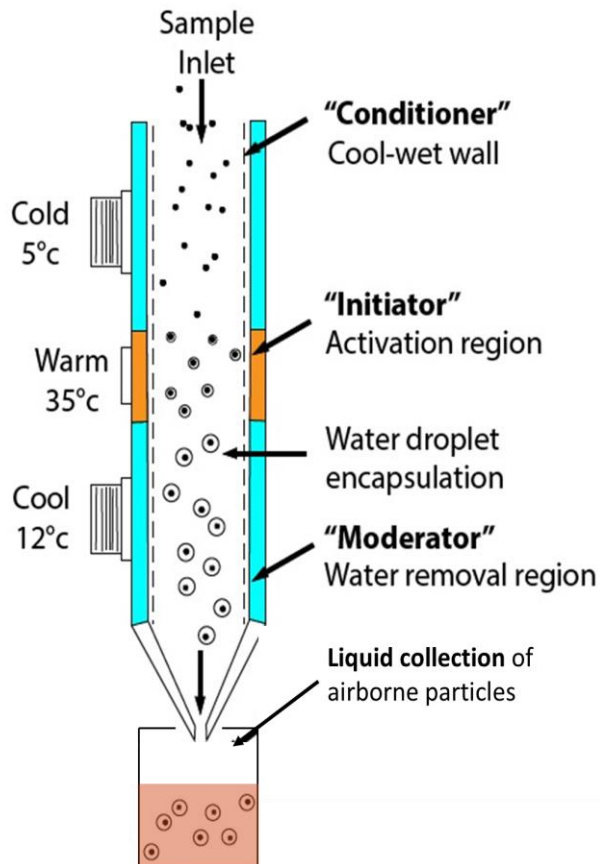
# New Design



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

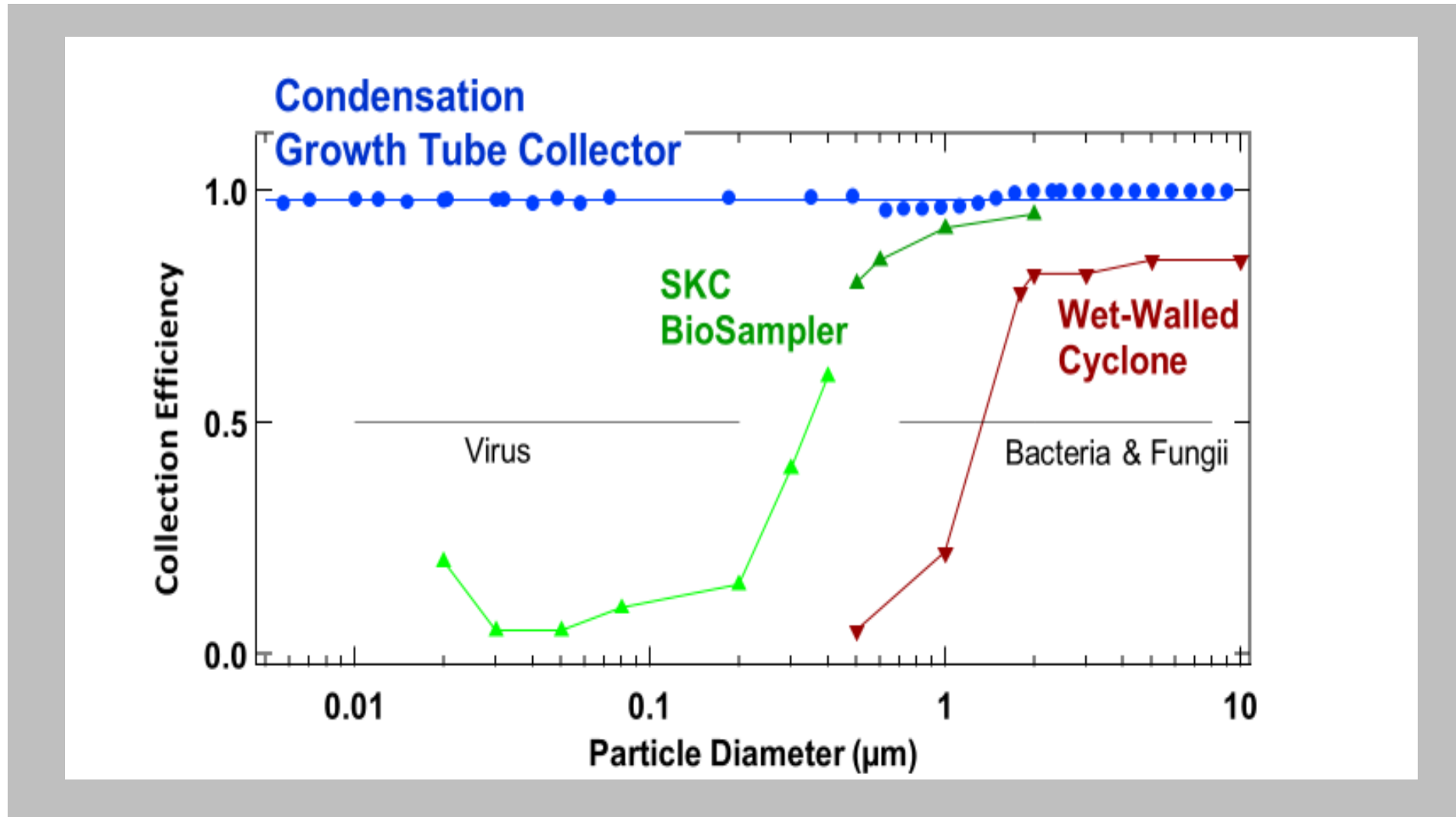


Moderate sample flow temperatures never exceed  $30^{\circ}\text{C}$ . Exit flow temperature  $<18^{\circ}\text{C}$ ; dewpoint  $<20^{\circ}\text{C}$ .

