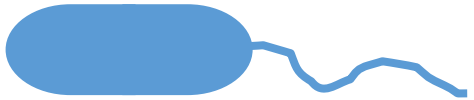


Introduction.

Fundamentals of bacterial genetics

Pavel Drevinek
(modified by Melter)

Human body:

3x 10^{13} human cells
3,8x 10^{13} bacterial cells
(38 trillions)
~ 0.2 kg

Earth:

- 10^{30} bacterial cells

	Cell number	Gene number	Weight
Human	30 trillions $(3.0 \times 10)^{13}$	20-25 thousand $(2.0 \times 10)^{4}$	70-100 kg
Microbes	38 trillions $(3.8 \times 10)^{13}$	2-20 milions $(2.0 \times 10^{6} - 2.0 \times 10)^{7}$	0.2 kg
	1.3x more bacteria	100x more bacteria	**350-500x more human**

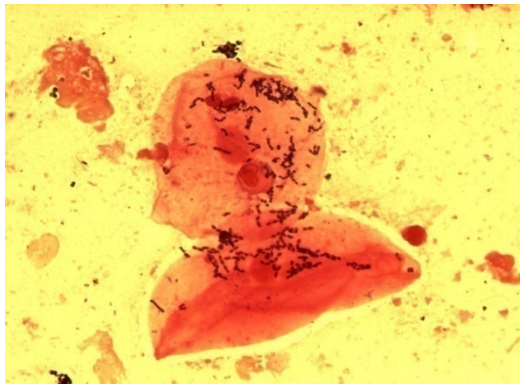
Jakub Hurych et al.

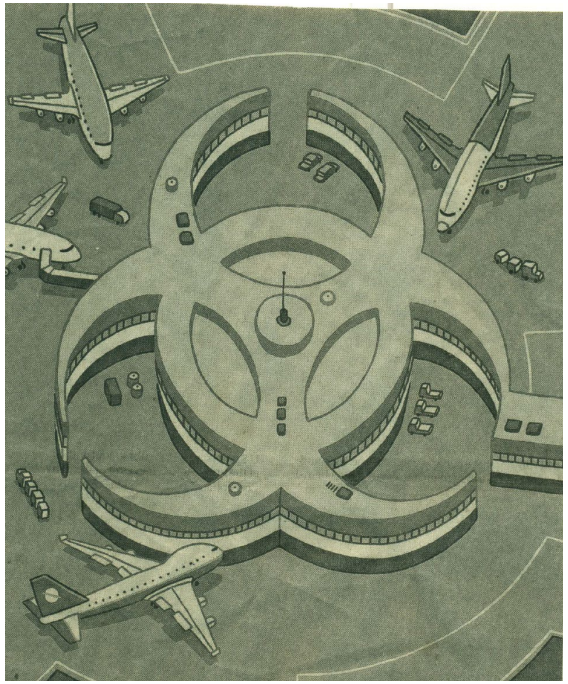
Human body:

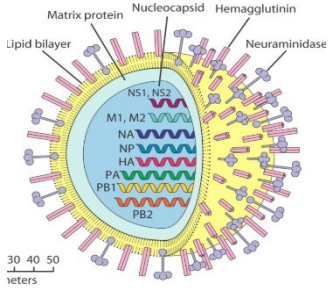
3x 10^{13} human cells
3,8x 10^{13} bacterial cells
(38 trillions)
~ 0.2 kg

Earth:

- 10^{30} bacterial cells



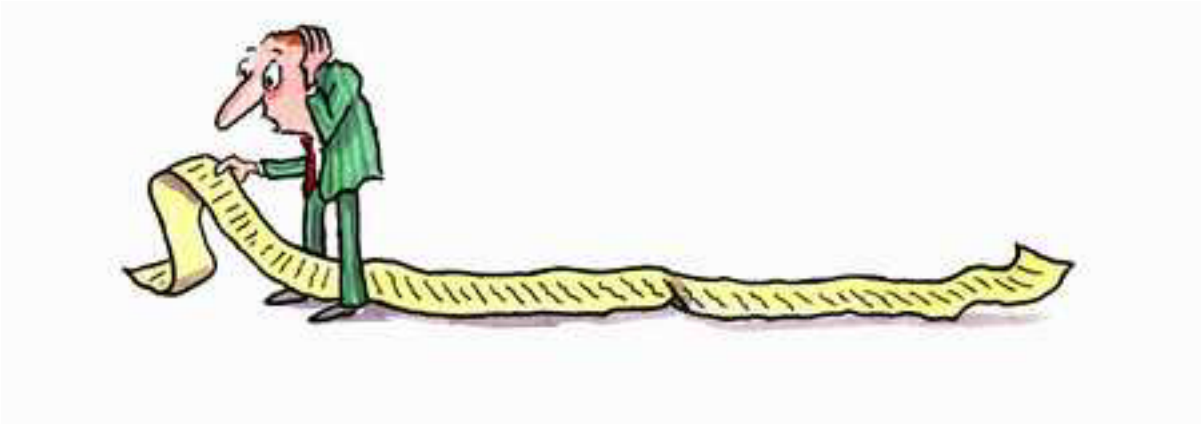




The Subject of Medical Microbiology

- General microbiology
  properties of microorganisms, their pathogenicity, their interaction with a host, pathogenesis of infectious diseases, residential microbiota (flora), antibiotics

- Special microbiology
  individual microorganisms:
  - bacteria
  - viruses
  - fungi
  - parasites



- Clinical microbiology
  microbiological examination, diagnostics of infectious agents in relation to clinical picture, antimicrobial therapy

Lectures summer semester

Bacterial cell structure. Pathogenicity.
Molecular microbiology.
Antimicrobial therapy I.
Antimicrobial therapy II.

Lectures summer semester

Bacterial cell structure. Pathogenicity.
Molecular microbiology.
Antimicrobial therapy I.
Antimicrobial therapy II.
G+ cocci I (Staphylococci).
G+ cocci II (Streptococci and enterococci).
G+ rods (Corynebacteria, listeria, clostridia).
G- rods I (Enterobacteria). Anaerobic bacteria.
G- rods II (Pseudomonads and other G- nonferementers, campylobacter).
Difficult to culture (fastidious) bacteria.
Atypical bacteria I (rickettsia, bartonela, chlamydia, mycoplasma).
Atypical bacteria II (Mycobacteria. Spirochetes).

