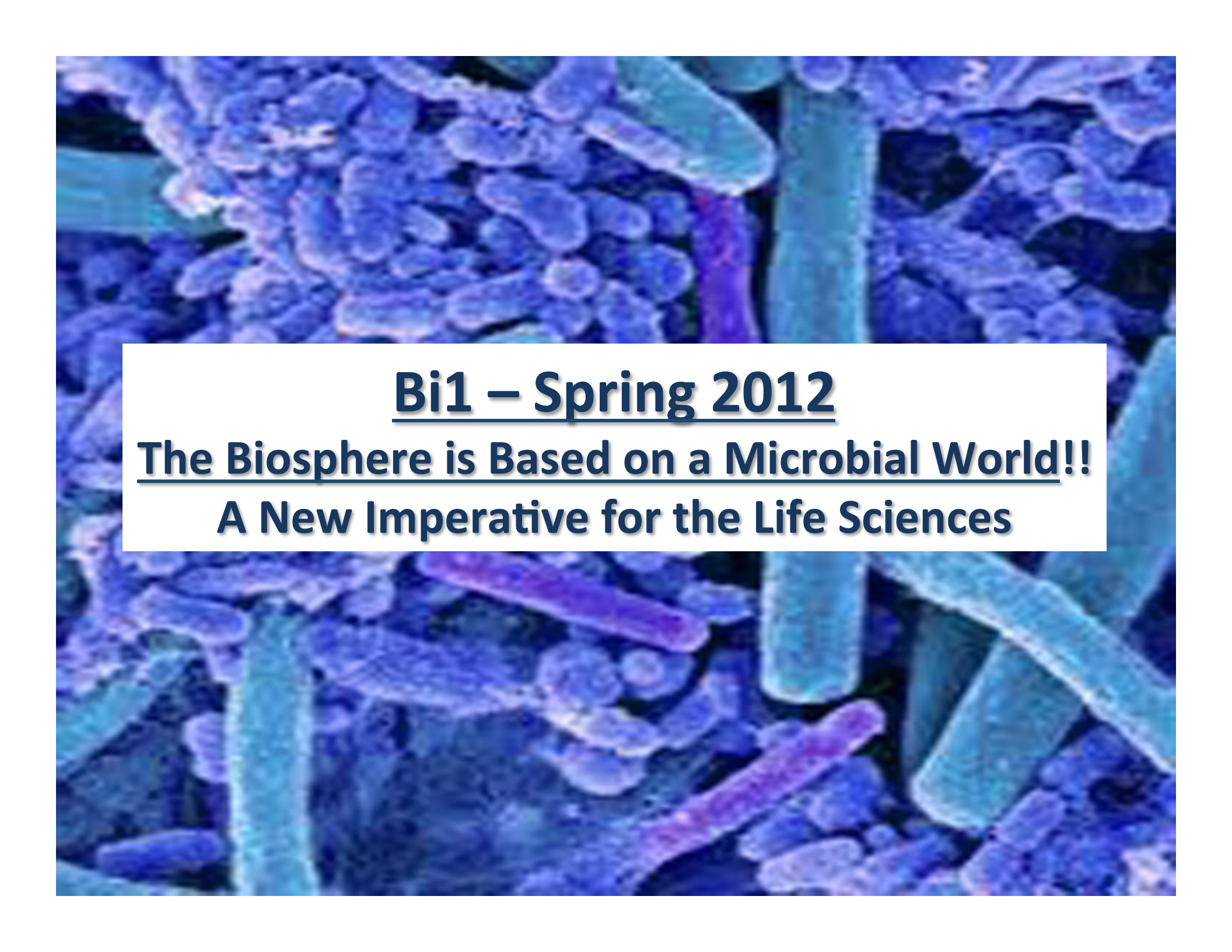




Bi1 – Spring 2012

The Biosphere is Based on a Microbial World!!

A New Imperative for the Life Sciences

Anton van Leeuwenhoek – The Father of Microbiology

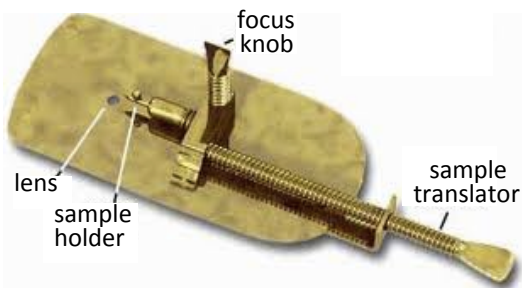
[1632-1723]



**1683 – DISCOVERED BACTERIA IN CHEEK SWAB
'ANIMICULES'**



Leeuwenhoek's instrument



Two questions arose:

- 1) What are they?
- 2) What are they doing?

HUNTINGTON LIBRARY – “Beautiful Science: Ideas that Changed the World”

FAST FORWARD ~300 years1977



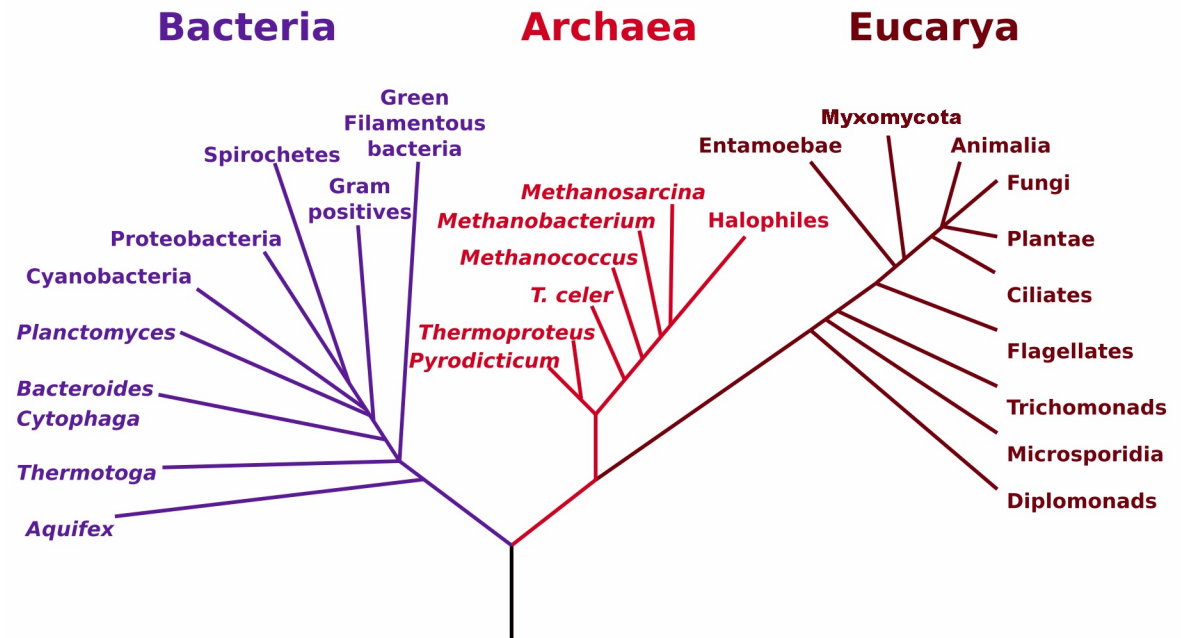
WHO MIGHT THIS BE,
AND WHY IS HE FAMOUS IN BIOLOGY?

FAST FORWARD ~300 years1977



Carl Woese (b. 1928)

Phylogenetic Tree of Life



Woese *et al.* (1990) *PNAS* 87 (12): 4576–9.

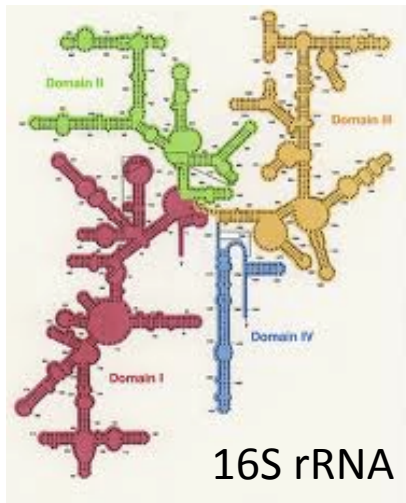
WHAT TECHNIQUE DID
WOESE USE TO DERIVE THIS
TREE?
i.e., what was his 'instrument'?

FAST FORWARD ~300 years1977

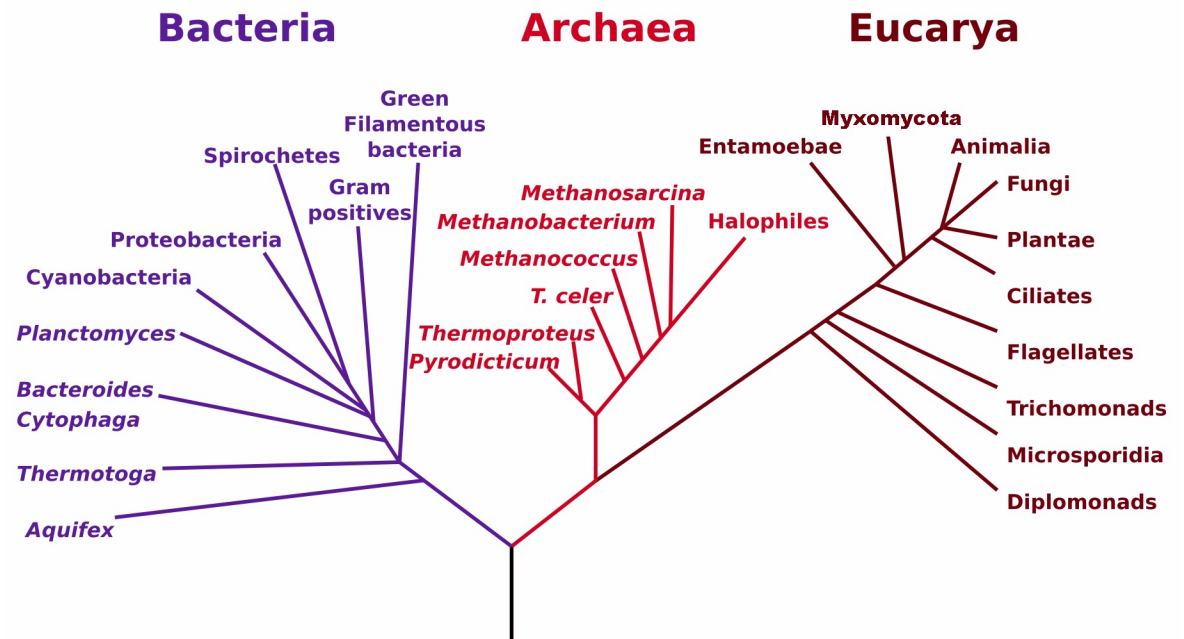


Carl Woese (b. 1928)

Woese's 'Instrument'



Phylogenetic Tree of Life



Woese *et al.* (1990) *PNAS* 87 (12): 4576–9.

