



Better Food. Better Health. Better World.

# eDNA Soil microbiome and One Health Approach

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# Environmental DNA

## 1 What is eDNA?

Environmental DNA refers to genetic material obtained from environmental samples without requiring direct sampling of organisms. Sources include cells, tissues, secretions, excretions, and decomposing material shed by organisms into their environment.

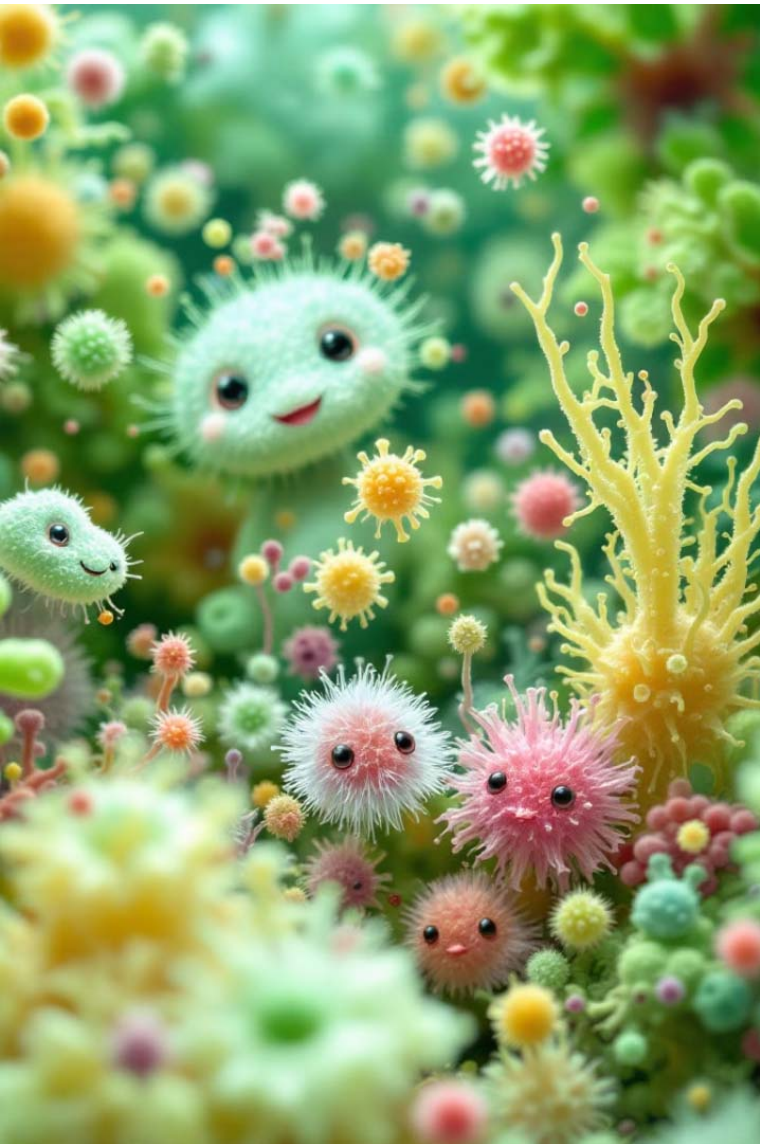
## 2 Sample Collection

eDNA sampling involves collecting water, soil, air, or sediment from ecosystems. Collection methods vary by habitat type, with water filtration being common in aquatic environments and specialized extraction techniques for soil and sediment samples.

## 3 Advantages Over Traditional Methods

- High Sensitivity – Detects even trace amounts of DNA.
- Non-Invasive – No need to capture or disturb organisms.
- Cost-Effective – Reduces fieldwork time and labor.
- Rapid Analysis – Faster than traditional biodiversity assessments.
- Long-Term Monitoring – Enables real-time tracking of ecosystem recovery





# The Community of Life

## Microbiota

Microbiota refers to the collection of microorganisms within a specific environment. It includes bacteria, archaea, fungi, protists, and viruses, representing the diverse array of life forms at a microscopic level. The composition can vary greatly depending on environmental factors such as pH, temperature, and nutrient availability.

## Microbiome

The microbiome is more than just the sum of microbial inhabitants; it encompasses the entire ecological niche, including the microbiota, their combined genetic material, and the surrounding environment. It emphasizes the functional roles of these microorganisms, focusing on their metabolic activities and interactions within the ecosystem, providing a comprehensive view of ecosystem processes.

