Microbiology: What is it?

- Study of organisms who are too small to be seen without a microscope.
- Study of small organisms or microorganisms. NOT just Bacteria!
- Study of single celled organisms. The original cell biology!
- Categories & subjects based on the type of organisms:

(1) Viruses – Virology (acellular)

(2a) Bacteria – Bacteriology (e.g. Prokaryotes)
(2b) Archea – Archeaology? (already taken)

(3) Fungi – Mycology

(4) Algae – Phycology

(5) Protozoa – Protozoology

WHAT IS A MICROORGANISM?

“There is no simple answer to this question. The word ‘microorganism’ is not the name of a group of related organisms, as are the words ‘plants’ or ‘invertebrates’ or ‘fish’. The use of the word does, however, indicate that there is something *special* about small organisms; we use no special word to denote large organisms or medium-sized ones.

- Sistrom (1969)

Reasons to study Microbiology:

(1) Bacteria are part of us! E. coli lives in our gut and produces essential vitamins (e.g. K).

(2) Infectivity & Pathogenicity; MO's have the ability to cause disease in compromised &/or heathy hosts.

(3) MO's in the environment; Bioremediation or use of MO's to breakdown waste compounds like oil, pesticides, etc. Mineral cycling of elements like N, S, Fe, etc.

(4) Applied Microbiology or use in agriculture and industry.

(5) Understand basic biological processes: Evolution, Ecology, Genetics, etc.

WHY STUDY MICROBIOLOGY?

"The role of the infinitely small is infinitely large."

- Louis Pasteur (1862)

WE ARE NOT ALONE!

"We are outnumbered. The average human contains about 10 trillion cells. On that average human are about 10 times as many microorganisms, or 100 trillion cells...As long as they stay in balance and where they belong, [they] do us no harm…In fact, many of them provide some important services to us. [But] most are opportunists, who if given the opportunity of increasing growth or invading new territory, will cause infection."

- Sullivan (1989)

Natural Microbial Populations

- Typical soil: ~10^9 MO's per gram
- Typical fresh water: ~10^6 to 10^7 MO's per ml
- Open Ocean: ~10^5 to 10^6 MO's per ml

- Complexity (soil): 10^4 to 10^5 different prokaryote-sized genomes per gram

Prokaryotes: The unseen majority

Whitman et al., 1998 PNAS

Table 5. Number and biomass of prokaryotes in the world

Environment	No. of prokaryotic cells, $\times 10^{28}$	Pg of C in prokaryotes*
Aquatic habitats	12	2.2
Oceanic subsurface	355	303
Soil	26	26
Terrestrial subsurface	25–250	22–215
Total	415–640	353–546

*Calculated as described in the text.

Pg = Petagram or 10^{15}grams

Prokaryotes: The unseen majority

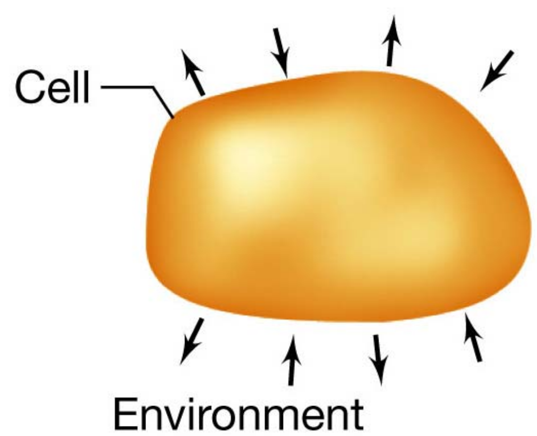
Whitman et al., 1998 PNAS

	Total C (Pg)	Total N (Pg)	Total P (Pg)
Plants:	560	12-20	1-2
Prokaryotes:	350-550	70-120	7-12

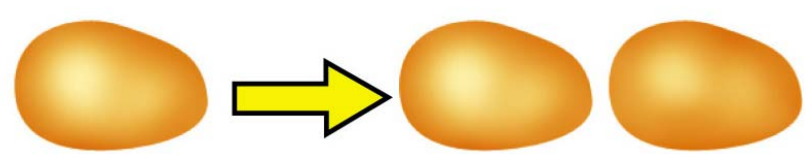
Take Home Message: Prokaryotes contain 60 to 100% the cellular carbon of all plants along with ~10x the N and P of plants!

Hallmarks of cellular life

1. Metabolism
Uptake of chemicals from the environment, their transformation within the cell, and elimination of wastes into the environment. The cell is thus an *open* system.

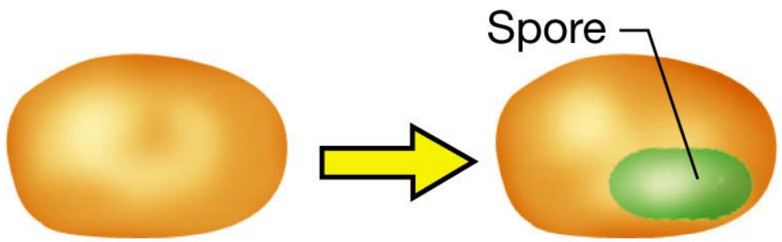


2. Reproduction (growth)
Chemicals from the environment are turned into new cells under the direction of preexisting cells.

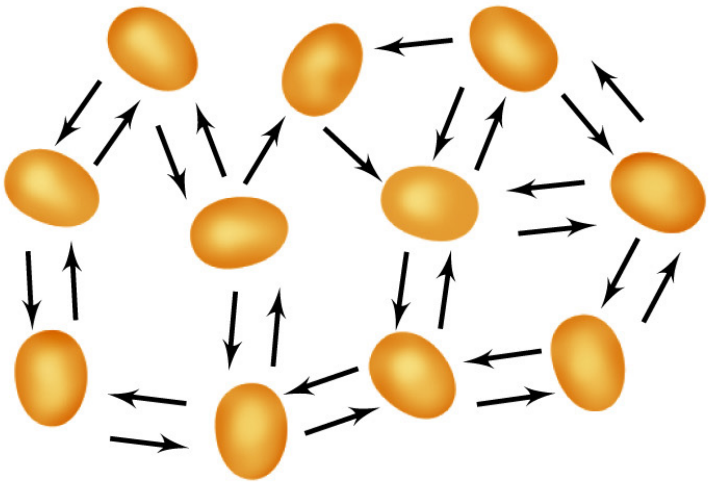


Hallmarks of cellular life

3. Differentiation
Formation of a new cell structure such as a spore, usually as part of a cellular *life cycle*.



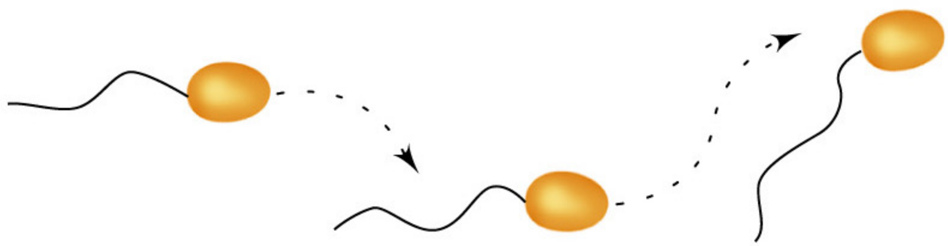
4. Communication
Cells *communicate* or *interact* primarily by means of chemicals that are released or taken up.



Hallmarks of cellular life

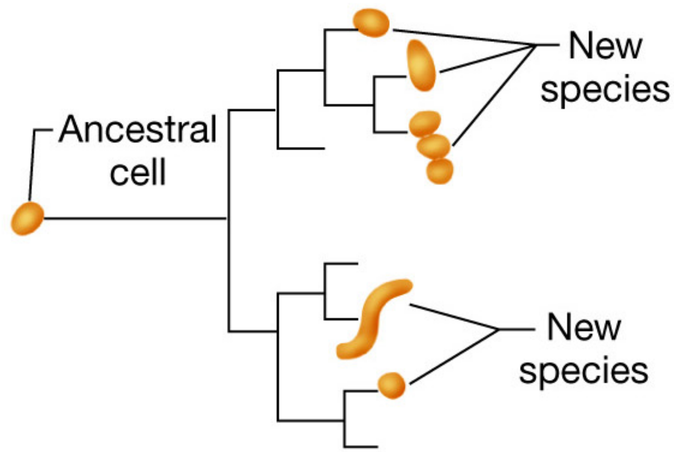
5. Movement

Living organisms are often capable of self-propulsion.