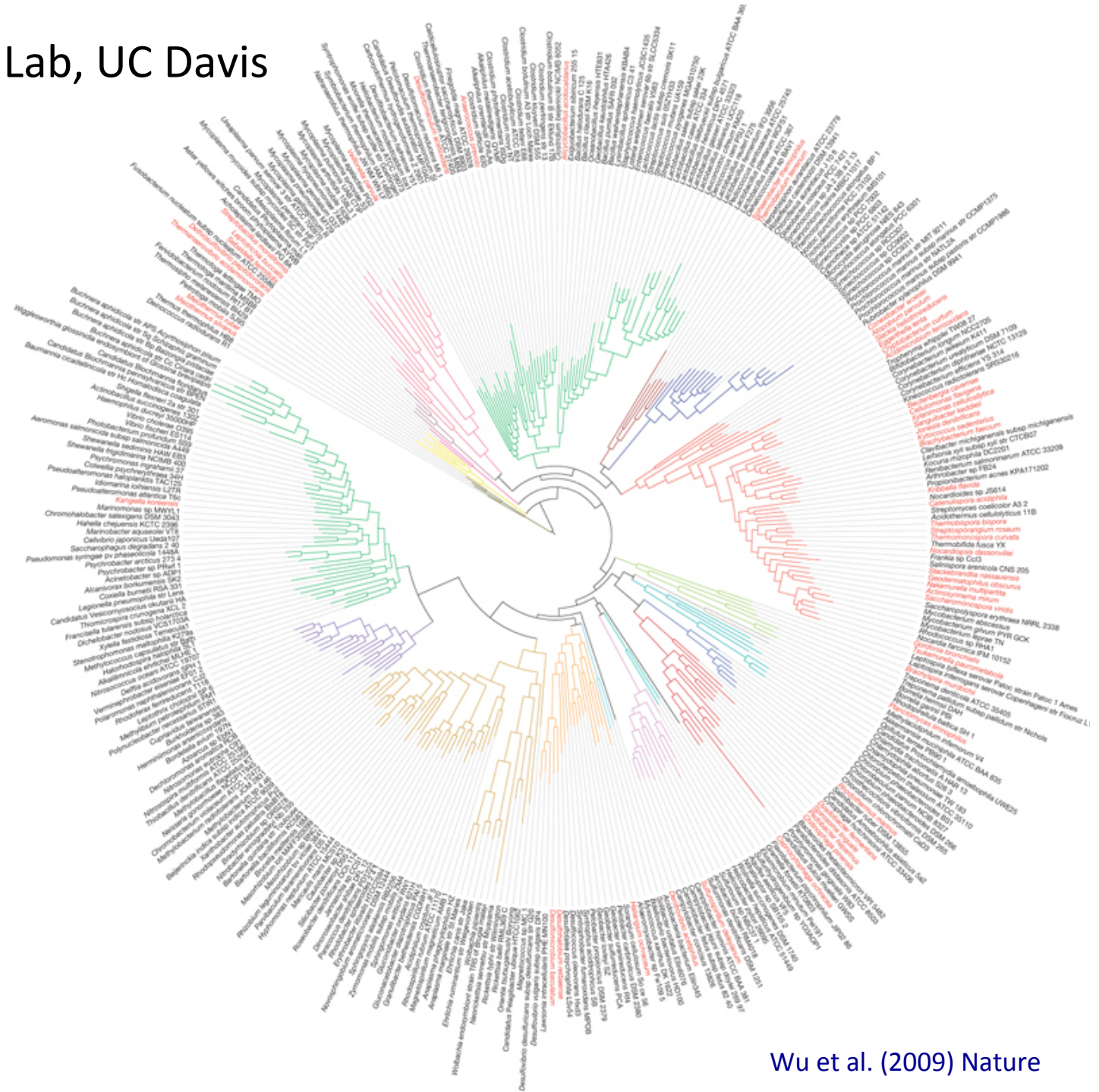
Jonathan Eisen's Lab, UC Davis

Enabled by:

PCR!!!!

[??]

Kary Mullis
Science 1985



Wu et al. (2009) Nature

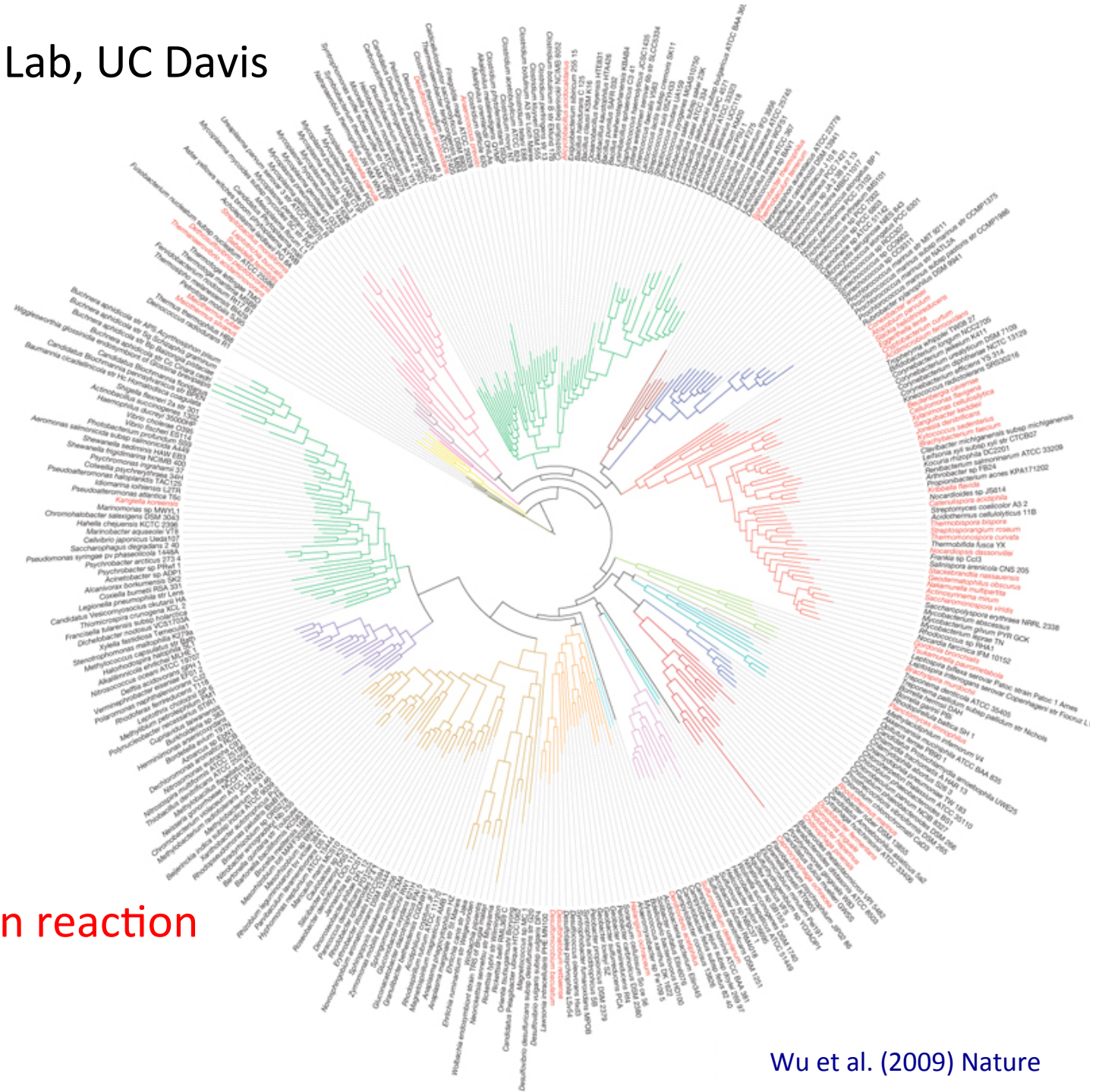
Jonathan Eisen's Lab, UC Davis

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PCR!!!!