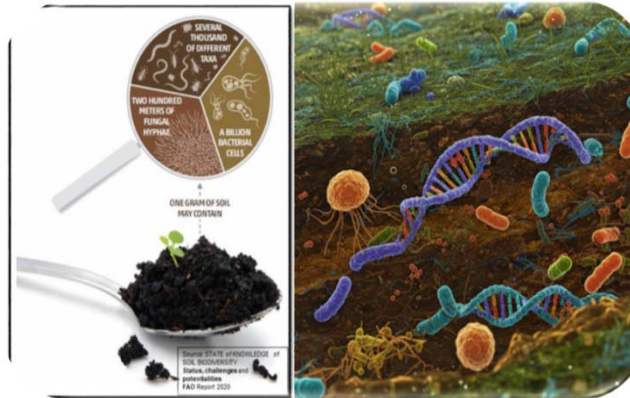


# Soil Microbiome: Biodiversity



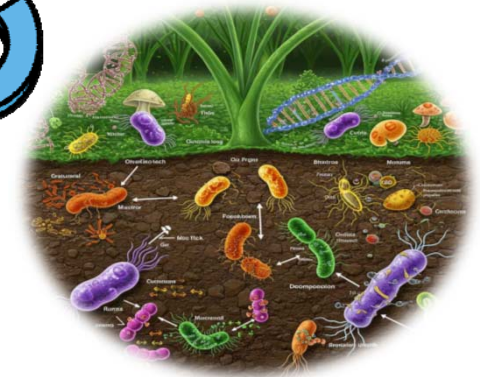
Functional Diversity

Nutrient Cycling & Contaminant degradation



Taxonomic Richness

Millions of species per gram, Genetic Reservoir  
Vast untapped genomic resources

