

# INTRODUCTION TO MICROBIOIMES

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Illustration by Kim Carney / Fred Hutch

-  
A small  
problem

-  
From  
Microbiology  
to Microbiome  
studies

-  
Vocabulary

# Studying microbes is a challenge

small

$$1\mu\text{m} = 1000 \text{ nm}$$

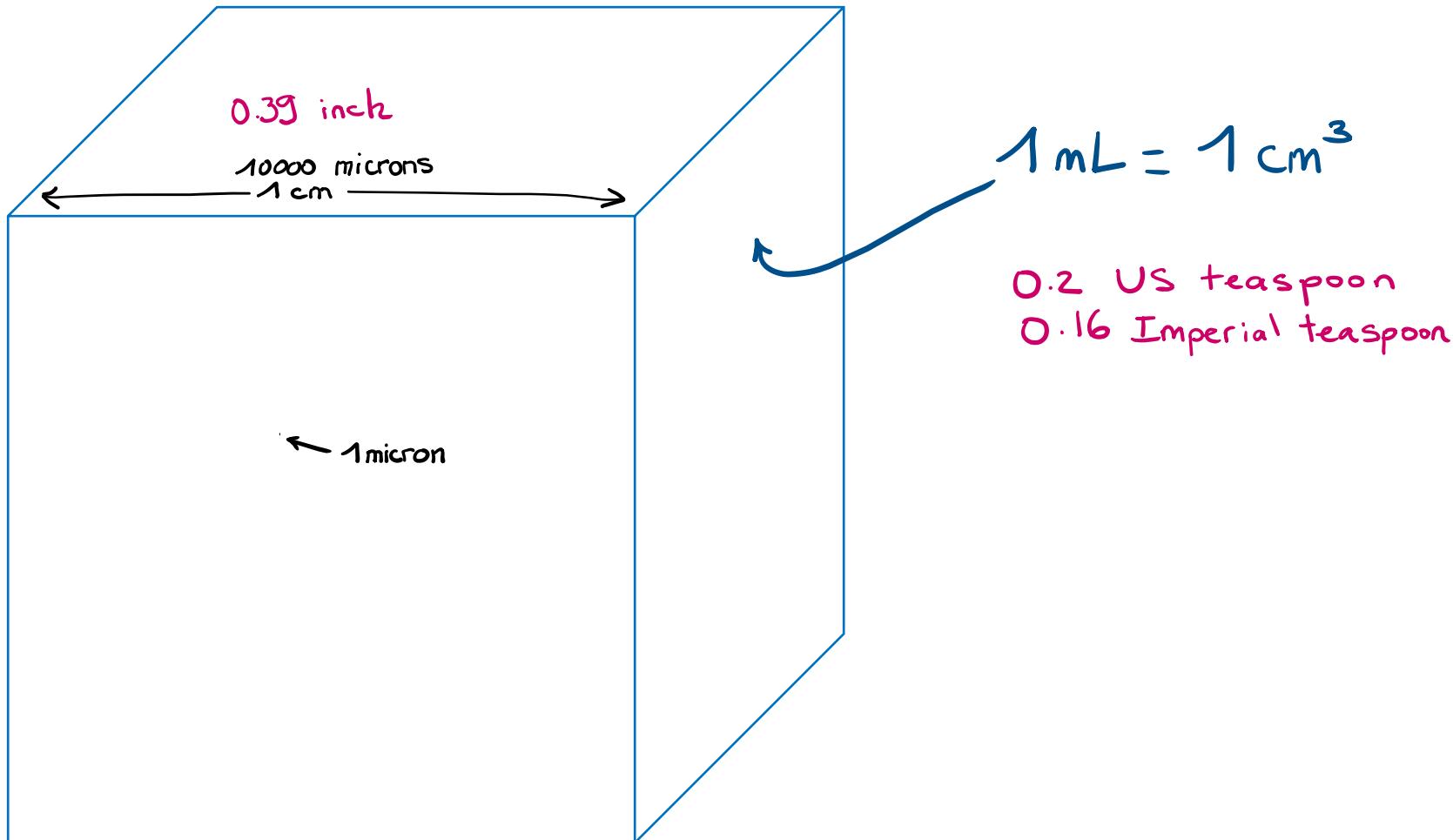
Resolution limit  
→ eye

cell membrane ... 4 nm

1 atom ..... 0.1 nm

100  $\mu\text{m}$   
→ light microscope  
200 nm (5 pixels)

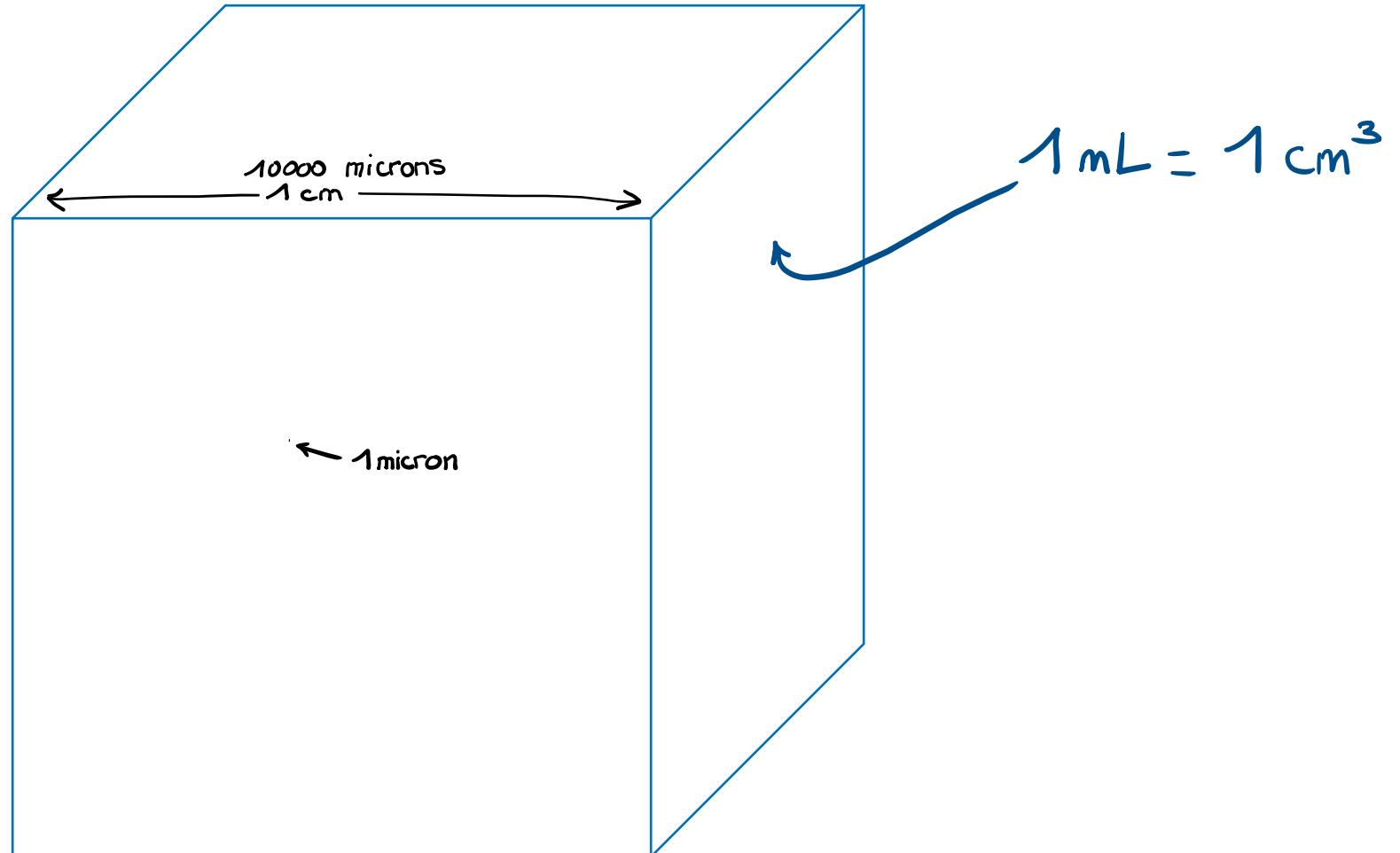
→ electronic microscope  
0.2 nm



How many  $1 \mu\text{m}^3$  microbes can you put in 1 ml ?