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Science 1985

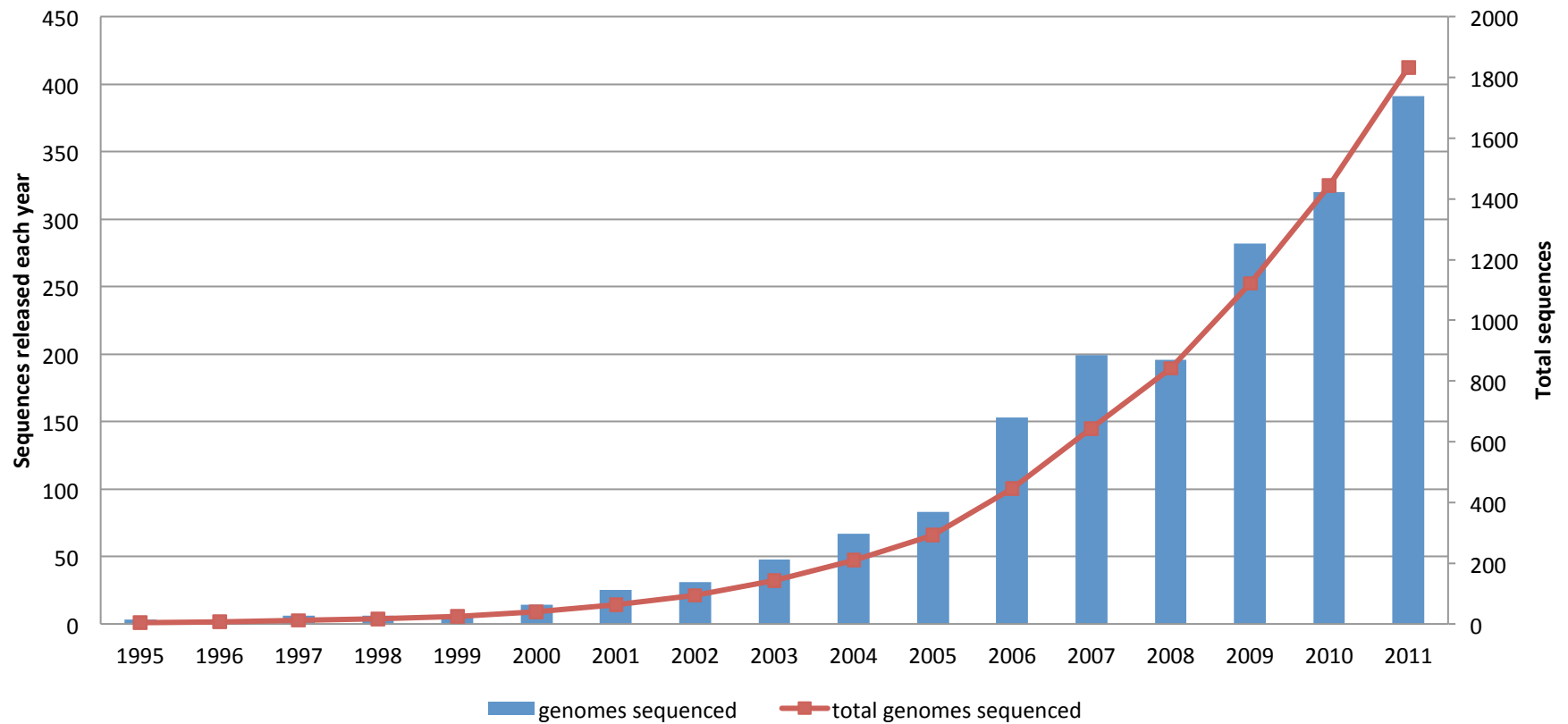
polymerase chain reaction



Wu et al. (2009) Nature

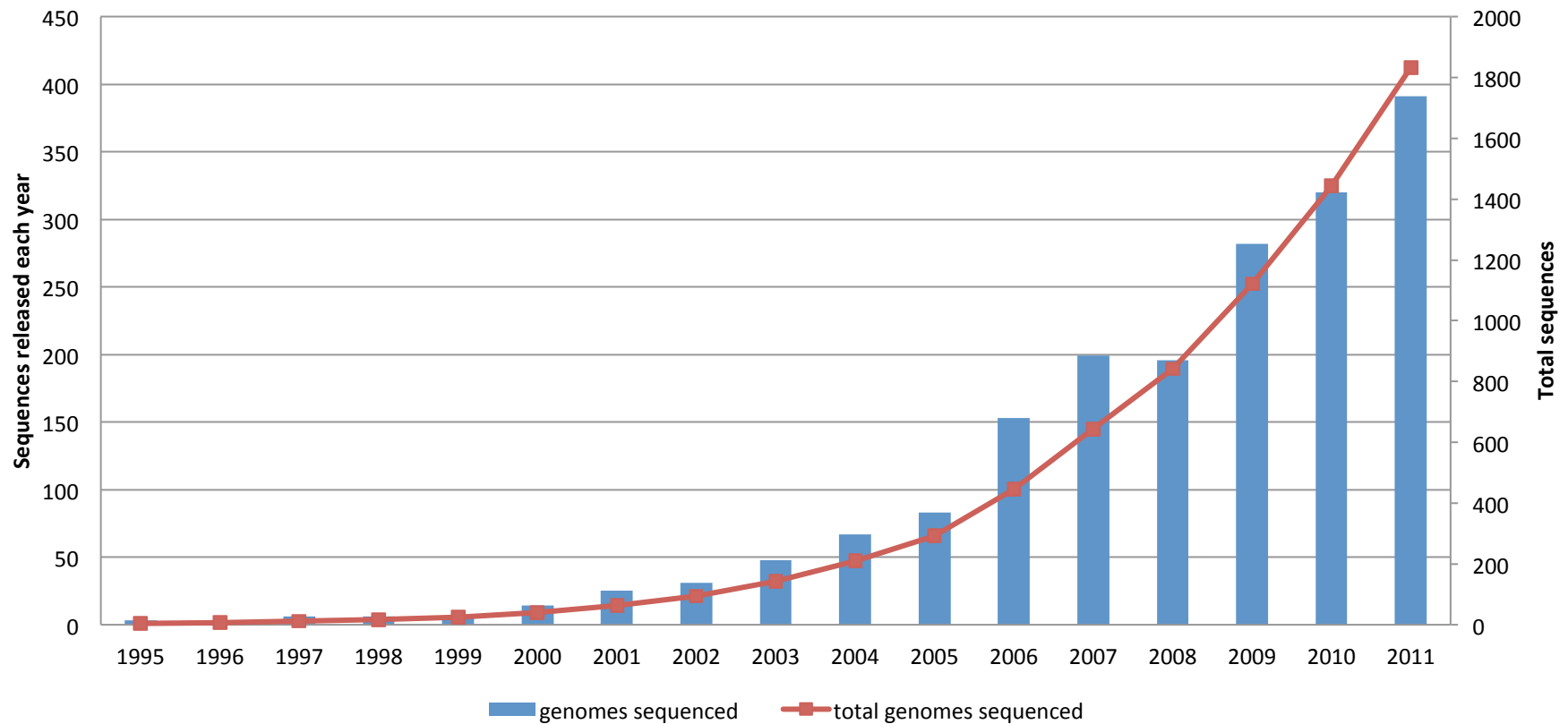
Heading to the '\$1' genome

Sequenced bacterial genomes



Heading to the '\$1' genome

Sequenced bacterial genomes



Optical physicist, Bill Banyai (Complete Genomics, Mountain View, CA)
2012 technology pushes the companies capacity to 100,000 genomes/year

Maybe a little before it's time, but....

Lysed cells are placed in the chamber – plug it into a PC

Complete genome sequence (unassembled) available within a few minutes to hours



\$900

<http://www.wired.com/wiredenterprise/2012/03/oxford-nanopore-sequencing-usb/>

Human genome project:

start 1989-90

finish 2003

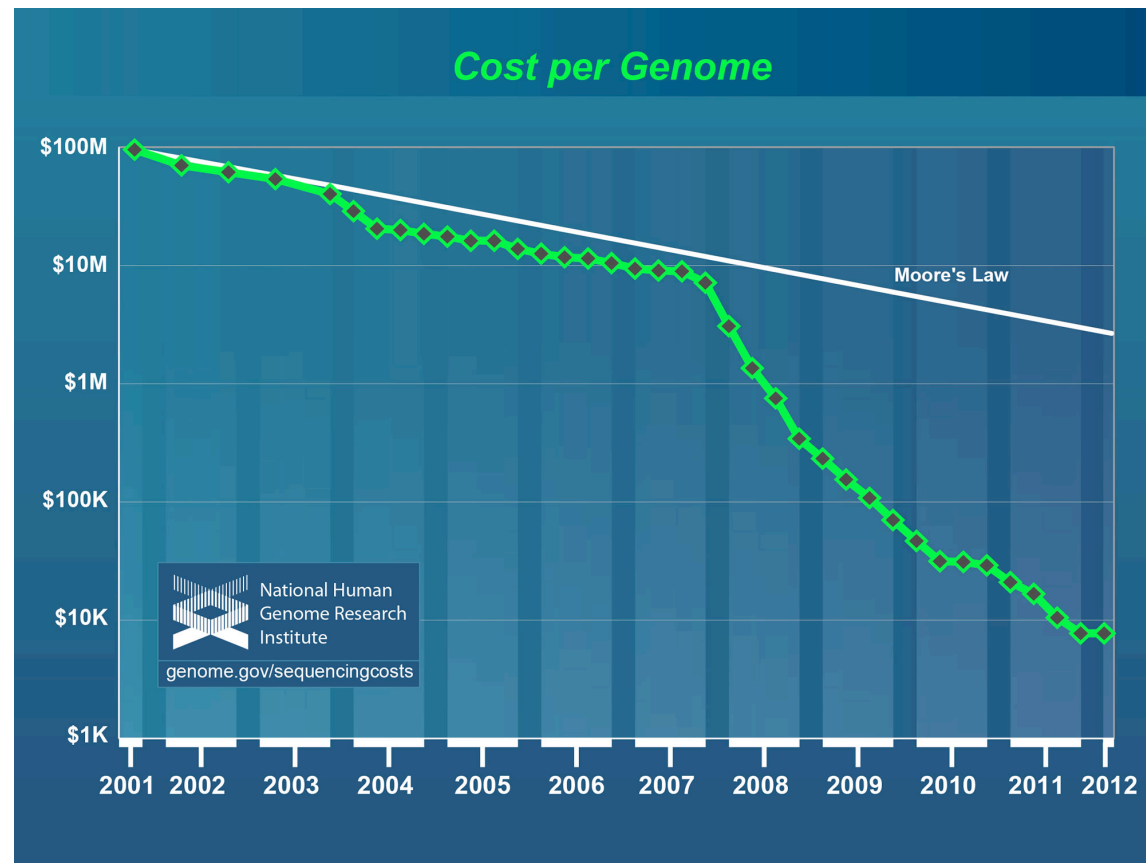
Cost: \$3 billion

Human genome project:

start 1989-90

finish 2003

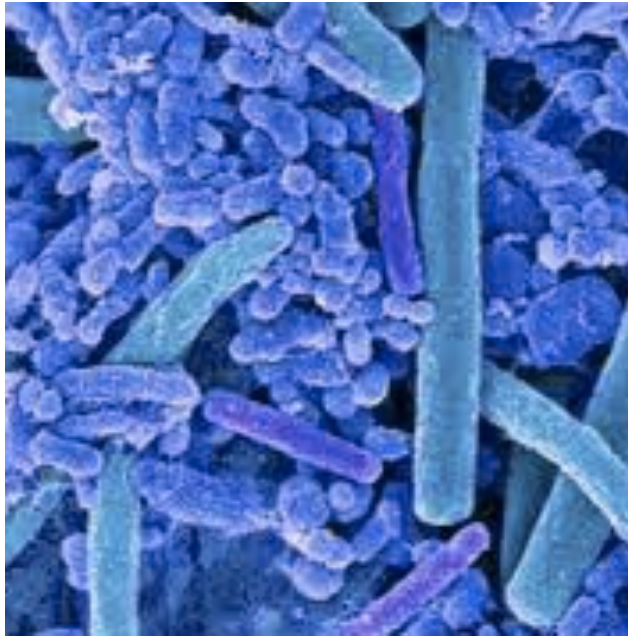
Cost: \$3 billion



GATTACA is here!
[1997]