Lectures winter semester

CAVE!

no longer practicals/seminars during winter semester

Medical mycology
General virology
Viral exanthem rash
Herpesviruses
Protosoa
Helminths

Lectures winter semester

CAVE!

no longer practicals/seminars during winter semester

Medical mycology
General virology
Viral exanthem rash
Herpesviruses
Protosoa
Helminths
Alimentary infections
Respiratory infections
Respiratory viruses
Haemorrhagic fevers
Bloodstream infections. Sepsis.
Healthcare associated infections

Lectures winter semester

CAVE!

no longer practicals/seminars during winter semester

Neuroinfections
Infections in pregancy.
Sexually transmitted infections.
Urinary tract infections.
Virus HIV and hepatitis viruses
Bone and joint infections
Soft tissue infections
Microbiota
Clostridioides difficile infections
MDR bacteria
Vaccination

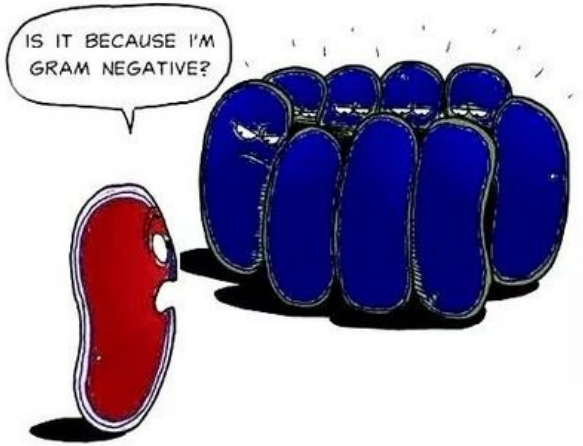
How to not get lost in bacterial classification?

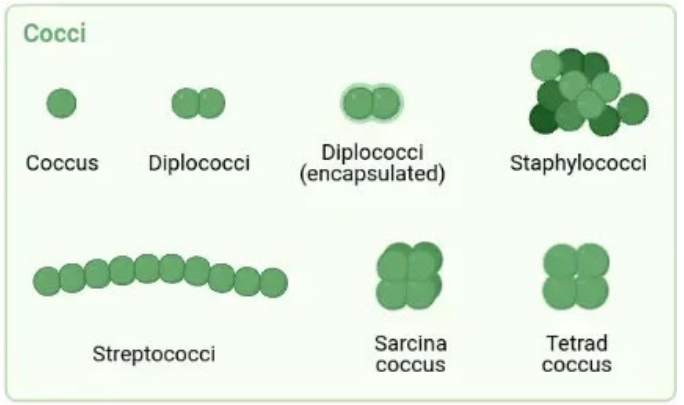
Gram staining:
- Gram positive (G+)
- Gram negative (G-)

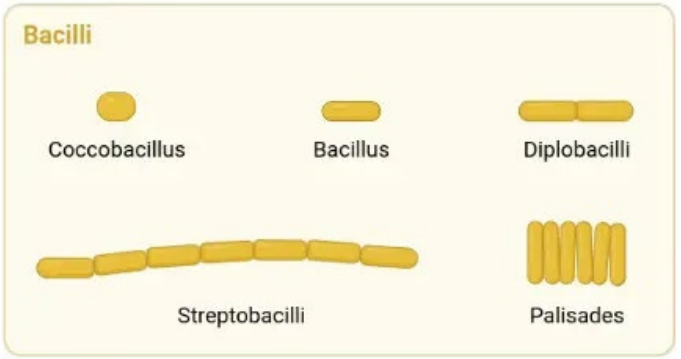
Bacterial cell shape:
- cocci
- rods (bacilli)

Relation to oxygen:
- aerobes
- anaerobes

Hans Christian Gram
1853 - 1938





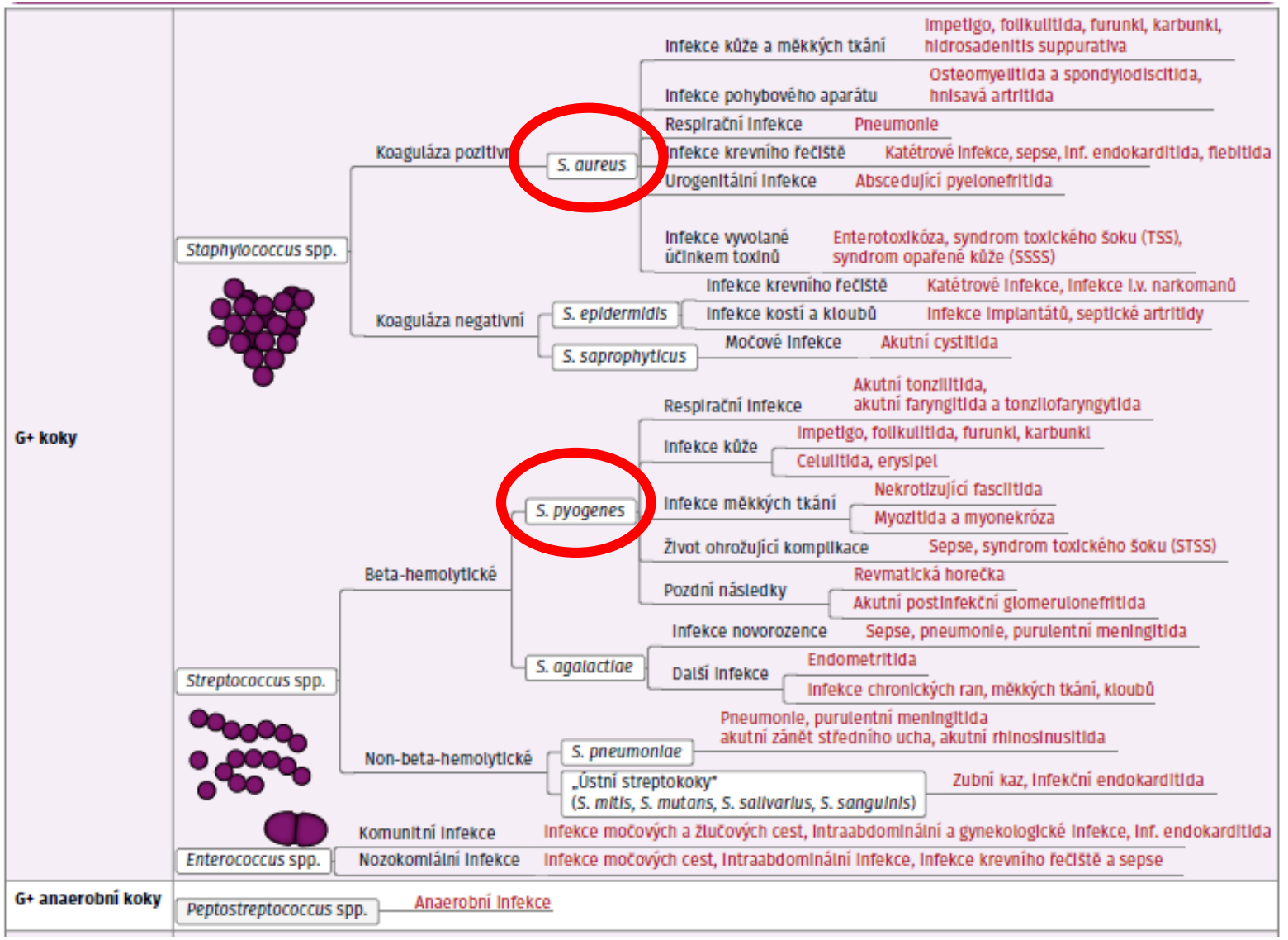


... always a grey zone can be found

- not stainable with Gram
- coccobacilli and other shapes
- facultative anaerobes

