

A photograph of a New York City subway train moving along an elevated track. The train is dark-colored with silver doors and windows. In the background, the city skyline is visible under a warm, orange and yellow sunset sky. A street below is filled with cars and traffic lights.

The Subway's Invisible Microbiome

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Executive Director, The International MetaSUB Consortium



Every surface you touched today had microbes on it



You're surrounded by a living, invisible ecosystem of microbes

Pattaya Bay, Thailand



Cities aren't just concrete and steel, they're biological systems

Outline



Presence

Subways host a living mix of microbes from people, air, soil, and the city itself.



Detection

We use DNA to reveal this invisible ecosystem without sampling people



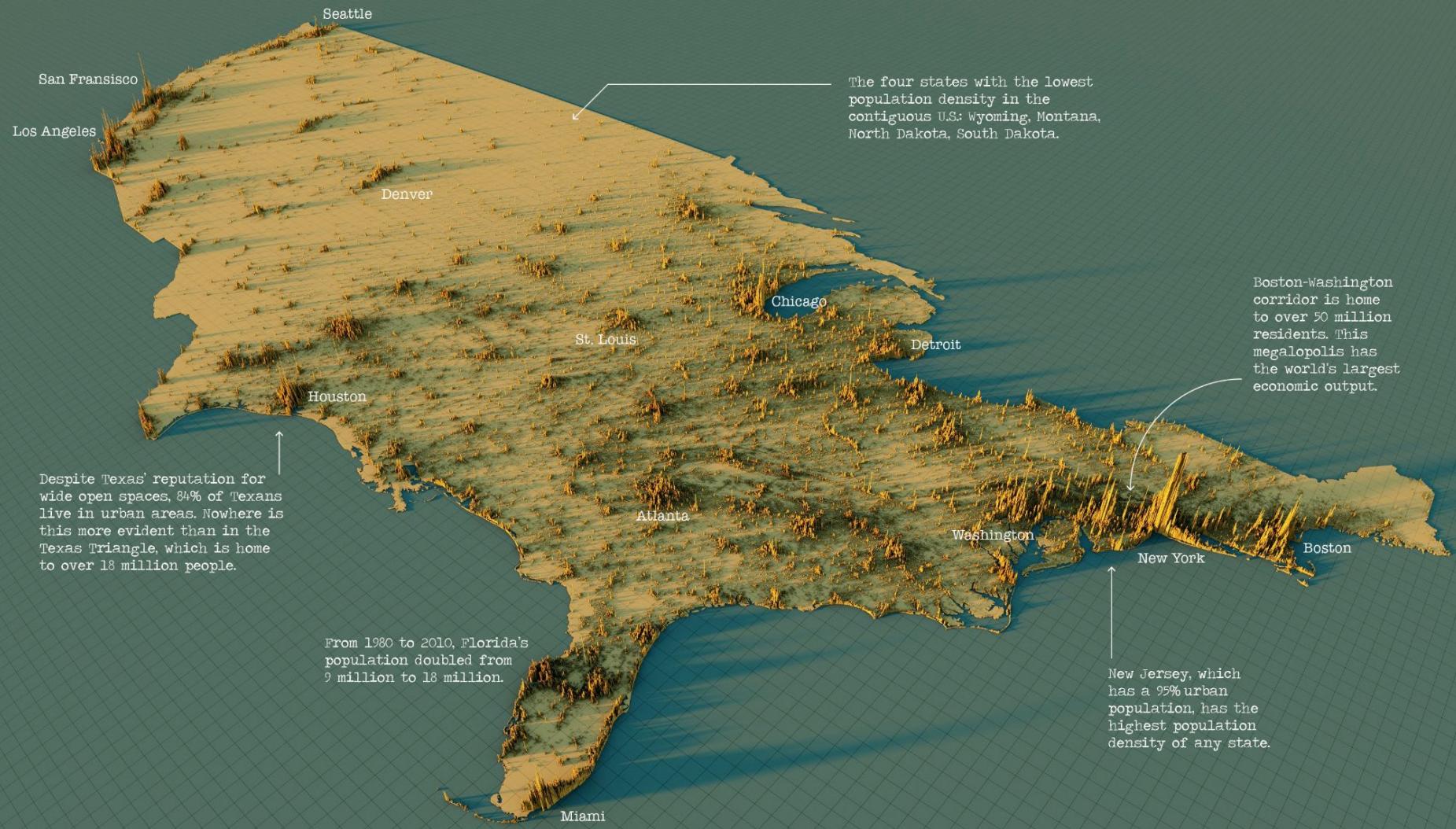
Impact

Microbial signals help us monitor health risks and design safer, more resilient cities

Urbanization

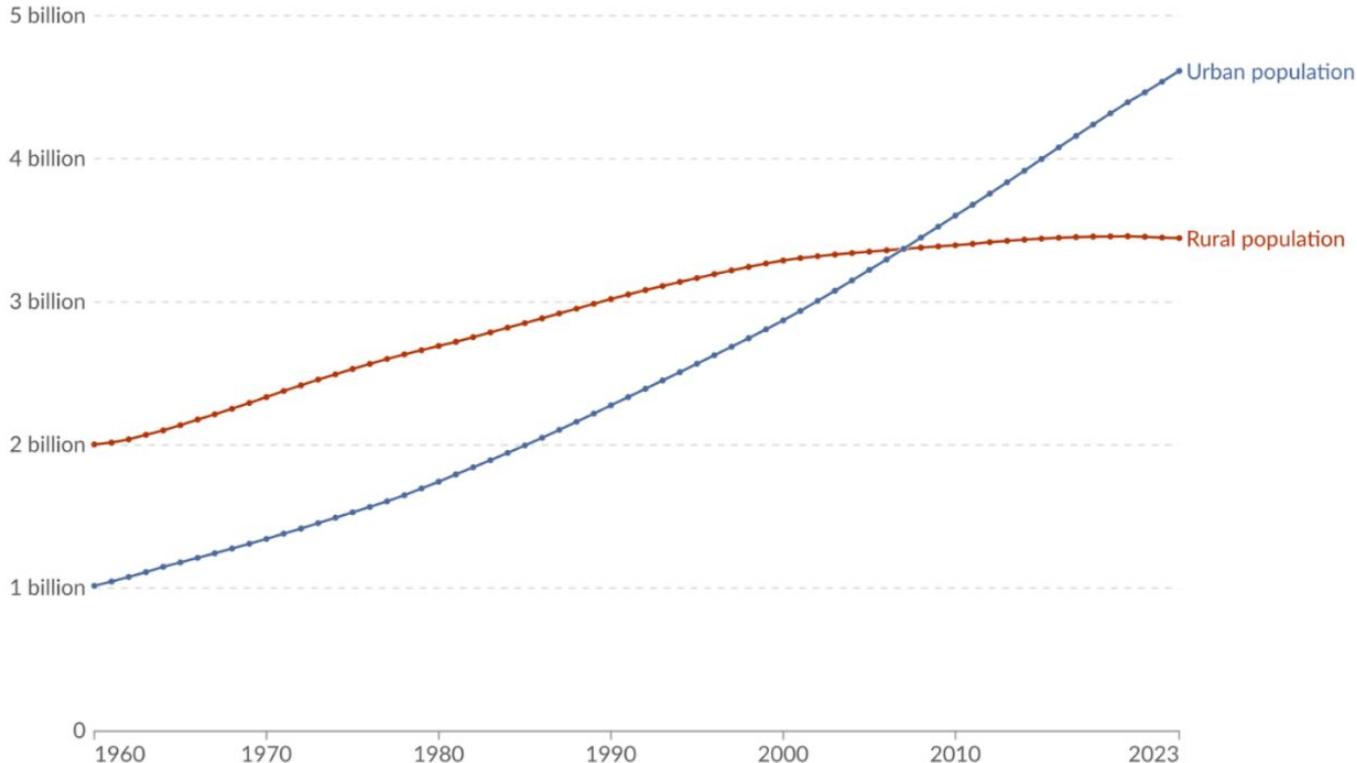


J.M. 183



Number of people living in urban and rural areas, World

Our World
in Data



Data source: World Bank based on data from the UN Population Division (2025)

OurWorldInData.org/urbanization | CC BY

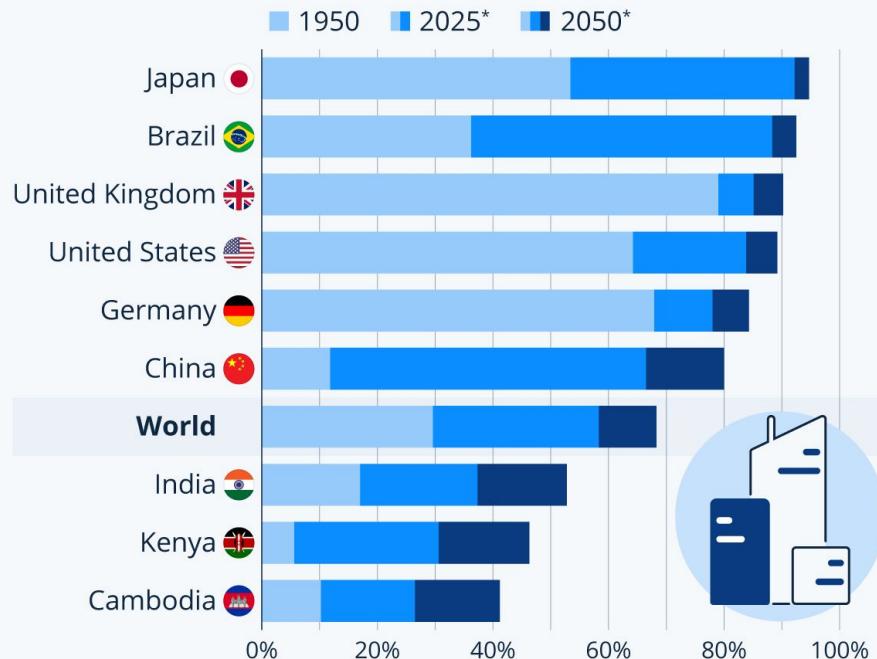
Note: Because the estimates of city and metropolitan areas are based on national definitions of what constitutes a city or metropolitan area, cross-country comparisons should be made with caution.

Trends in Urbanization

Accelerating population growth in cities worldwide, driven by economic opportunity, technological connectivity, and climate pressures, is reshaping infrastructure, public health, and ecological systems at unprecedented scales.

7 in 10 People to Live in Urban Areas by 2050

Estimated share of population residing in urban areas at mid-year in 1950, 2025 & 2050 in selected countries



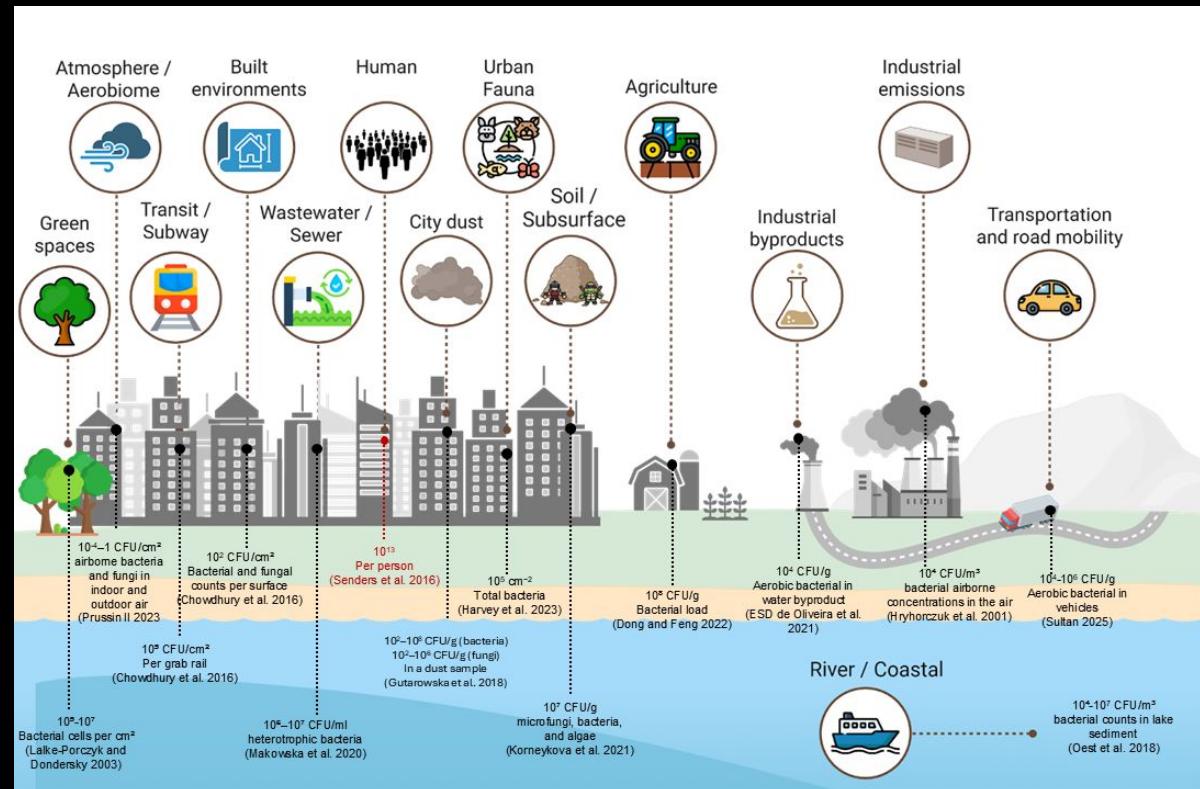
* Projection

Source: UN Population Division



Determinants of Urban Microbial Ecology

The urban microbiome reflects interactions between people, infrastructure, climate, and the environment.