VIDEO

Traits



Microbes

Small ($\sim 0.2 - \sim 750 \mu\text{m}$; aver $2 \mu\text{m}$)

Short generation times ($< 10 \text{ min}$)

Large population sizes

**Propensity *for* horizontal
gene transfer** (pangenome limitless)



Eukarya

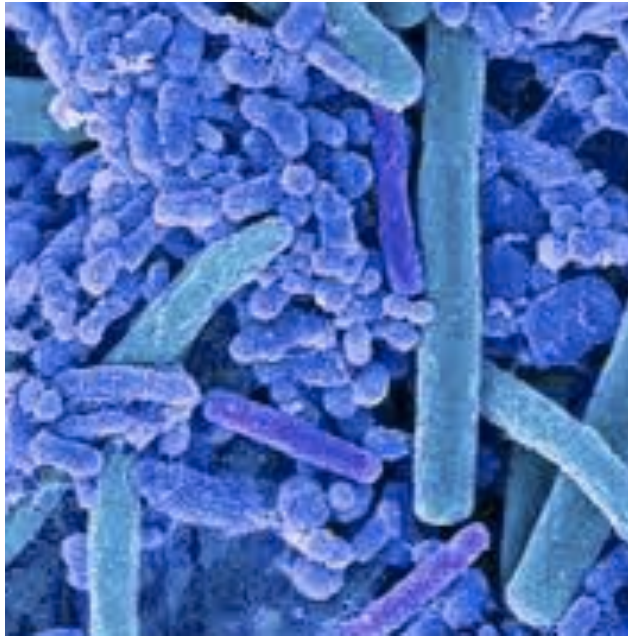
Large ($80 \mu\text{m}$ to 30 m ; aver mm-cm)

Long generation times (days – decades)

Small population sizes

**Propensity *against* horizontal
gene transfer**

Traits



Microbes

Small ($\sim 0.2 - \sim 750 \mu\text{m}$; aver $2 \mu\text{m}$)

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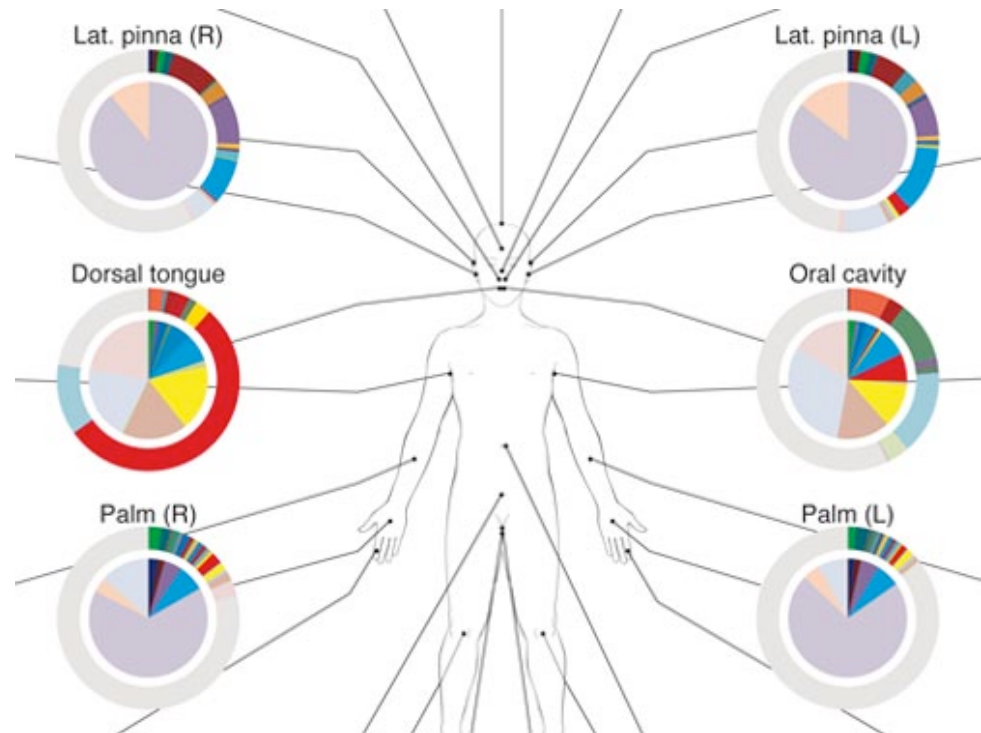
By partnering with one another, eukaryotes and bacteria increase their scope.

Perhaps you aren't the person you think you are.

The 'Ecosystem'



Victoria Orphan, Prof. Caltech



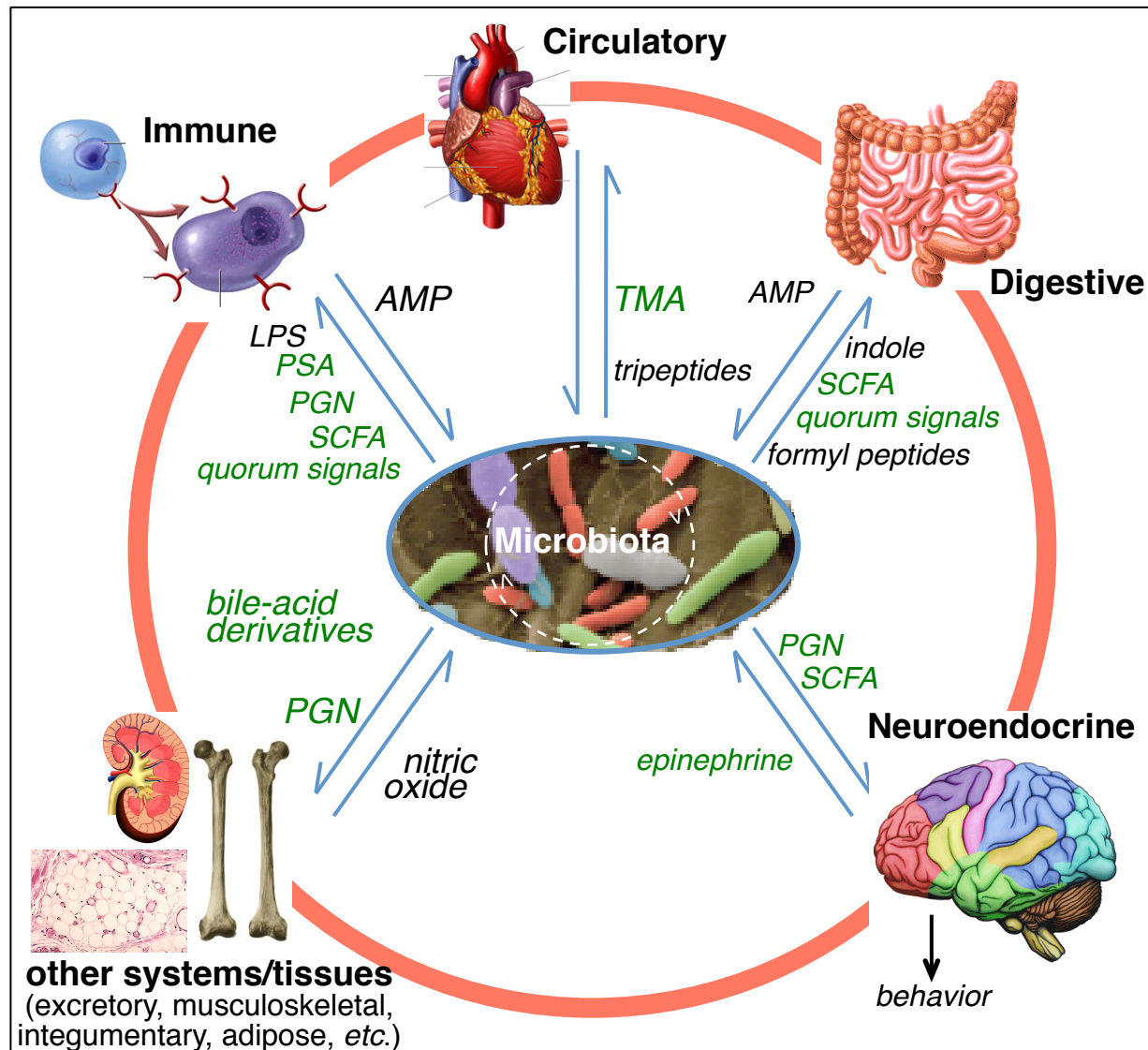
Host:bacterial partners -

1:10 cell number (10^{13} host cells/ 10^{14} bacterial cells)