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

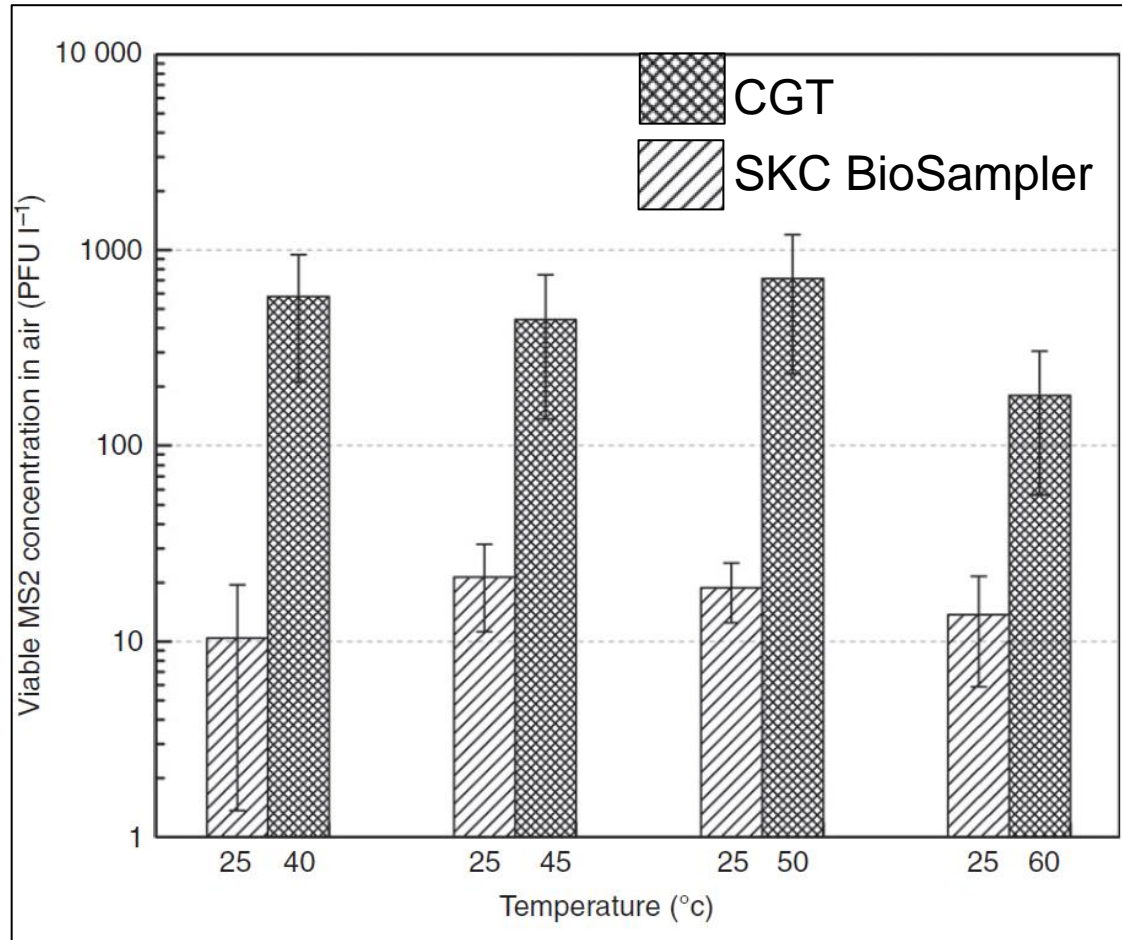
Droplets grown to nominal  $3\mu\text{m}$  diameter are easily captured by bounce-free, soft inertial impaction on to a solid surface or into liquid