Passenger Volume Across U.S. Subway systems

New York City Subway: ~2.04 billion trips in 2024, making it by far the busiest rapid transit system in the United States.

Washington Metro Metrorail: ~166.7 million trips in 2024 across the Washington, DC metropolitan area.

Chicago “L”: ~127.5 million trips in 2024 on its heavy rail network.

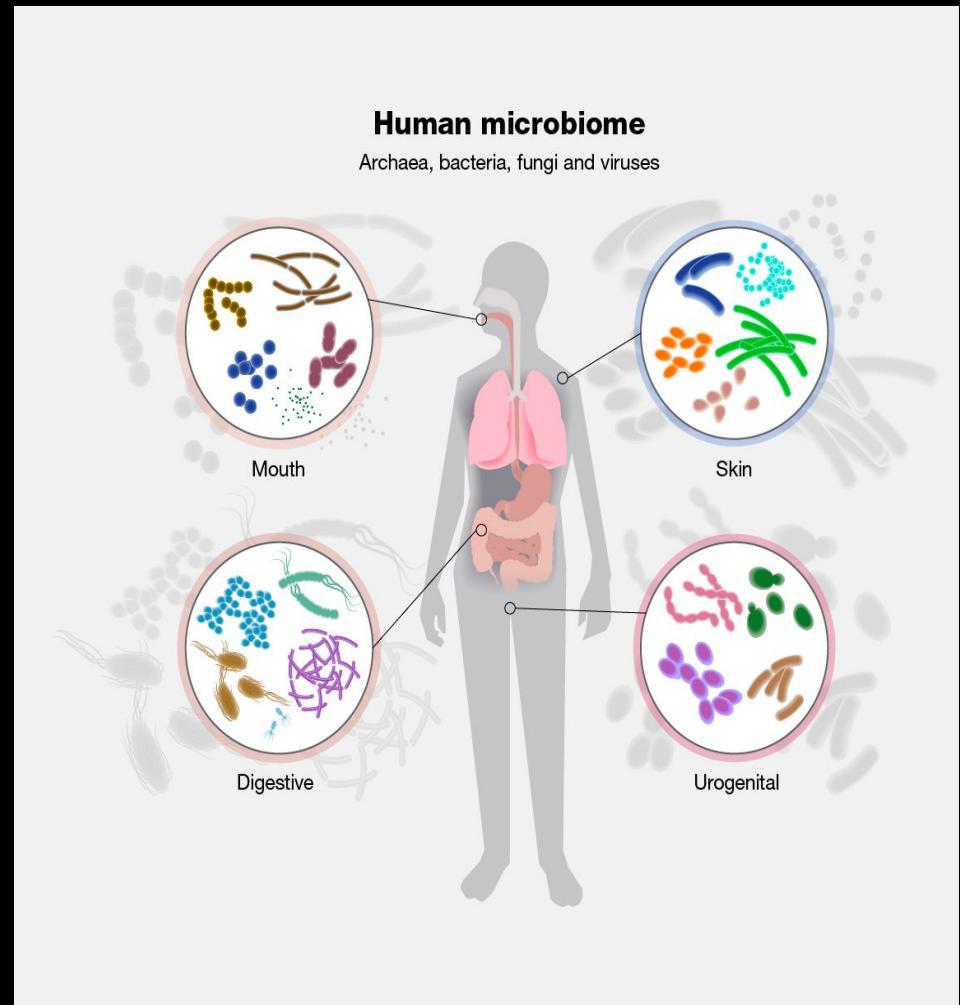




What is a microbiome?

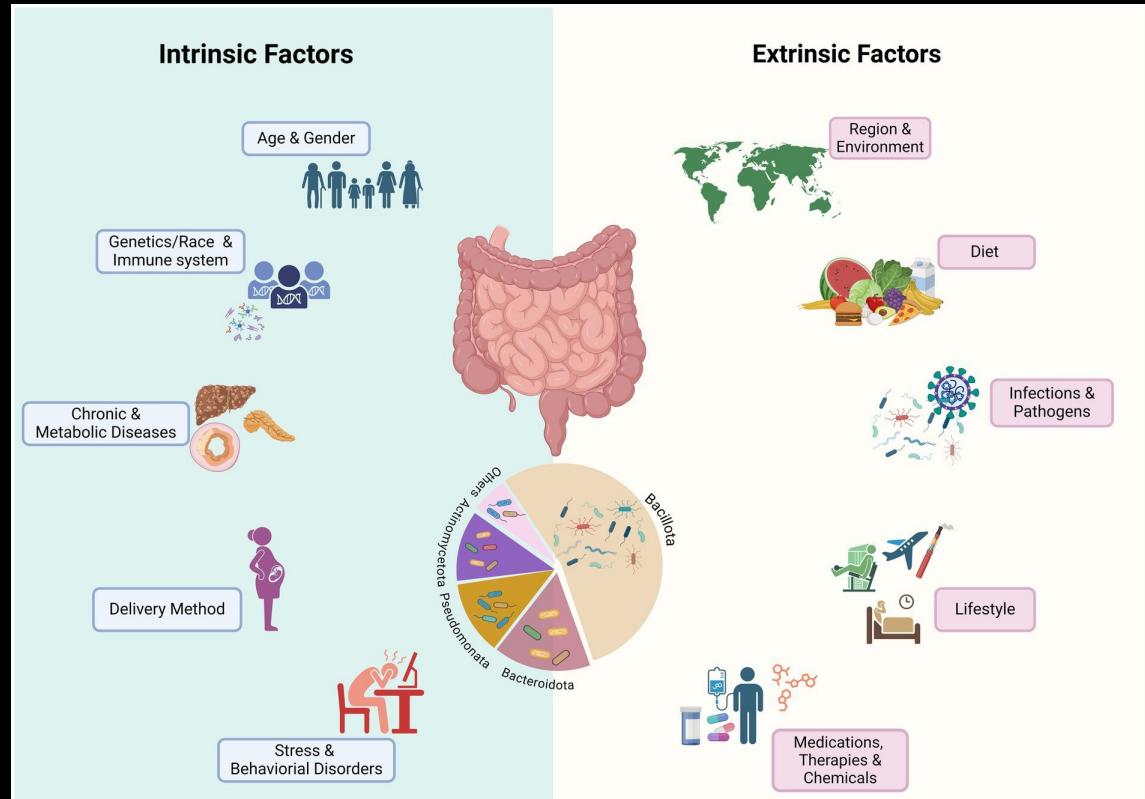
What is a microbiome?

A **microbiome** is the collection of all microbes, including bacteria, fungi, viruses, and their genes, that inhabit an environment.



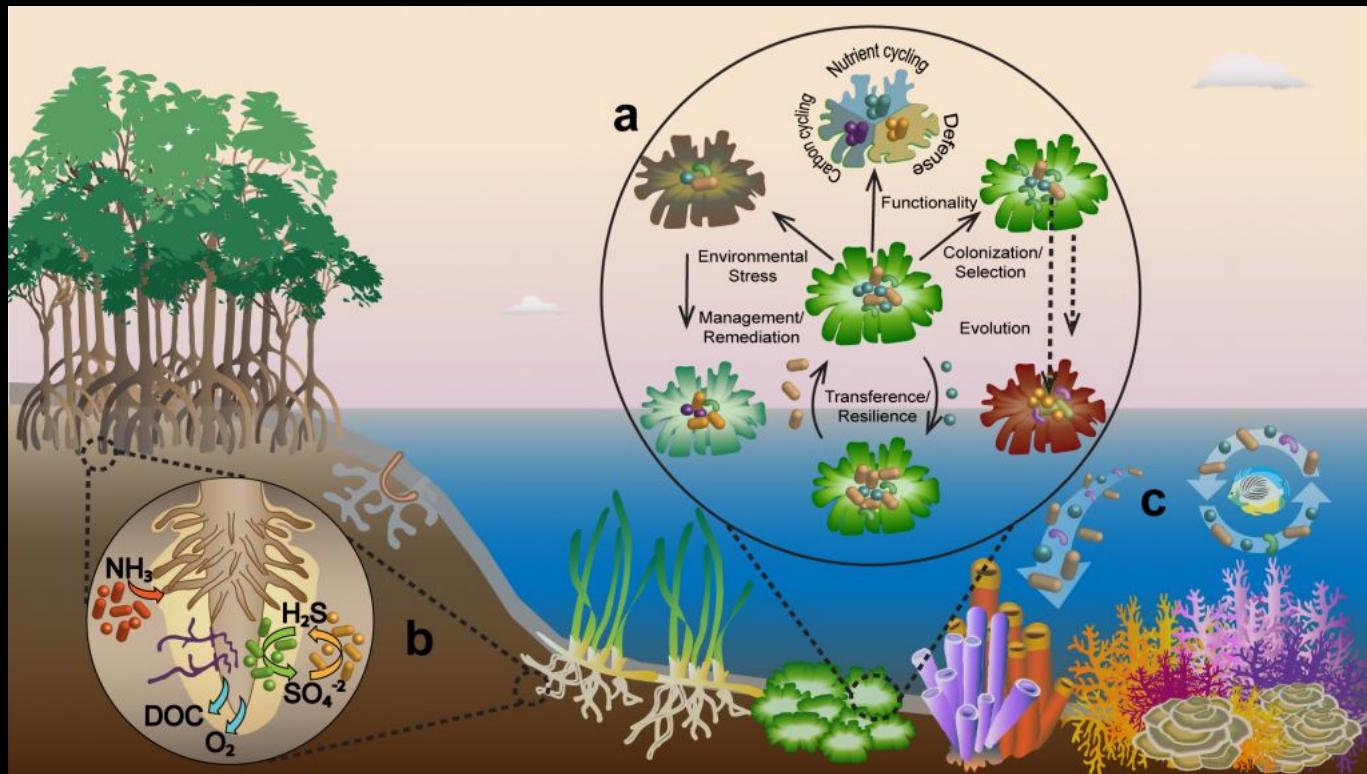
What influences the microbiome?

Dysbiosis is an imbalance of microorganisms in your body, which can affect your health and well-being.



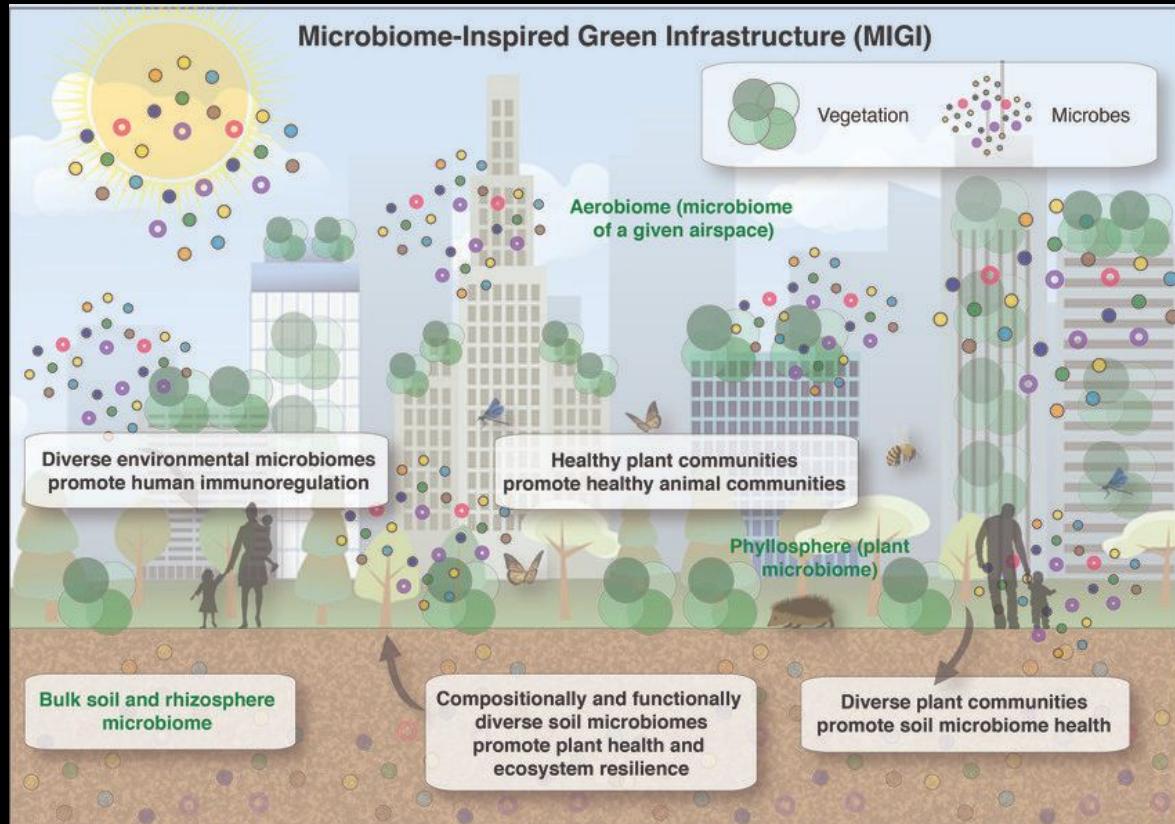
The life around us

The environmental microbiome shapes the air, surfaces, and microbes we encounter.