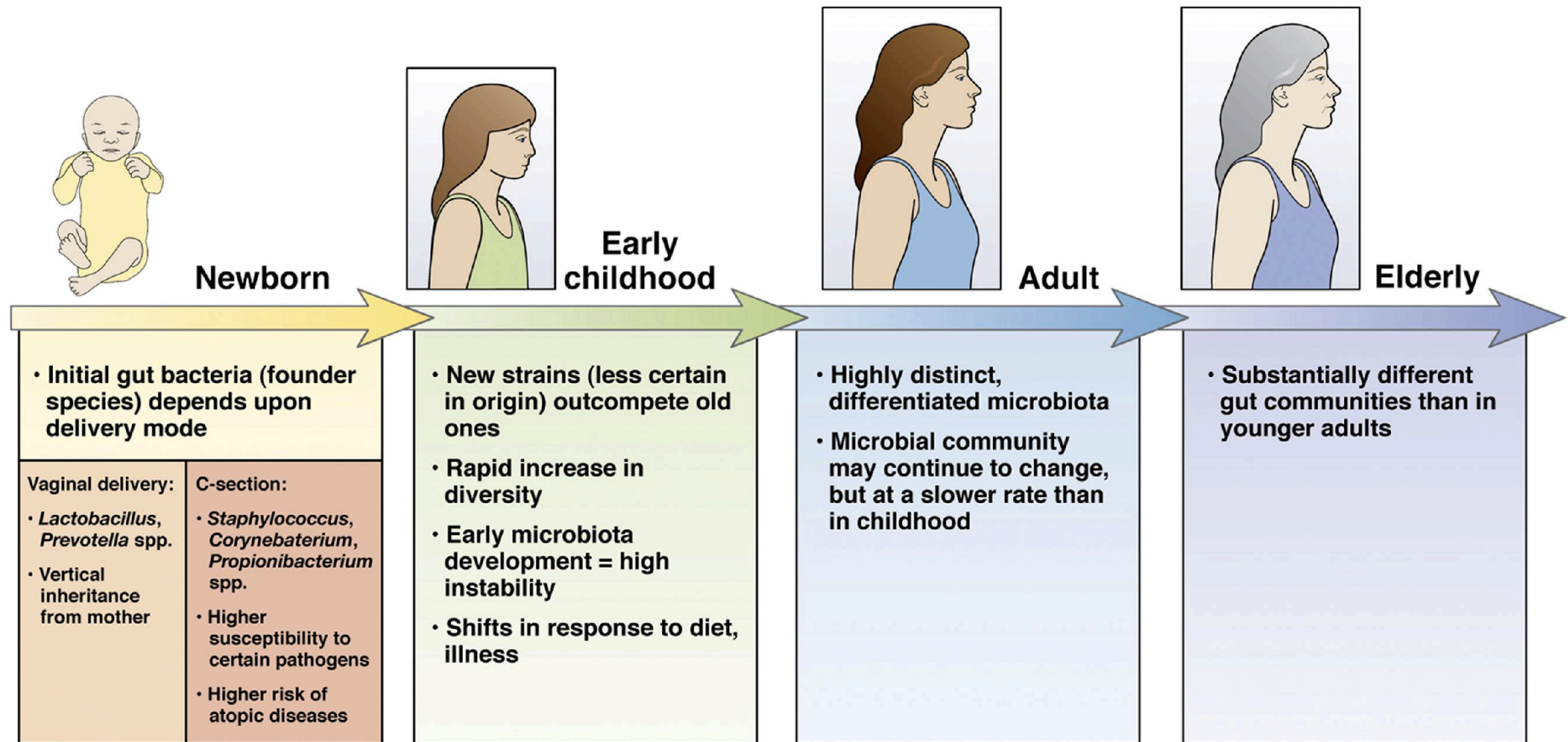
1:1 gene number (30,000 in 10^{13} /3,000 in 10^{14})

1:200 gene diversity

Mammalian microbiota have profound effects on host biology:



Symbioses – classic nested ecosystems



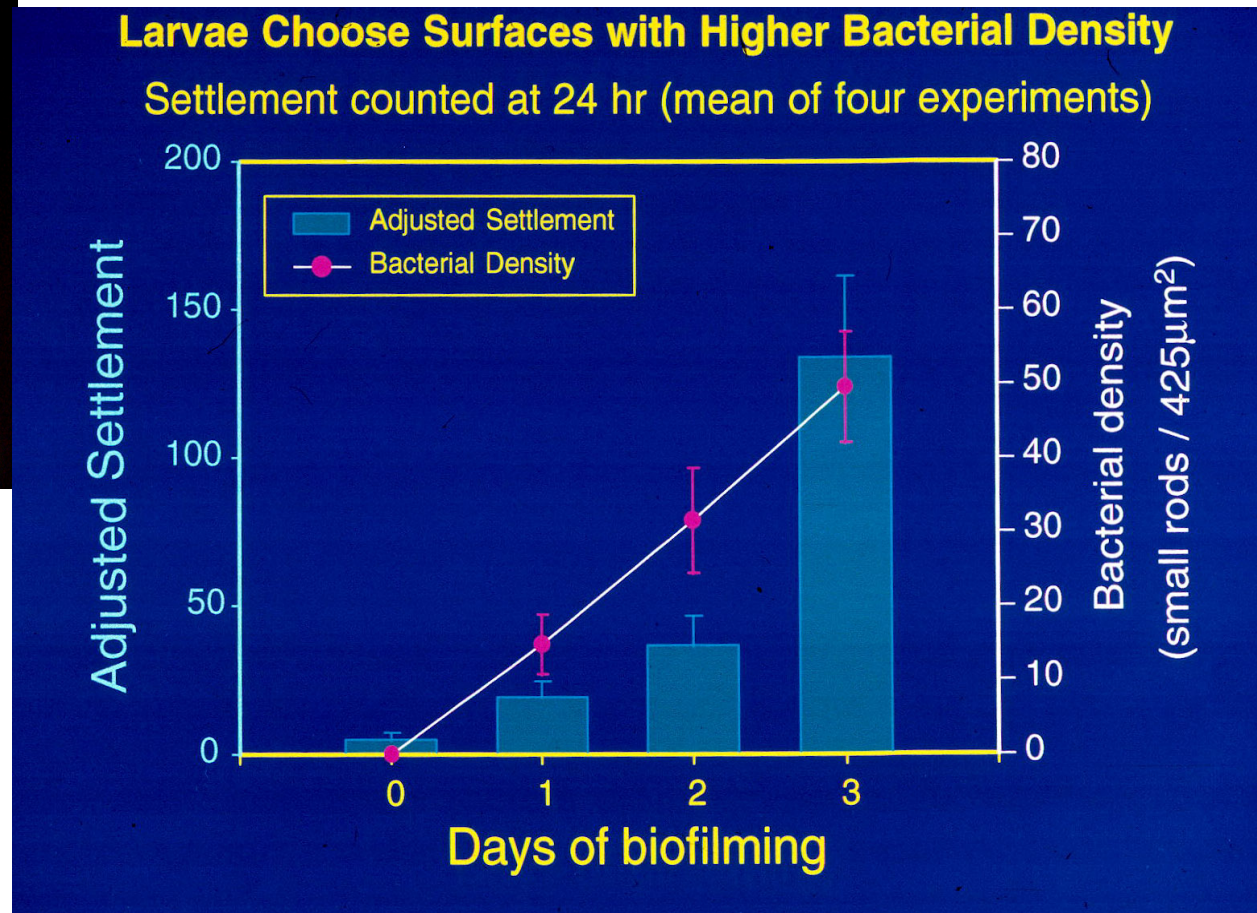
HUMANS HAVE BEEN THE FOCUS, but what of other animals?

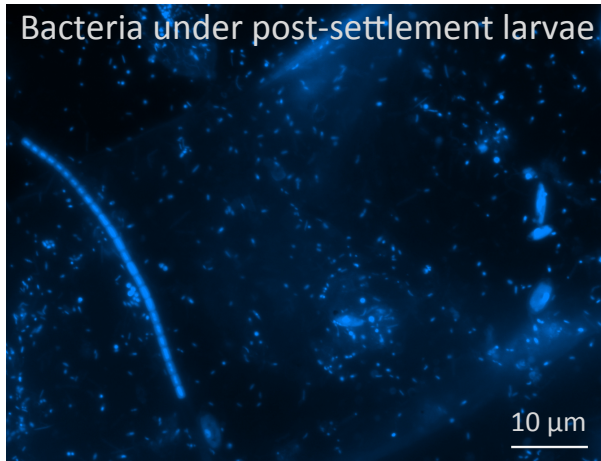
Many, if not most marine invertebrate larvae that settle on hard substrates require bacterial biofilms for settlement and/or metamorphosis.



Hydroides elegans

BACTERIAL BIOFILMS





IDENTIFYING THE MECHANISM

Hadfield (Ying Huang) and Callahan lab:

Identified a bacterial species, *Pseudoalteromonas luteoviolacea*, that is a strong inducer of metamorphosis.

Defined genes essential for induction of larval settlement



Bacterial biofilms



Colonies of
Hydroides elegans

FOULING COSTS THE US NAVY
>\$1,000,000,000/yr





TAKE HOME

New technology has revealed that animals and plants are deeply imbedded in the microbial world, and all aspects of their biology are likely to be affected.



A microscopic image showing a dense population of bacteria. The bacteria are primarily rod-shaped (bacilli) and are stained in shades of purple and blue. Some bacteria appear as thin, elongated rods, while others are more clustered or shorter. The background is a light, grainy texture. Overlaid on the center of the image is the text "GOOD LUCK!!!".

GOOD LUCK!!!

Dr. Nathan Wolfe

Founder and CEO Global Viral Forecasting Initiative (GVFI)

Lorry I. Lokey Visiting Professor, Stanford



2011 Time 100 Influential People in the World

NYT, NPR, New Yorker, National Geographic...

TED talks, CNN w/ Anderson Cooper, Colbert Report

When your parents ask you what you
learned at Caltech this year,
remember this...

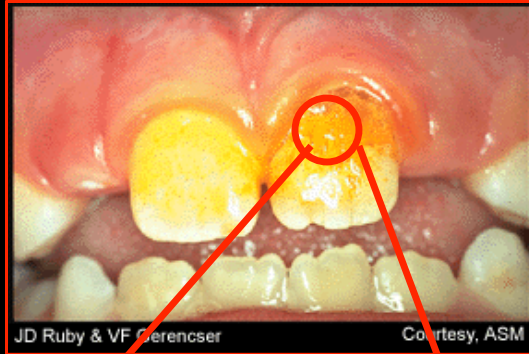


“Effect of antibacterial home cleaning and handwashing products on infectious disease symptoms”
Annals of Internal Medicine (2004) 140:321-330

Fallacy no. 1: bacteria are “germs”

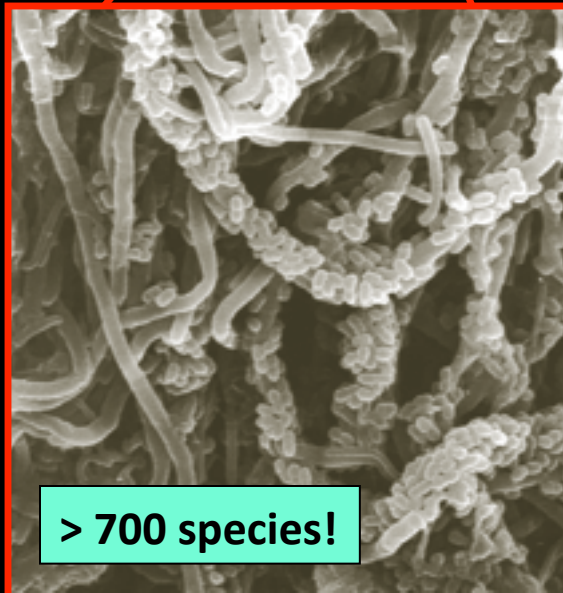
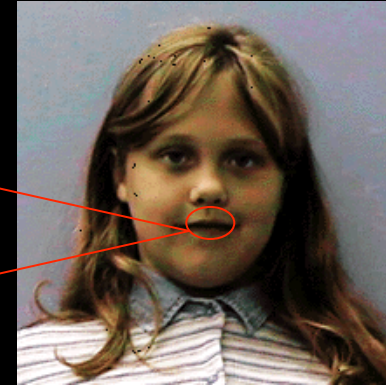
Fallacy no. 2: bacteria are simple/boring

Germ, Germ, Everywhere



Germ Poem

by Candice



Germ, germ everywhere
Even on a little pear,
Germ, germ all around,
Even on the dirty ground.
Germ, germ make me sick,
Especially on a candy stick.
Germ, germ are so small,
Even on a bouncy ball.