# 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

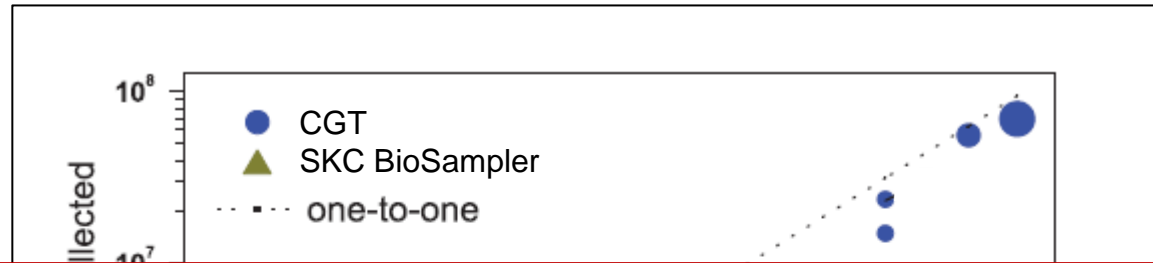


Condensation Growth Tube = CGT

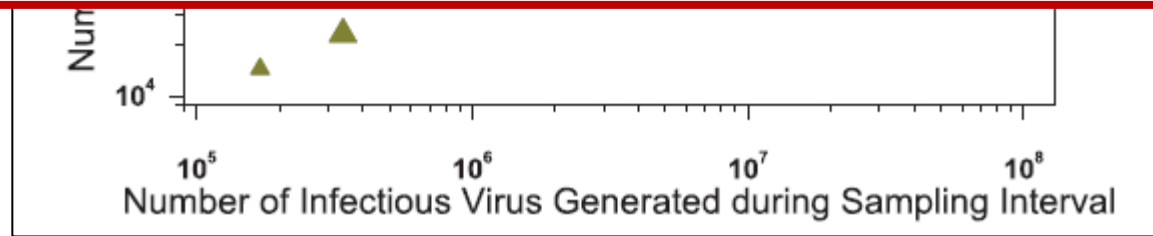
M. Pan et al., Journal of Applied Microbiology; 120, 805-815: 2016.



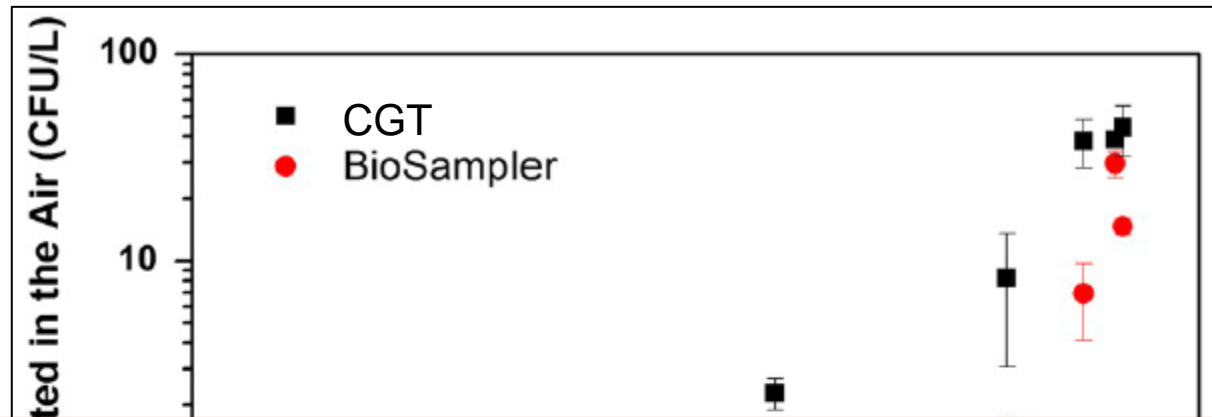
# Collection of infectious *viable* influenza H1N1 virus aerosol