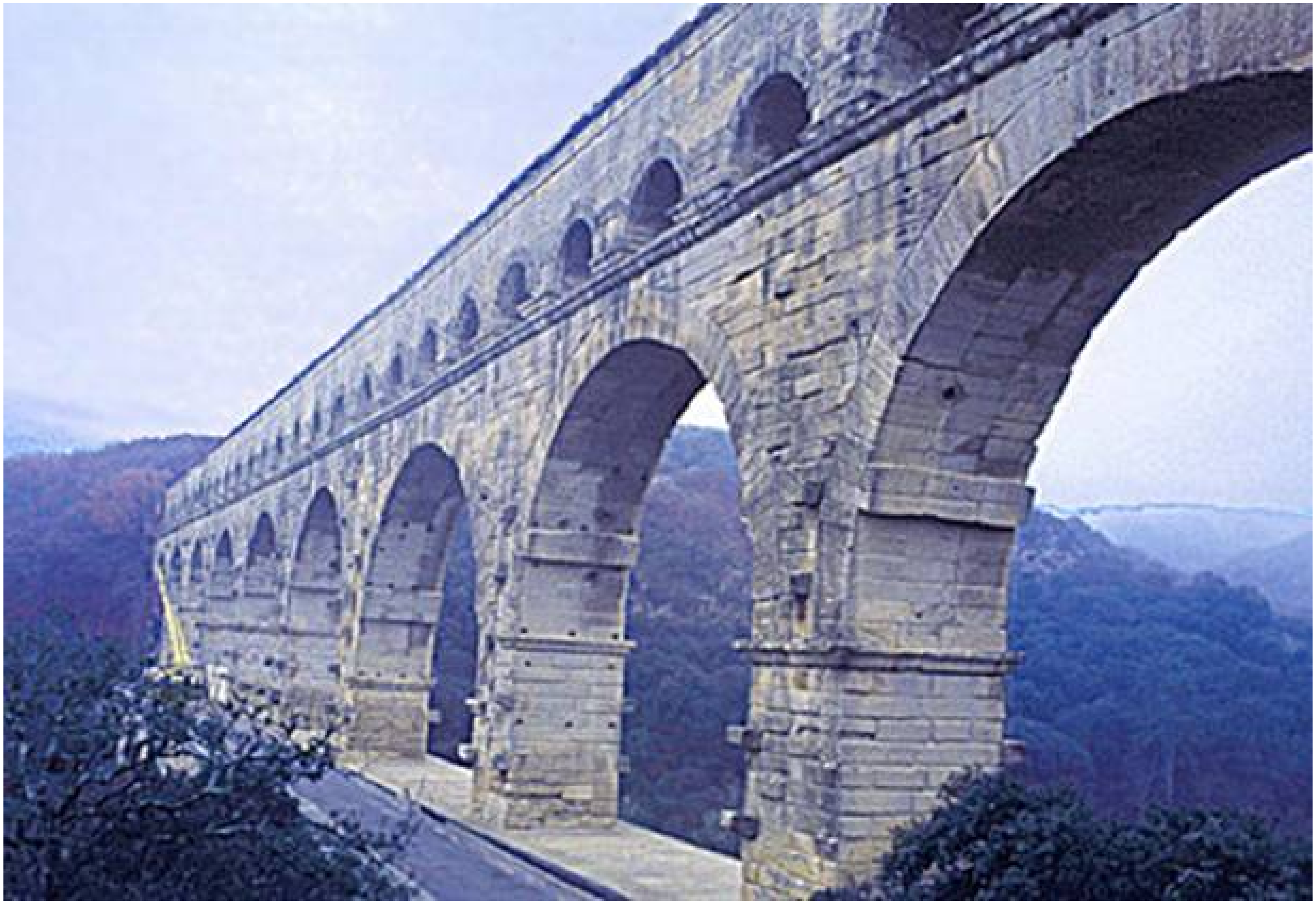


6. Evolution

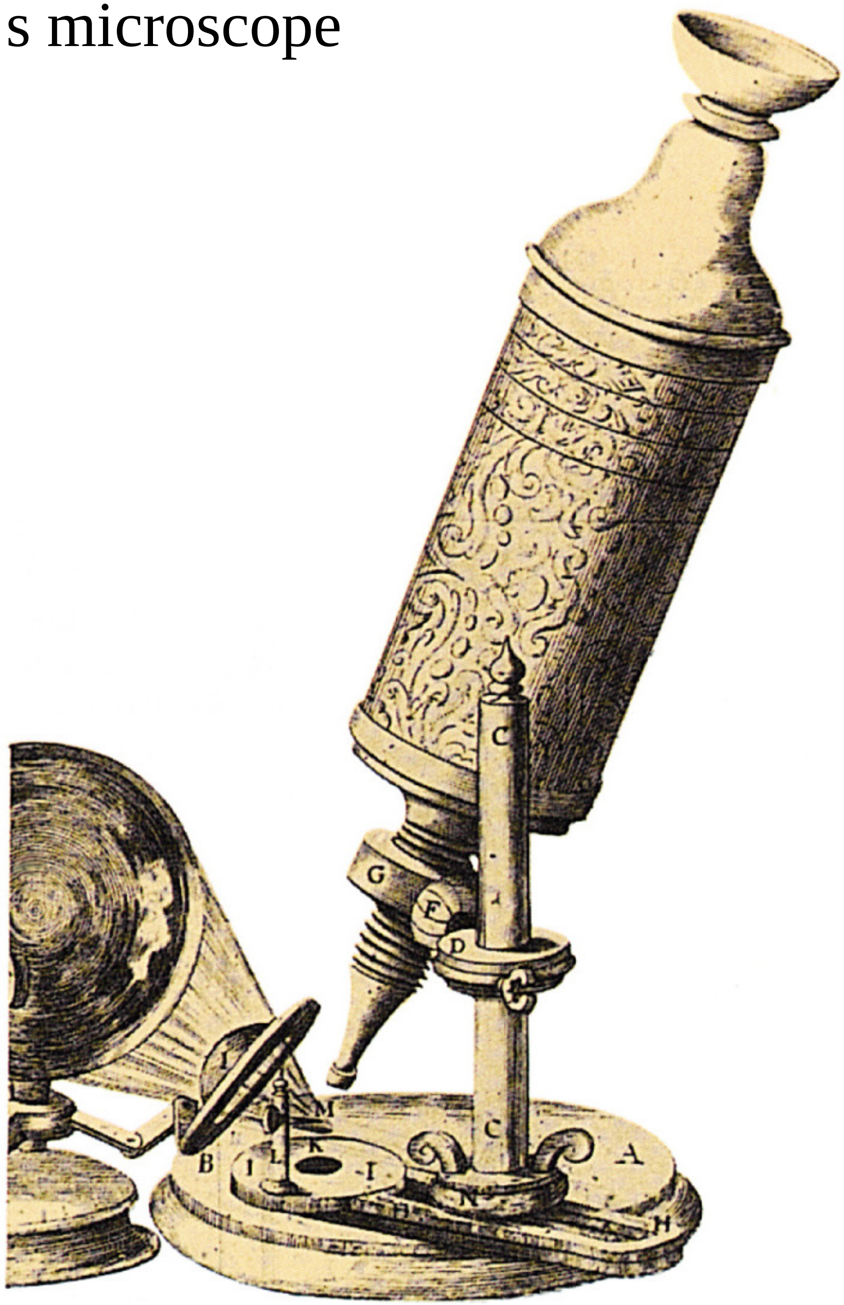
Cells *evolve* to display new biological properties. Phylogenetic trees show the evolutionary relationships between cells.