Urban multispecies health

Environmental microbiomes are the foundations of our ecosystems, and are essential to plant and animal health (including humans)

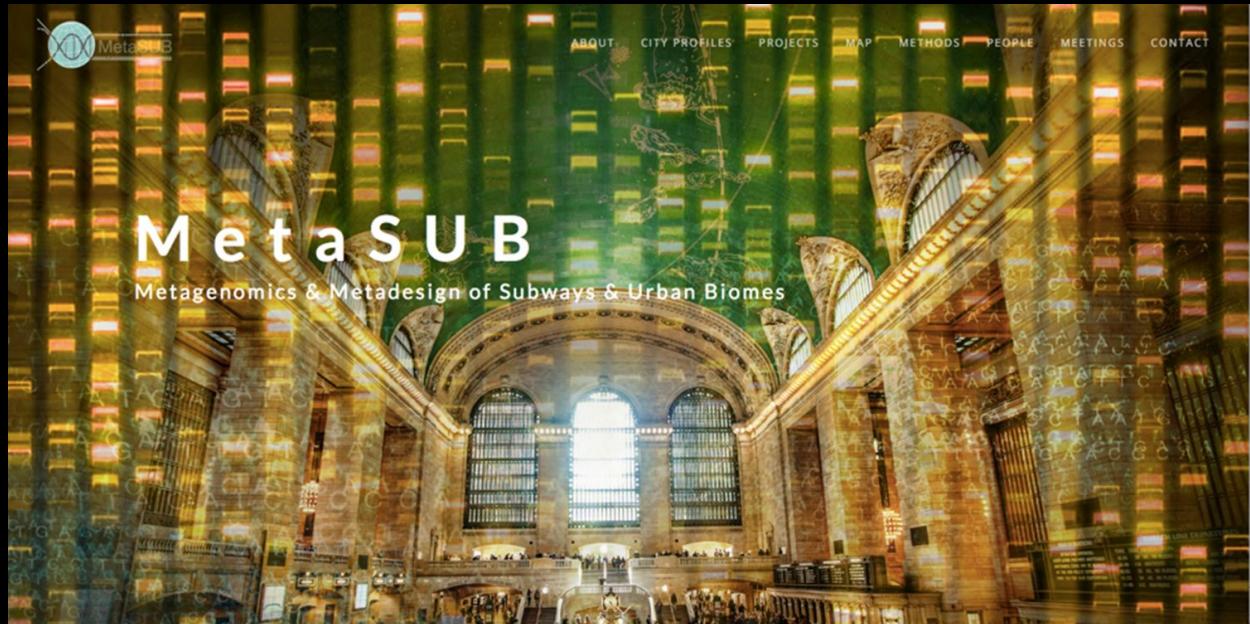




Do cities have a
microbial signature?

MetaSUB: The Global Urban Microbiome Consortium

MetaSUB (est. 2015) is an international research consortium mapping the microbial ecosystems of cities worldwide to understand how urbanization shapes microbial diversity, public health, and planetary biology.





gCSD: Global City Sampling Day

From 2016–2026, MetaSUB conducted coordinated global city sampling to systematically characterize urban microbial communities across major metropolitan transit systems worldwide





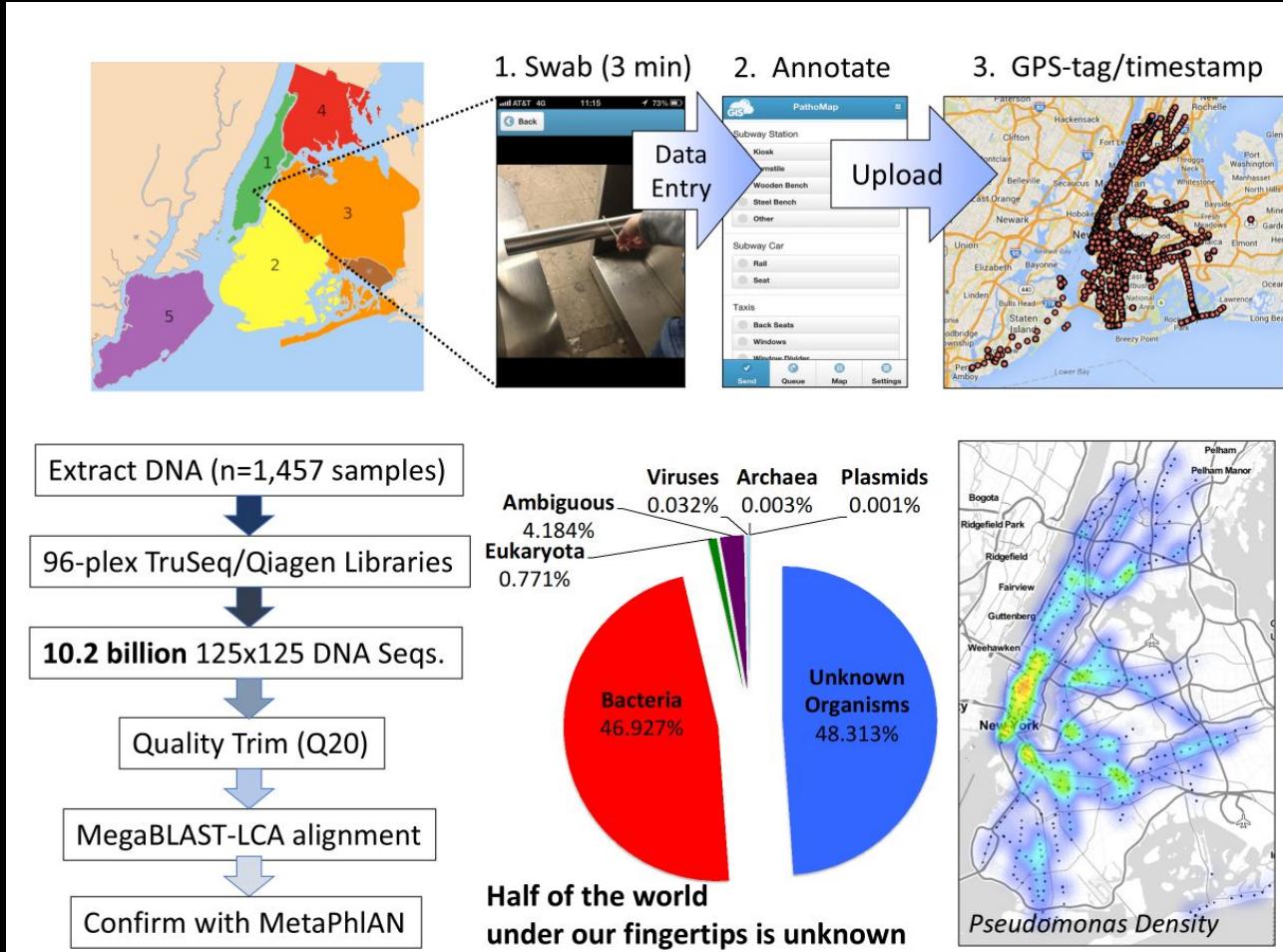


A collage of black and white photographs depicting various scenes from Indonesian society and infrastructure. The images include a man working on a large industrial pipe, a woman in a uniform standing next to a vehicle, a person in a mask looking at a smartphone, and a view of a bridge under construction.

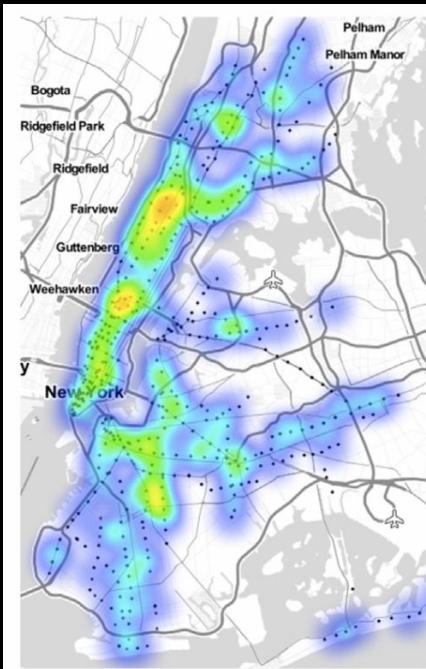
What have we found?

End-to-End Global Urban Metagenomics

A city-wide survey of New York City's metagenome spanning all five boroughs, with samples collected from 466 subway stations across 24 subway lines.