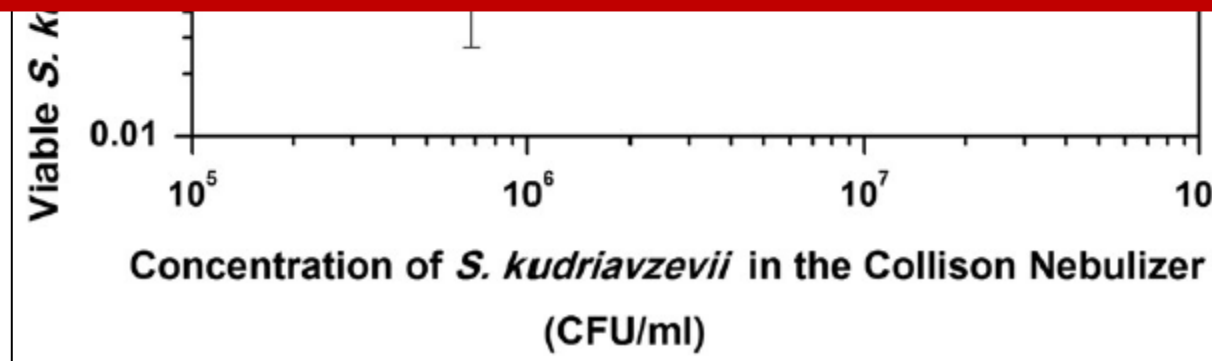
Sampling period (min)	Number of tests	Collection efficiency of infectious H1N1	
		BioSampler	CGT
5	7	$4.4 \pm 2.6\%$	$67 \pm 10\%$
10	3	$6.0 \pm 0.8\%$	$83 \pm 12\%$
15	3	$8.2 \pm 4.3\%$	$80 \pm 07\%$
All Runs	13	$5.6 \pm 3.0\%$	$74 \pm 12\%$