G+ cocci

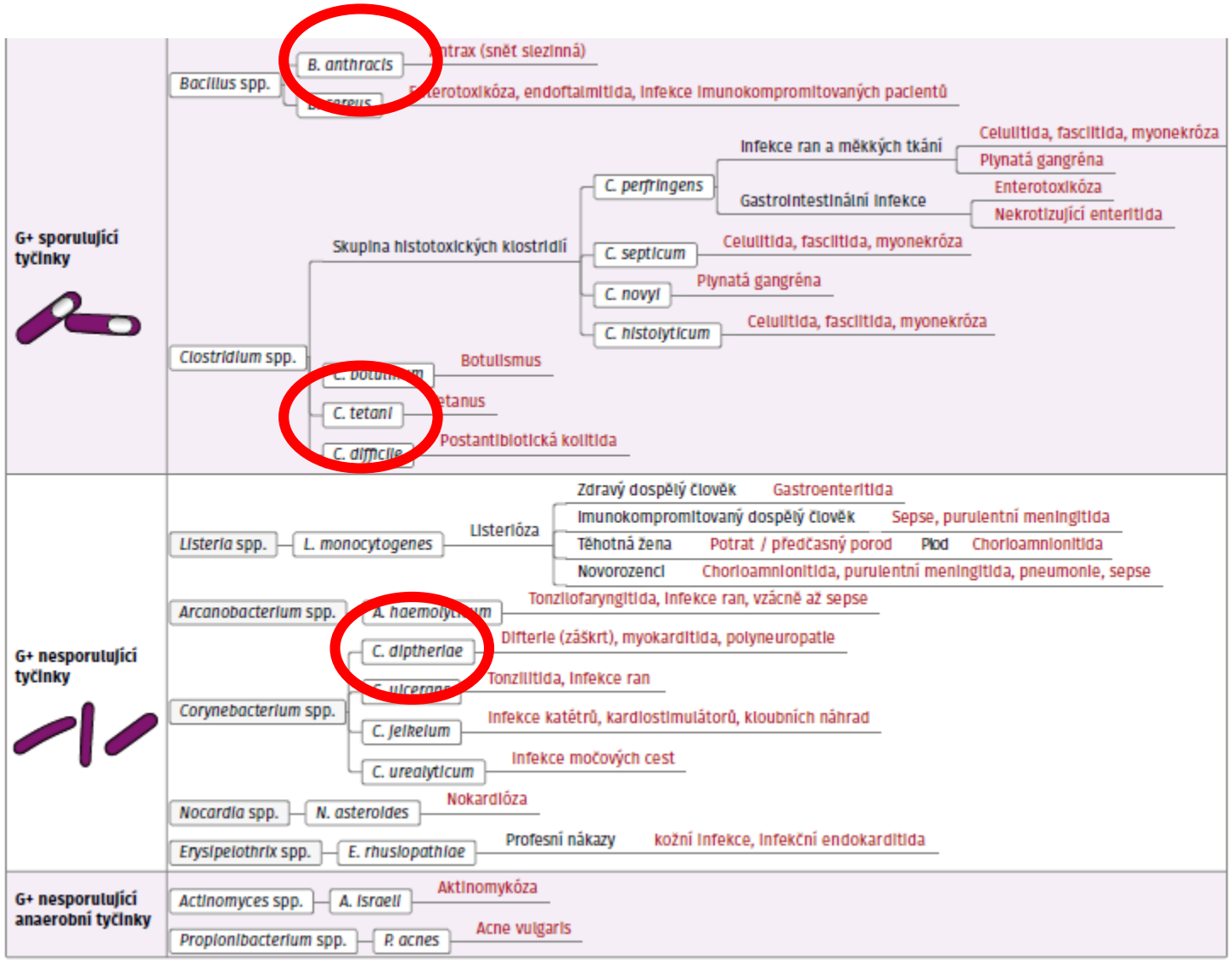
Genus name Species name



pyogenic infections

pyogenic infections

G+ rods (spore forming: yes or no)