$$1 \text{ cm}^3 = (10^4)^3 = 10^{12} \mu\text{m}^3$$

1 trillion

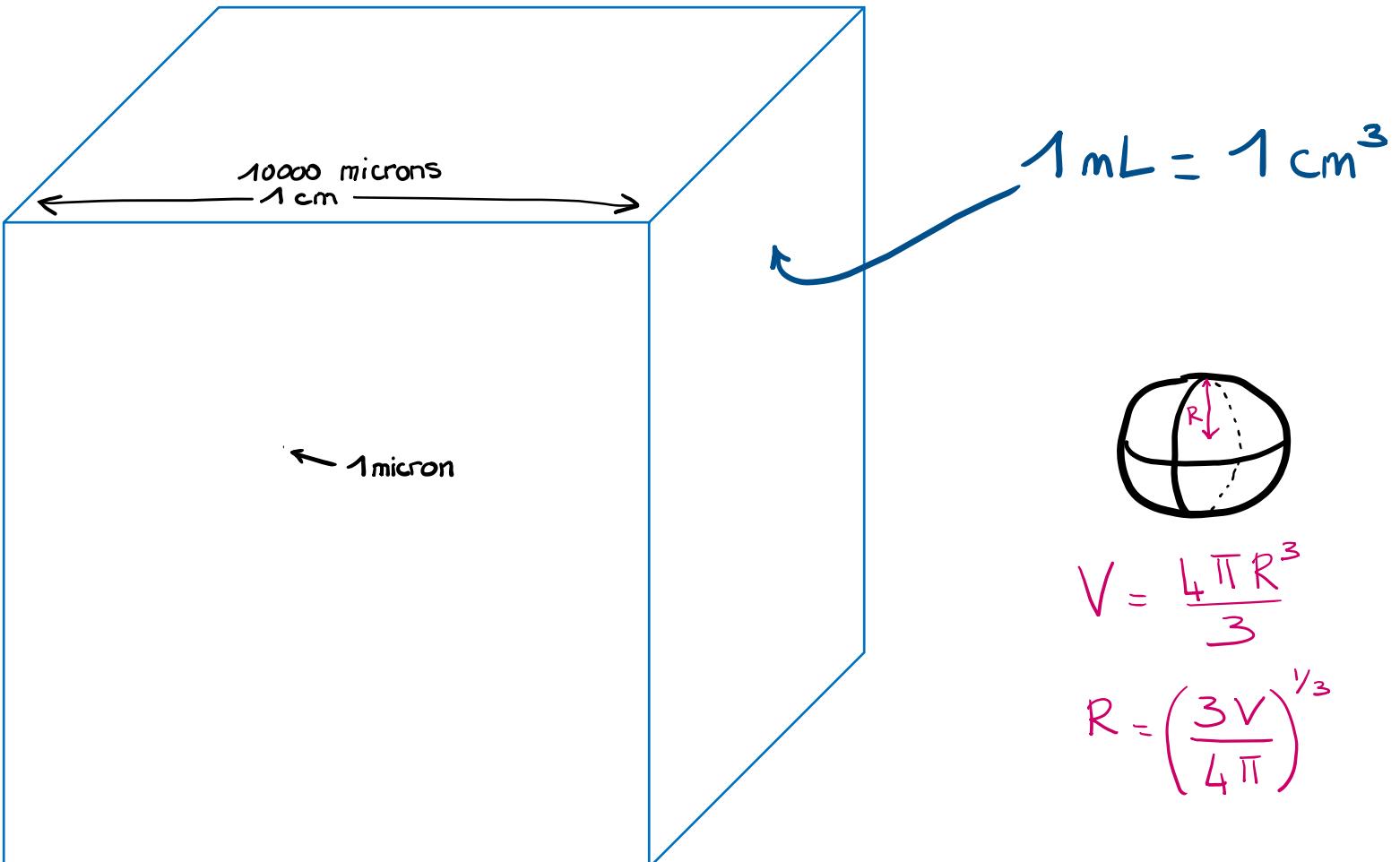


1 g of soil has a volume of  $1\text{cm}^3$  and hosts 1 billion microbes ( $10^9$ )

What is the distance between two cells?

- $9.99 \times 10^{11} \mu\text{m}^3$  are not cells
- For each cell there are  $999$  other  $\mu\text{m}^3$
- each cell is alone in a ball of radius:

$$R = 13 \mu\text{m}$$



1 g of soil has a volume of 1cm<sup>3</sup> and hosts 1 billion microbes (10<sup>9</sup>)

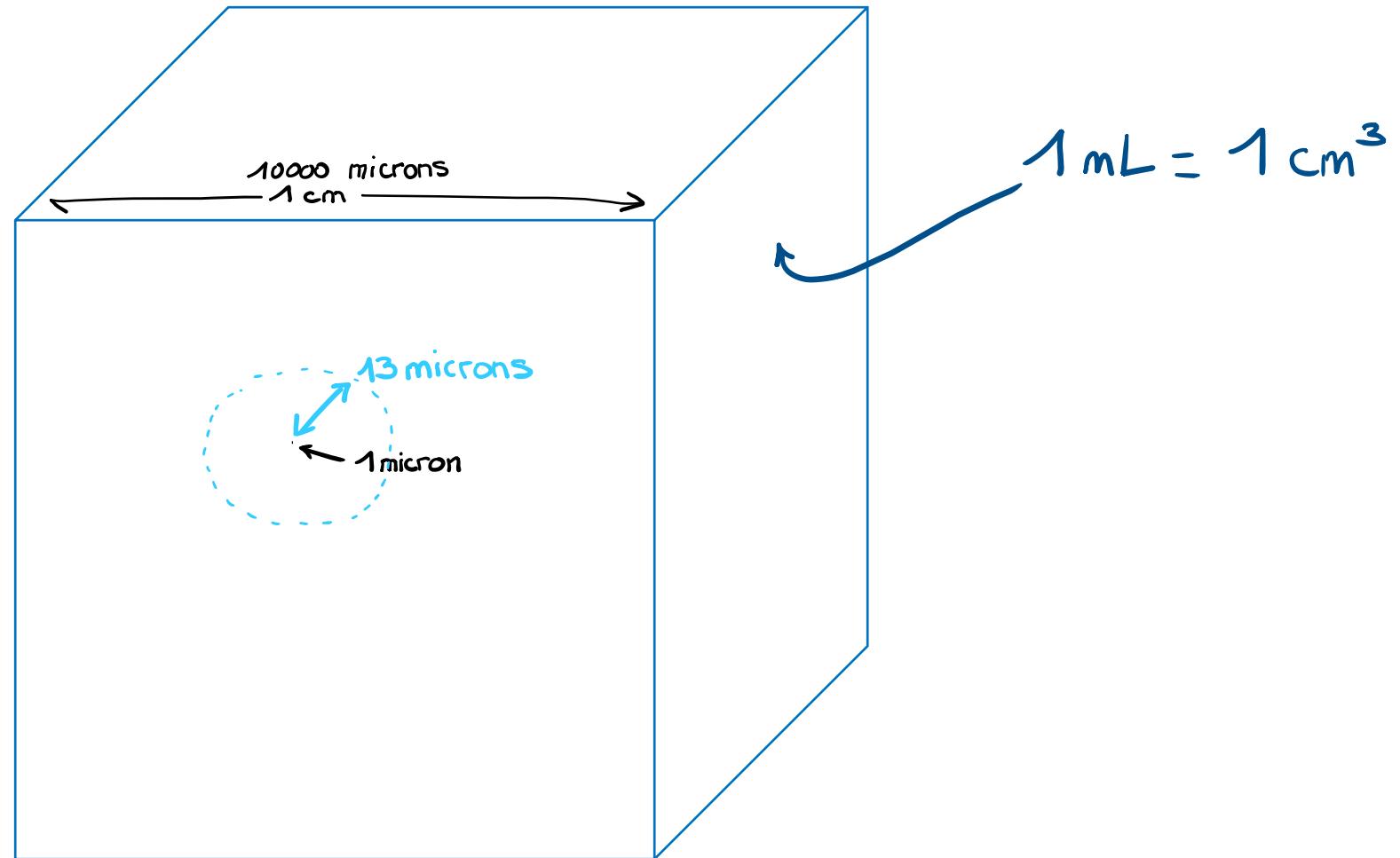
Each cell has 1-10 femtogram of DNA (10<sup>-15</sup> g)

How much DNA can you extract max from 1 g ?