# Collection of airborne viable bacteria and yeast

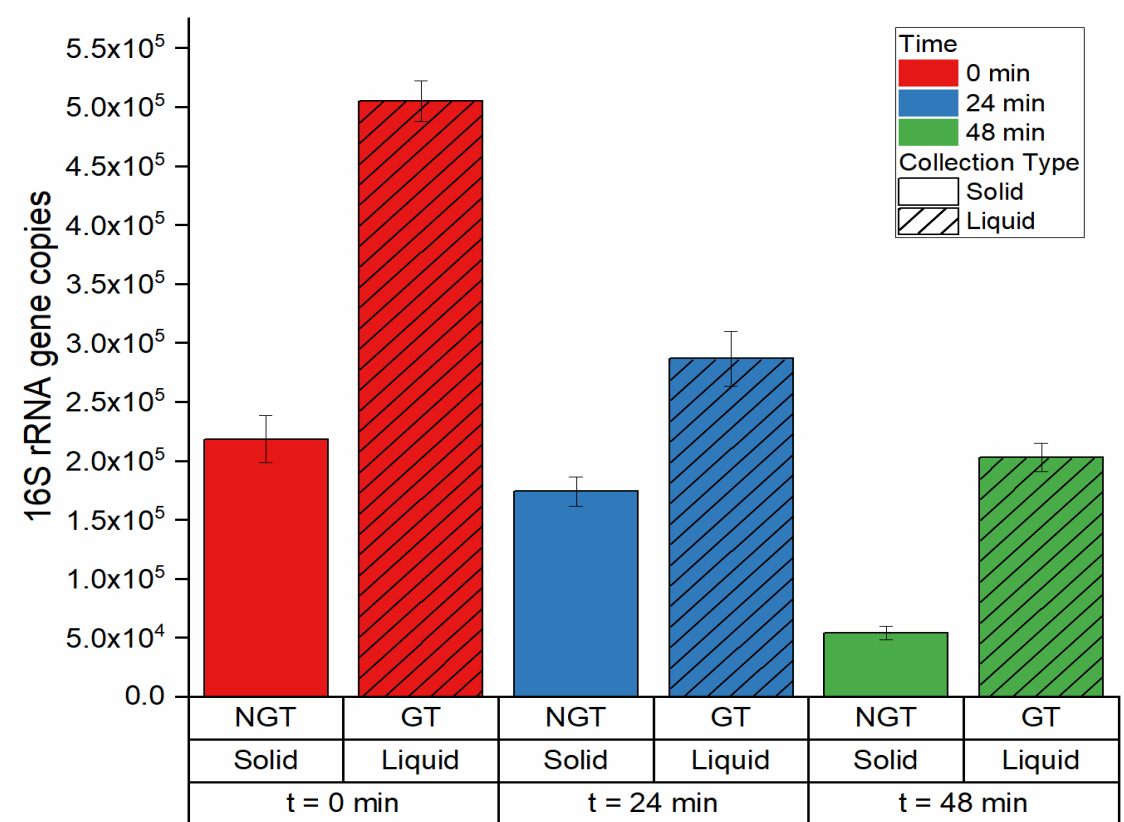
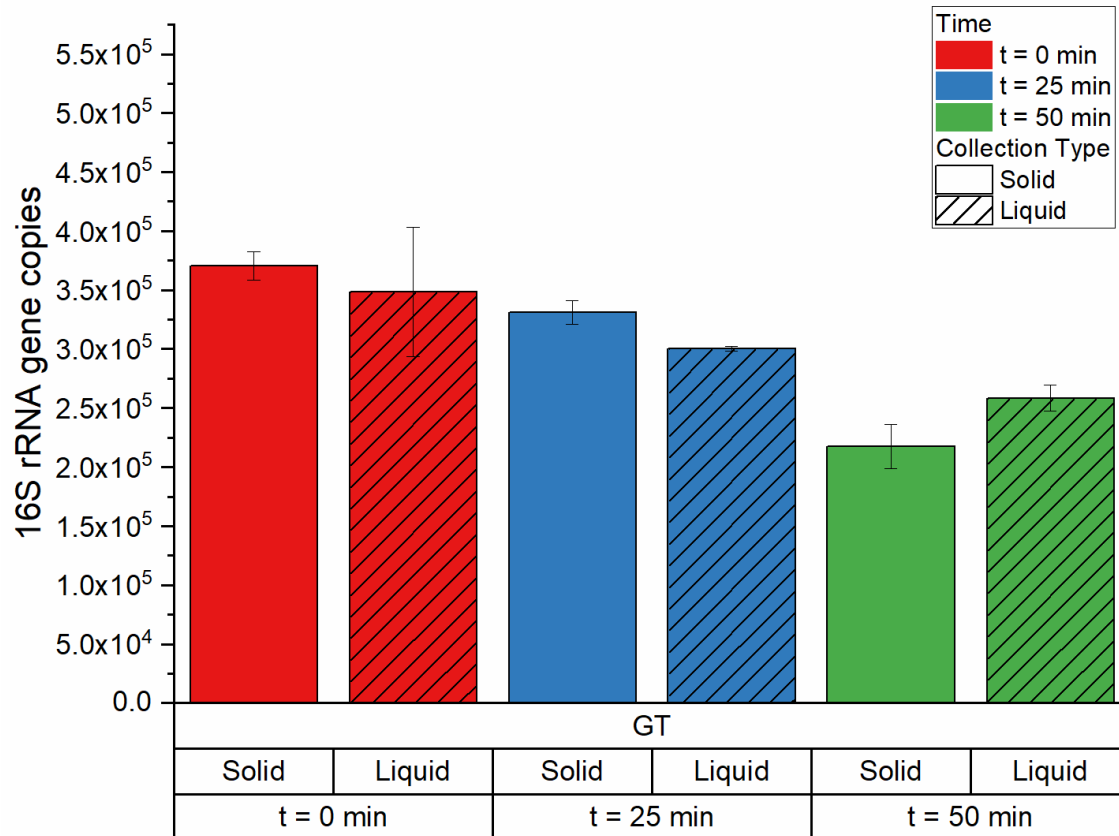