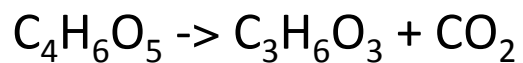
But let's not allow a few bad apples
spoil the whole lot...

*Out of > 30 MILLION bacterial species
less than 80 are pathogens!*

In fact, many bacteria enable our daily life...



Malolactic fermentation



“Live and active cultures”

Lactic acid bacteria are used in the production of \$20 to \$30 billion worth of fermented products per year in the United States.

They have given us the air we breathe...



cyanobacteria



chloroplast (plants)



O₂



Oxygenic photosynthesis

...and our ability to breathe it



α -proteobacteria



mitochondrion



ATP



Aerobic respiration

So let us dispell these myths...

~~Fallacy no. 1: bacteria are “germs”~~

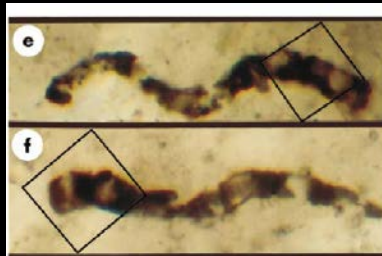
~~Fallacy no. 2: bacteria are simple/boring~~

... and celebrate the truth:

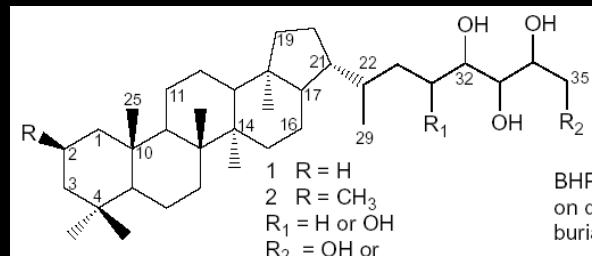
The microbial world is: ancient,
vast,
diverse and
crucial for our
future

The microbial world is: ancient,
vast,
diverse and
crucial for our
future

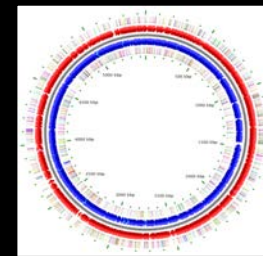
morphological fossils



biomarkers, isotopes

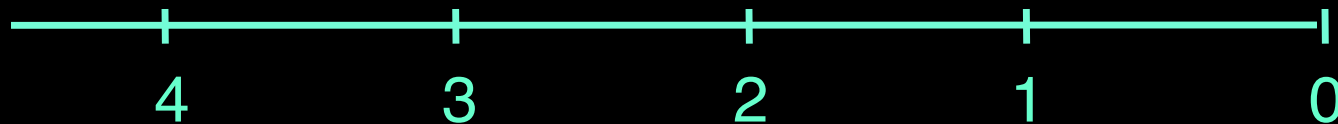


genomes



Cambrian Explosion →

MICROBIAL LIFE →



Billions of Years Ago (10^9)

How many microbes are there on Earth?

Human Population:

World	7,000,000,000	7×10^9
-------	---------------	-----------------

Microbial Population:

5,000,000,000,000,000,000,000,000,000,000	5×10^{30}
---	--------------------

Microbes = 200 trillion (10^{12}) Earth-Sun distances

1×10^{31} Viruses = 100 million light years

Where do they live?

On Humans:

Skin:	$5-50 \times 10^3$	/sq. inch
Groin, Axillia:	5×10^6	/sq. inch
Teeth	$5-50 \times 10^6$	/sq. inch
Colon:	300×10^9	/g

Total per person: (70 trillion, 70×10^{12})

~10X number of human cells in an adult body
The gut microbiome is estimated to contain $\geq 100X$
the number of genes in the human genome!

Where do they live?

Air:

Detected as high as 34-46 mi

5.0×10^{19}

Bacteria nucleate snowflakes

Animals:

All Humans

4.0×10^{23}

Adults excrete own body weight in fecal bacteria each year

Domestic animals, Termites

5.0×10^{24}

Soils:

2.5×10^{29}

#s microbes in 1 teaspoon soil = #s humans in Africa

Aquatic:

Marine and Freshwater

1.0×10^{29}

Subsurface:

Terrestrial and Deep Ocean

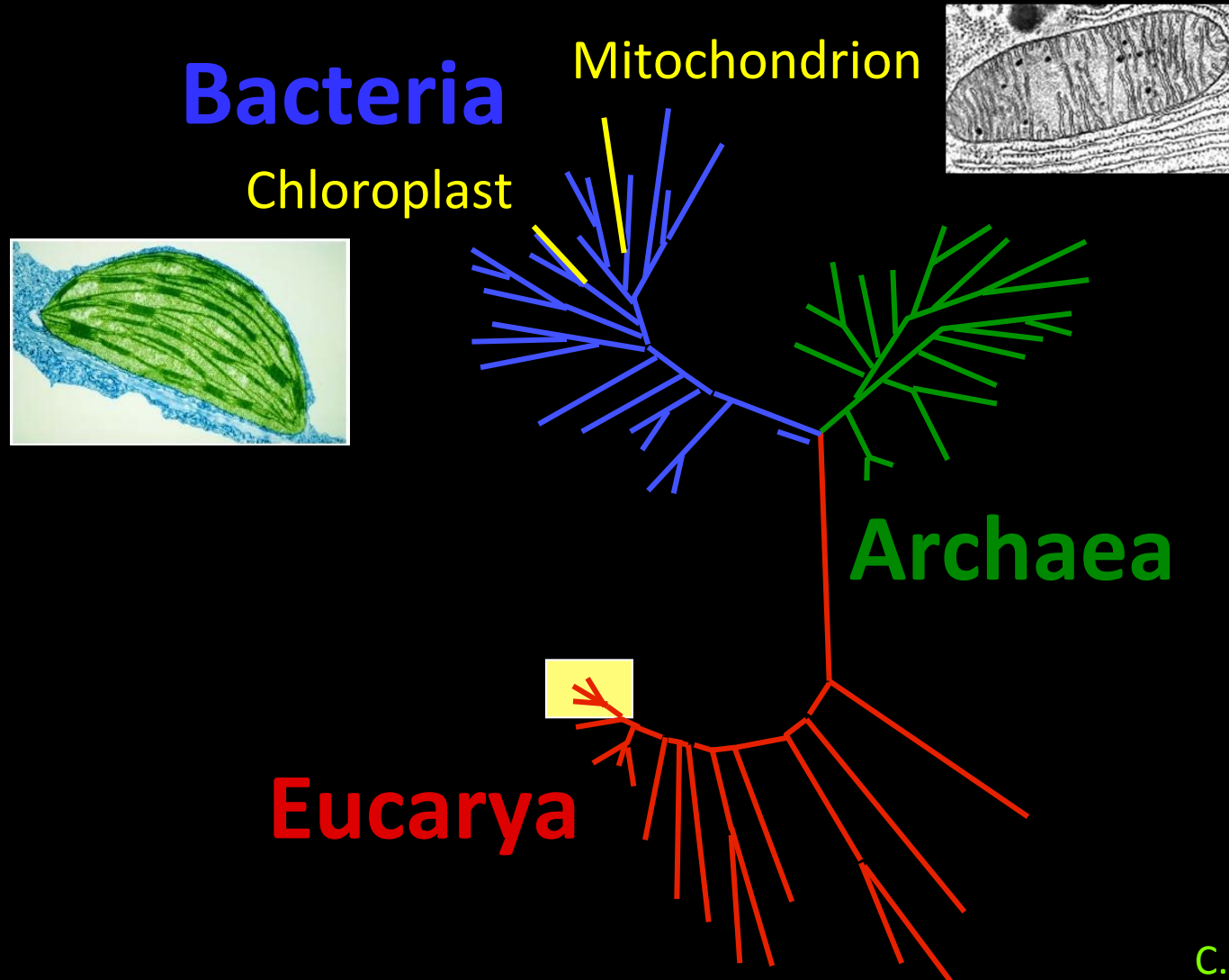
Detected as deep as 2 mi.