Roman Aqueduct: Sanitation Age

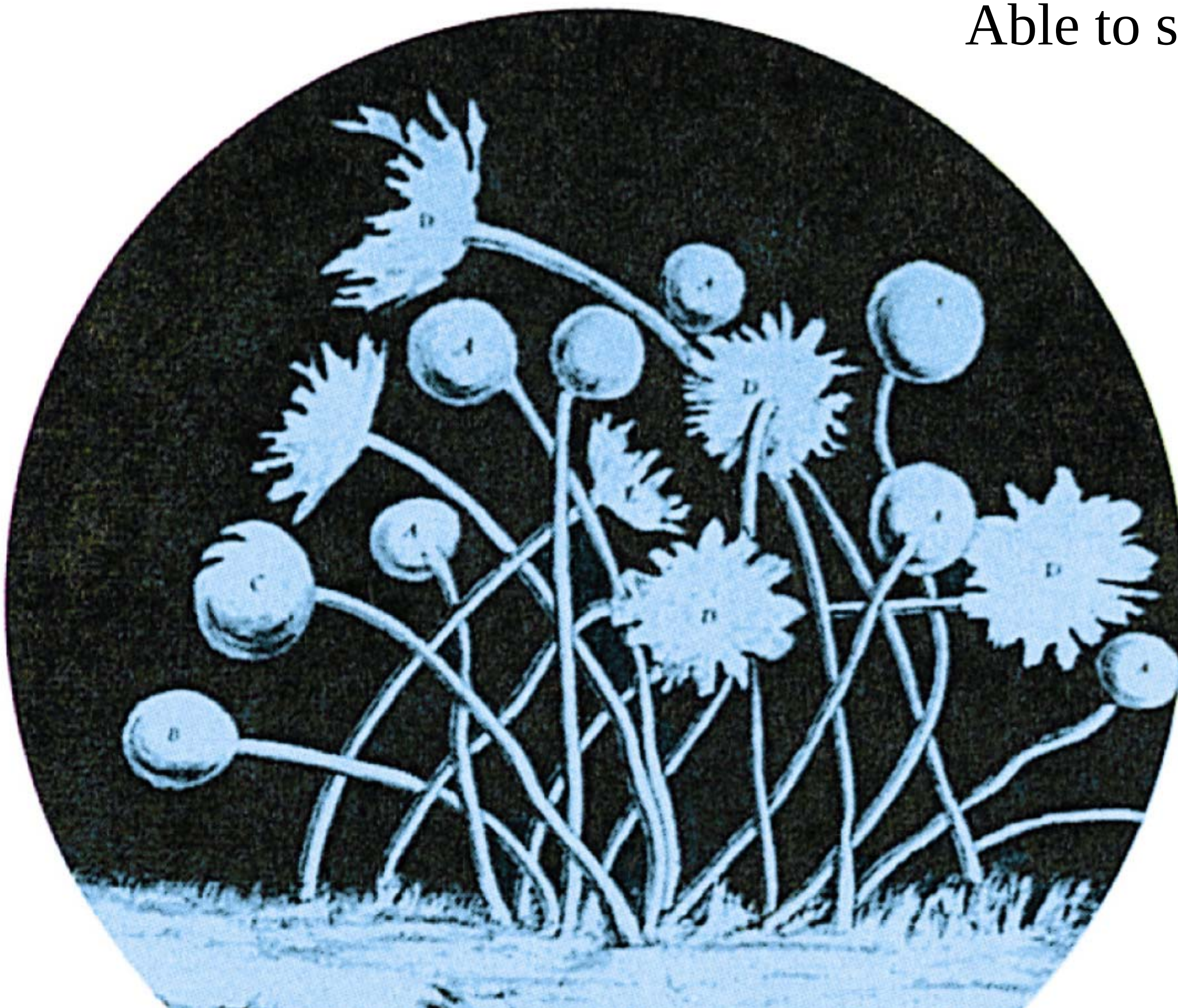


Robert Hooke’s microscope



(a)