Spatial Patterns and Environmental Perturbations in the NYC Subway Microbiome



Hurricane-Flooded,
Unique species
10
49
All species
578

Uptown &
The Bronx

1



South Ferry
24 hour booth
Elev to mezz

M5
M15
M20

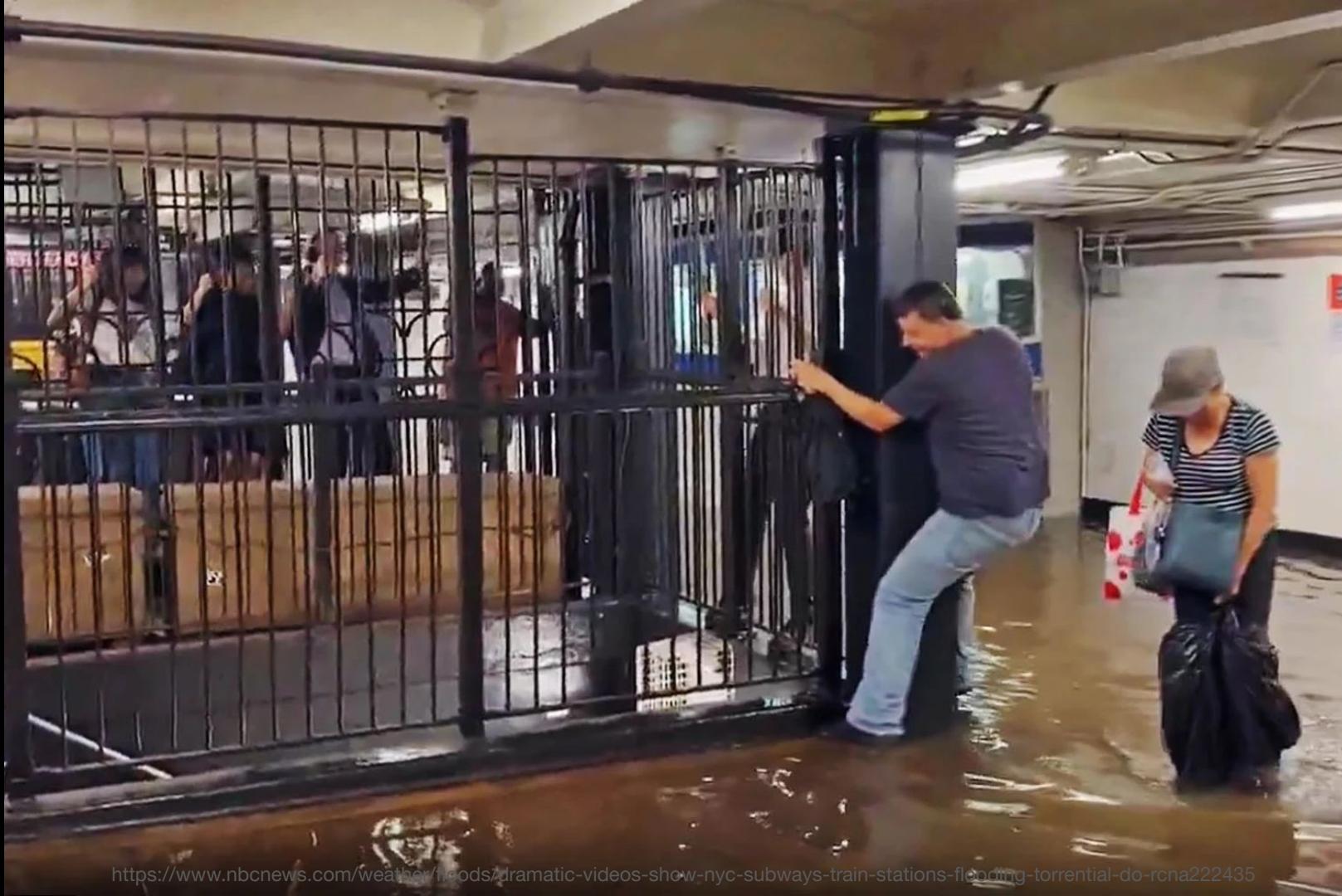
R

FERRY P. HARRIS
FERRY BOOTH
STATUE OF LIBERTY

R50
W13
IVY

H

Ferry to Staten Island &
Statue of Liberty Ellis Island



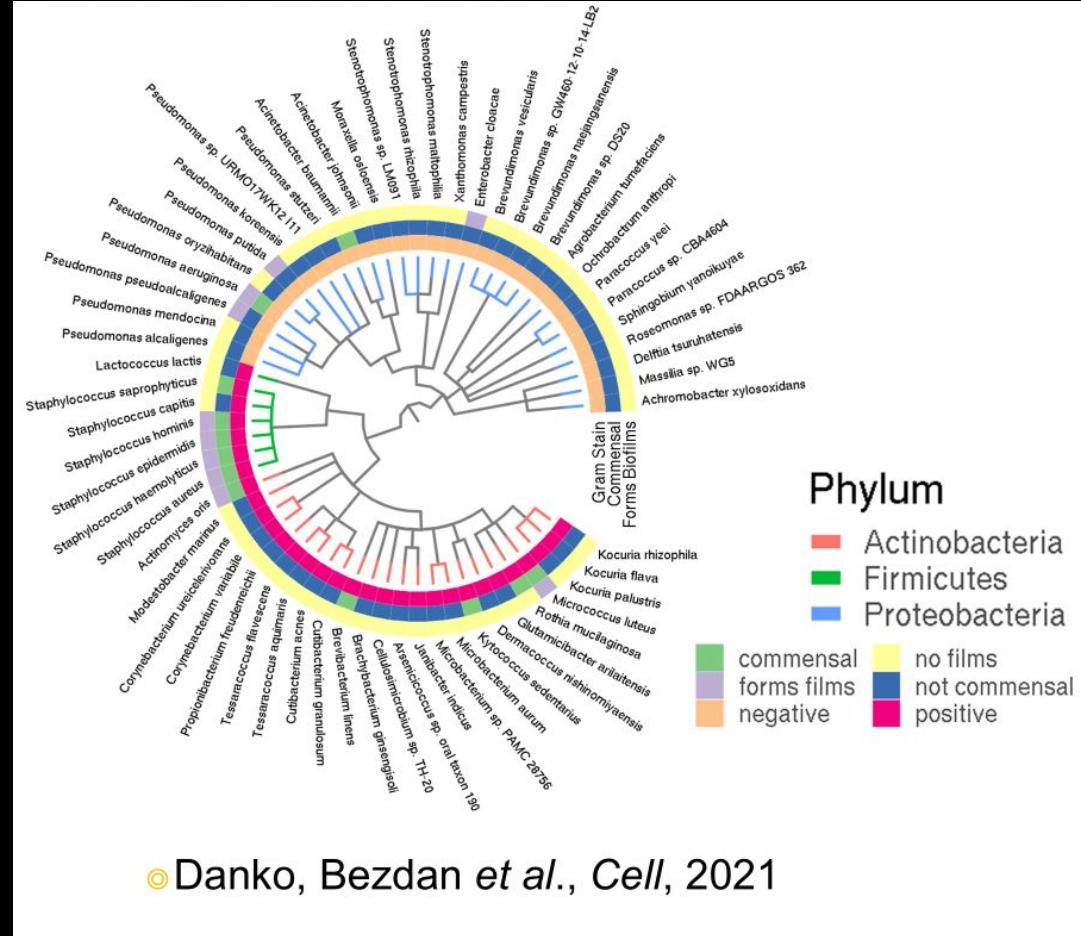
<https://www.nbcnews.com/weather/hoods/dramatic-videos-show-nyc-subways-train-stations-flooding-torrential-do-rcna222435>



<https://ny1.com/nyc/all-boroughs/news/2023/05/29/nyc-weather-rain-state-of-emergency-flood>

A Universal Microbial Signature of Cities

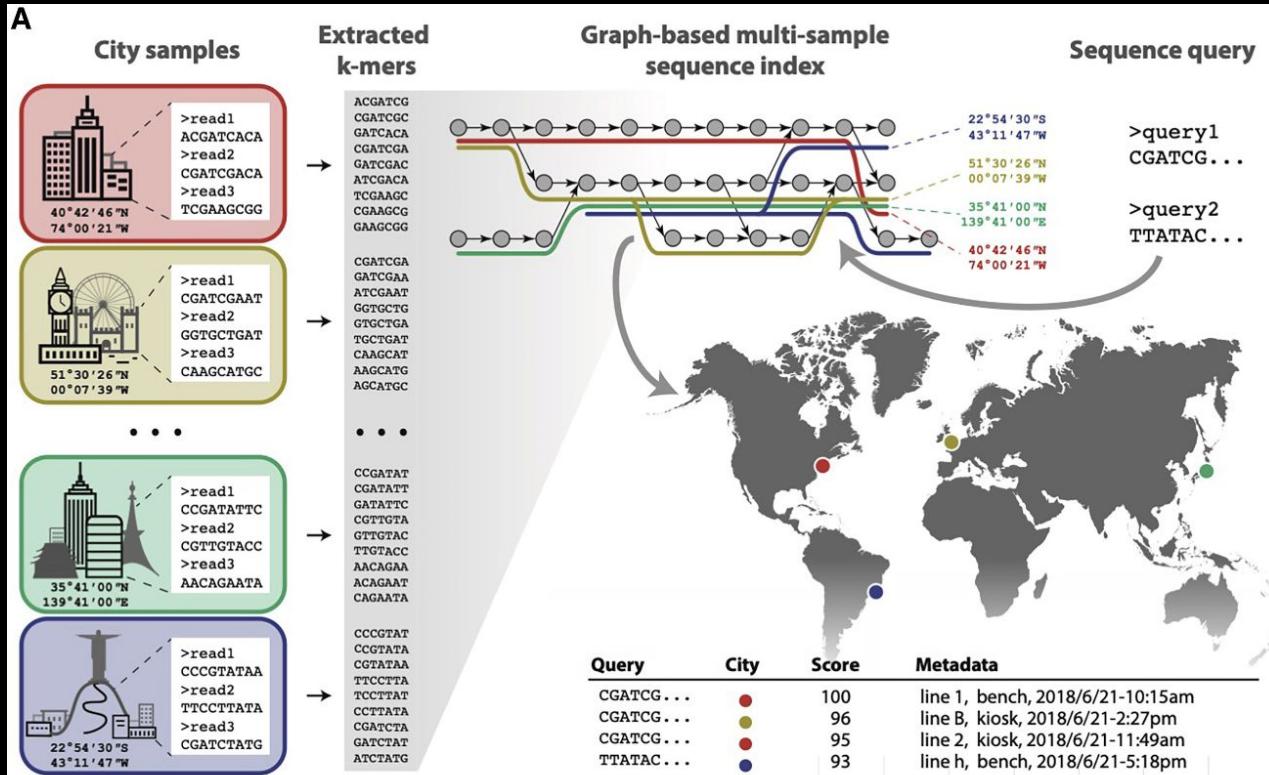
We identified a **core set of 31 microbial species** that appeared in **>97 % of the 4,728 urban metagenomic samples** collected from mass-transit systems across 60 cities worldwide, forming a “urban core” distinct from common human-commensal microbes



◎ Danko, Bezdan *et al.*, *Cell*, 2021

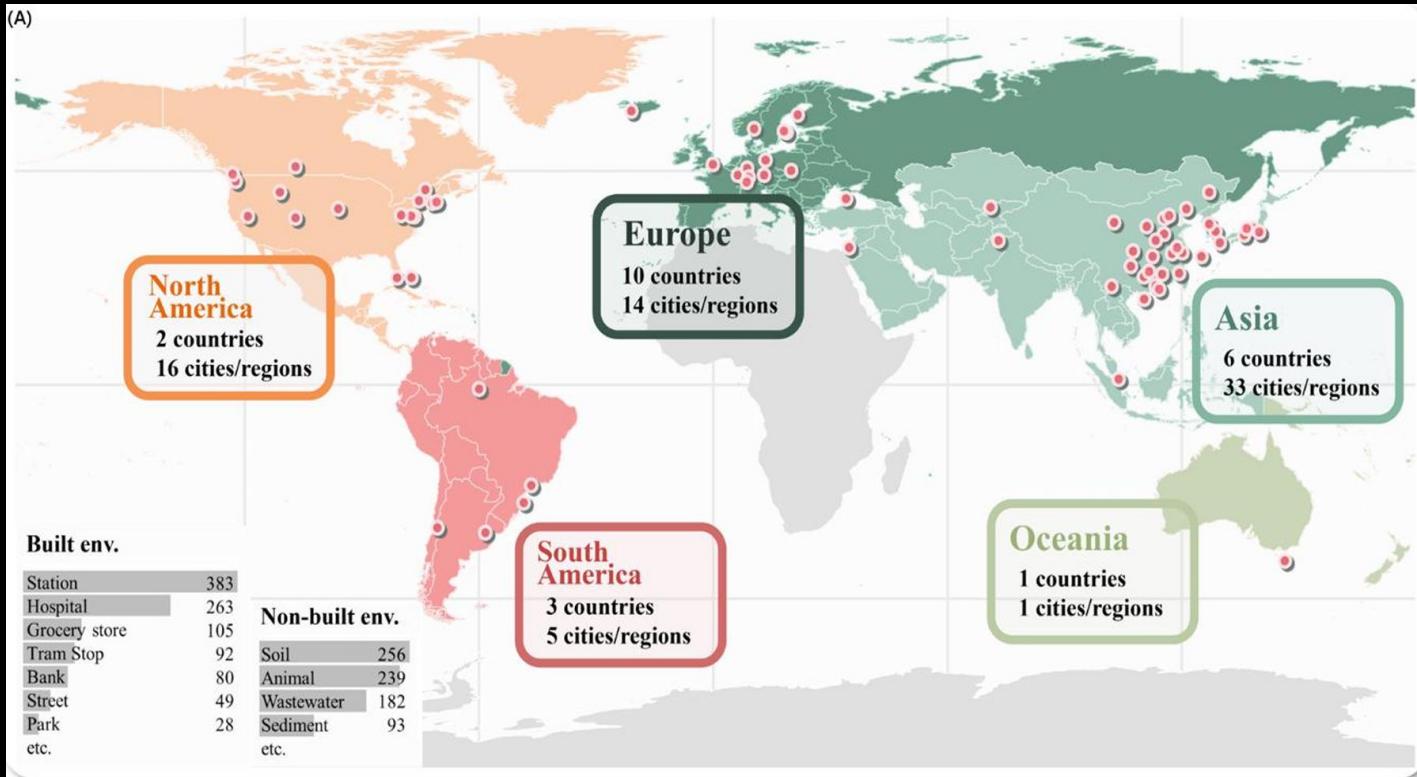
Graph-Based Representation of Global Urban Metagenomes

*City-scale metagenomes are encoded as a **k-mer graph** that enables rapid sequence matching and global origin mapping*



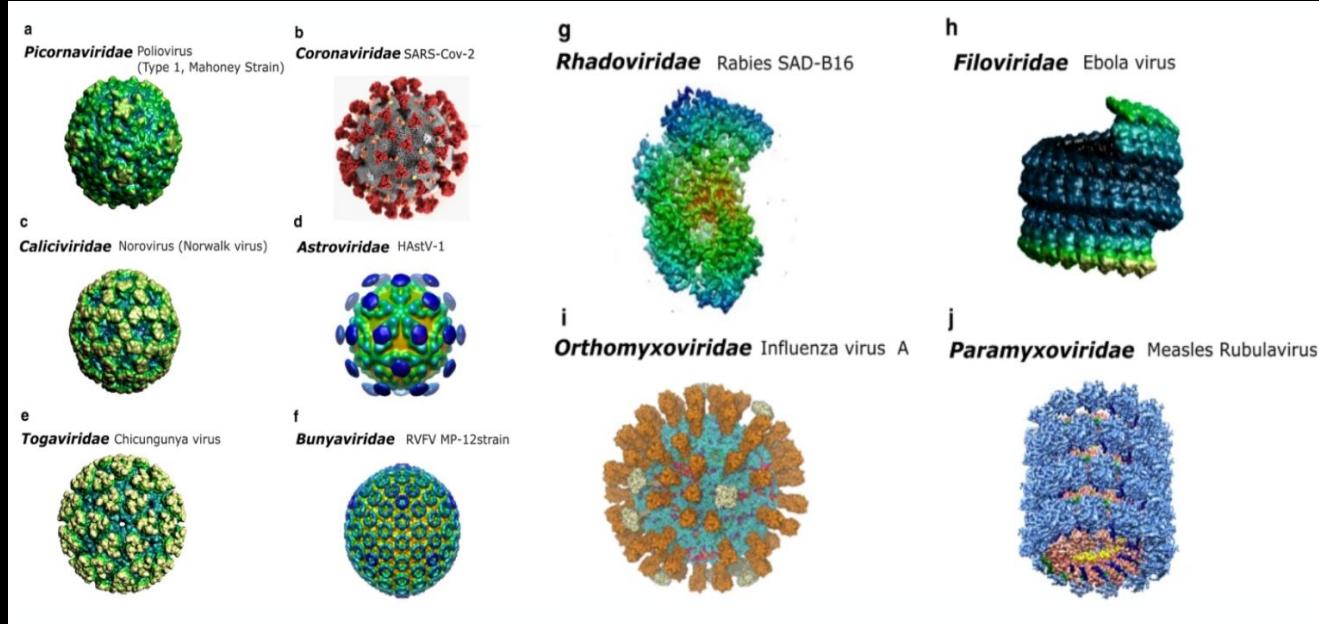
The Urban & Peri-urban RNA Virus Atlas (UPVAtlas)

UPVAtlas maps
54,945 RNA viruses
from 2,922 samples
(collected 1H 2020)
across 102 cities,
revealing urban
RNA viral diversity
was previously
unknown.