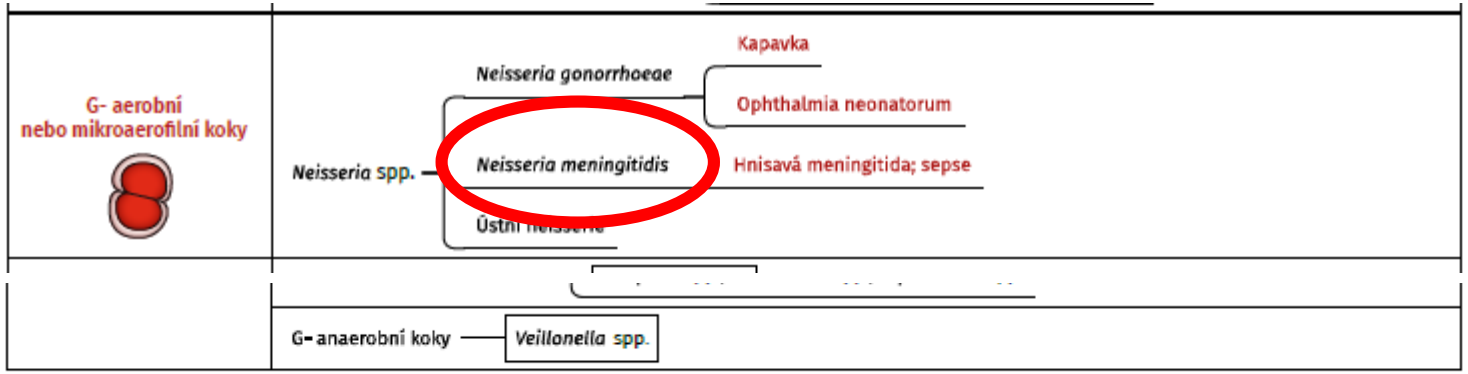


anthrax

tetanus

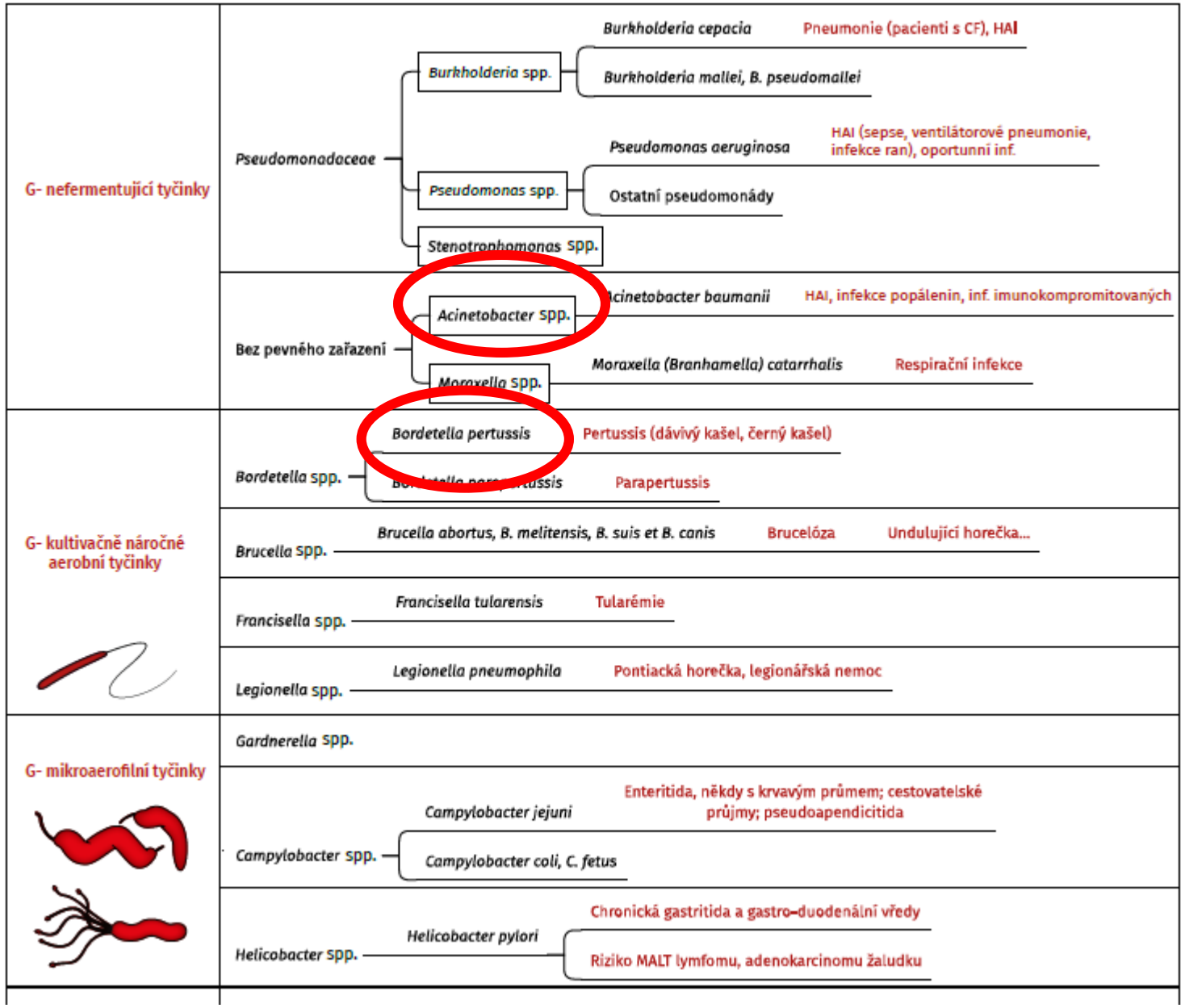
diphtheria

G- cocci



meningitis
(not the only one)

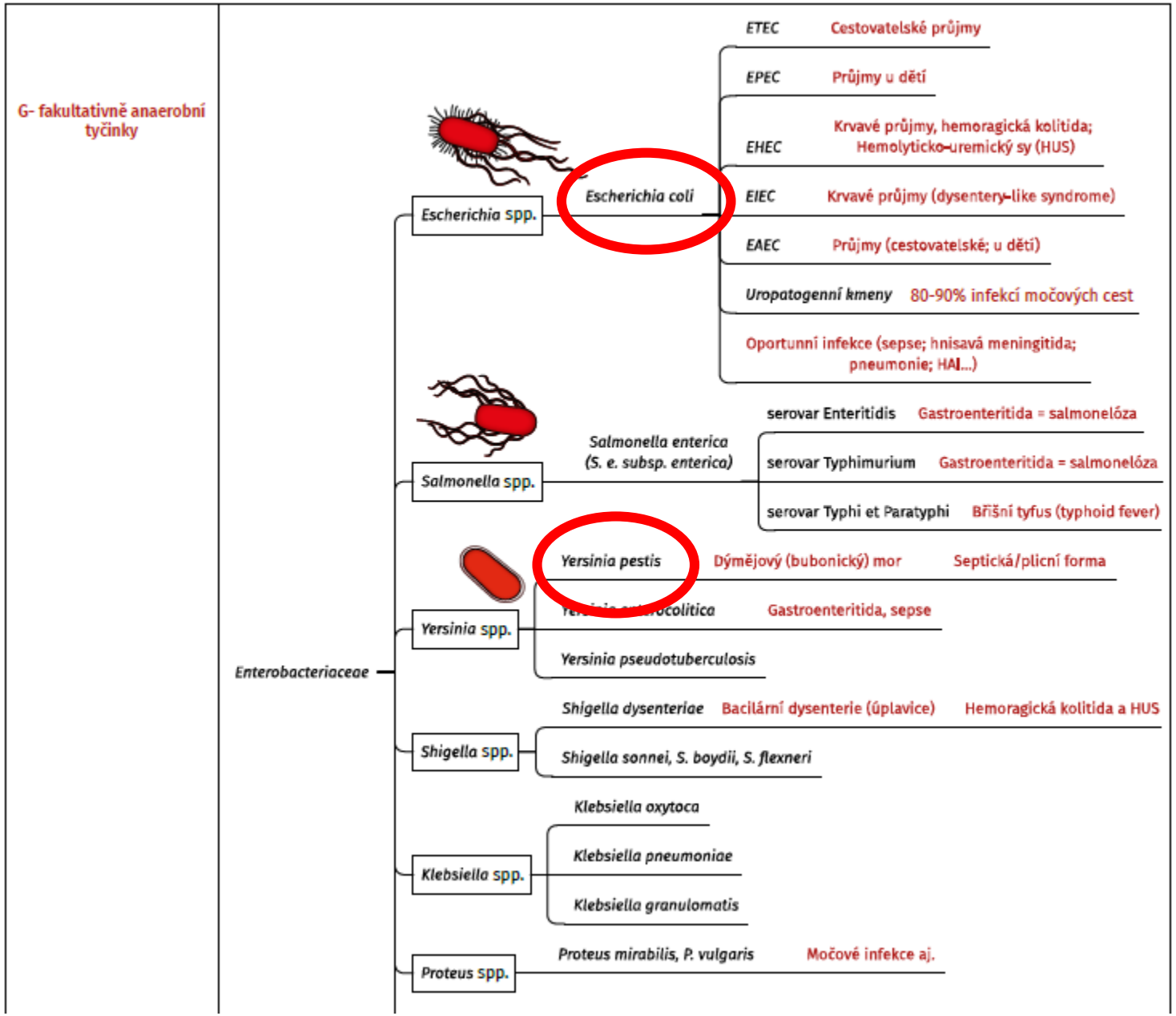
G- rods (part I)