$$\rightarrow 10^9 \times 10^{-15} = 10^{-6} \text{ g} = 1 \mu\text{g}$$

$$\rightarrow 10^9 \times 10^{-14} = 10^{-5} \text{ g} = 10 \mu\text{g}$$

1 - 10  $\mu\text{g}$



-> sampling

-> library prep

-> controls

-> function

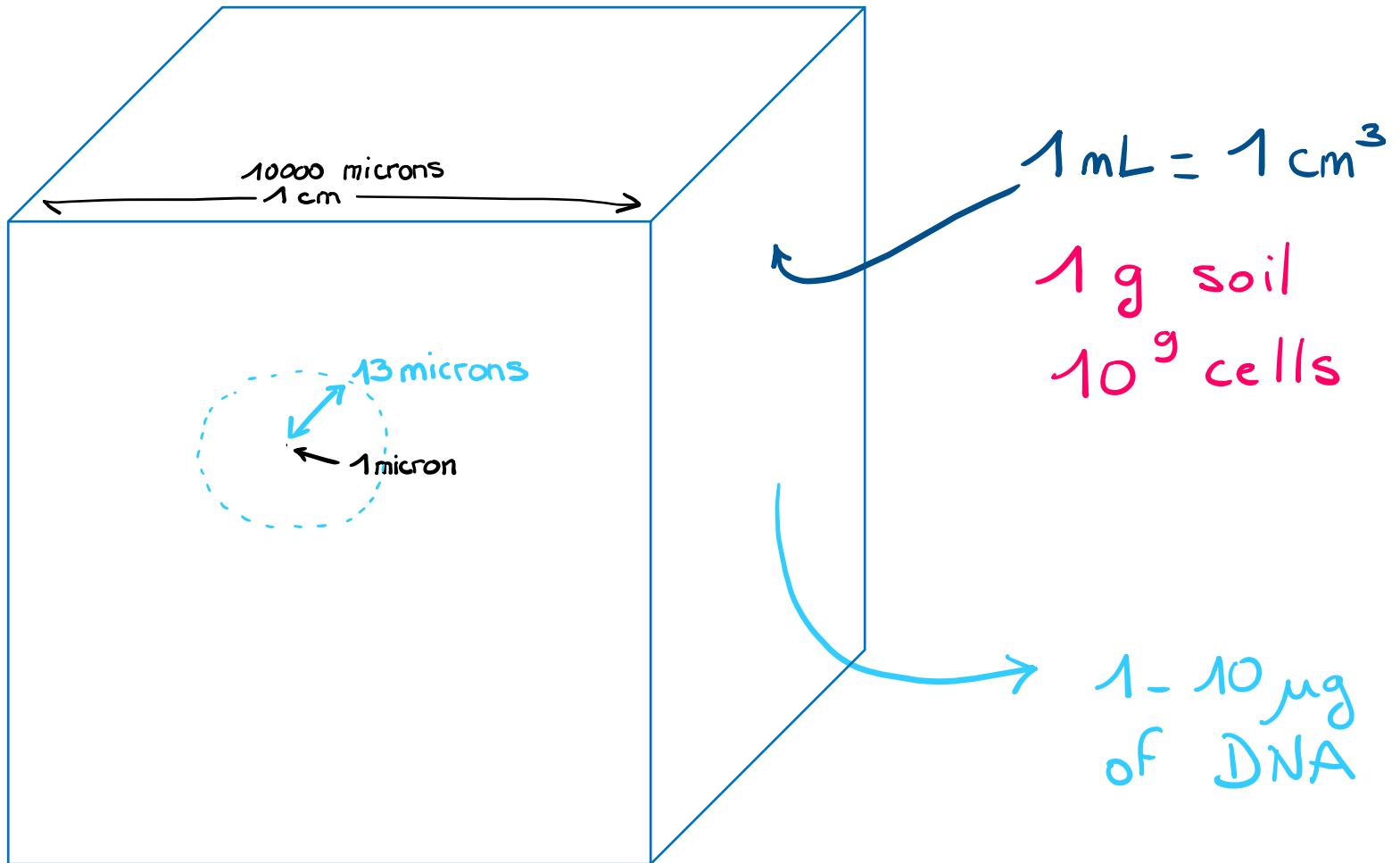




Illustration by Kim Carney / Fred Hutch

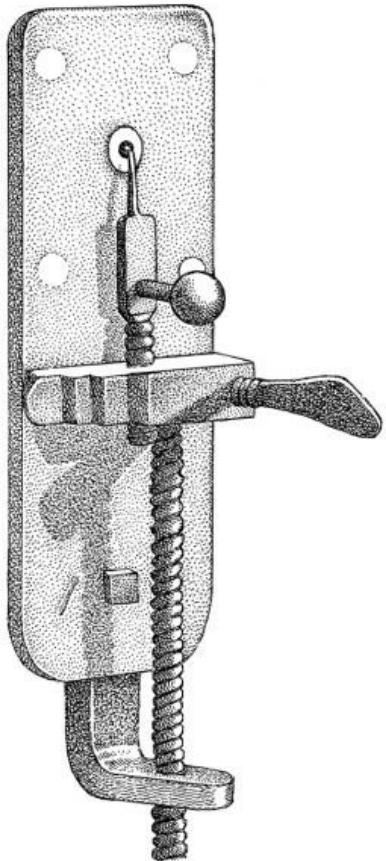
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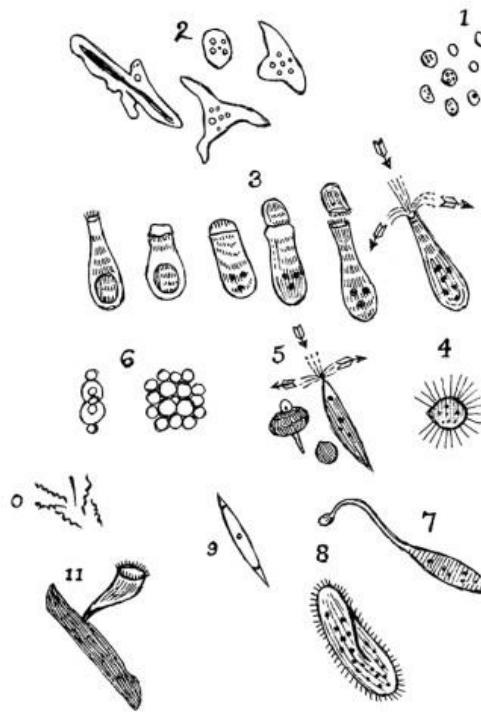
-  
Vocabulary

# Antonie van Leeuwenhoek 1632-1723

1670s first  
microscope



LEEUWENHOEK'S  
MICROSCOPE

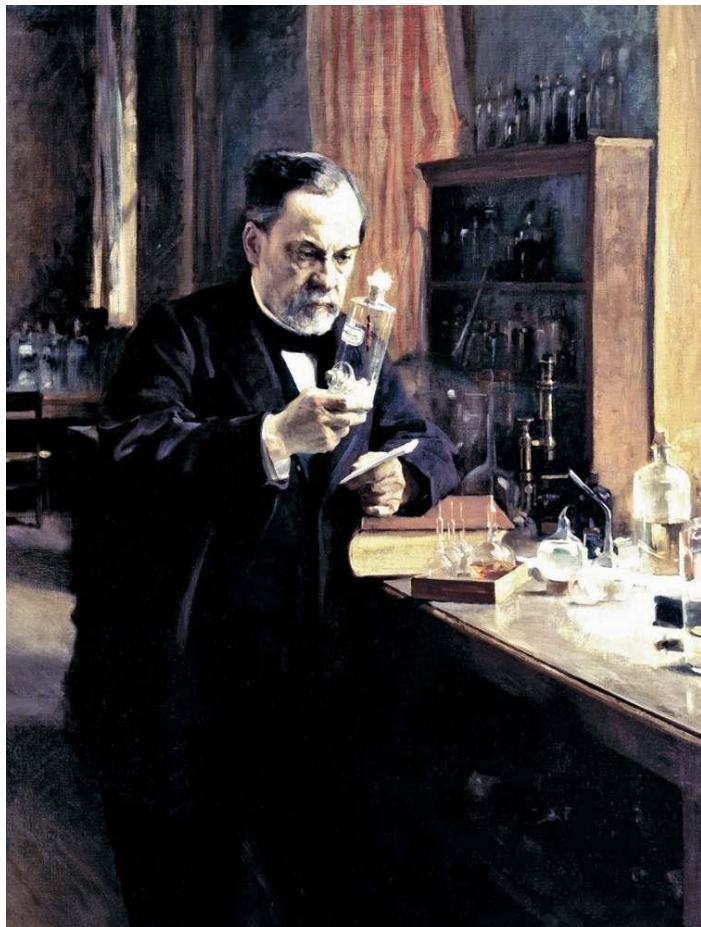


LEEUWENHOEK'S  
ANIMALCULES



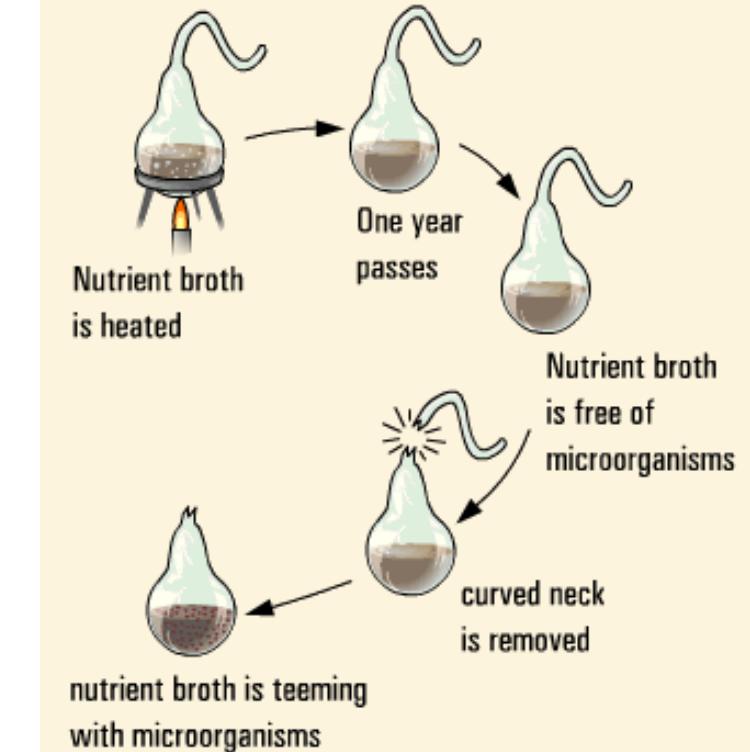
*A portrait of Antonie van Leeuwenhoek  
by Jan Verkolje*