Able to see Mold

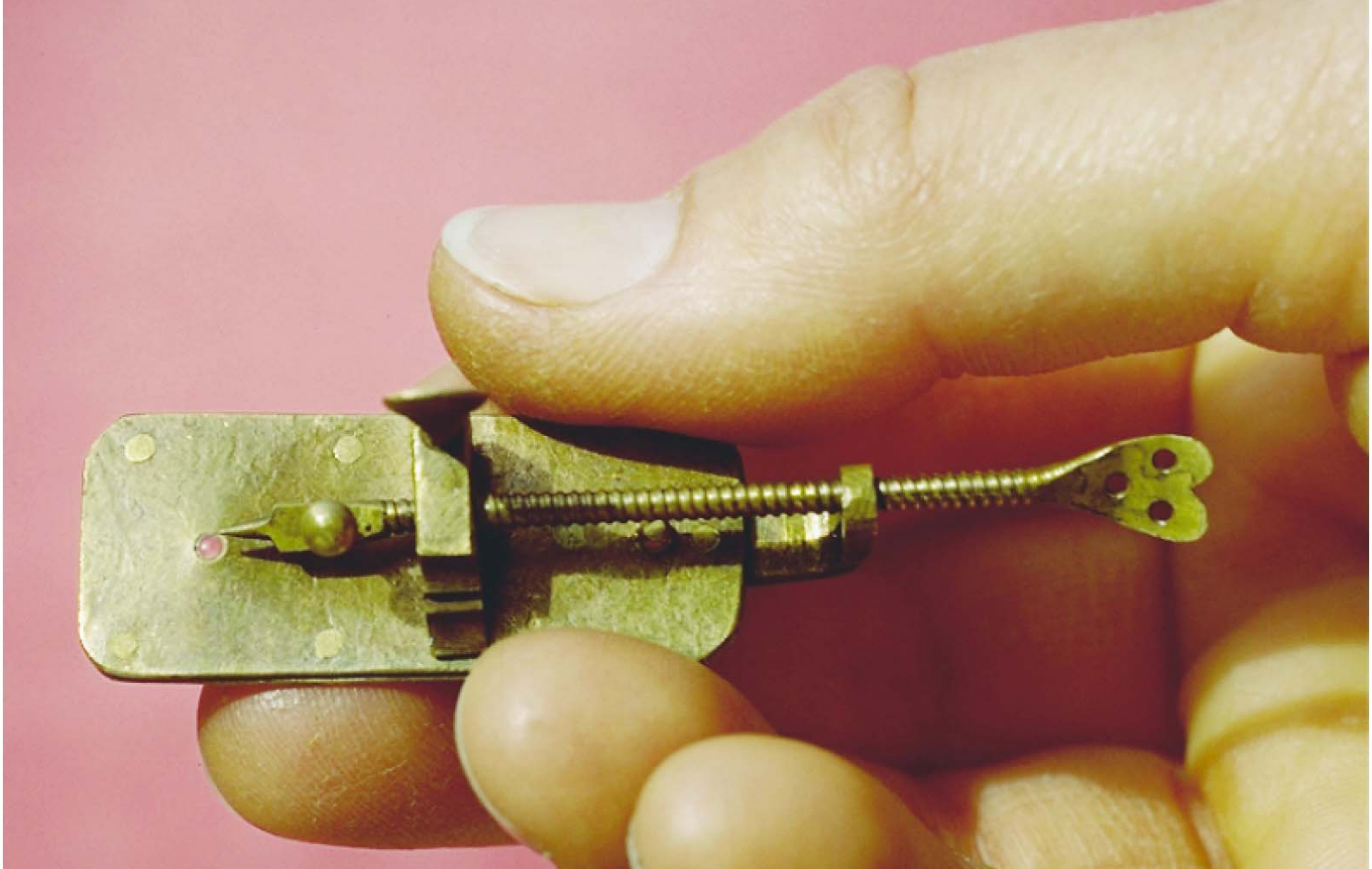


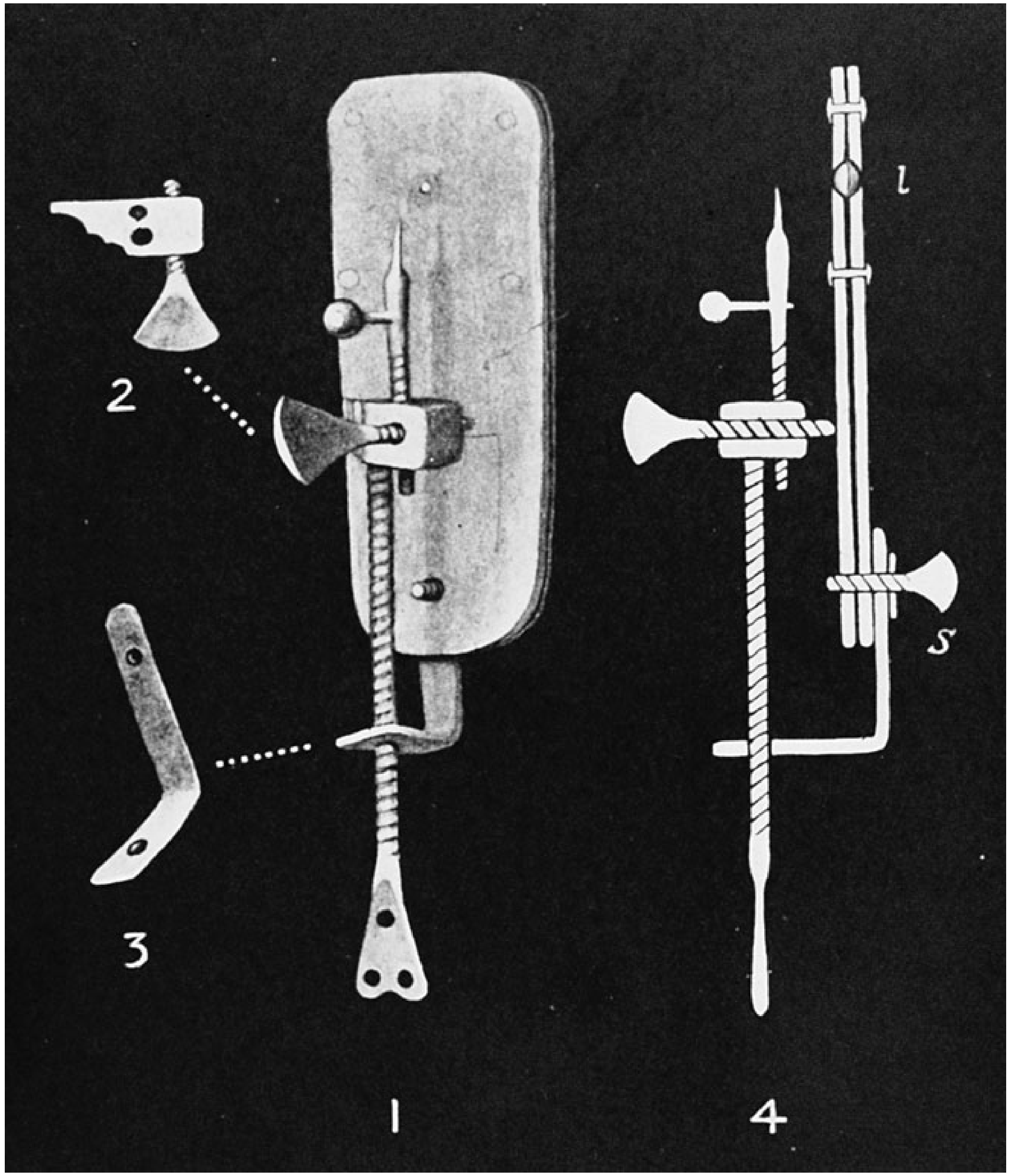
(b)

ANTONIUS A LEEUWENHOEK.

Regiæ Societatis Londinensis membrum.

Verkolje pinx: *A. de Blois fe.*

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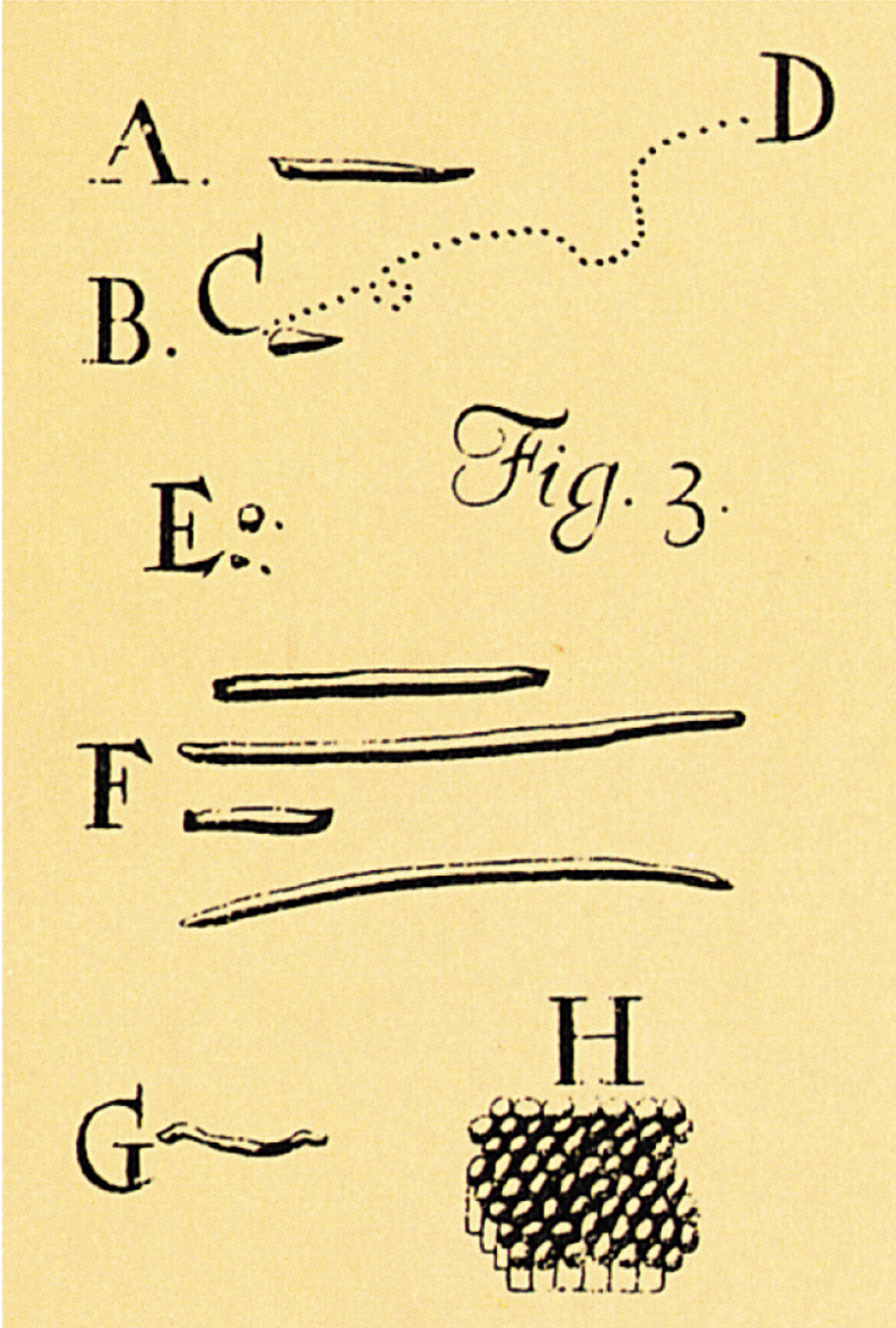
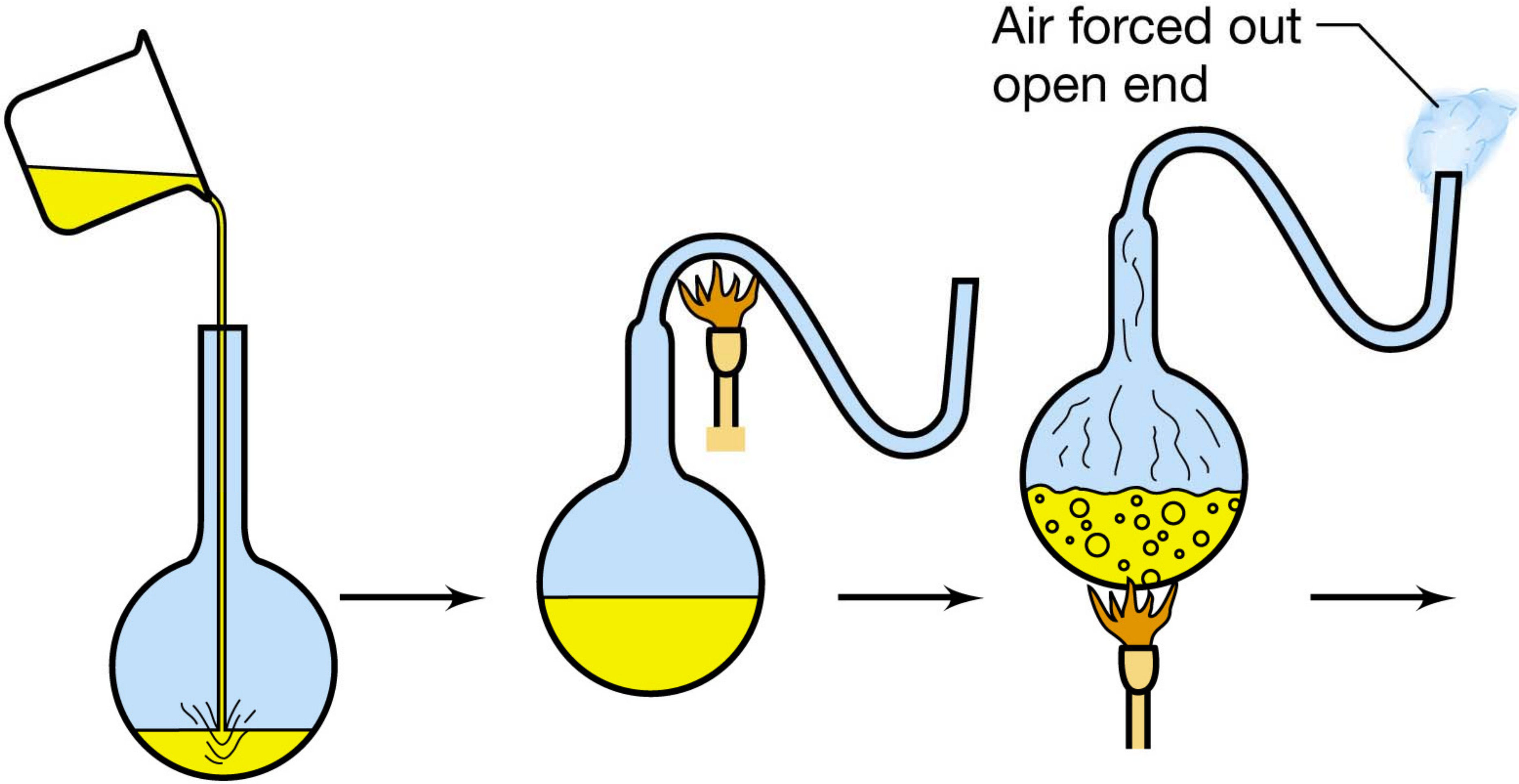