nosocomial infections
(not the only one)

whooping cough

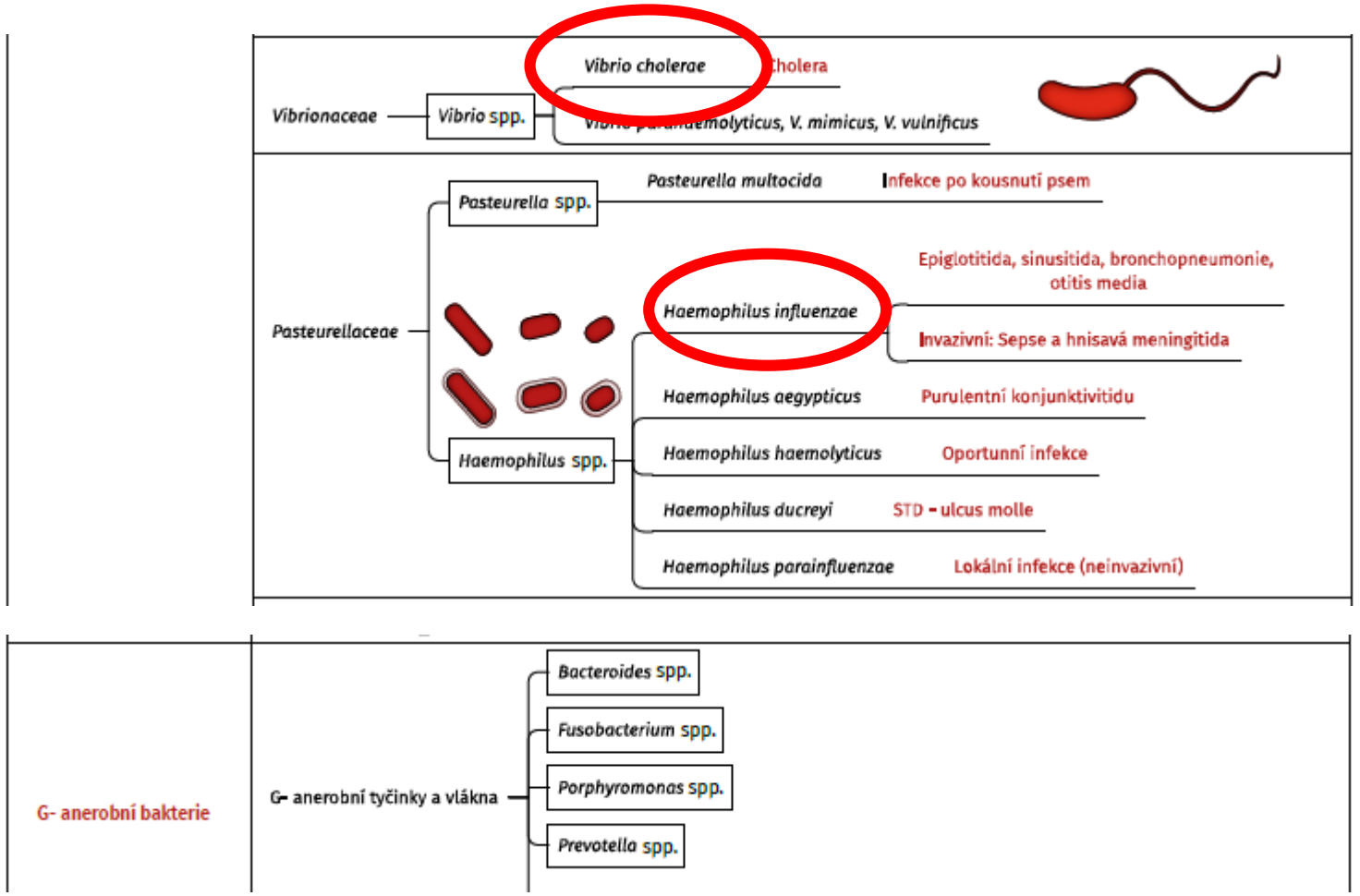
G- rods (part II)



pyogenic infections
diarrhoea
(not the only one)

plague

G- rods (part III)



cholera

respiratory infections, meningitis
(not the only one)

and you already know 12 bacteria (of 120+)