# Louis Pasteur 1822-1895



Science History Institute/Gregory Tobias

## Pasteur's Experiment



# Robert Koch

## 1843-1910

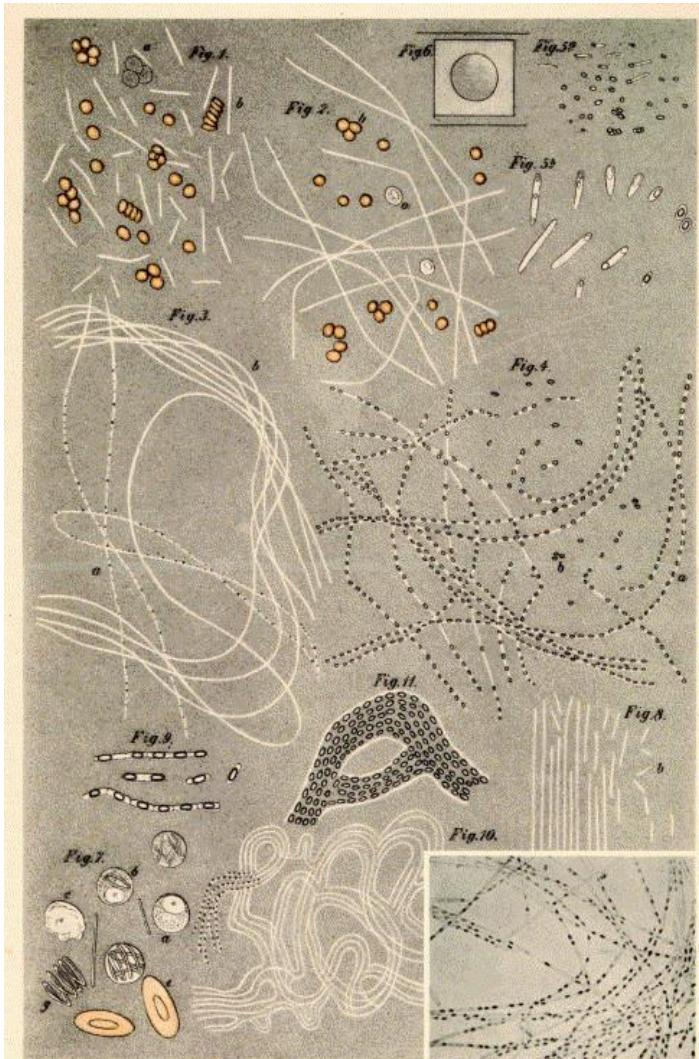
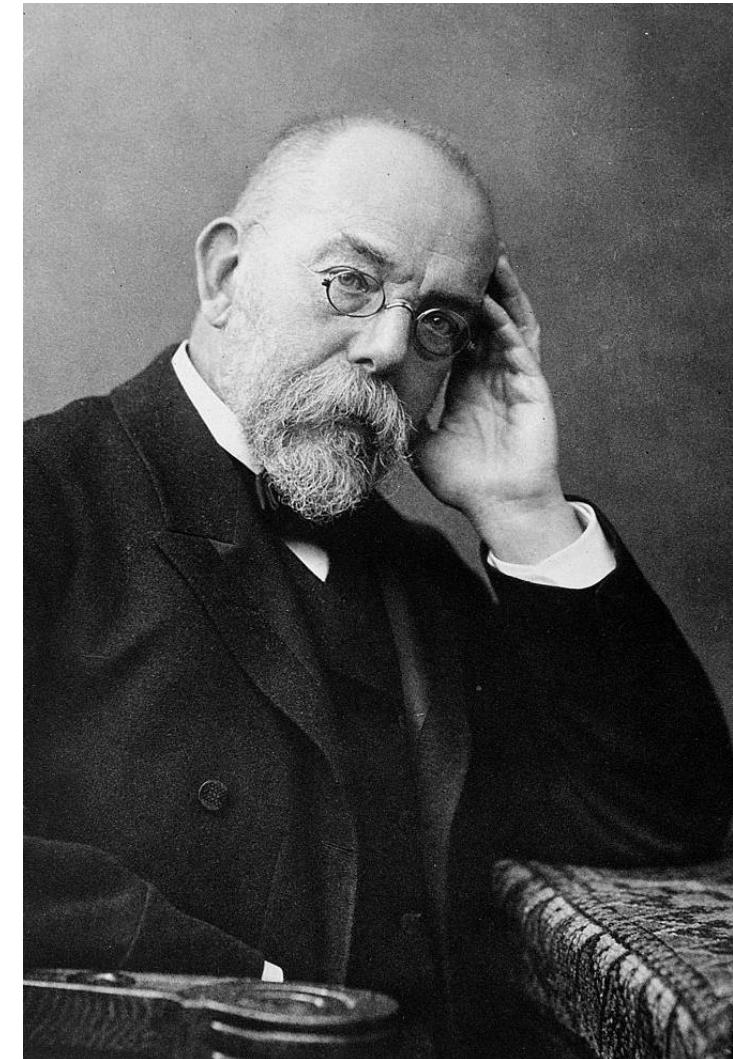
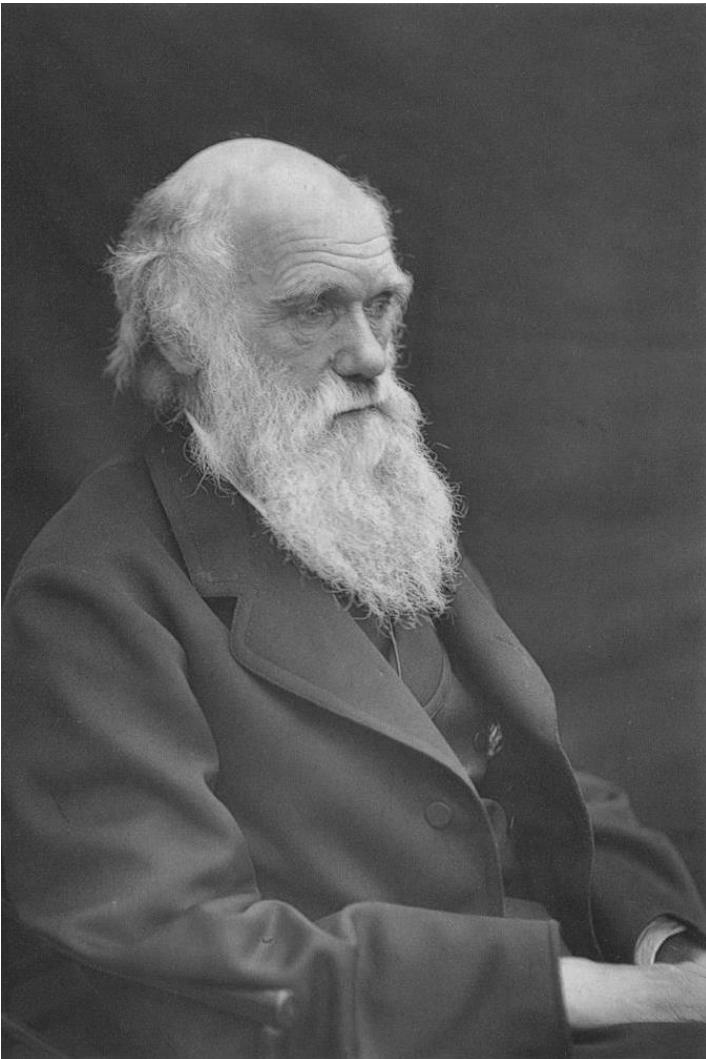


planche extraite de *Die Aetiologie der Milzbrand-Krankheit, begründet auf die Entwicklungsgeschichte des Bacillus Anthracis*, 1876.



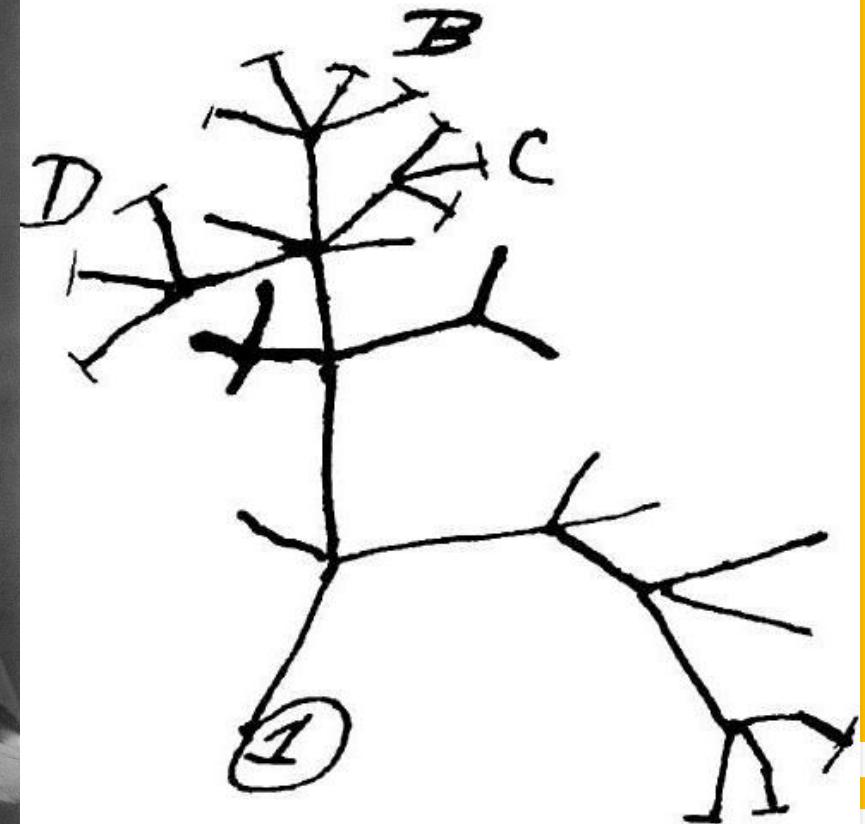
photogravure after a photo by Wilhelm Fechner around 1900