3.8×10^{30}

} New frontier

The microbial world is: ancient,
vast,
diverse and
crucial for our
future

Today we know that the 3 domains of life are
predominantly microbial



C. Woese, N. Pace



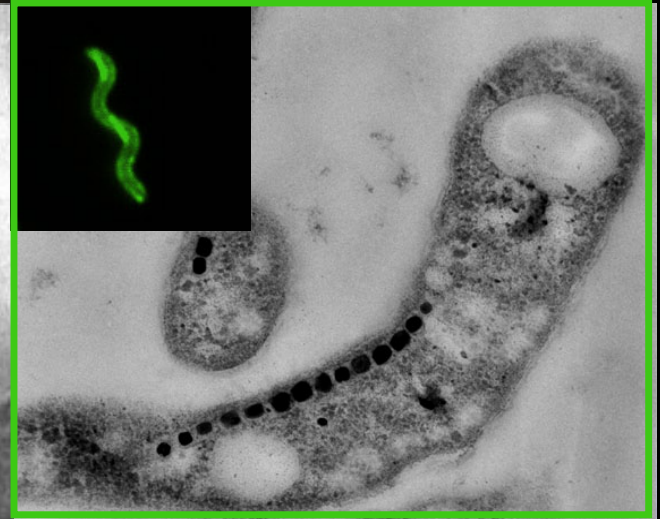
Thiomargarita namibiensis
Diameter 0.75 mm



Fruit fly

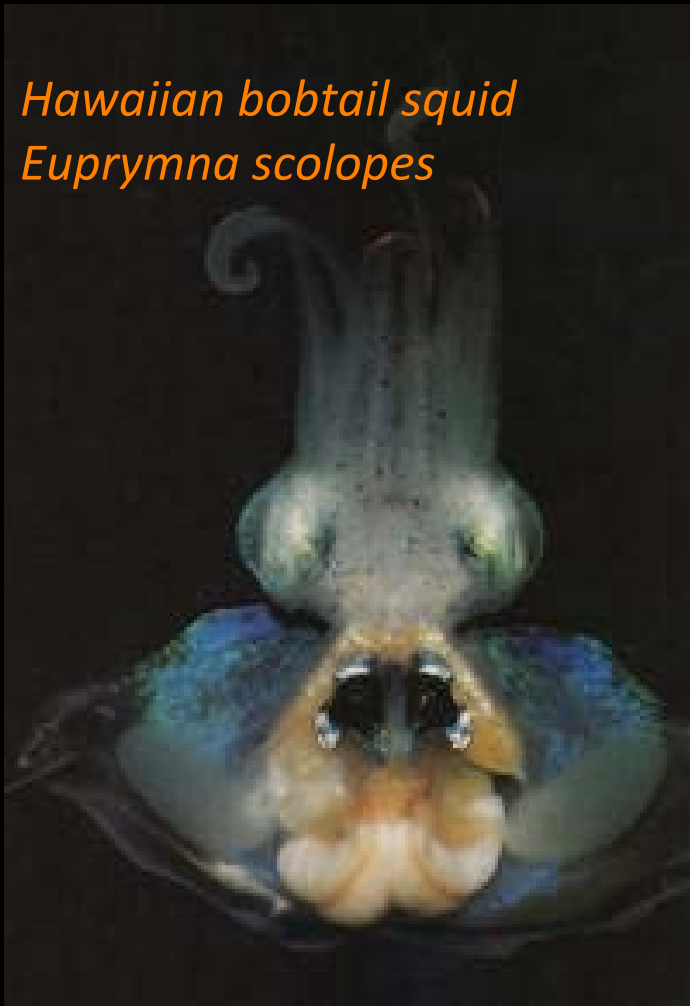


1 mm



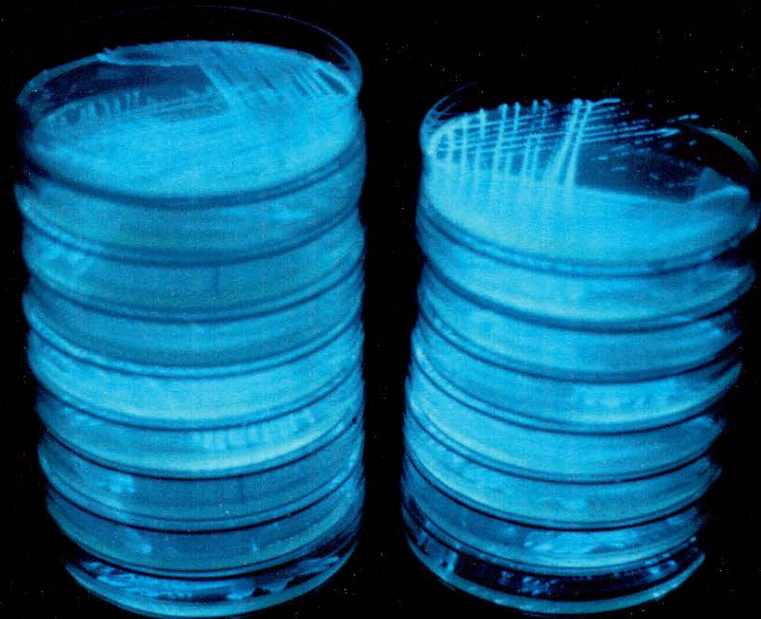
Some bacteria glow in the dark...

Hawaiian bobtail squid
Euprymna scolopes



Ruby and Mcfall-Ngai

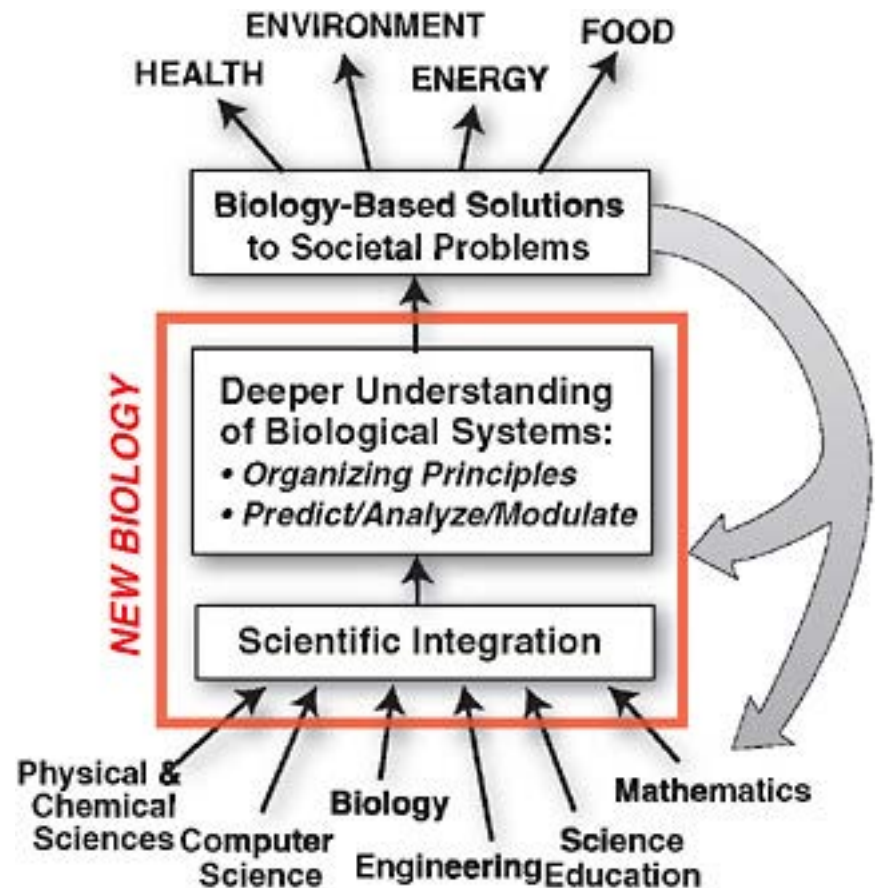
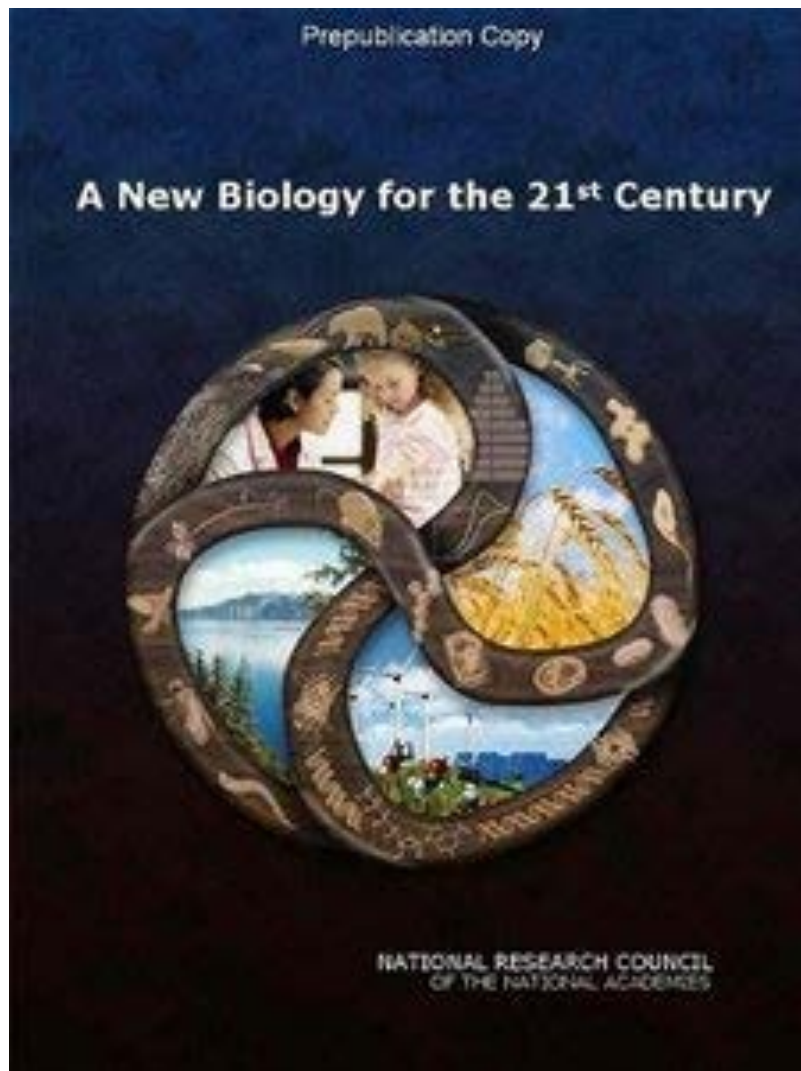
Vibrio fischeri, bioluminescence



Egland and Leadbetter

The microbial world is: ancient,
vast,
diverse and
crucial for our
future

Going forward, how will biology impact society?



HEALTH

- Asthma
- Autism
- Celiac disease
- Colon cancer
- Inflammatory bowel disease
- Obesity
- ???