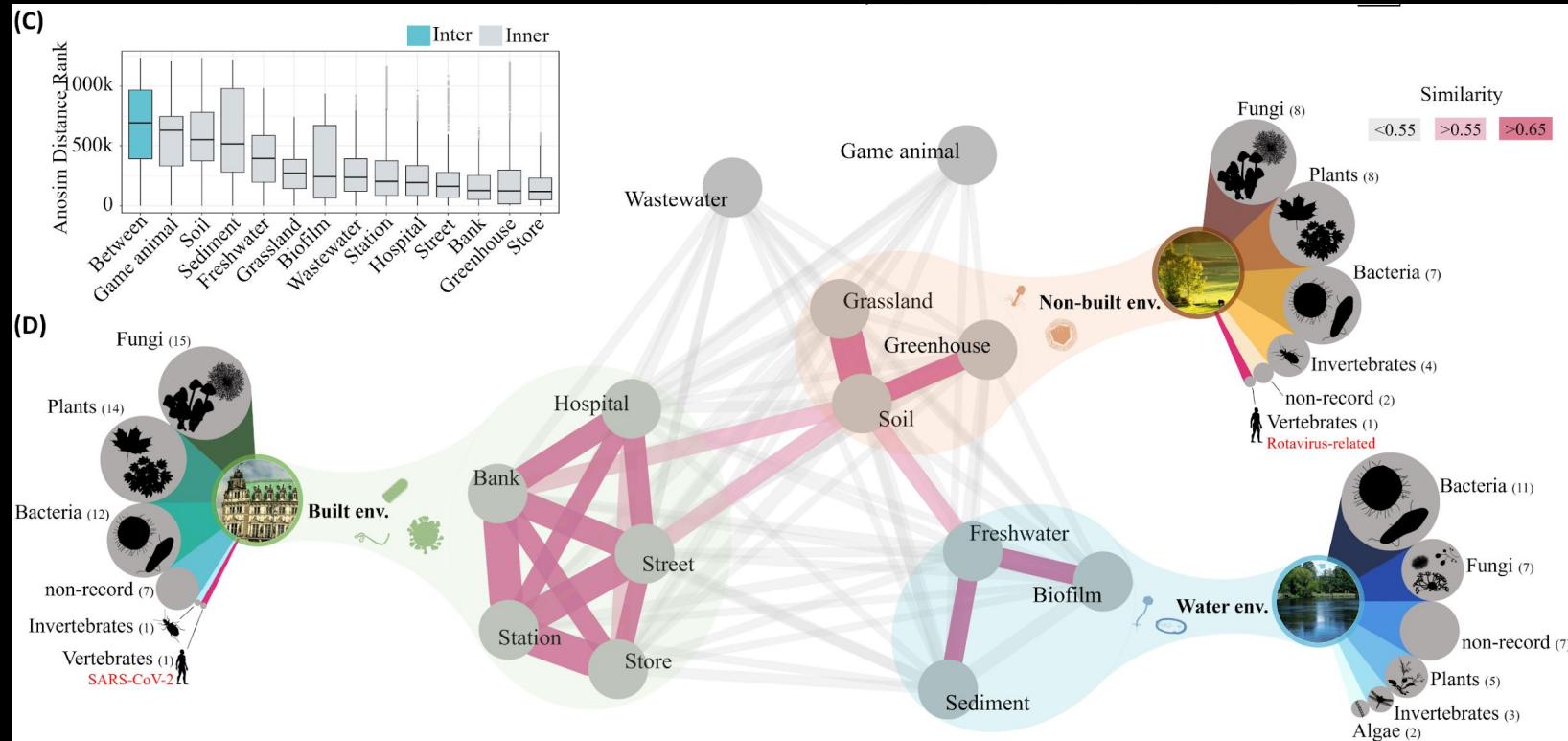


Mapping the Urban RNA Virosphere

RNA viruses matter in cities because they evolve quickly where people, animals, and environments constantly mix, creating early signals of emerging health threats

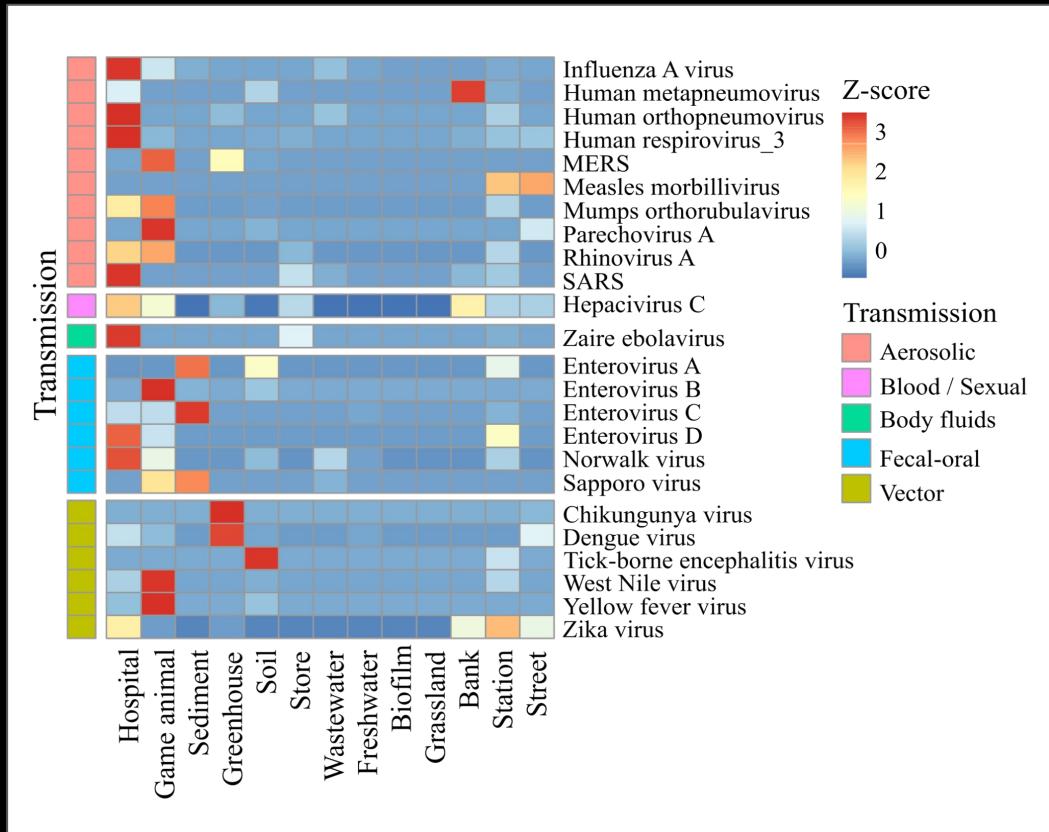


Understanding RNA viruses in Urban Environments



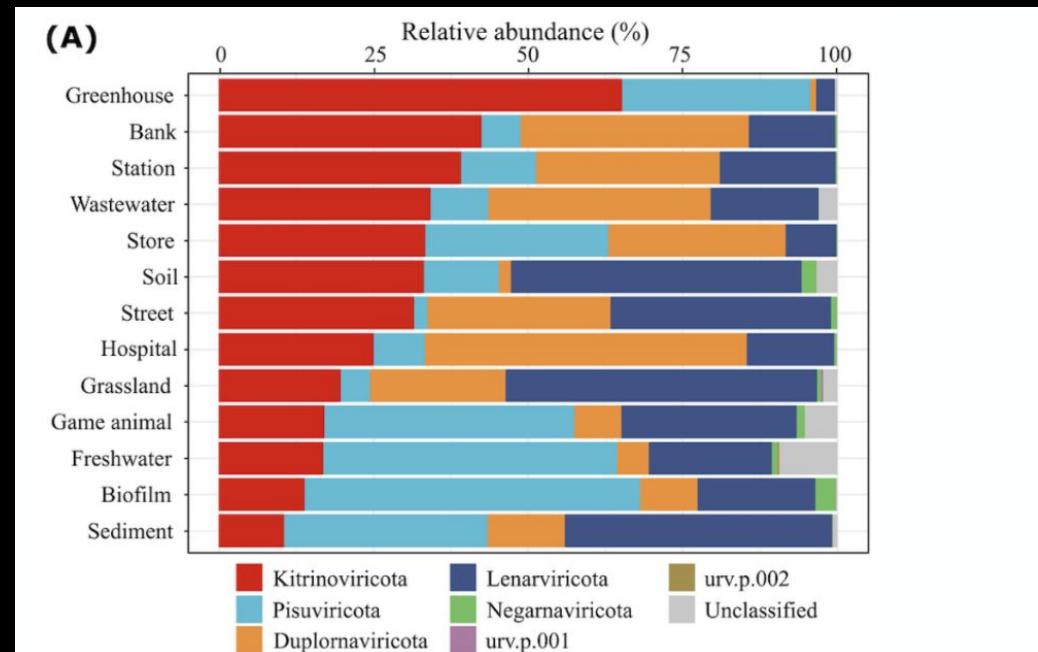
Pathogenic RNA Viruses Across Urban Environments

Human pathogenic RNA viruses vary across distinct environmental settings



UPVAtlas Highlights

- **Deepest metatranscriptomic profiling of global cities to date.**
We examined ~3K samples (collected 1H2020), containing >100B reads to study RNA virus biology in urban environments, their hosts, and pathogenicity.
- **Our analysis uncovered two novel *Duplornaviricota* phyla** supporting the polyphyletic nature of this clade, with support from the published literature (Neri et al., 2022, Zayed et al., 2022).
- **Selection analyses of RdRp identified amino acid sites with directional selective pressures**, this may describe local adaption of viral groups.