# Charles Darwin 1809-1882



Getty Images

I think

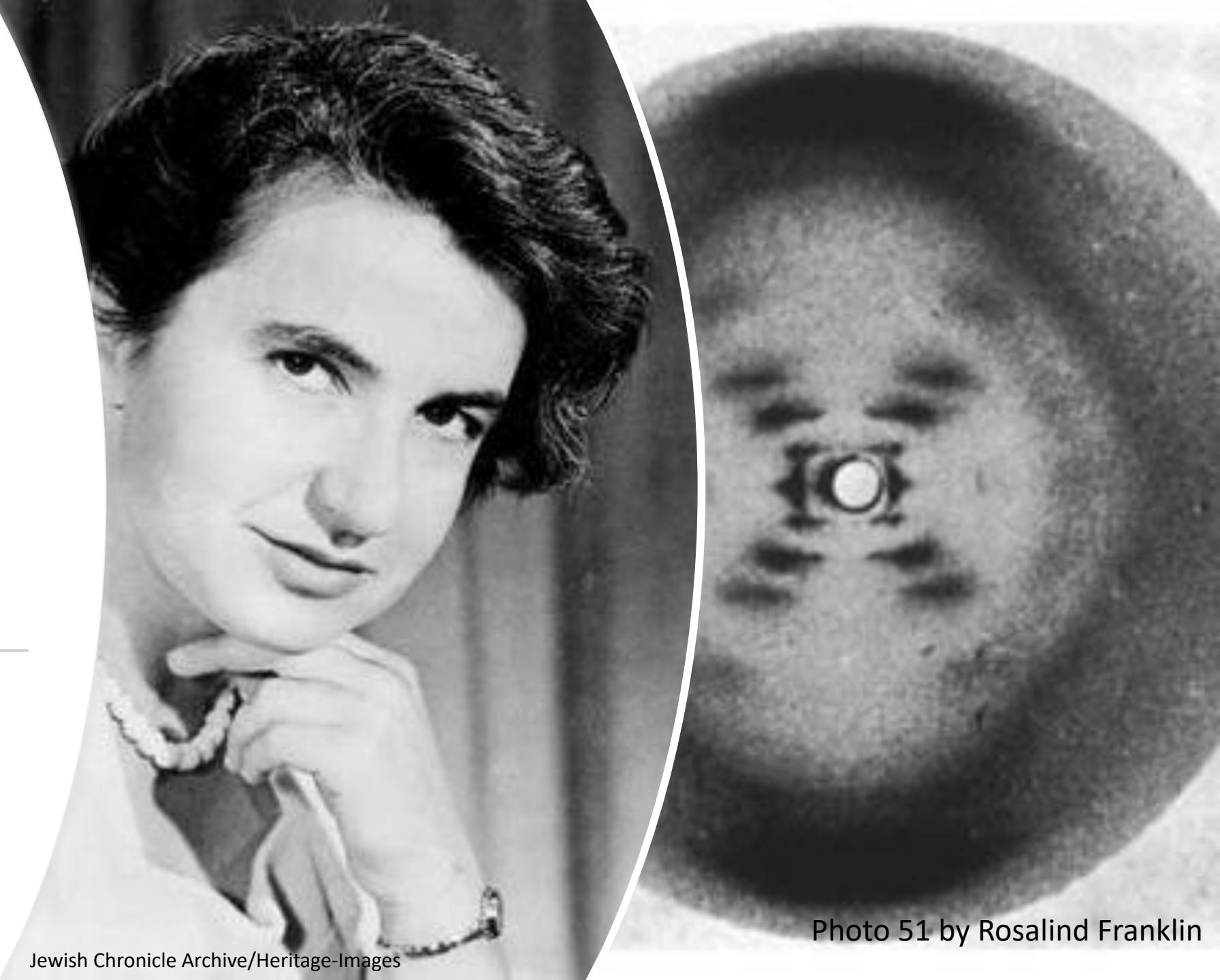


First Notebook on Transmutation of Species (1837).

# Rosalind Franklin 1920-1958

1951

"The results suggest a helical structure (which must be very closely packed) containing 2, 3 or 4 co-axial nucleic acid chains per helical unit, and having the phosphate groups near the outside."



Jewish Chronicle Archive/Heritage-Images

Photo 51 by Rosalind Franklin

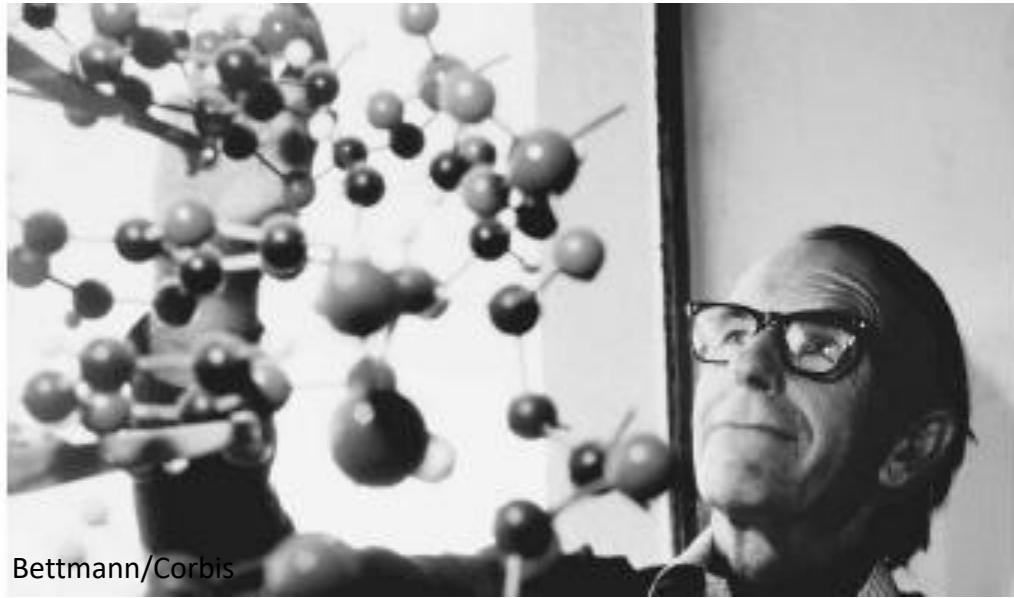
Francis Crick  
1916-2004

James Watson  
1928-

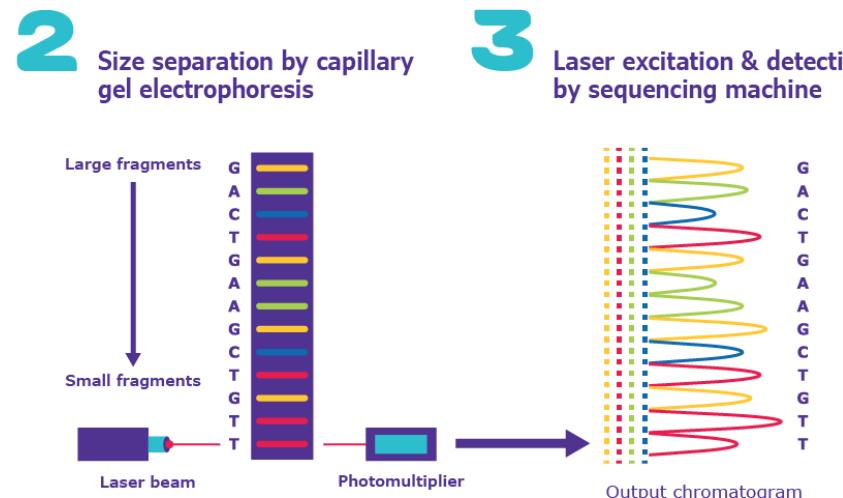
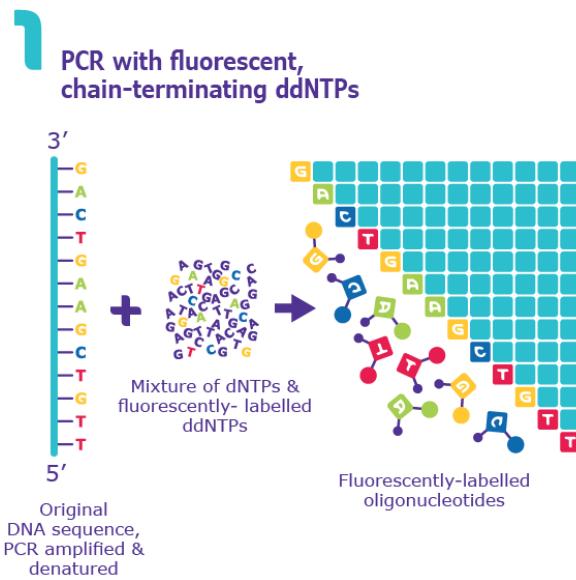
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WATSON, J., CRICK, F. Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid. *Nature* **171**, 737–738 (1953).  
<https://doi.org/10.1038/171737a0>





Frederick Sanger  
1918-2013

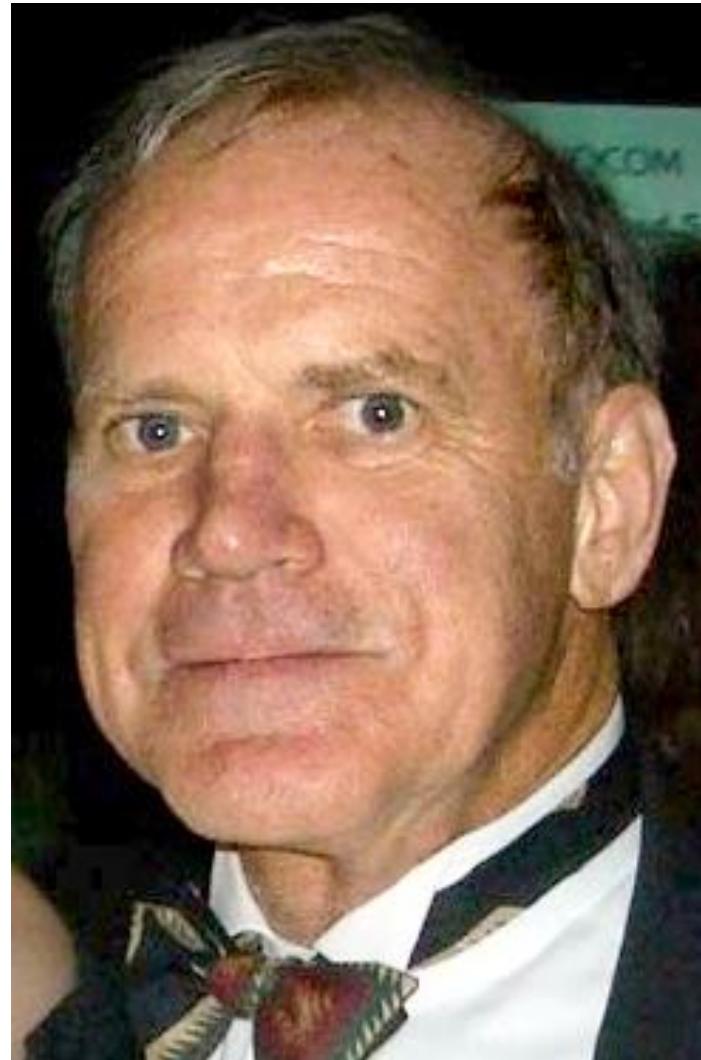


1977 Sanger sequencing  
First Generation via "chain termination method"

# Kary Mullis

## 1944-2019

Mullis, K.F.; Faloona, F.; Scharf, S.; Saiki, R.; Horn, G.; Erlich, H. (1986). "Specific enzymatic amplification of DNA in vitro: The polymerase chain reaction". Cold Spring Harbor Symposia on Quantitative Biology.