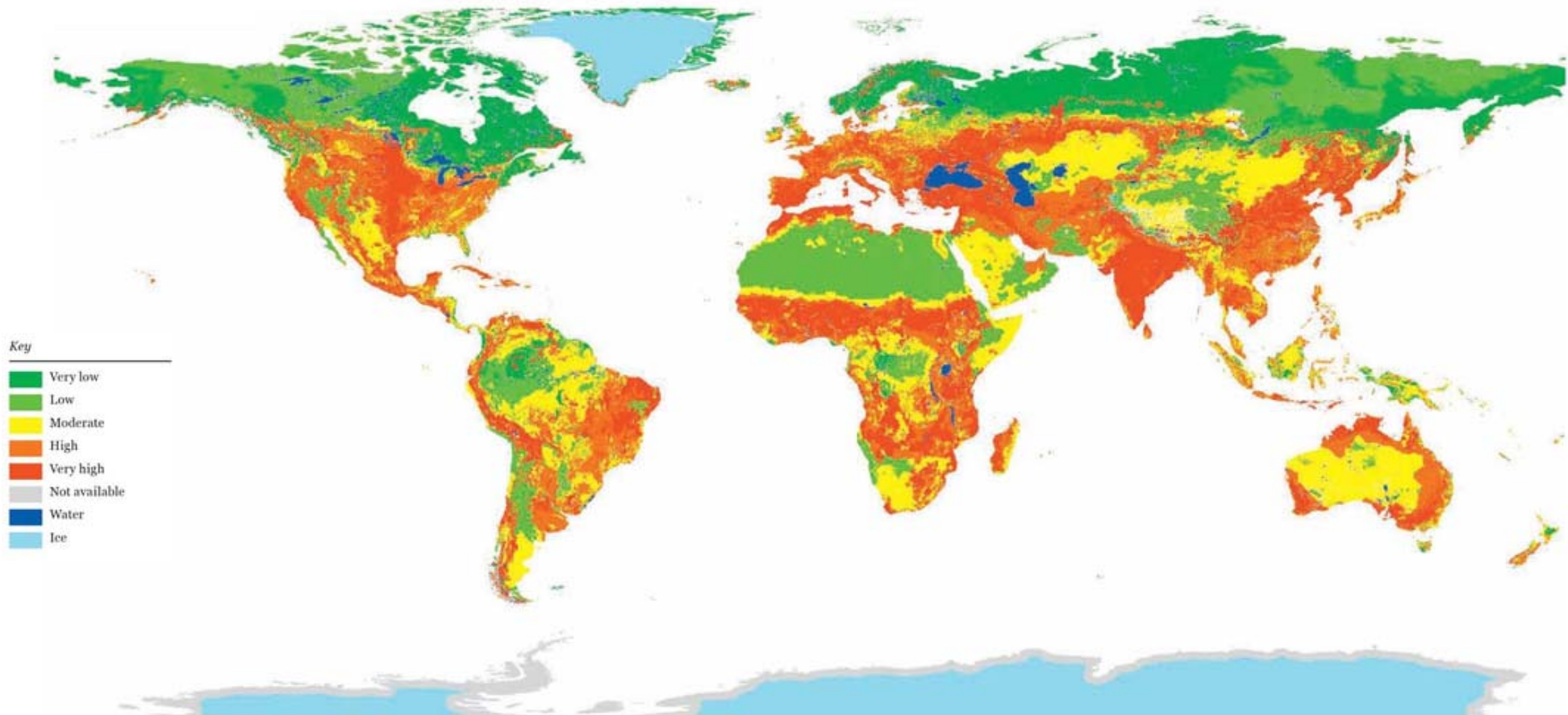


Microbial Communities

Networks of interdependent species

Soil microbiome and its biodiversity are fundamental to the functioning of soil ecosystems, supporting various processes that are essential for soil health and overall environmental sustainability. The more diverse the microbial community, the more resilient the soil becomes, with the capacity to perform essential ecological services over the long term.

# Threats to soil biodiversity



# One Health: Interconnections

## What is One Health?

- The One Health concept recognizes the interconnection between human health, animal health, and environmental health.
- By applying this framework, researchers and practitioners aim to create more effective, cross-disciplinary health policies and interventions that account for the environment, human health, and animal health simultaneously.



## Why One Health is Important

The One Health approach can: prevent outbreaks of zoonotic disease in animals and people. Improve food safety and security. Reduce antimicrobial-resistant infections and improve human and animal health.

# Linking Soil Microbiome to One Health

The soil microbiome is essential for the health of all living things.  
Mainly healthy soil supports plant growth, providing nutritious food for humans and animals



**Plant Health:** soil microbes enhance plant growth by improving nutrient absorption, protecting against diseases, and supporting root development.



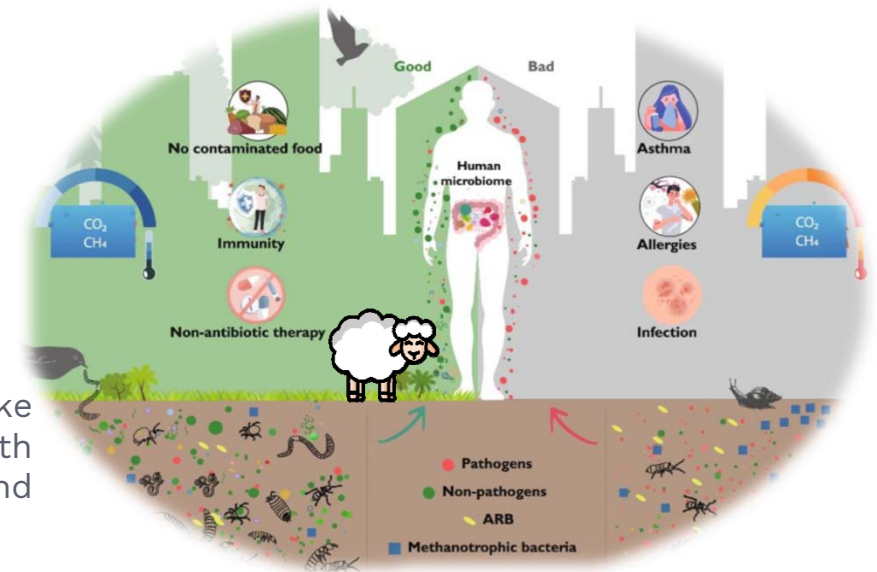
**Animal Health:** grazing animals interact with soil microbes, which influence their digestion, immunity, and health. Soil can also harbor pathogens.



**Human Health:** exposure to soil microbes (through activities like gardening) affects our microbiome and immunity. Soil health impacts food quality, but soil can also carry pathogens and antibiotic resistance genes.



**Environmental Health:** soil microbes aid carbon sequestration, nutrient cycling, and pollutant degradation, supporting ecosystem balance.