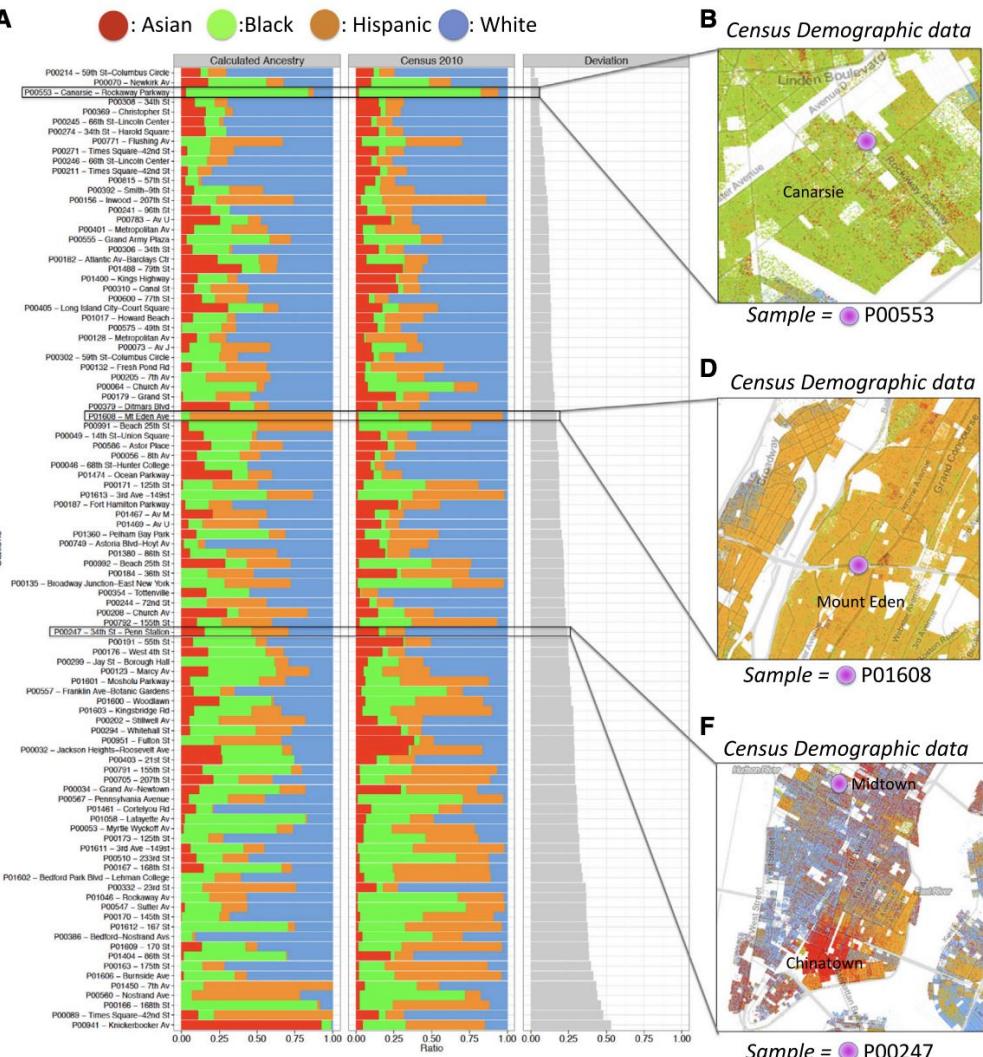
Why This Actually Matters to You

We don't need to sample people to protect people

Human Ancestry Predictions from Subway Metagenomes Mirror Census Data

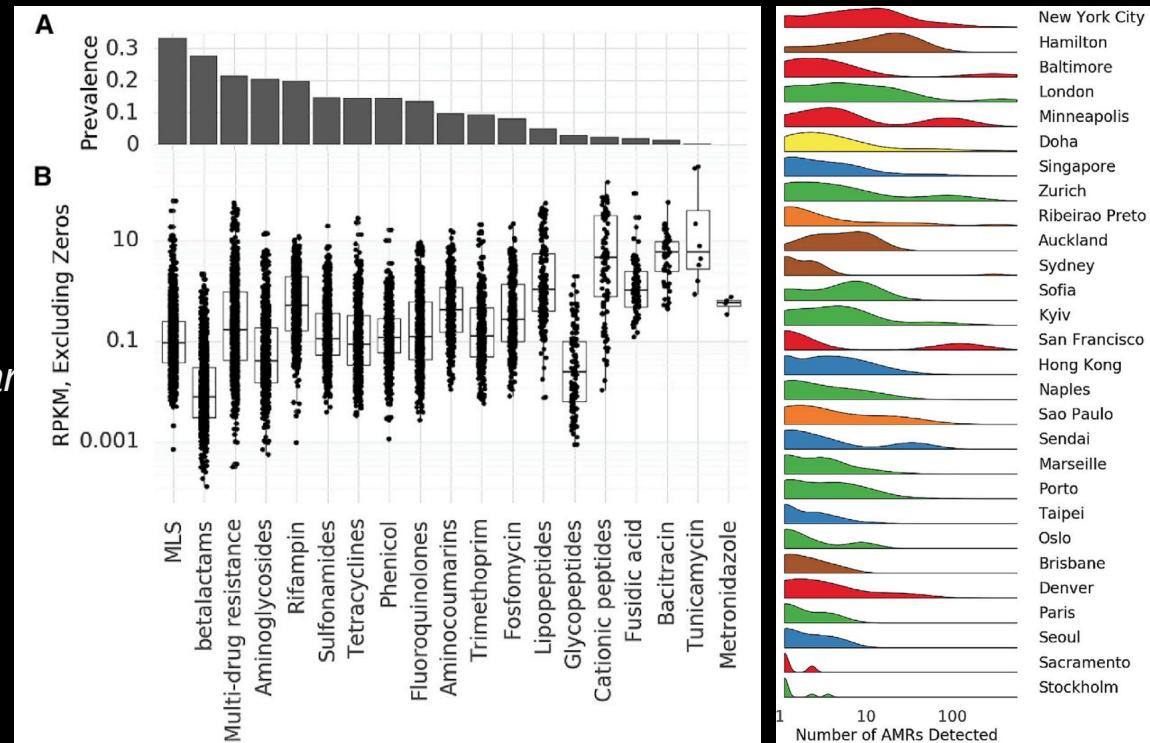
Population-level signals in environmental DNA can reveal where communities may face different disease risks or exposures.

Ethical considerations



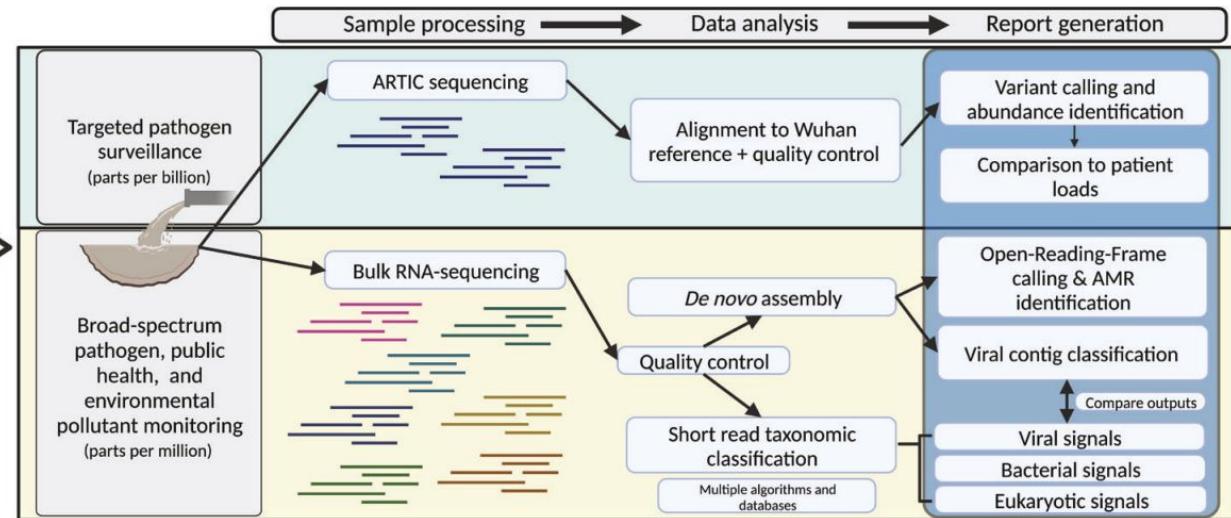
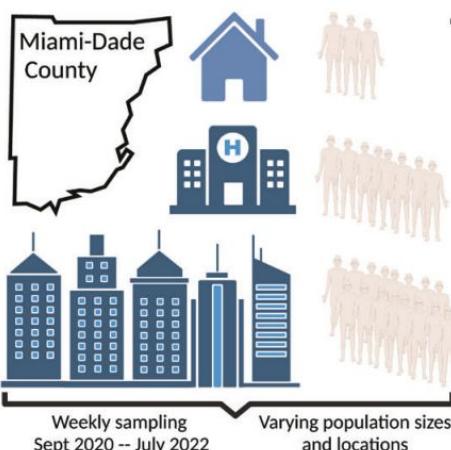
Prevalence of Antimicrobial Resistance (AMR) Genes Across Major Drug Classes

This analysis examines the distribution of AMR genes conferring resistance to particular antimicrobial drug classes.



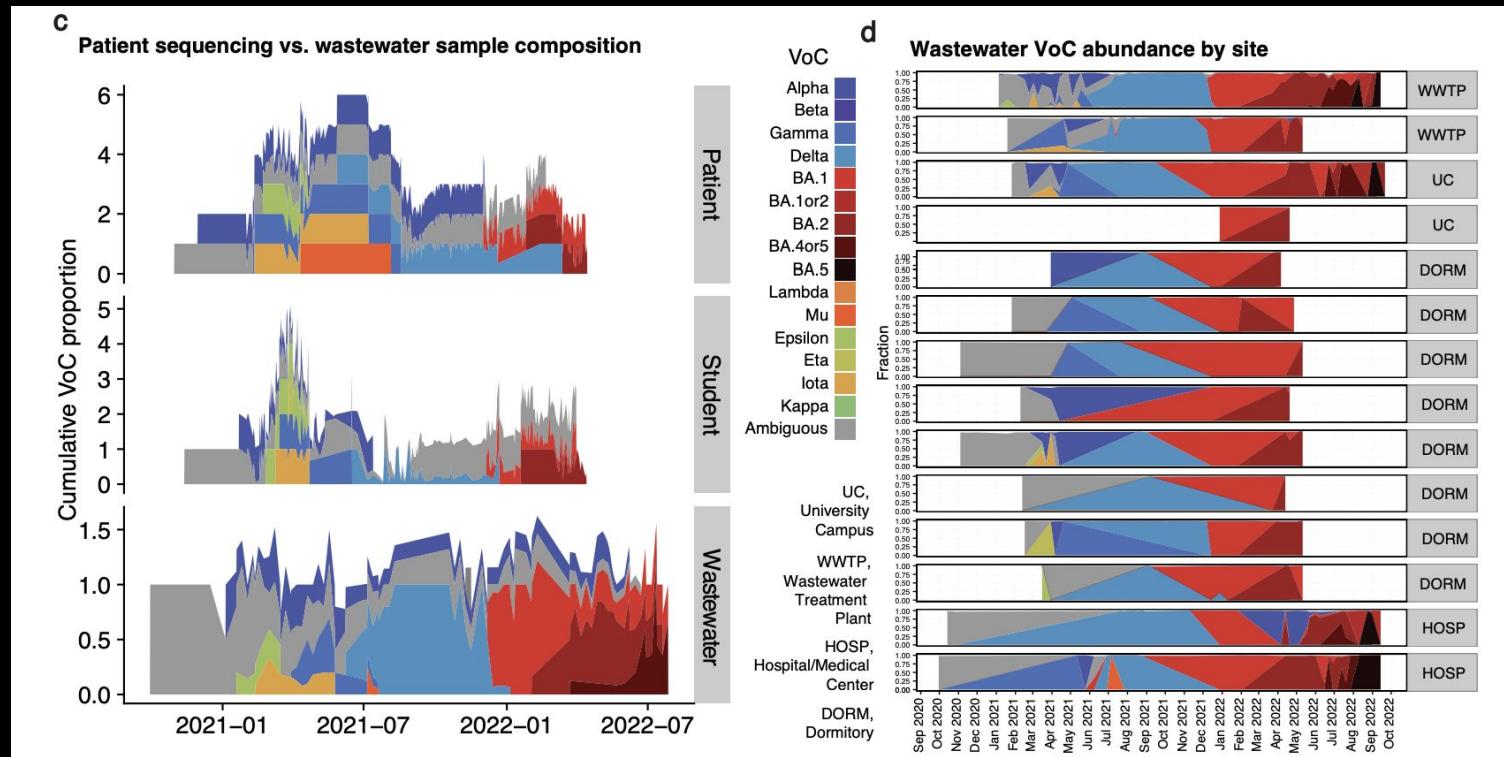
Urban sampling collected in weekly intervals between 2020 and 2022 from 34 sites within Miami-Dade

a



b

Variation in wastewater SARS-CoV-2 VoCs across time in different sampling sites



Wastewater Monitoring in the U.S.

*CDC's Wastewater Program collects and displays wastewater (sewage) data from communities across the United States.
(Image: January 2026)*

Wastewater Data Snapshots

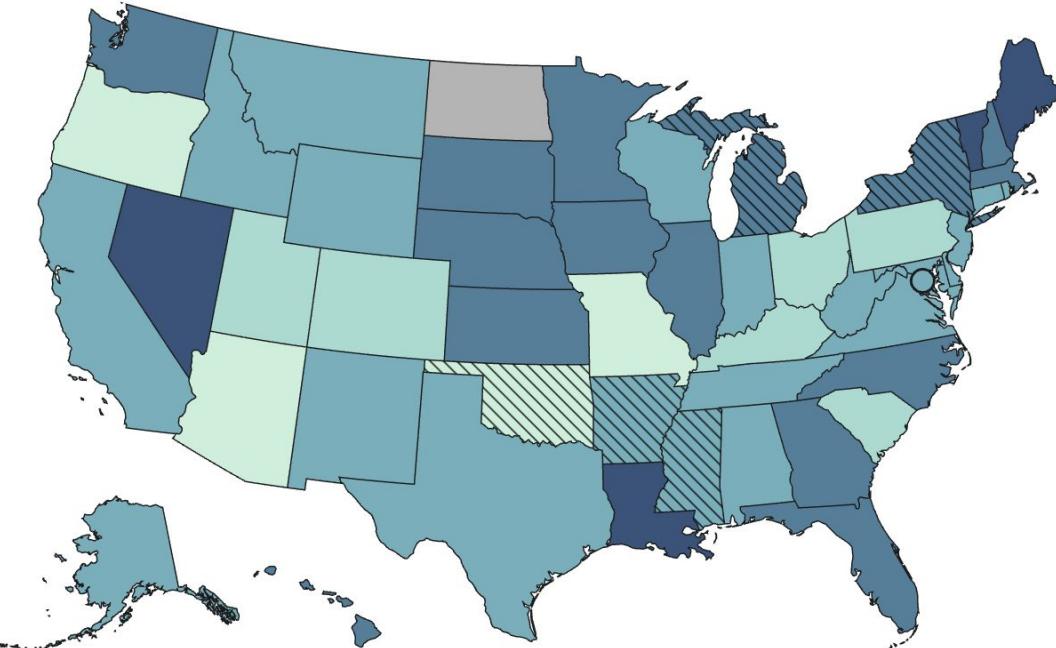
Explore the most recent data for common respiratory pathogens.