One PCR Cycle

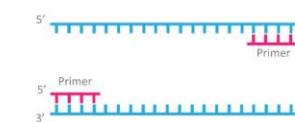
Template DNA



Denaturation



Annealing



Extension



New DNA Strands

# Carl Woese 1928-2012

Woese, Carl R.; George E. Fox (1977). "Phylogenetic structure of the prokaryotic domain: the primary kingdoms"

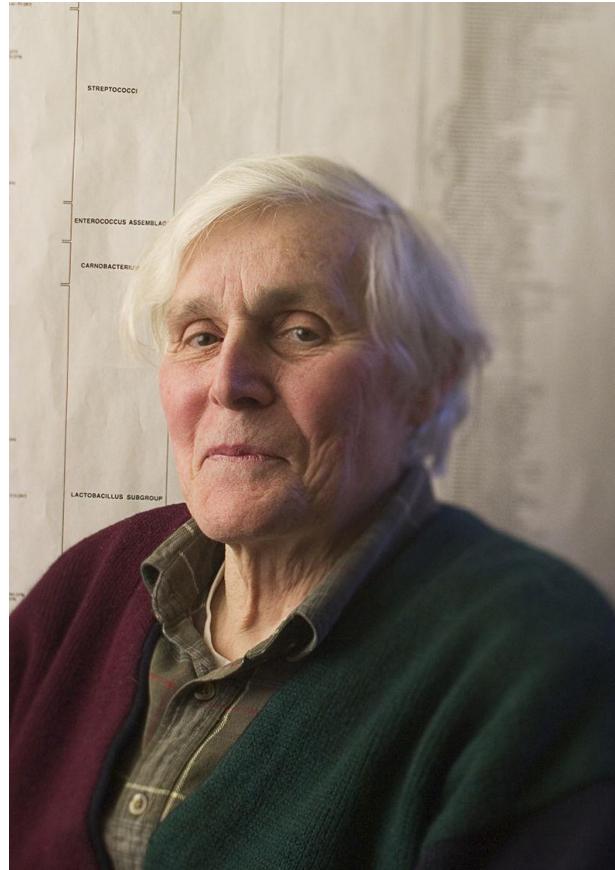
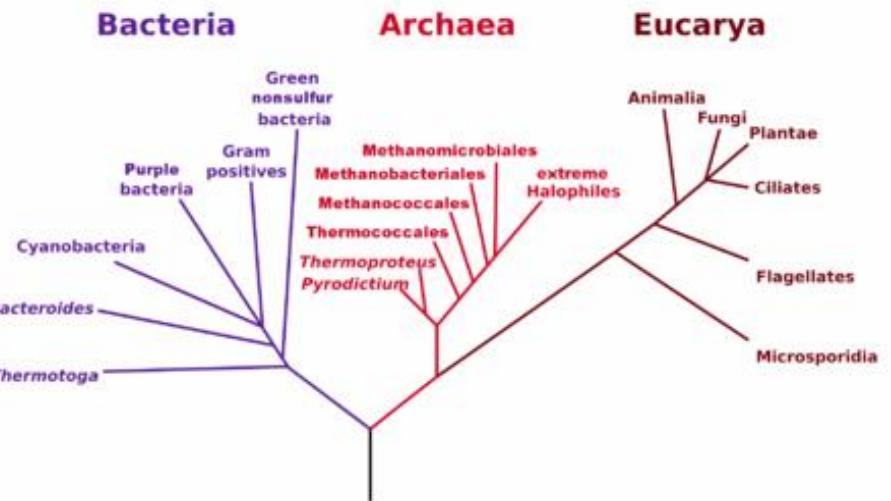


Photo by Don Hamerman  
University of Illinois at Urbana-Champaign

## Phylogenetic Tree of Life



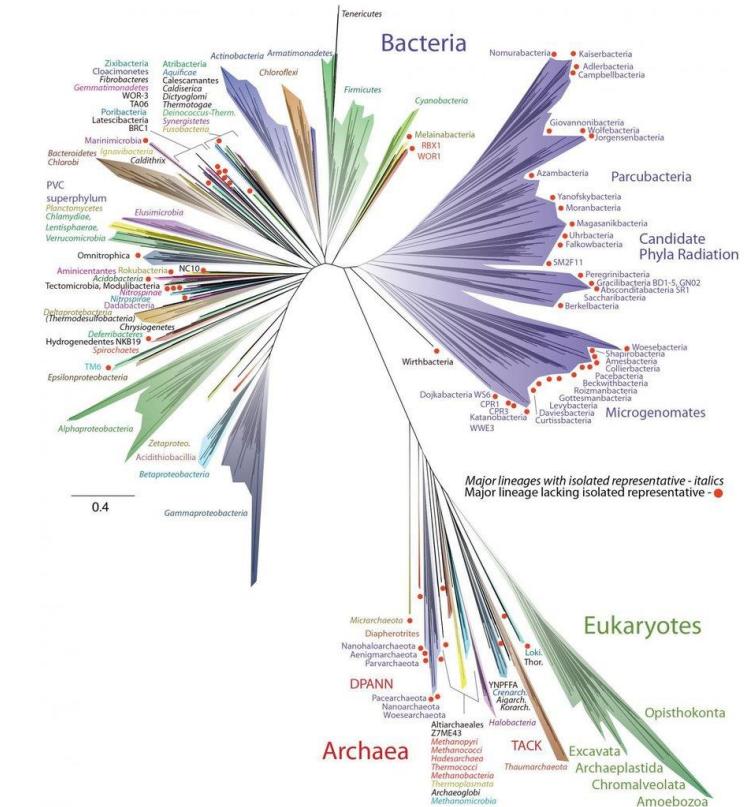
Woese, Carl R.; Kandler, O; Wheelis, M (1990).  
Proc Natl Acad Sci USA. **87** (12): 4576–9.

# Jill Banfield 1959-

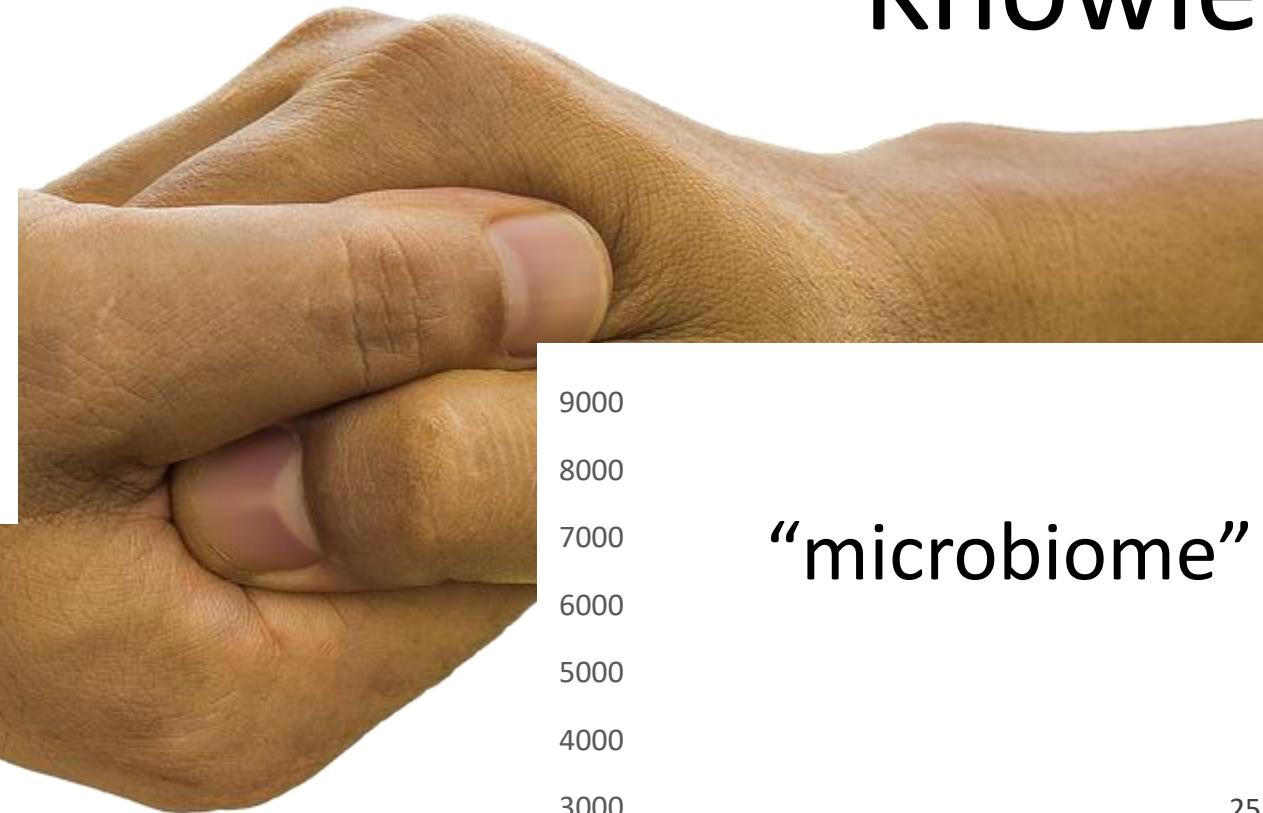
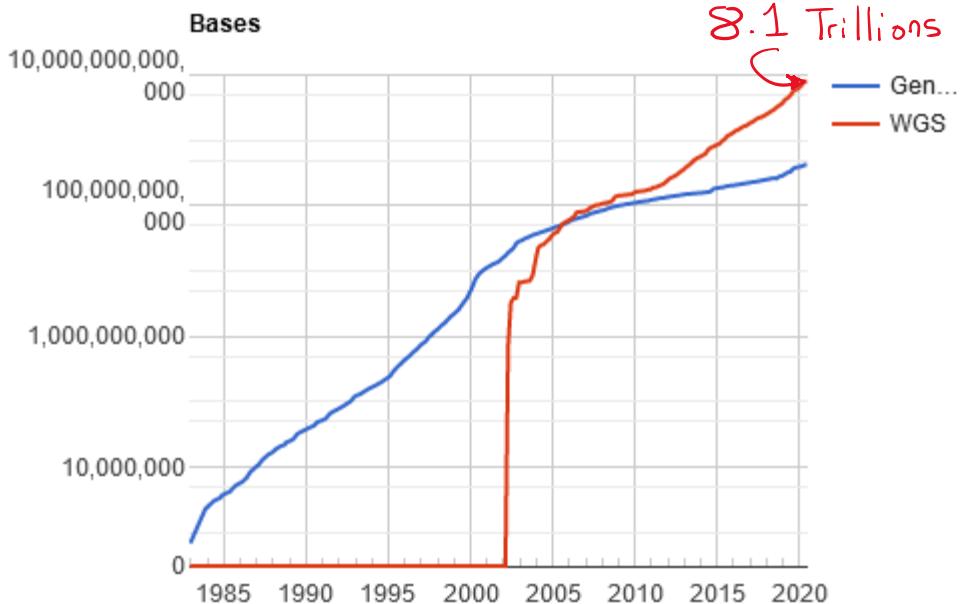
Hug, L., Baker, B.,  
Anantharaman, K. et al. A new  
view of the tree of life. *Nat  
Microbiol* 1, 16048 (2016).  
<https://doi.org/10.1038/nmicrbiol.2016.48>