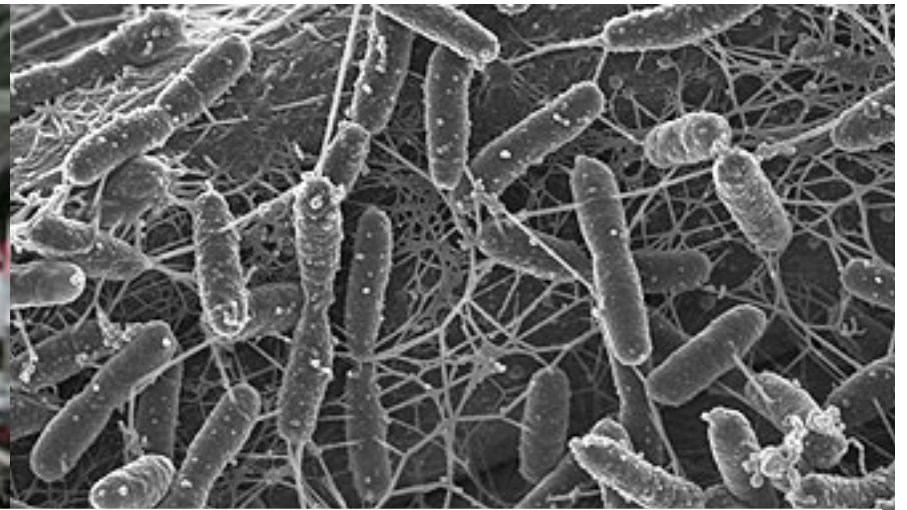
ENVIRONMENT

Diverse microbial communities
metabolize (break down) oil





Prof. Ken Nealson

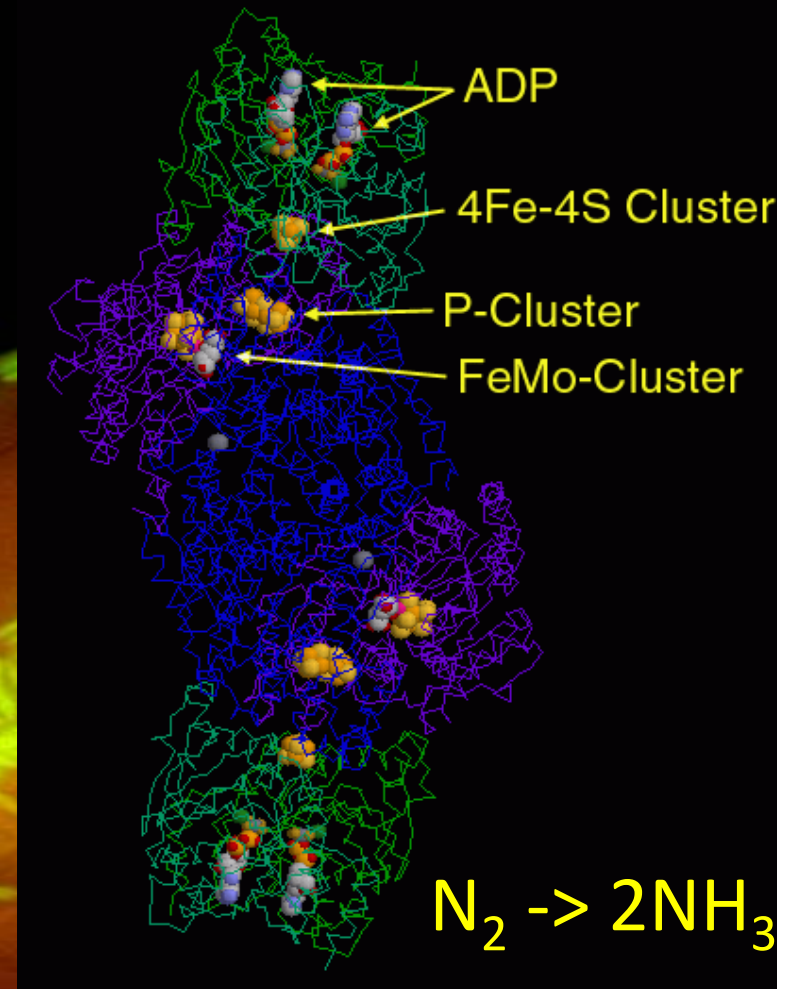


ENERGY

Microbial fuel cells, biofuels



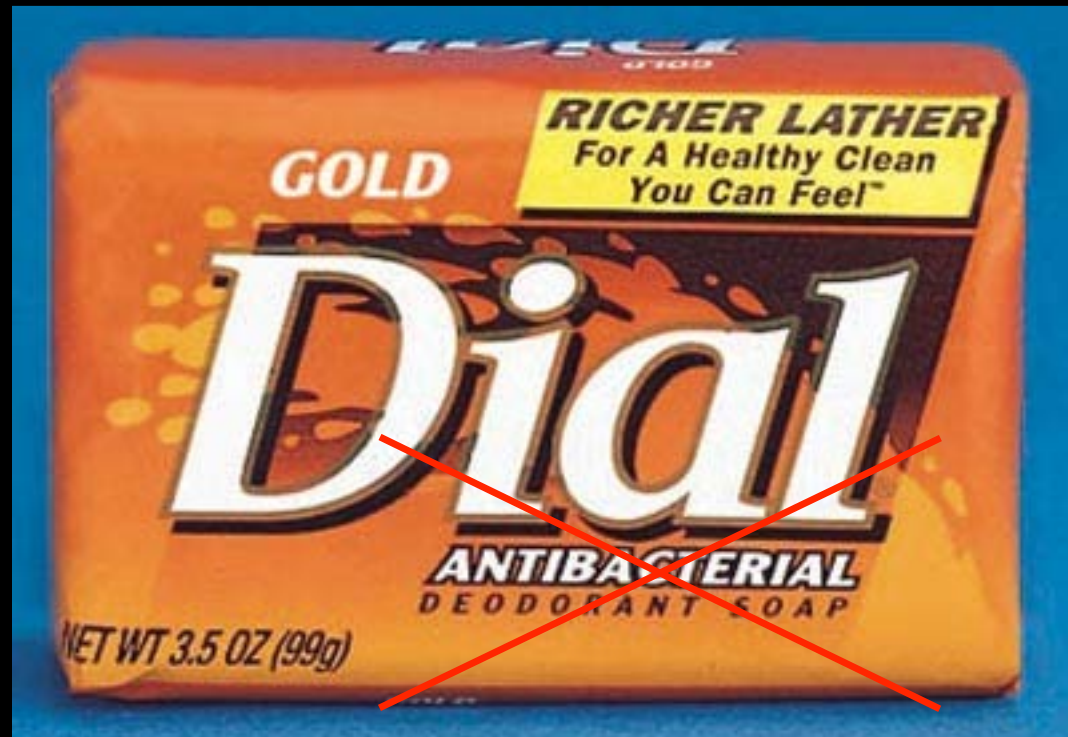
FOOD



Pseudomonads, Rhizobiales
biocontrol agents, natural fertilizers

Guido Bloemberg

In conclusion...



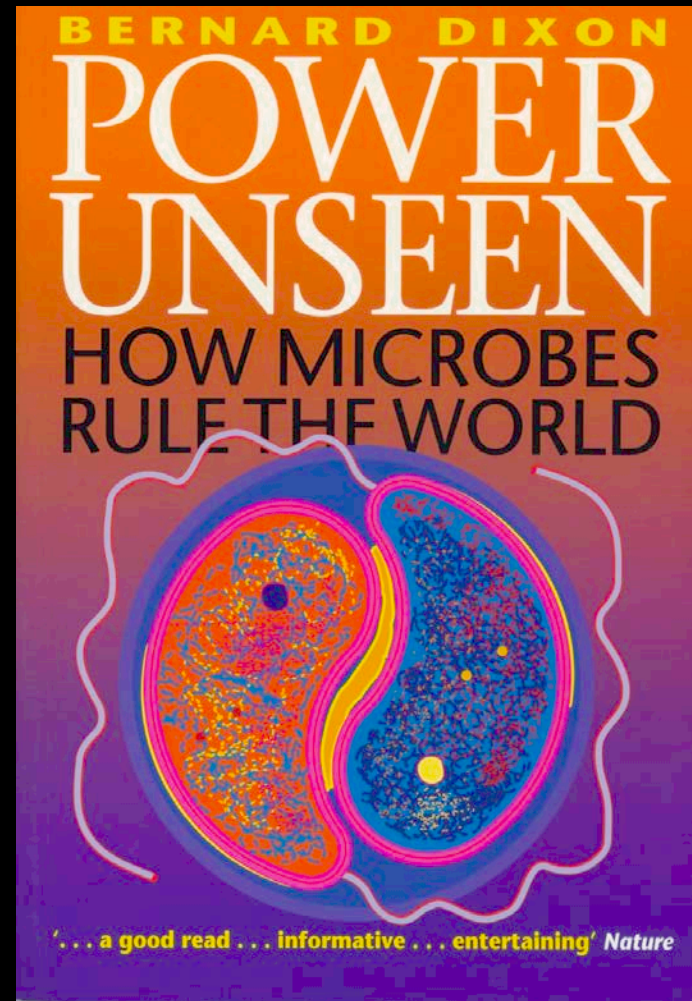
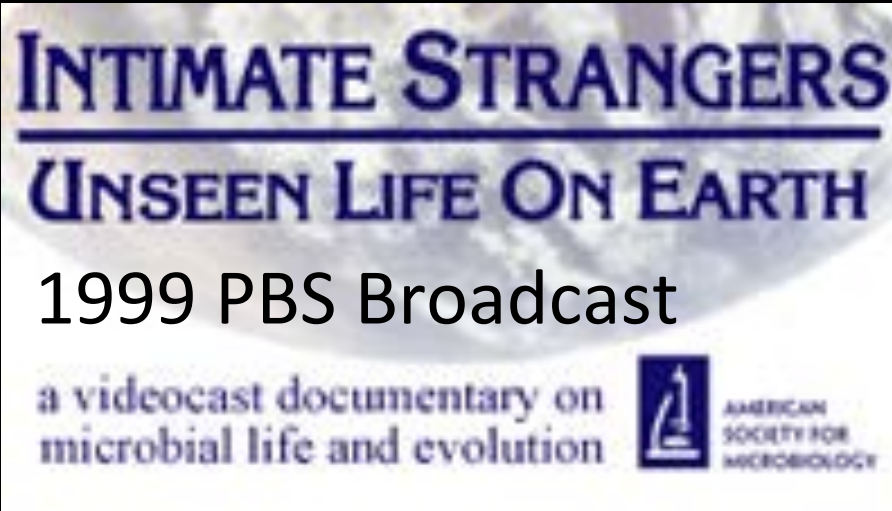
Let us celebrate the microbe!

First in.

Last out.



<http://www.microbeworld.org/index.php>





**Thank you
Margaret!!!**



Thanks for going on this adventure
with us, and let us know if you'd
like to TA next year to help make
Bi1 even better

We leave you with a song by
Frank Sinatra, "That's Life"

Have a great summer!!