Covid-19 Influenza A RSV

Wastewater Viral Activity



⊗ *Limited Coverage



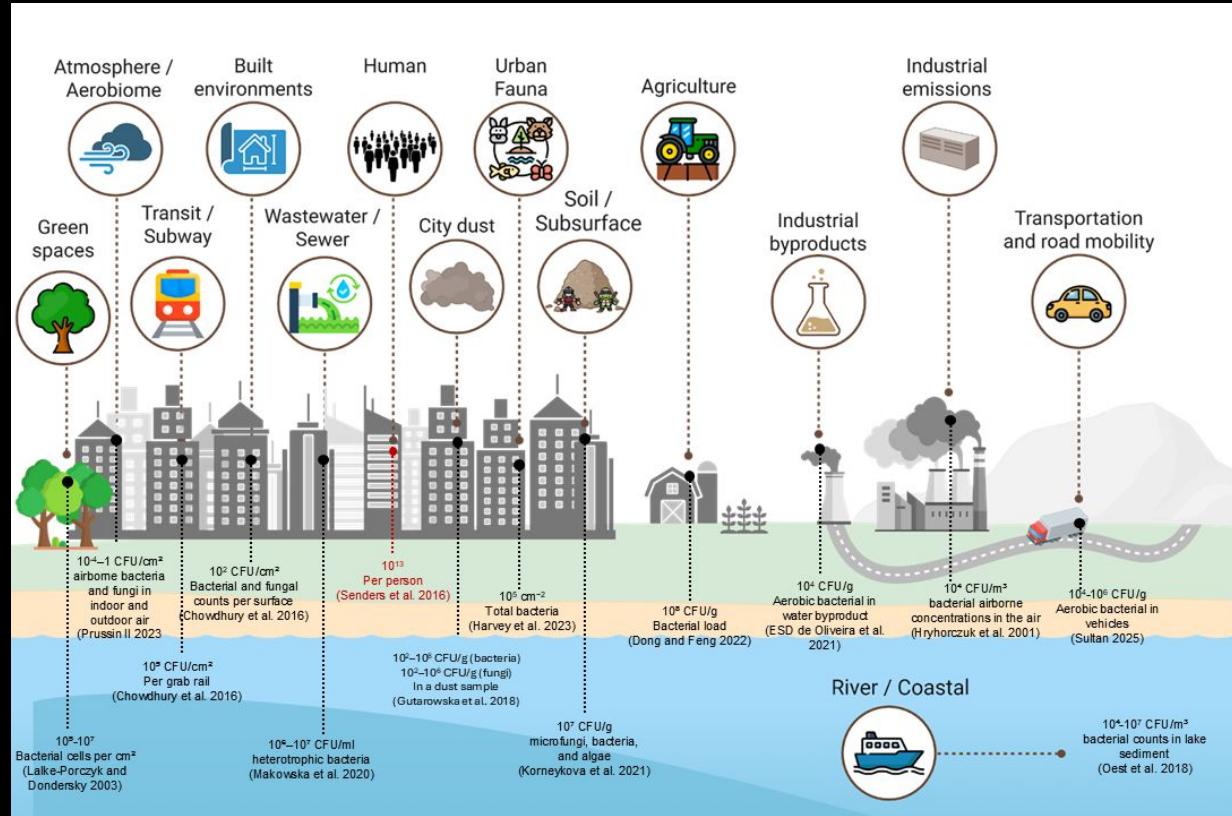
Mapping the Living City





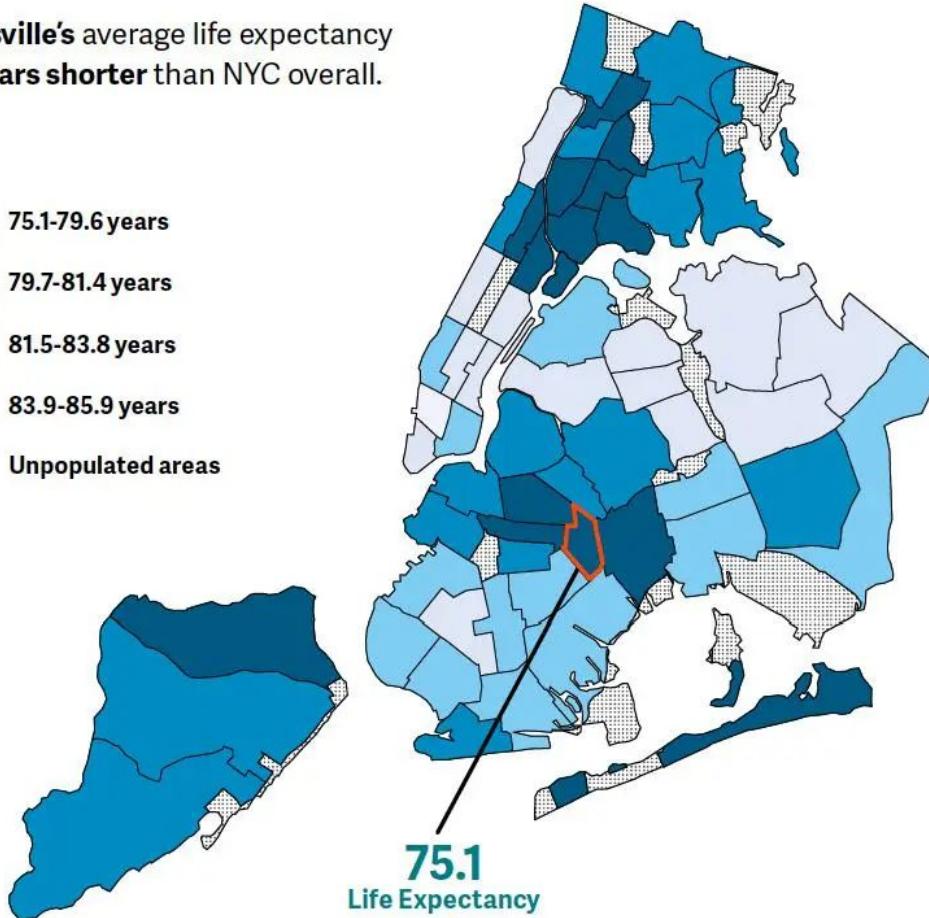
Harnessing the urban microbiome for the future of cities

Cities of the future will be judged not just by air and water quality, but by how well they sustain healthy urban microbiomes



Urban microbiomes are consequential, measurable, and inseparable from the health of the populations that live within them.

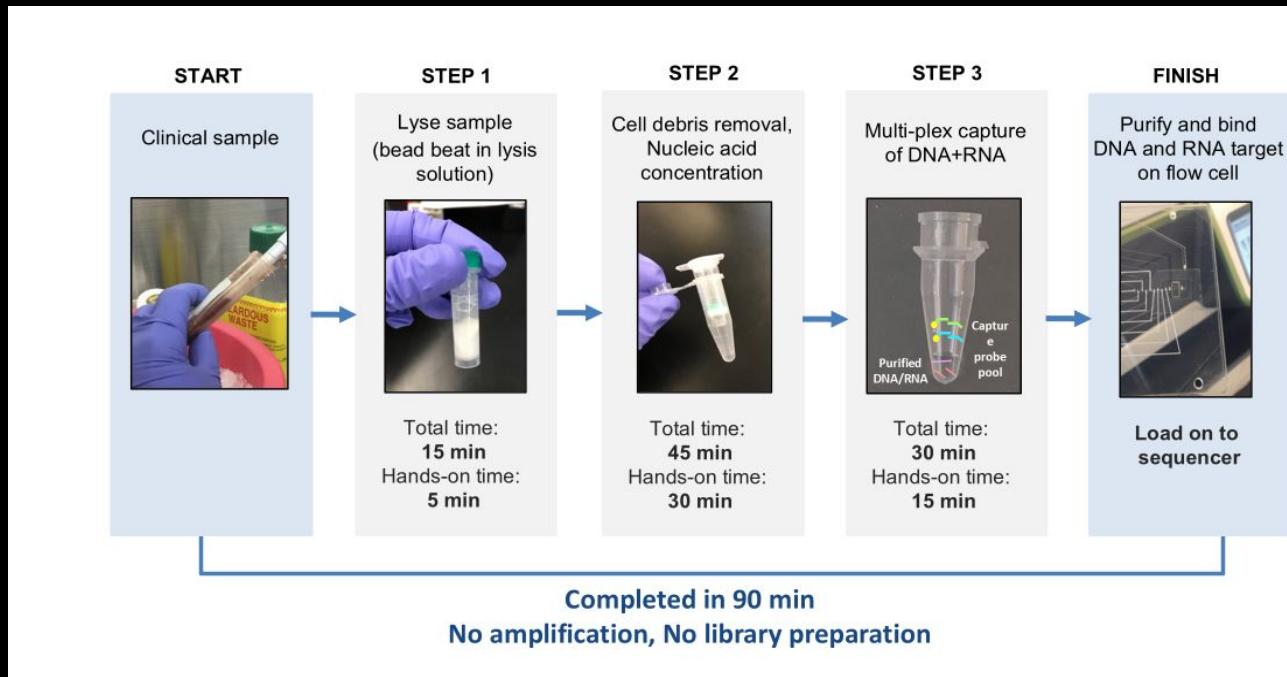
Brownsville's average life expectancy is **6.1 years shorter** than NYC overall.



Source: NYC DOHMH,
Bureau of Vital Statistics, 2006-2015

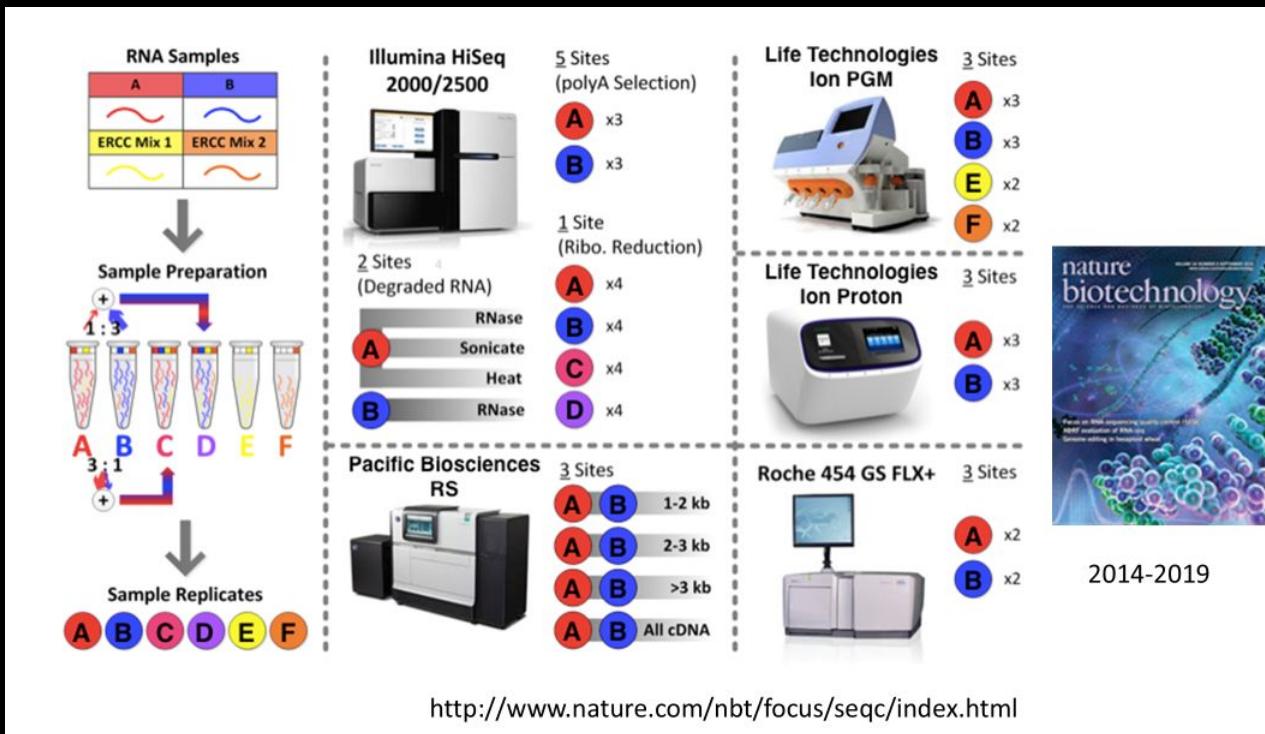
Learning from Clinical Pipelines

*Applying
high-throughput,
standardized clinical
sample processing to
accelerate and scale
microbiome studies.*