A.
D
B. C.
Fig. 3.
E.
F
G
H

Louis Pasteur

Pasteur’s swan-necked flasks

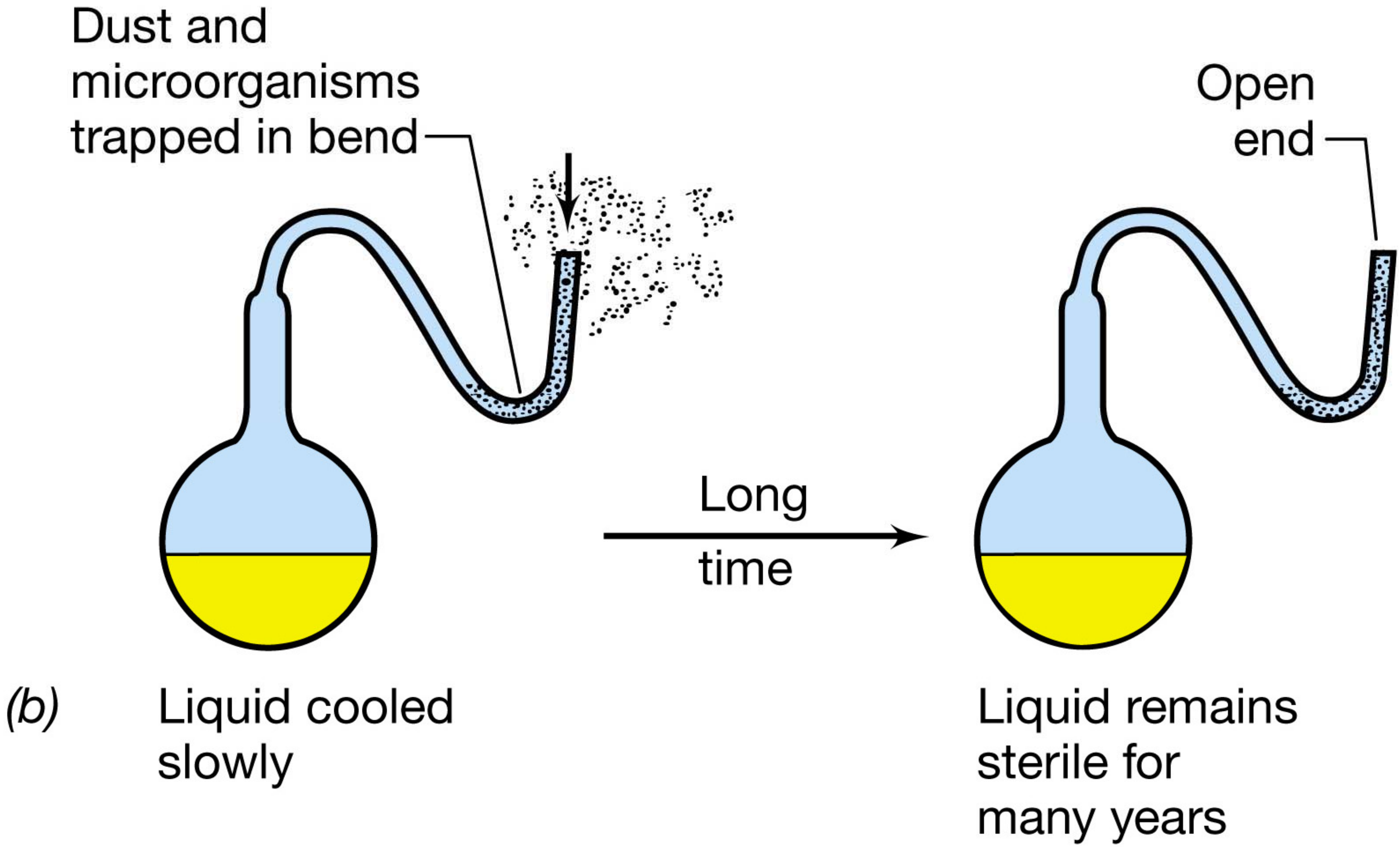


(a) Nonsterile liquid poured into flask

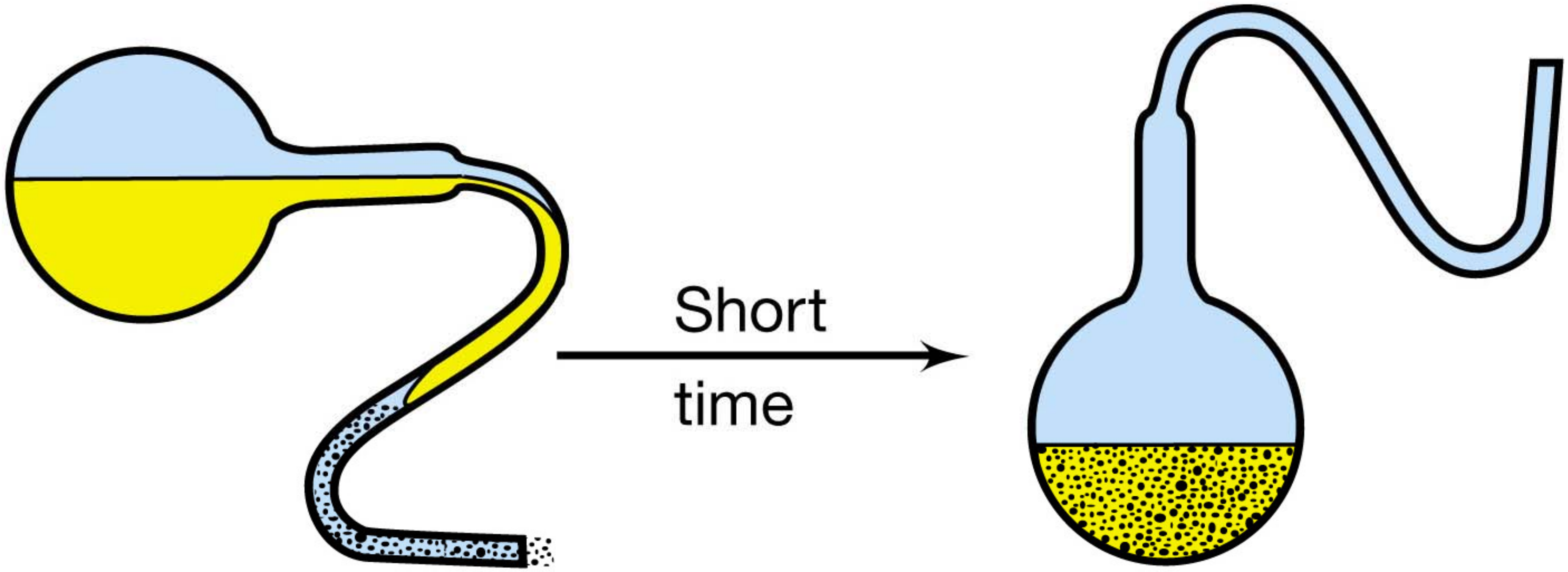
Neck of flask drawn out in flame

Liquid sterilized by heating

Pasteur's swan-necked flasks

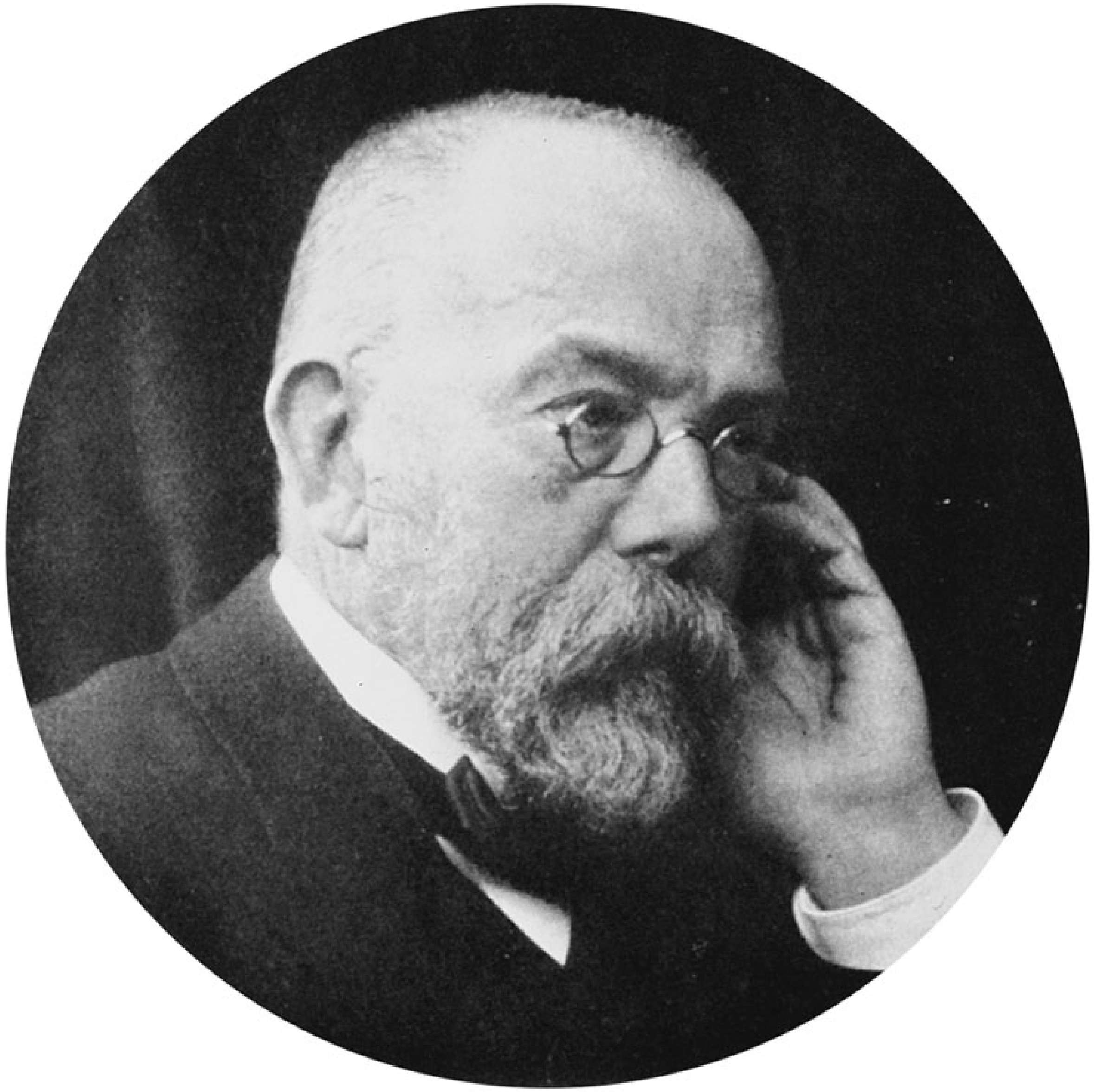