Who is who

Prof. Dřevínek

Doc. Melter

Dr. Hurych

Dr. Romanov

Dr. Lžičařová

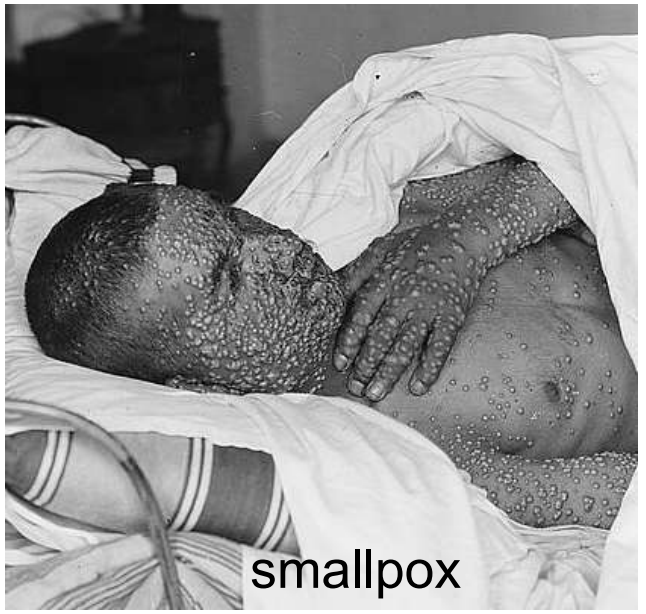
Dr. Gryndlerová

Dr. Hubáček

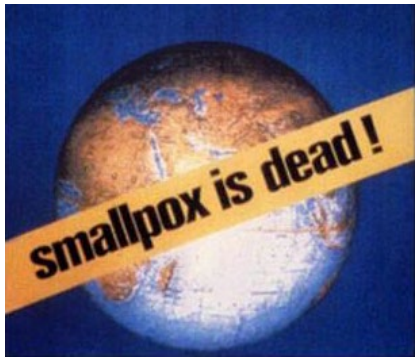
Prim. Nyč

Other big names

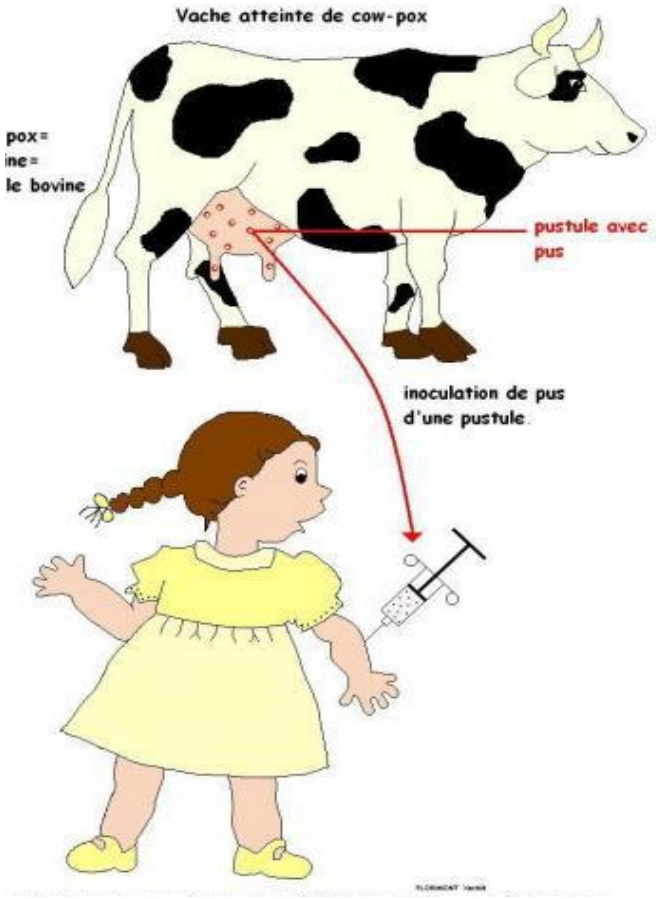
Edward Jenner
1749 – 1823



smallpox



eradication 1980



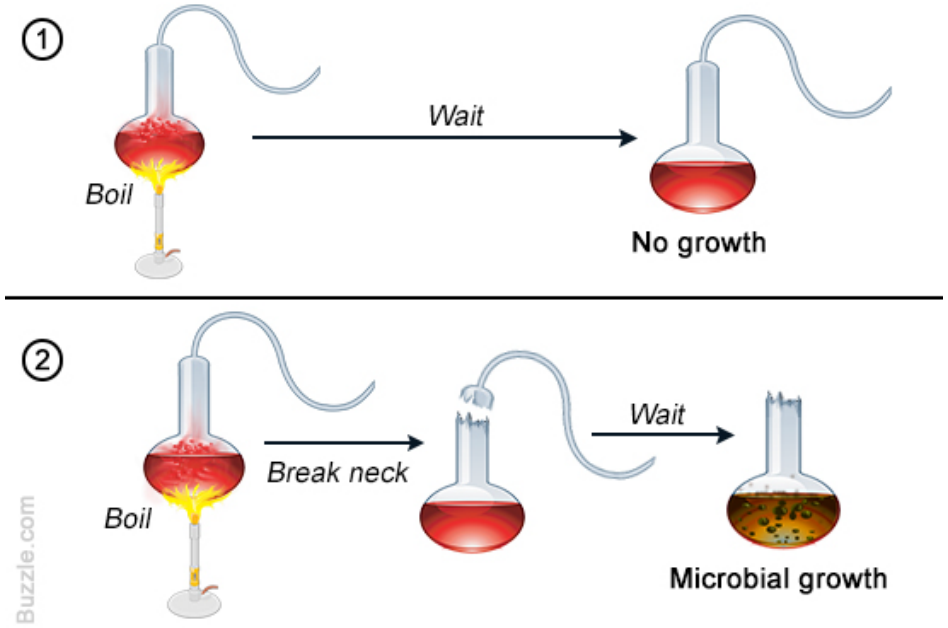
vaccination 1796

See also:
https://www.youtube.com/watch?v=BkyMYHIX9KM

"Greatpox" = Syfilis; one of signs of secondary stage
(ultrarare today)

Treponema pallidum

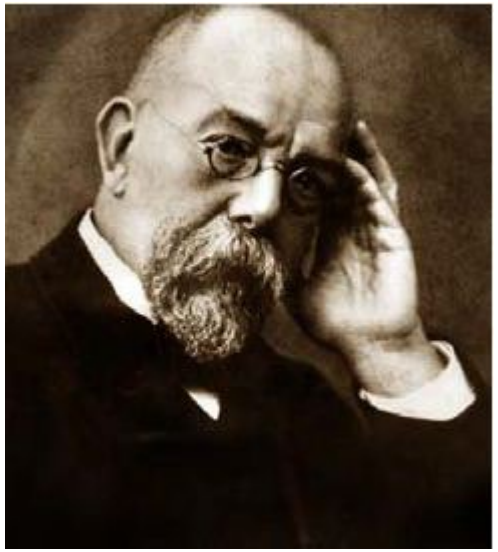
Louis Pasteur
1822 – 1895
Germ theory



~~Spontaneous generation, miasma~~

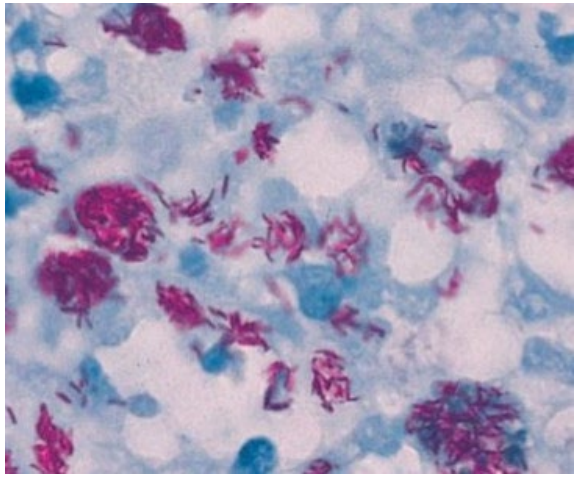
Vaccine against anthrax (in animals) and rabies