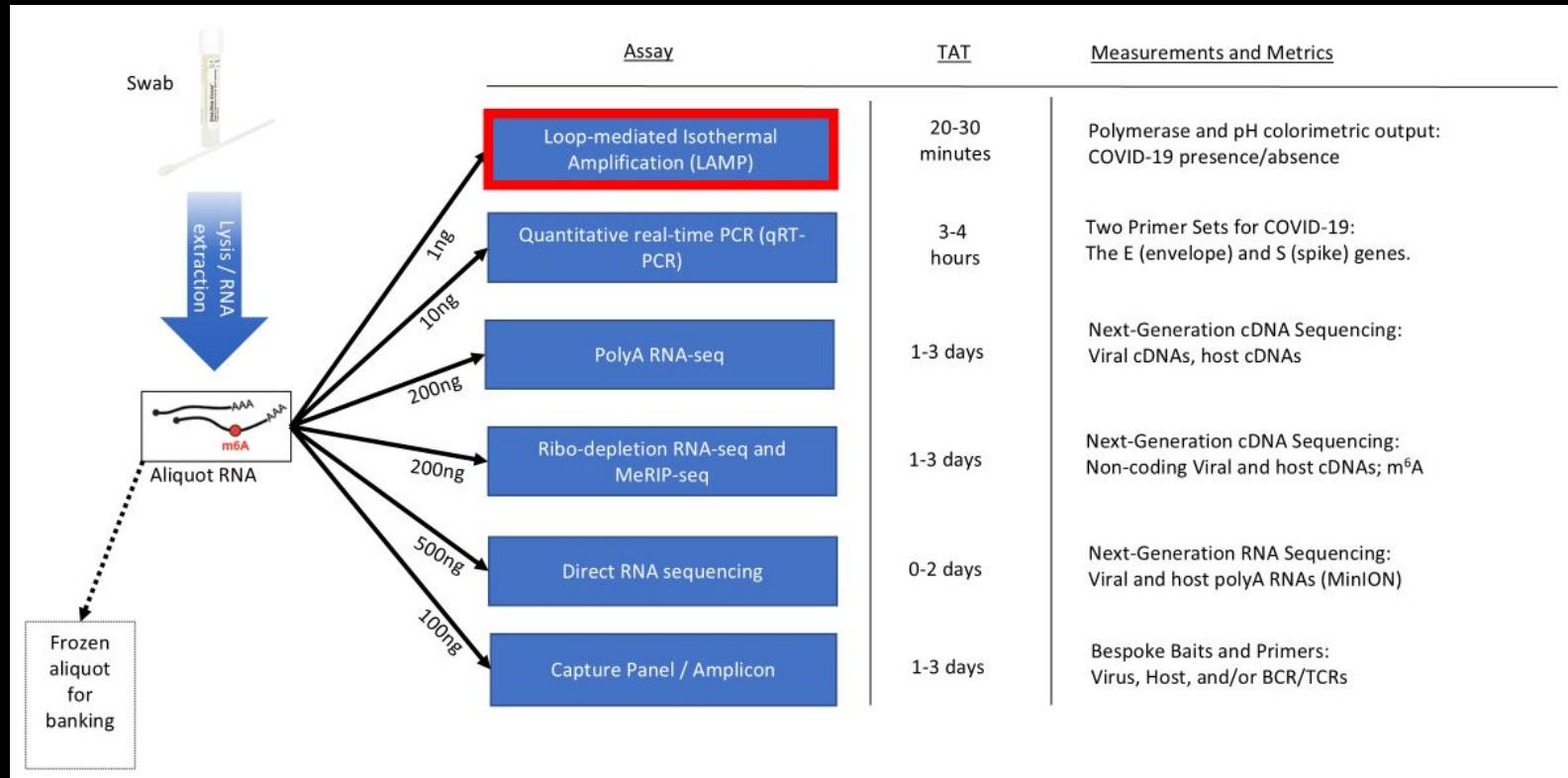


Many Paths to Sequencing

Samples can be profiled using diverse sequencing strategies, each offering different trade-offs in resolution, cost, and biological insight



A Spectrum of Molecular Techniques



Planetary Genomics





Mars Sample Return

Mars Sample Return would be NASA's most ambitious, multi-mission campaign that would bring carefully selected Martian samples to Earth for the first time.

• FUTURE MISSION

[Mission Concept](#) →

[Mars Rock Samples](#) →

[NASA to Explore Two Landing Options](#) →

Get involved! Visit metasub.org

<https://bit.ly/MetaSUB>



Additional ongoing projects: metasub.org/projects

METACATS: DOMESTIC CAT CORONAVIRUSES & MICROBIOME

The MetaCats Project aims to study the prevalence of SARS-CoV-2 and other coronaviruses in domestic cats, along with their microbial communities or microbiomes. Studies suggest that cats may be more permissive to the SARS-CoV-2 virus infection, however lack of field studies leave a lack of understanding to the transmissibility of the virus in these animals.

2020 – Present

[READ MORE ➔](#)



OLYMPIOME: OLYMPIC GAMES SAMPLING

As a part of a global consortium to monitor cities, the aim of the project is to pioneer the first-ever, city-scale collection and measure of the Olympics, dubbed the Olympiome. The project will track the localization, transit, and persistence of these visitors' metagenomes and determine where they colonize and change the local urban metagenome of the host city, including the presence and the fluctuations of medically relevant entities such as anti-microbial resistance markers (AMRs) and phages.

2016, 2021

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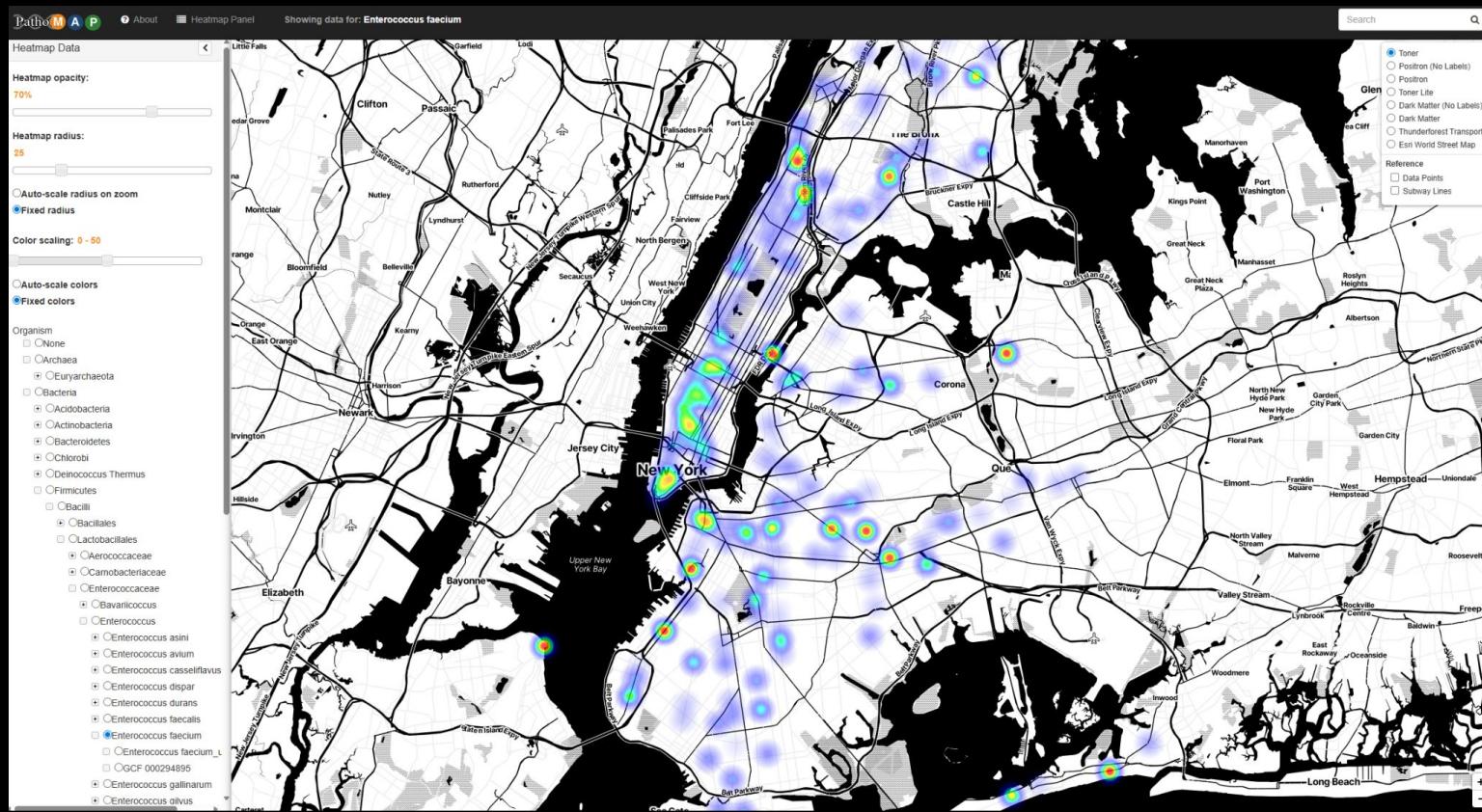
THE EXTREME MICROBIOME PROJECT

The Extreme Microbiome Project (XMP) is a project launched by the Association of Biomolecular Resource Facilities Metagenomics Research Group (ABRF MGRG) that focuses on whole genome shotgun sequencing of extreme and unique environments using a wide variety of biomolecular techniques.

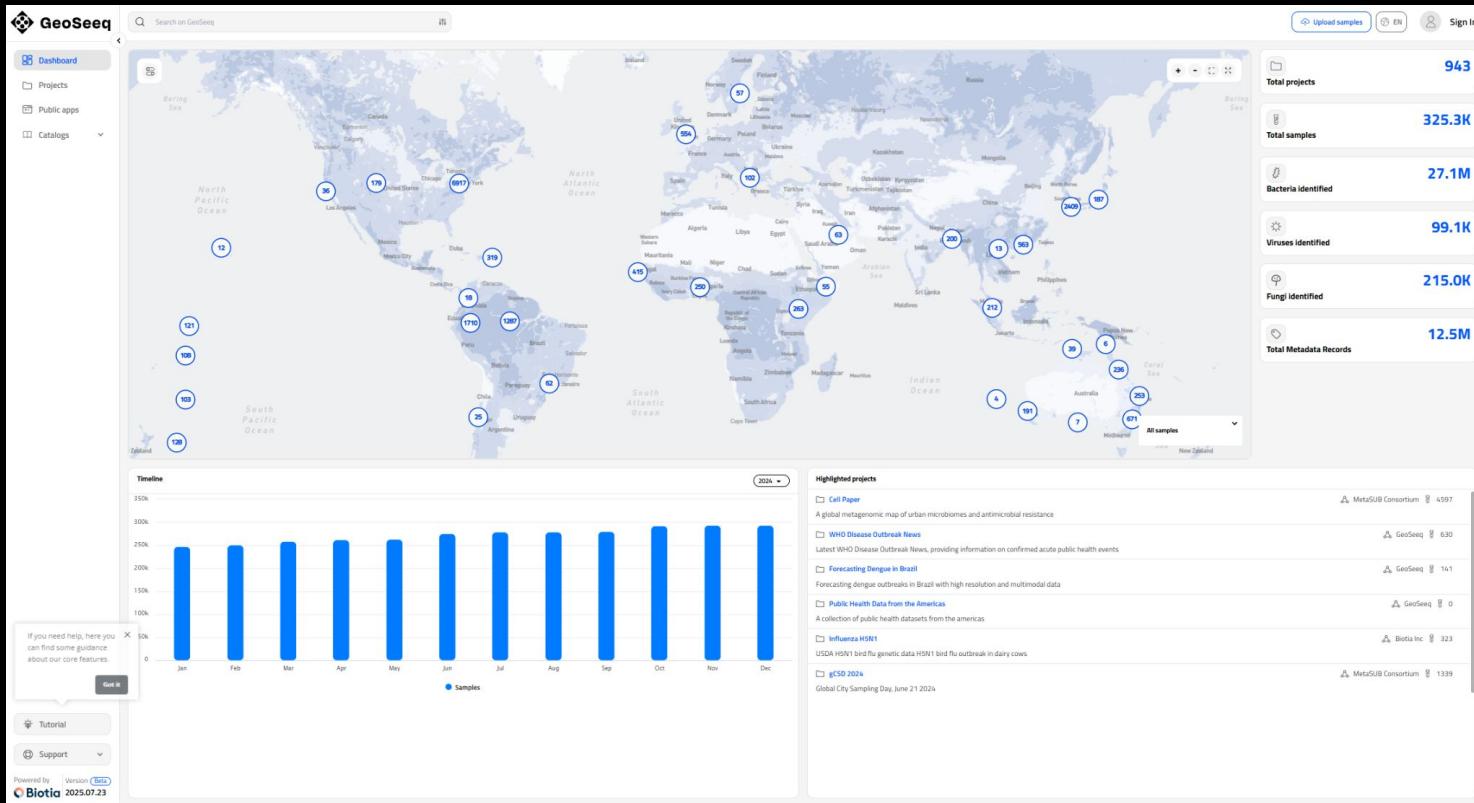
2014 – Present

[READ MORE ➔](#)

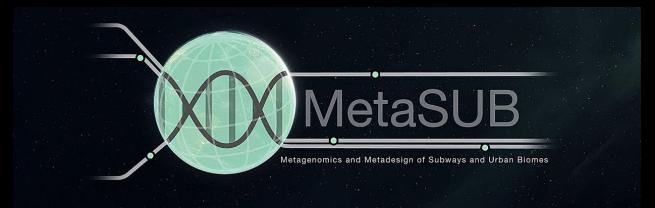
Resources: pathomap.org/map



Resources: portal.geoseeq.com



Thank you to all members of the Mason lab!



**Weill Cornell
Medicine**