Pasteur’s swan-necked flasks



(c) Flask tipped so microorganism-laden dust contacts sterile liquid

Microorganisms grow in liquid



Robert Koch

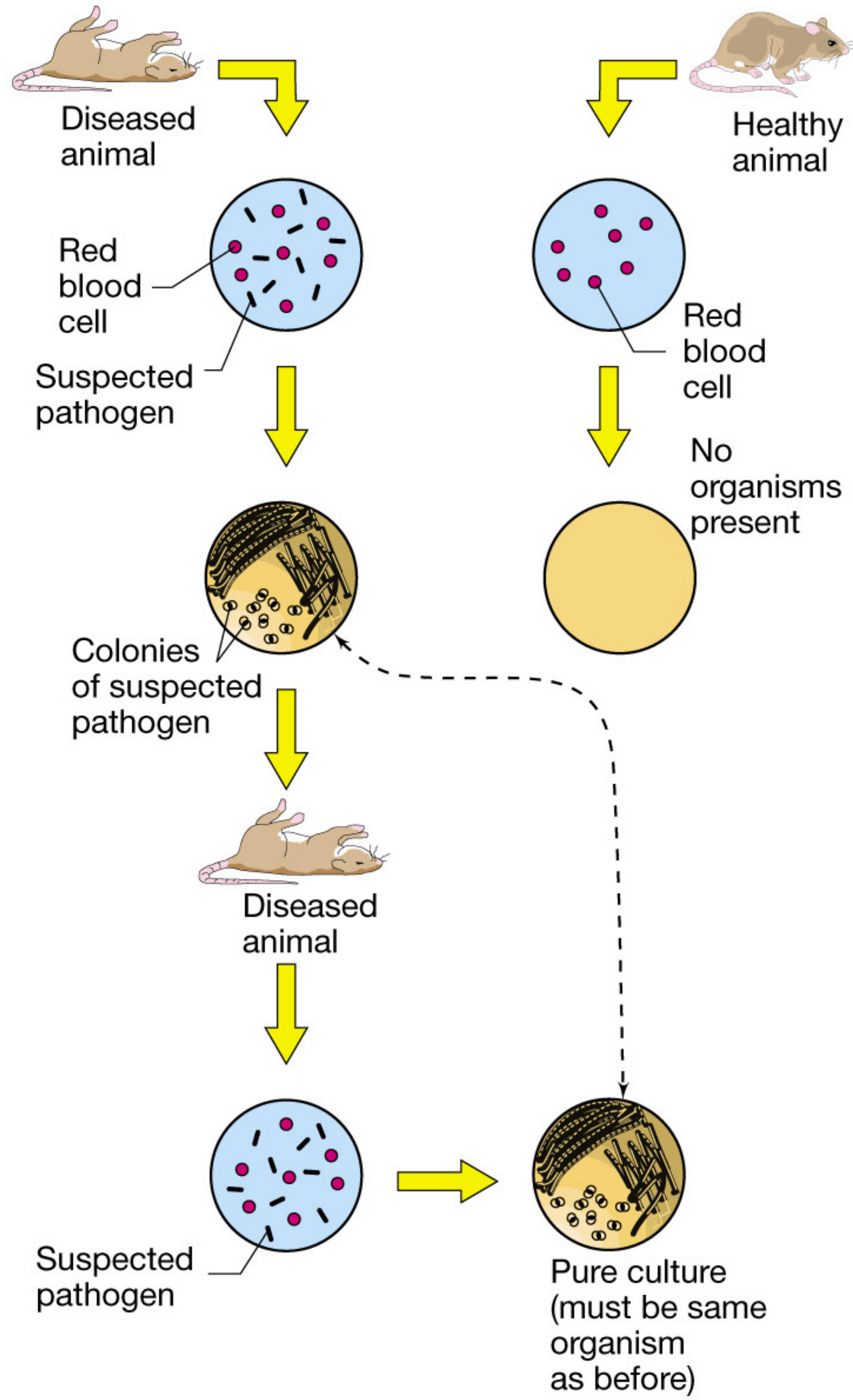
Koch's Postulates:

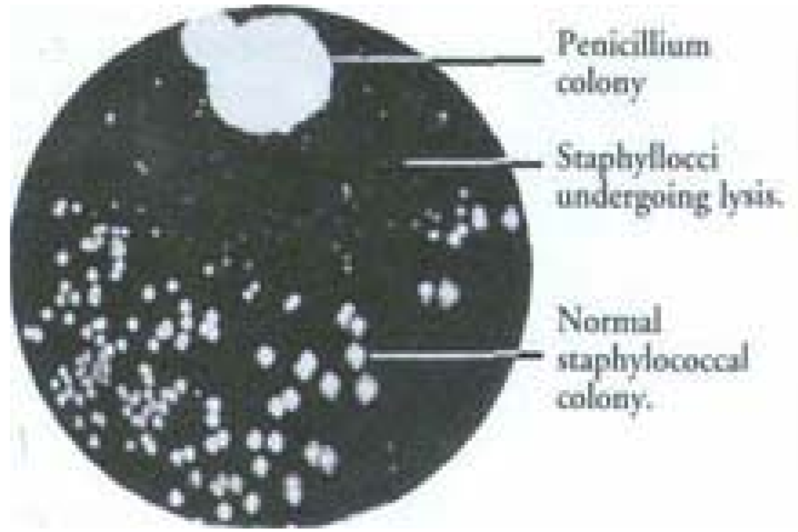
(1) The suspected pathogenic organism should be present in all cases of disease and absent from healthy animals.