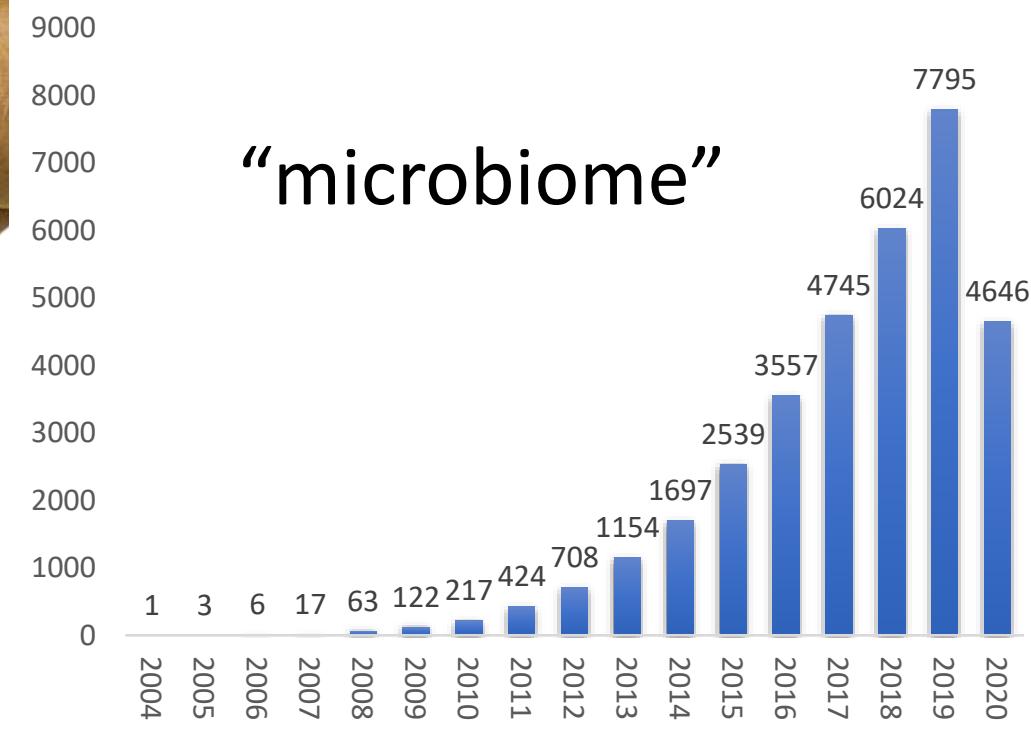
Photo by Duncan Hull



## GenBank and WGS Statistics



Technology



"microbiome"

# Next frontiers in microbiome research

- > from presence to function / activity
- > quantification / spatialization
- > multiomic by design