<https://news.flinders.edu.au/blog/2023/02/20/26002/>



# Factors impacting the Soil Microbiome

## Climate Change

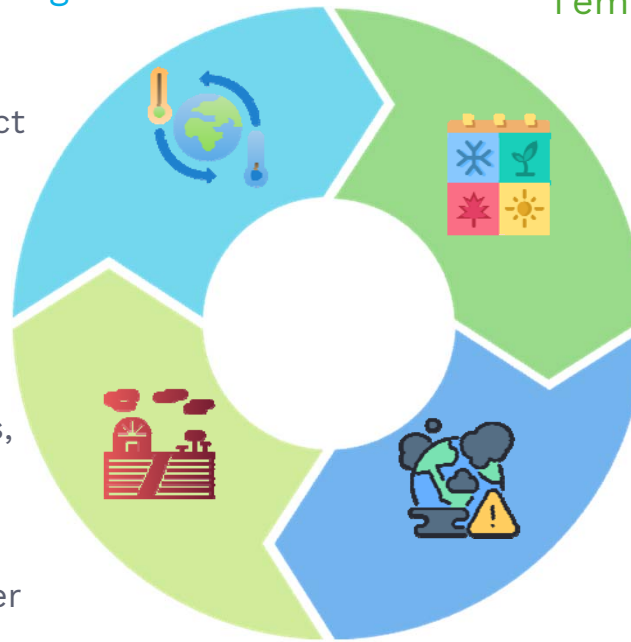
Climate change, including changes in temperature and precipitation patterns, can have a significant impact on the soil microbiome.

## Temporal variability

Seasonal Changes: temperature and moisture fluctuations influence microbial dynamics throughout the year.  
Successional Changes: over time, microbial communities evolve due to changes in vegetation, organic matter, and soil conditions..

## Human activities

Agricultural Practices: use of fertilizers, pesticides, and crop rotation impacts microbial diversity and soil health.  
Land Use Changes: deforestation, urbanization, and land degradation alter microbial habitats.



## Pollution

Pollution, including heavy metals, industrial chemicals, and Polymer-Based Materials contamination disrupt microbial communities.  
The two main sources of microbiome degradation are Agro Chemicals and Plastics.

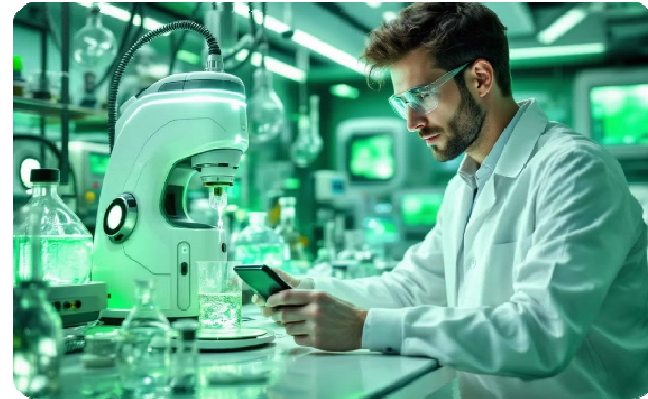


# eDNA – Applications in soil microbiome



## Biodiversity Assessment

eDNA analysis provides a rapid and non-invasive method for assessing biodiversity. It can identify unknown microbial species, beneficial and pathogenic organisms, track changes in community composition over time and identify potential threats to soil health.



## Functionality Assessment

eDNA analysis reveals the functional roles of microbial communities in soil (e.g. nitrogen fixation, organic matter decomposition, contaminant degradation). The functionality assessment is essential for understanding soil productivity, resilience, and sustainability. By eDNA we can also monitor the spread of antimicrobial resistance genes in soil, a potential health threat.

# Metagenomic Approaches to eDNA Analysis

- 1 Targeted Sequencing - Metabarcoding**  
Uses PCR amplification of specific genetic markers (e.g., 16S rRNA for bacteria, COI for animals, ITS for fungi) to identify taxonomic groups of interest. This approach is highly sensitive for detecting specific taxa but limited to detecting organisms that contain the target sequence.
- 2 Shotgun Metagenomics**  
Sequences all genetic material in a sample without targeting specific regions. This provides a comprehensive view of community composition and functional potential. While more expensive, it yields greater taxonomic resolution and functional insights.
- 3 Long-read Sequencing**  
Technologies like Oxford Nanopore and PacBio generate longer sequence reads that improve taxonomic assignment accuracy and facilitate genome assembly from complex communities. These technologies are particularly valuable for resolving closely related species.