(2) The suspected organism should be grown in pure culture.

(3) Cells from a pure culture of the suspected organism should cause disease in a healthy animal.

(4) The organism should be reisolated and shown to be the same as the original.





In 1928, Alexander Fleming, a microbiologist working at St. Mary's Hospital in London discovered penicillin. Initially due to purification difficulties and the substance's instability he dismissed the substance as a laboratory curiosity. In 1939, Drs. Howard Florey and Ernst Chain working at Oxford, used freeze drying to stabilize pure penicillin. Using the freeze dried formulation they were able to carry out successful trials, demonstrating the antibiotic's effectiveness. Fleming, Florey and Chain shared the 1945 Nobel prize in medicine for this work.

Archaeoglobus fulgidus Genome

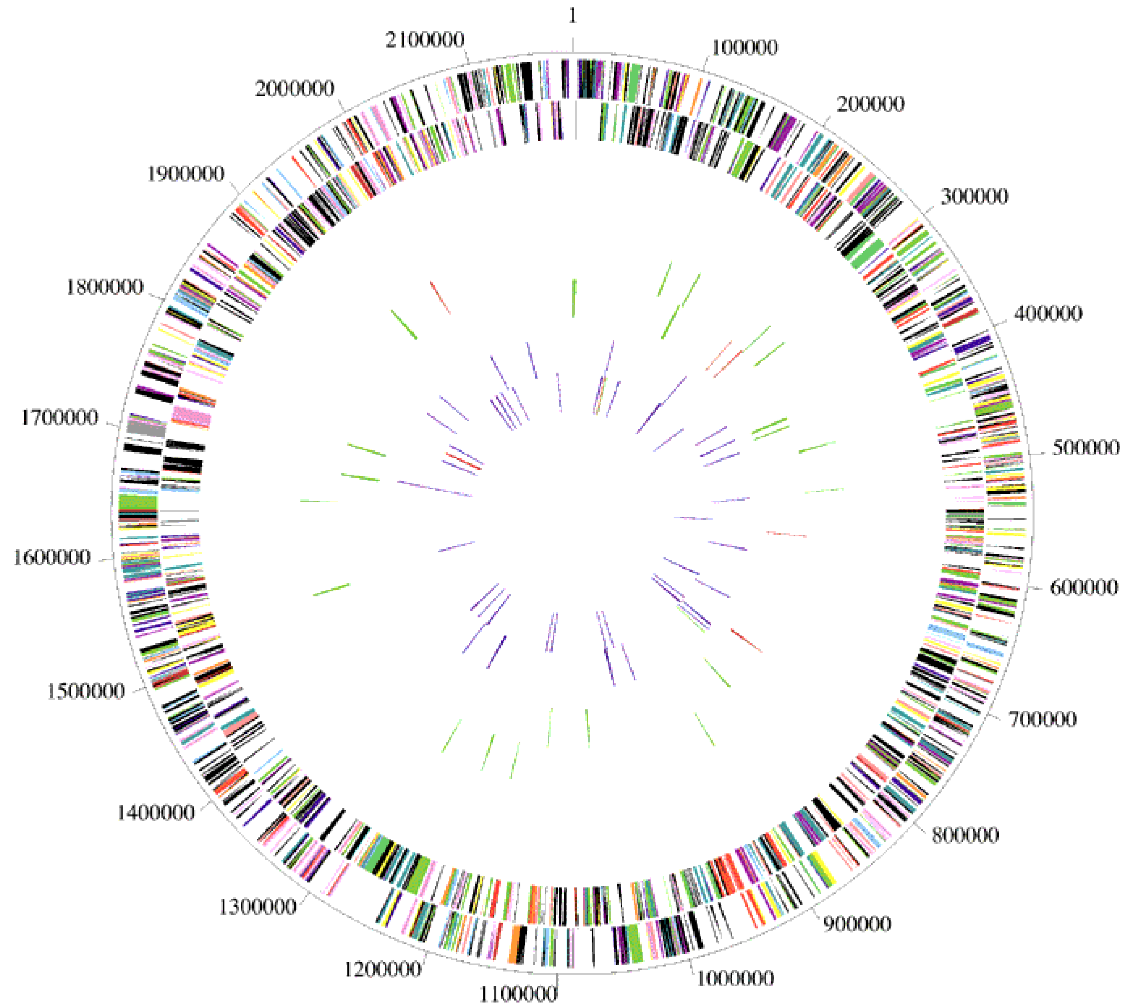
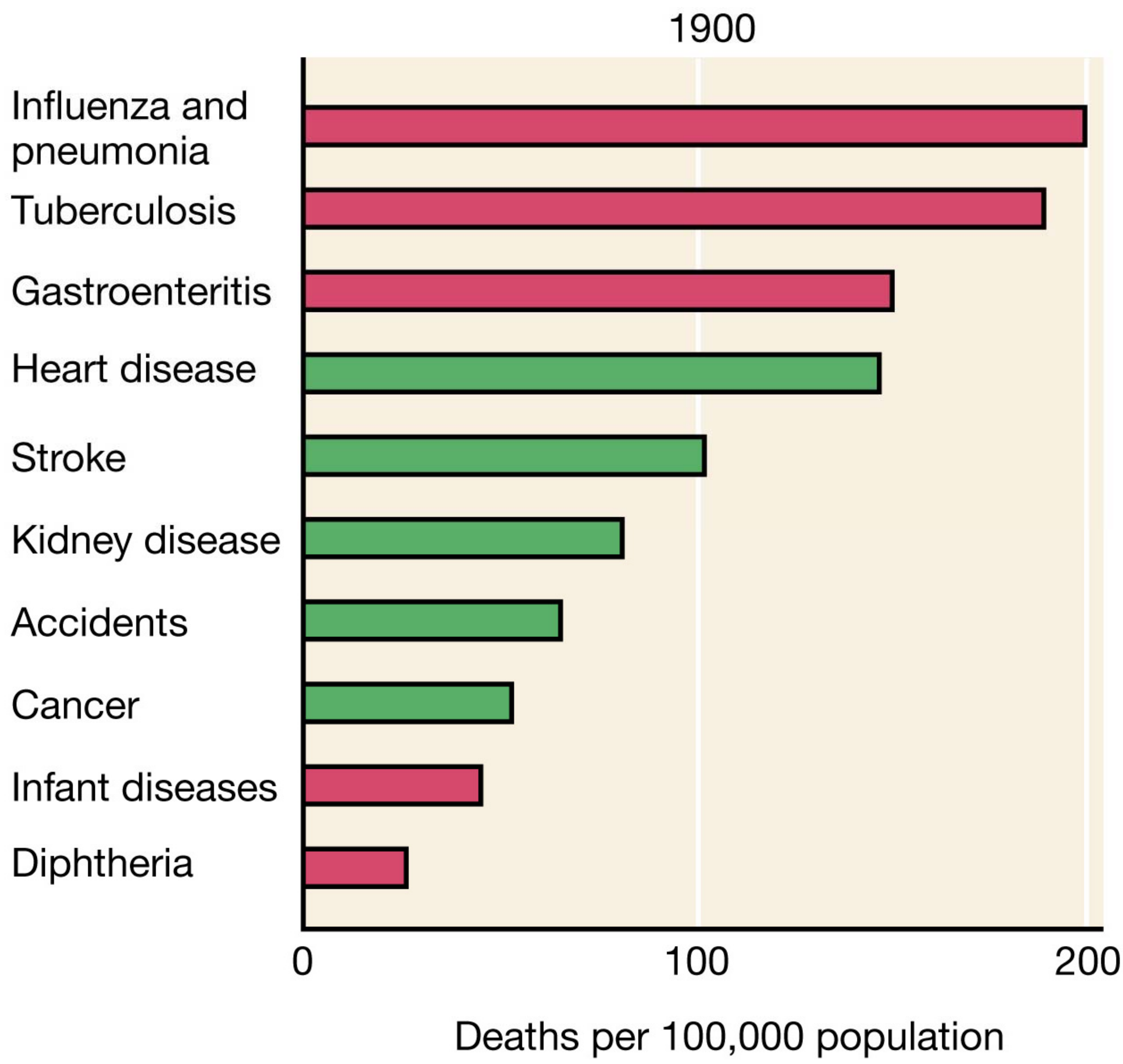