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Vocabulary

# -ome      -omics

○ Microbe  
Microorganism → ○○○○○ Microbial community  
○ Microbiome / omics

病毒 Virus → ○○○○○ Virome / omics

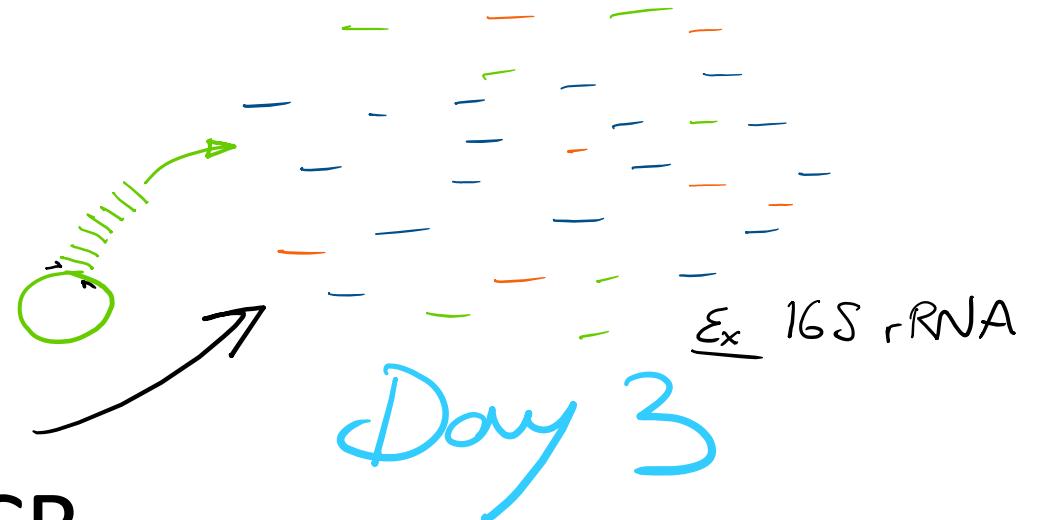
Gene → Genome / omics

Transcript → Transcriptome / omics

Protein → Proteome / omics

Metabolite → Metabolome / omics

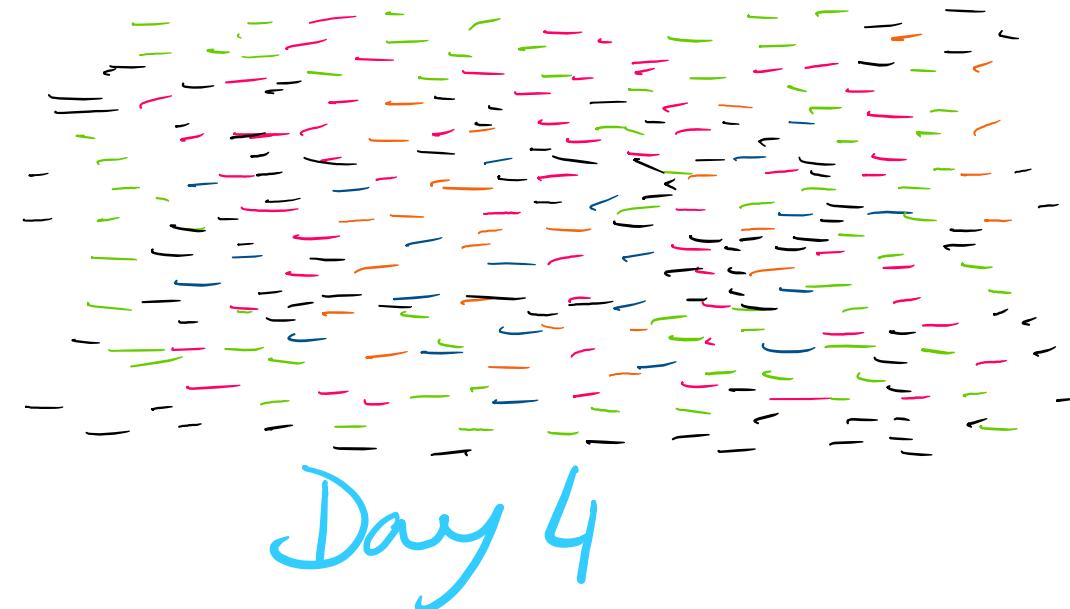
Amplicon sequencing



PCR

Day 3

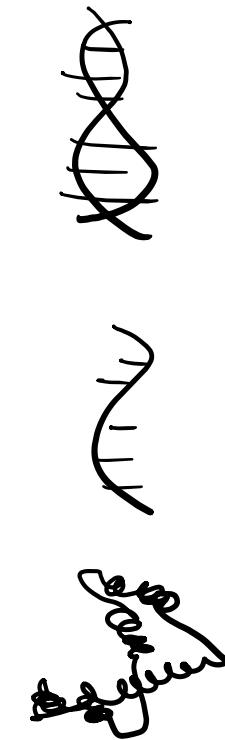
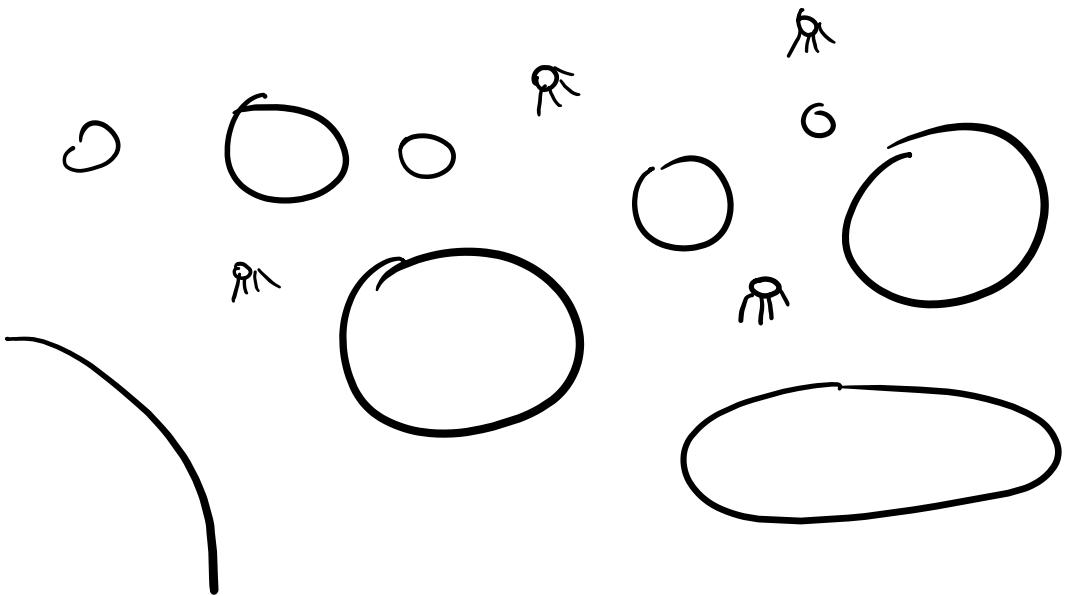
Metagenomic



Total  
DNA

Day 4

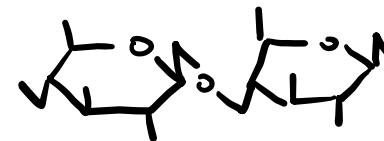
# Meta -



Metagenome

Metatranscriptome

Metaproteome



Metabolome

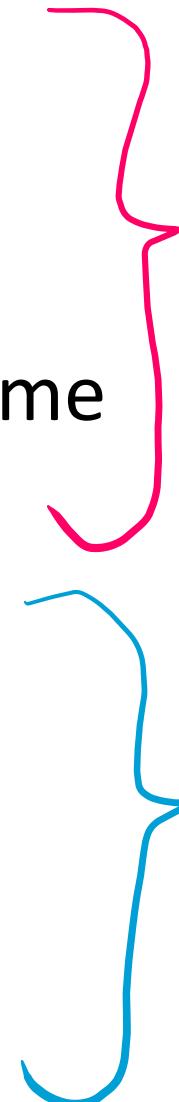


Metagenome

Metatranscriptome

Metaproteome

Metabolome



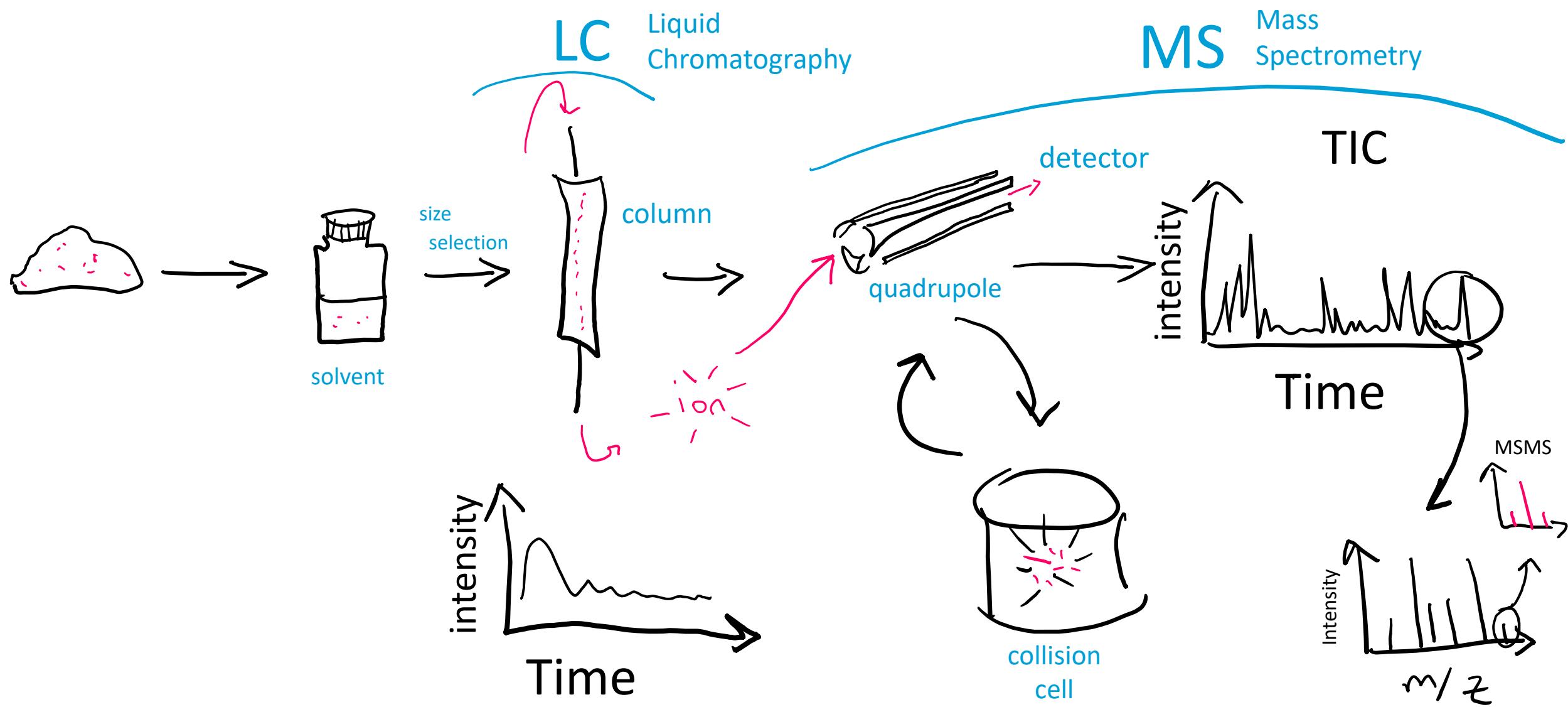
# Sequencing

*Next Generation Sequencing (NGS)  
High Throughput Sequencing (HTS)*



# Mass Spec

# Metabolomics LCMS





# YouTube

**MicroSeminar**  
716 abonnés

ACCUEIL VIDÉOS PLAYLISTS CHAÎNES DISCUSSION À PRO

Vidéos mises en ligne ▾ TOUT REGARDER

Aude Bernheim: Conceptual and mechanistic...  
240 vues • il y a 3 jours

Sean Gibbons: Reflections of the gut microbiota in blood  
192 vues • il y a 1 semaine

Arkadiy Garber: Extreme genome decay in young...  
153 vues • il y a 2 semaines

Thomas Hacek: Elements ab...  
182 vues • il y a 1 semaine

Ella Sieradzki: Rhizosphere-nitrogen dynamics through...  
1,4 k vues • Diffusé il y a 5 jours

Gary Trubl: Tracking active viral population dynamics...  
2,1 k vues • Diffusé il y a 1 semaine

Ashish Malik: Linking microbial communities to s...  
4,5 k vues • Diffusé il y a 2 semaines

Flora Vincent: giant virocell  
Sous-titres

**Penn State Microbiome Center**  
60 abonnés

ACCUEIL VIDÉOS PLAYLISTS CHAÎNES À PROPOS

Vidéos mises en ligne TOUT REGARDER

Prospector array technology provides an exponential increase in scale and throughput.  
39:23

Viruses are key members of marine ecosystems  
1:17:40

Penn State Microbiome Center Presents  
Estelle Couradeau  
Ecosystem Science and Management  
Harvesting the power of soil  
31:38

Penn State Microbiome Center Presents  
Sharifa Crandall, PhD  
Plant Pathology & Environmental Microbiology (PPEM)  
Assistant Profes...  
Soilborne Disease Dynamics  
29:00

**'omics**  
merenlab.org

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ACCUEIL VIDÉOS PLAYLISTS CHAÎNES DISCUSSION

Vidéos en ligne ► TOUT REGARDER

Week 03  
An online seminar series on  
**Microbial 'Omics for beginners**  
1:35:50

Microbial 'Omics Seminar Series, Week 03: "Key..."  
1,4 k vues • Diffusé il y a 5 jours

Week 02  
An online seminar series on  
**Microbial 'Omics for beginners**  
1:11:01

Microbial 'Omics Seminar Series, Week 02: "The pow..."  
2,1 k vues • Diffusé il y a 1 semaine

Week 01  
An online seminar series on  
**Microbial 'Omics for beginners**  
1:41:34

Microbial 'Omics Seminar Series, Week 01: "A brief..."  
4,5 k vues • Diffusé il y a 2 semaines