# Metagenomic: data analysis

Bioinformatics uses computing and statistics to analyze biological data, especially genetic information, to uncover insights in genomics and other biological fields.



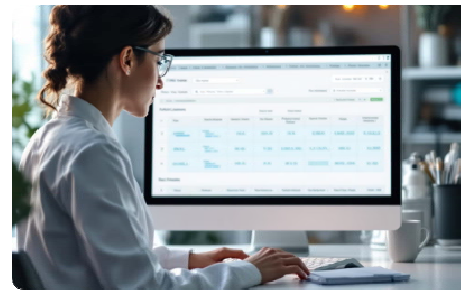
## Quality Control

Filtering to remove low-quality reads and artifacts.



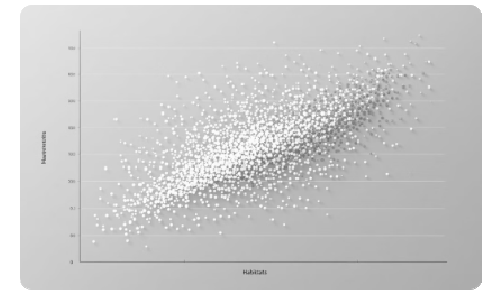
## Sequence Processing

Clustering sequences into OTUs for analysis.



## Taxonomic Assignment

Comparing sequences against databases for classification.



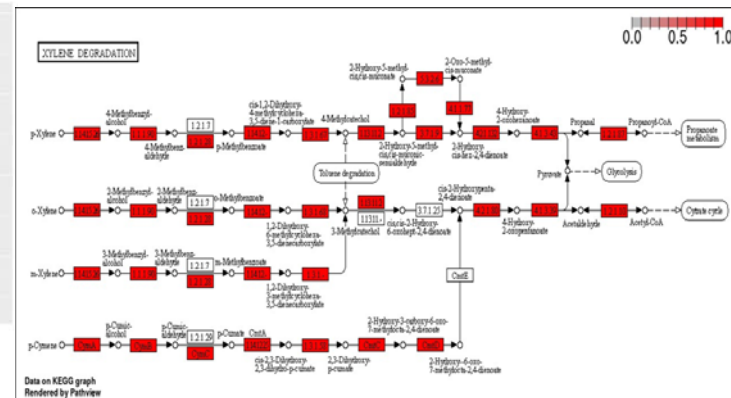
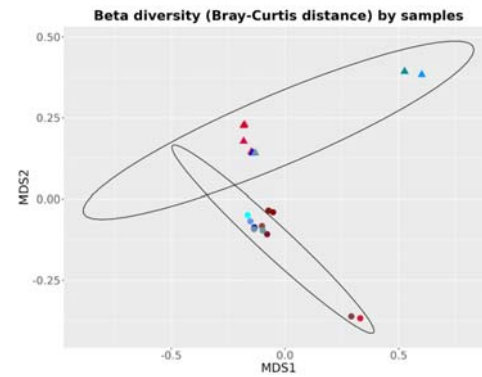
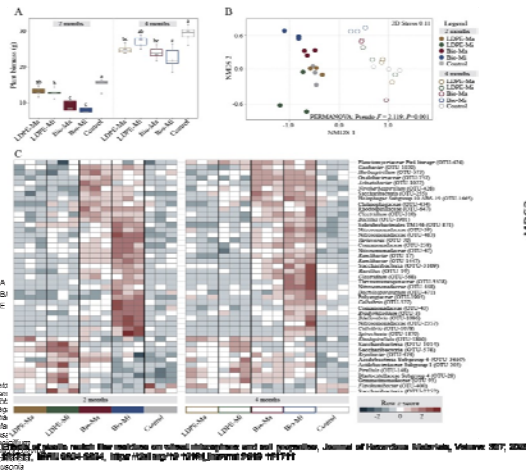
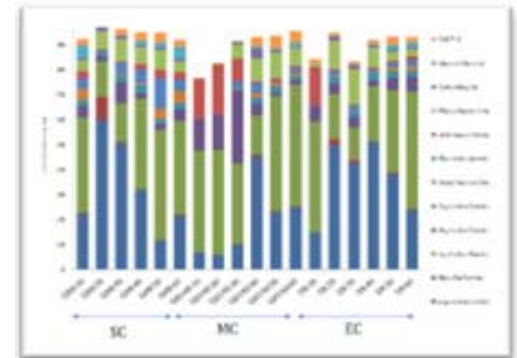
## Statistical Analysis

Analyzing community composition to reveal biodiversity patterns.