	BioSampler (CFU/L)	CGT (CFU/L)
YTG	147 ± 20	471 ± 175
PBS	146 ± 7	415 ± 61





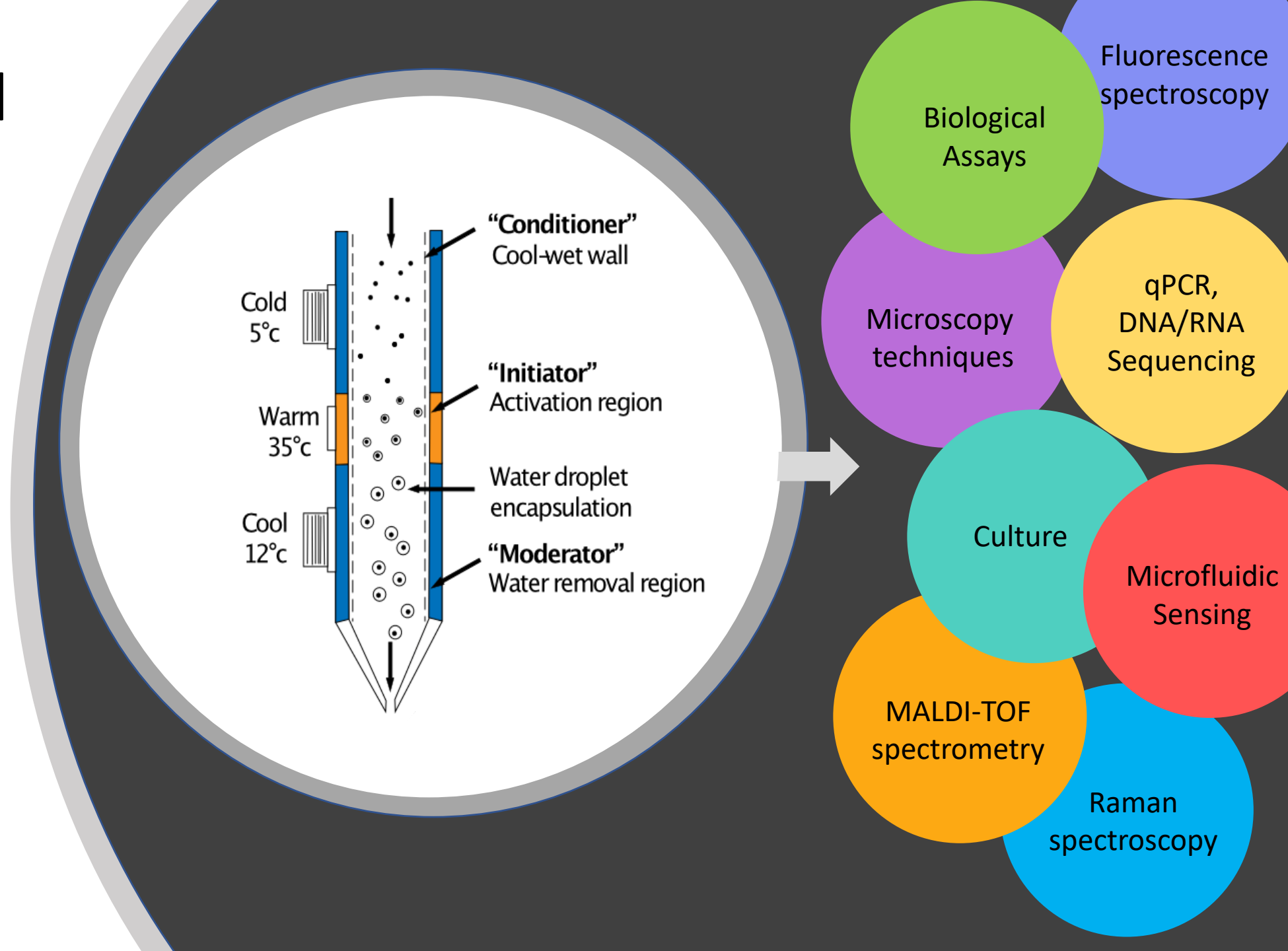
# Condensation Capture into Genomic Preservative



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





**Mount  
Sinai**



**UNIVERSITÉ  
LAVAL**



**Early Adopters**

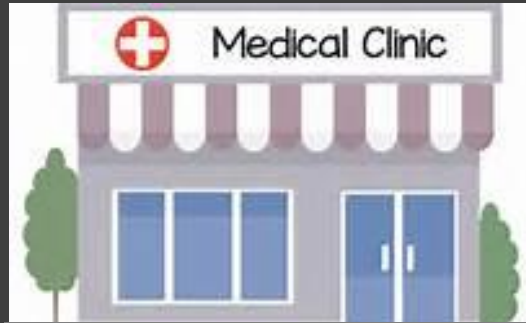
**Erasmus MC**  
Universitair Medisch Centrum Rotterdam







# 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 10 $\mu$ m
- Concentrated sample
- No temperature extremes – mimics the environmental conditions in the human lung
- No particle bounce or re-aerosolization
- Minimal sample handling  $\rightarrow$  low contamination potential

For a  
healthier  
future,  
together.



Aerosol Devices Inc

Thank you!

**Pat Keady**

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