See also: https://www.youtube.com/watch?v=1lLNZQVPpQA

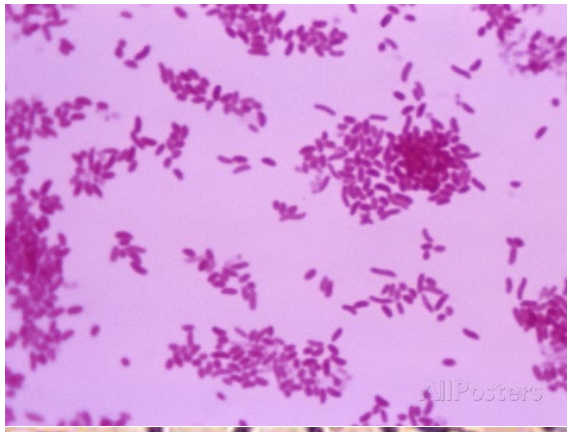


Robert Koch
1843 - 1910

Mycobacterium tuberculosis

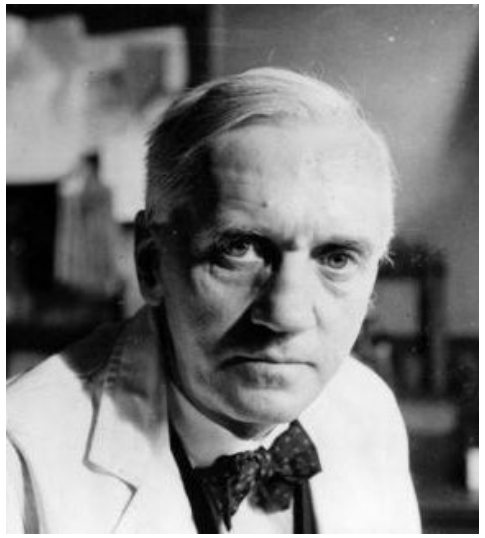


Vibrio cholerae



Bacillus anthracis and its spores

Se also: https://www.youtube.com/watch?v=XP-WXLsnMjY



Alexander Fleming
1881 - 1955

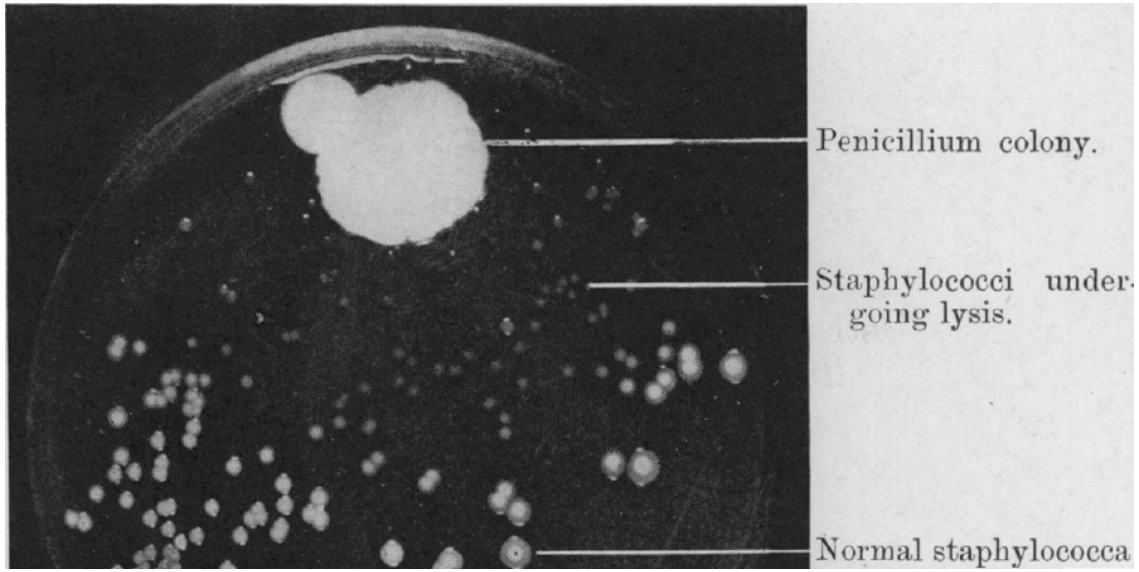
- Discovery of penicillin in 1928
- Go into therapy in 1941
  (Walter Florey, Ernst Chain)

ON THE ANTIBACTERIAL ACTION OF CULTURES OF A PENICILLIUM, WITH SPECIAL REFERENCE TO THEIR USE IN THE ISOLATION OF *B. INFLUENZÆ*.

ALEXANDER FLEMING, F.R.C.S.

From the Laboratories of the Inoculation Department, St Mary's Hospital, London.

Received for publication May 10th, 1929.

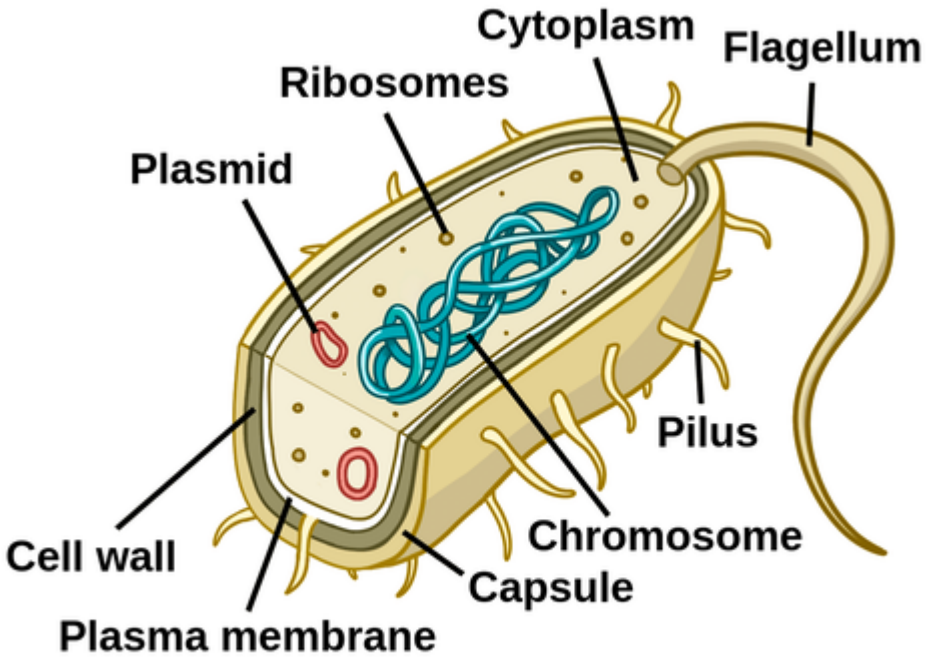


"That's funny"