# Case studies

Advances in metagenomic technologies make it possible to investigate microbial diversity, abundances and degradation pathways (for example studying contaminated sediments) as well as bacteria community shift (for example during bioremediation and bioaugmentation of the same sediments or using different plastic film mulching).

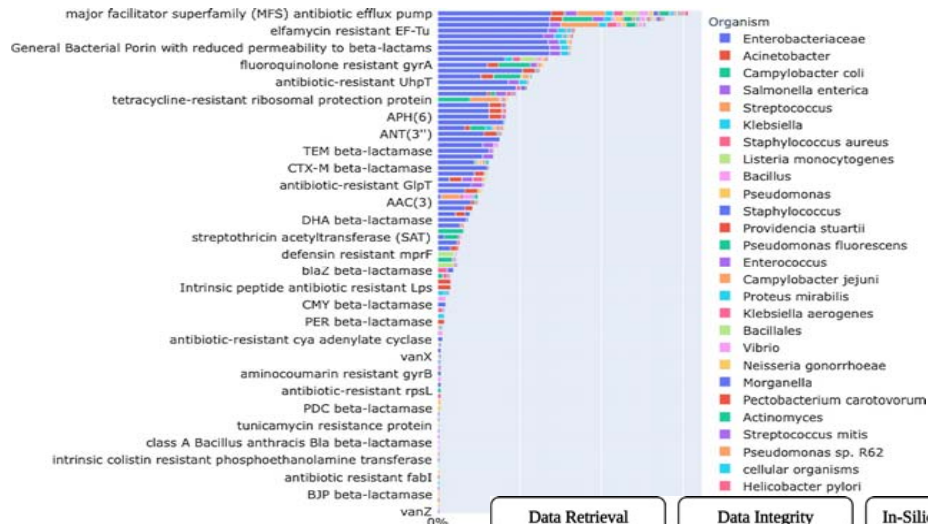


<https://doi.org/10.1016/j.jhazmat.2019.121711>

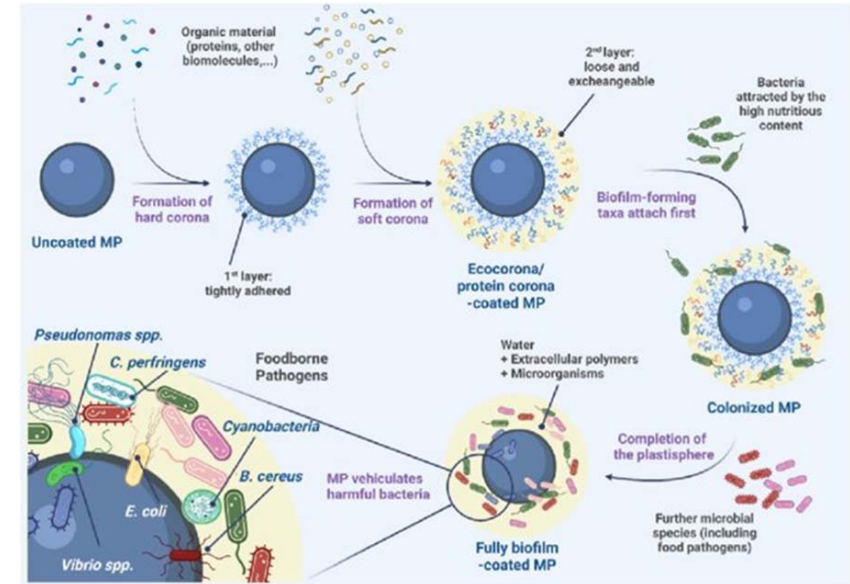
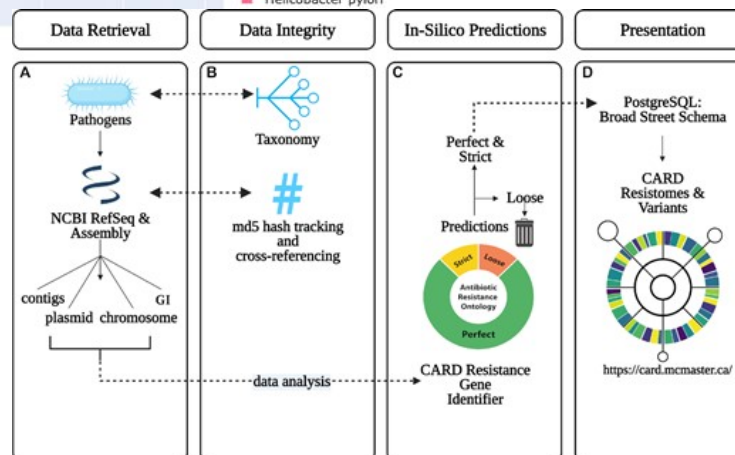
The data generated by metagenomics are extensive and complex, presenting challenges in interpretation. Skills in DNA analysis and the use of **advanced bioinformatics tools** are essential in this context.