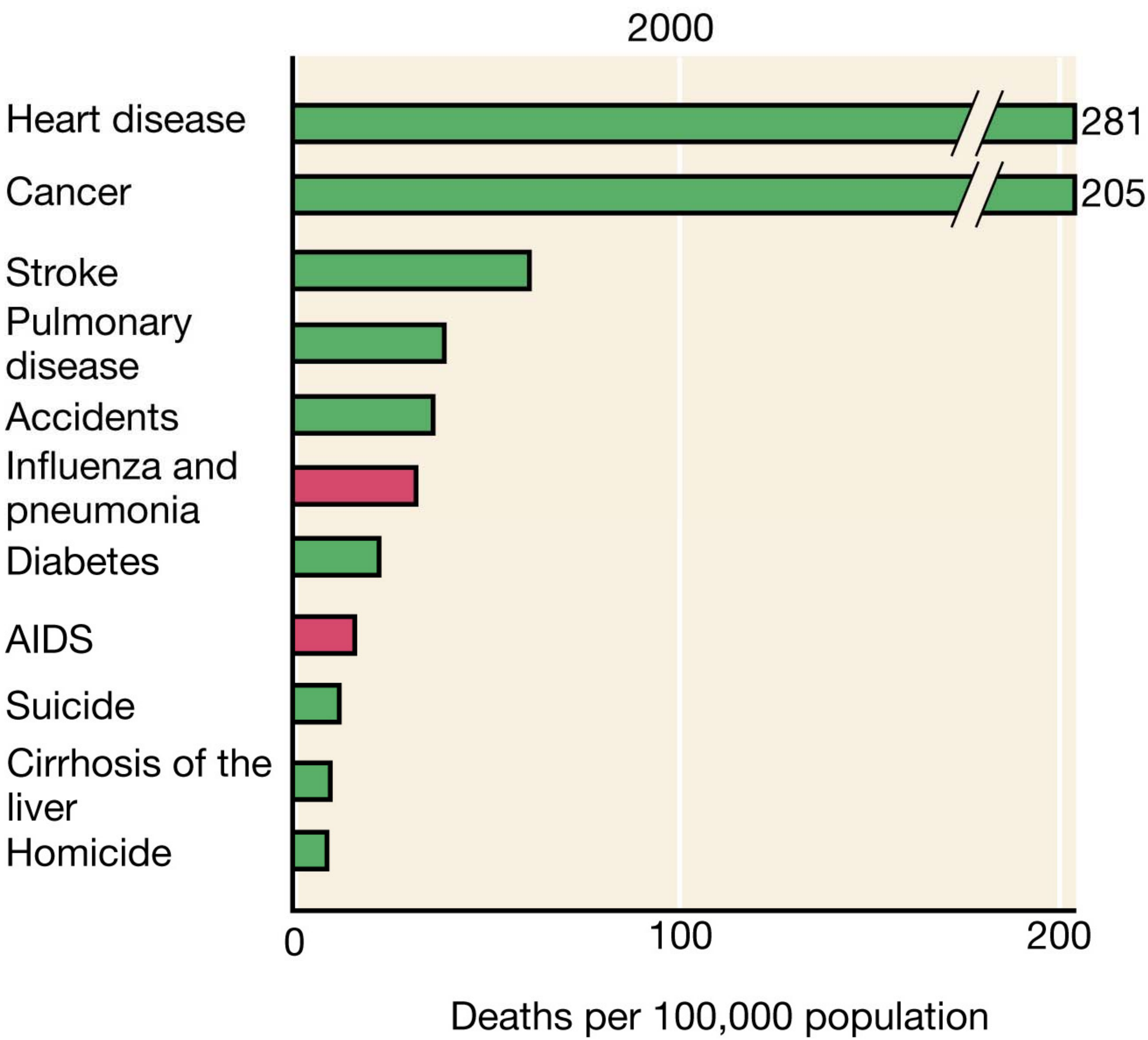
Figure Legend:

A circular representation of the *A. fulgidus* genome illustrating the location of each predicted coding region as well as selected features of the genome. Outer concentric circle: predicted coding regions on the + strand classified as to role. Second concentric circle: predicted coding regions on the - strand. Third and fourth concentric circles: IS elements (red) and repeats (blue) on the + and - strand, respectively. Fifth and sixth concentric circles: tRNAs (blue), rRNAs (red) and small stable RNAs (green) on the + and - strand, respectively.

Comparative death rates over the last century in terms of top 10 lists

Key:
Green are non-microbial diseases,
Red are microbial diseases.


1900
Influenza and pneumonia
Tuberculosis
Gastroenteritis
Heart disease
Stroke
Kidney disease
Accidents
Cancer
Infant diseases
Diphtheria
0
100
200
Deaths per 100,000 population


2000
Heart disease
281
Cancer
205
Stroke
Pulmonary disease
Accidents
Influenza and pneumonia
Diabetes
AIDS
Suicide
Cirrhosis of the liver
Homicide
0
100
200
Deaths per 100,000 population

Proteorhodopsin phototrophy in the ocean

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† *These authors contributed equally to this work*

Proteorhodopsin[1], a retinal-containing integral membrane protein that functions as a light-driven proton pump, was discovered in the genome of an uncultivated marine bacterium; however, the prevalence, expression and genetic variability of this protein in native marine microbial populations remain unknown. Here we report that photoactive proteorhodopsin is present in oceanic surface waters. We also provide evidence of an extensive family of globally distributed proteorhodopsin variants. The protein pigments comprising this rhodopsin family seem to be spectrally tuned to different habitats—absorbing light at different wavelengths in accordance with light available in the environment. Together, our data suggest that proteorhodopsin-based phototrophy is a globally significant oceanic microbial process.

From Nature, 2001

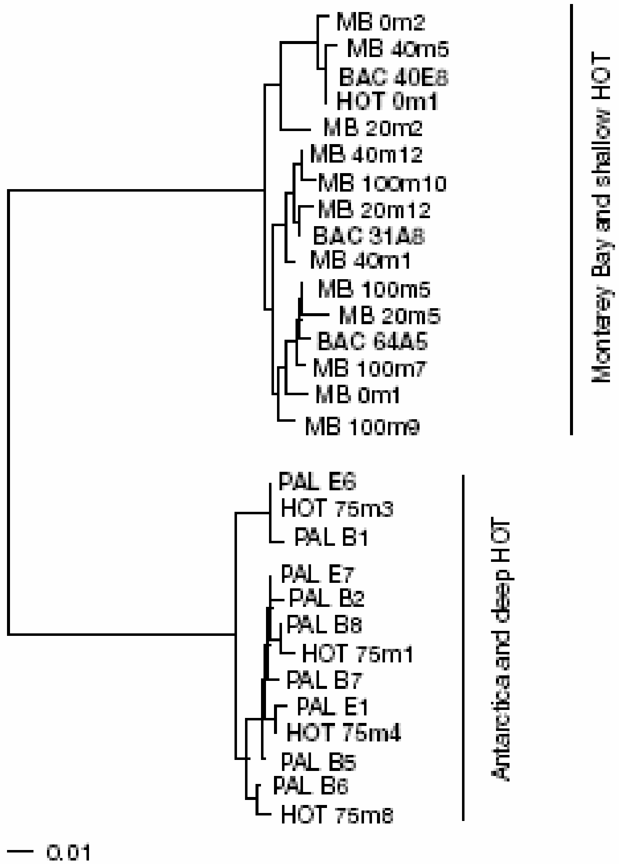

Figure 3 Phylogenetic analysis of the inferred amino-acid sequence of cloned proteorhodopsin genes. Distance analysis of 220 positions was used to calculate the tree by neighbour-joining using the PaupSearch program of the Wisconsin Package version 10.0 (Genetics Computer Group; Madison, Wisconsin). *H. salinarum* bacteriorhodopsin was used as an outgroup, and is not shown. Scale bar represents number of substitutions per site. Bold names indicate the proteorhodopsins that were spectrally characterized in this study.

Take Home Messages:

May the real "bacteriorhodopsin" Please stand up!

Major new way to make ATP in the ocean.

Two distinct "flavors" or evolutionary trajectories.