<https://doi.org/10.1016/j.chemosphere.2023.139280>

# Some case studies



Data collected by Comprehensive Antibiotic Resistance Database (CARD; <https://card.mcmaster.ca>)



Trends in Food Science & Technology 129(11) 10.1016/j.tifs.2022.08.021

The presence of microplastics in the environment is common. These particles are known to promote the formation of a biofilm on their surface, which provides a favorable environment for bacterial growth: this is known as a **plastisphere**. Recently, it has been discovered that plastispheres act as accumulation points and transport sites for antibiotic resistant bacteria (ARBs) and antibiotic resistance genes (ARGs).

# Challenges in eDNA Analysis

## Technical Limitations

PCR bias, primer specificity, and DNA degradation can lead to false negatives or skewed abundance estimates. Emerging technologies like digital PCR and capture enrichment methods are being developed to address these issues and improve detection sensitivity.

## Reference Database Gaps

Incomplete taxonomic coverage in reference databases limits identification of many organisms, particularly in understudied environments and taxonomic groups. International initiatives are actively expanding these databases through coordinated barcoding efforts.

## Environmental Factors

DNA persistence varies across environments (e.g., longer in cold, dark, anoxic conditions), and inhibitory compounds can interfere with detection. Researchers must account for these factors when designing studies and interpreting results.

## Bioinformatic Standardization

The fact that there are so many types of analysis makes it tricky to compare studies. The field is working toward standardized protocols for analysis and reporting to improve reproducibility and facilitate meta-analyses across studies.





# Emerging Technologies and Future Directions



## Portable Sequencing

Handheld devices like Oxford Nanopore's MinION enable on-site DNA sequencing, eliminating the need to transport samples to laboratories. These technologies are revolutionizing field-based research and environmental monitoring in remote locations.



## Machine Learning Integration

Advanced algorithms improving good microbiome practices, sequence classification accuracy and predicting ecological patterns from metagenomic data. These computational approaches help researchers navigate the massive datasets generated by modern sequencing technologies.



## Multi-omics Approaches

Combining Genomics with other molecular data (Transcriptomics Proteomics Metabolomics) to gain a comprehensive understanding of microbial communities, their functions, and their interactions with the environment.

eDNA analysis can be combined with chemical data to confirm contaminant degradation and remediation effectiveness.

# Key Takeaways



The soil microbiome is of pivotal importance within the One Health framework, given its direct influence on human, animal, and environmental health.



A deeper understanding of the soil microbiome is essential for improving agricultural practices, managing health risks, preserving integrity of ecosystems and restoring the contaminated ones. However, it must be noted that further research is needed to fully explore its potential.



eDNA analysis represents a significant advance in environmental research, providing a powerful tool for identifying and monitoring microbial communities and beyond. To maximize the effectiveness of eDNA, it is vital to continue the development of consistent protocols for sampling, processing, and analysis.



Standardization is essential to ensure reproducibility, and comparability across studies, ultimately enhancing the reliability of the data and its broader application in scientific research and environmental management practices



## Fostering a Holistic Approach to Global Health

The conference focused on the critical intersection between microbiomes, ecosystems and human health, emphasizing the importance of integrated solutions to global issues such as soil degradation, food insecurity, viral pandemics, and the accelerating climate crisis.

A groundbreaking gathering of international experts at the 2nd International Conference on Microbiomes, Biodiversity, and Their Impact on Global and One Health highlights the transformative potential of microbiome science in addressing the world's most urgent environmental and health challenges.

The event, hosted by USF Health's Microbiomes Institute, Institut Mérieux, and the Global Virus Network (GVN), was held February 3-5, 2025, at the University of South Florida (USF) in Tampa.





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Thank you

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