See also: https://www.youtube.com/watch?v=0ZWjzcsTd5M

Bacterial genome

- Its organization
- Its evolution

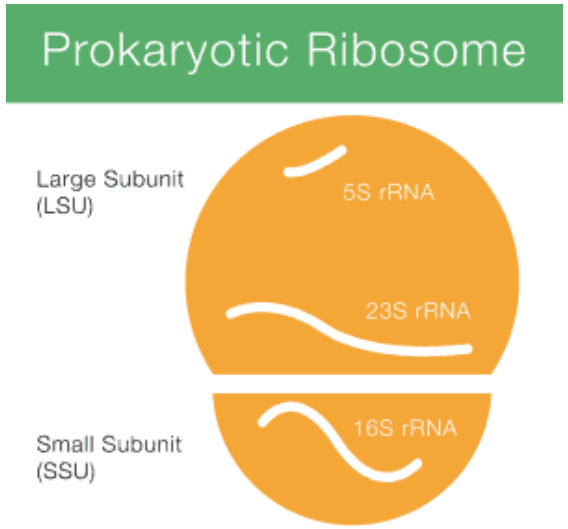


- chromosomal DNA (Mb units)
- extrachromosomal DNA (plasmid - hundreds kb)

Individual genes

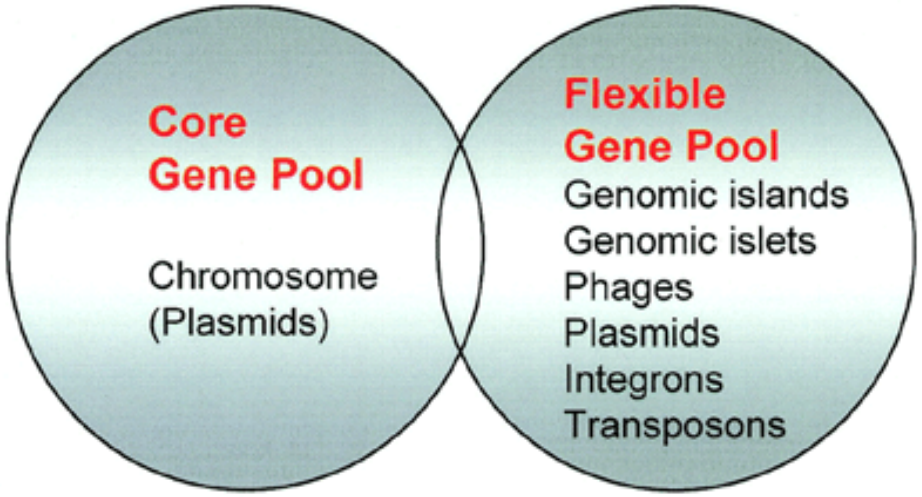
- **structural** (protein coding)

  a gene length ~ 1 kb
  structural genes ~ 90% of genome !



- **genes for rRNA** (16S rRNA, 23S rRNA, 5S rRNA)
- **genes for tRNA**
- additional non coding RNA (small RNA)

Genome structure



Housekeeping genes:
encoding

- ribosomes
- Cell wall
- Metabolic pathways
- DNA replication
- ...

Additional genes:
encoding

- Pathogenicity
- AB resistance
- Mobile genetic elements
- ...

→ genome plasticity and evolution

Mobile genetic elements

Inter bacteria:

transformation

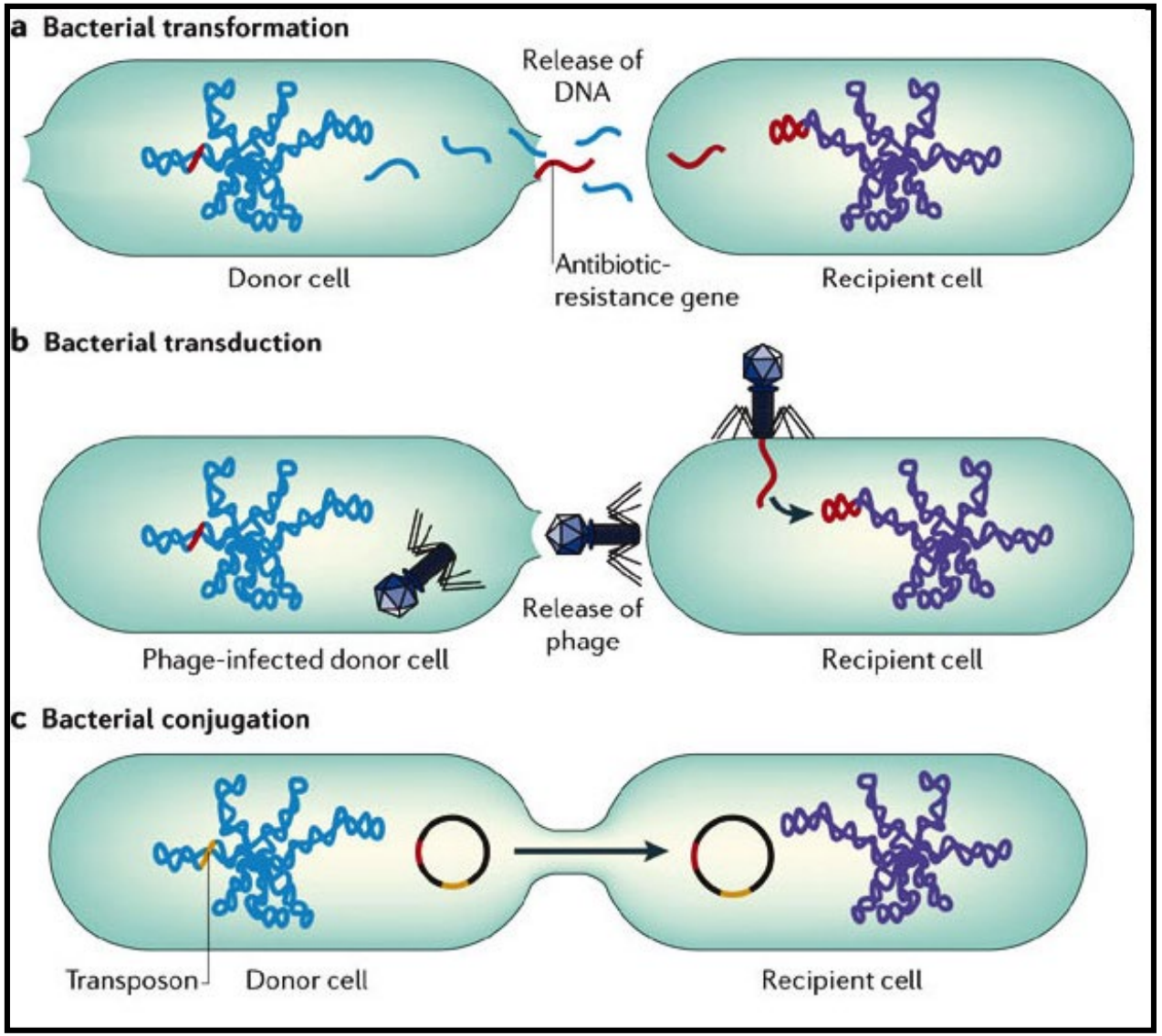
Bacteriophages → transduction

Plasmids → conjugation

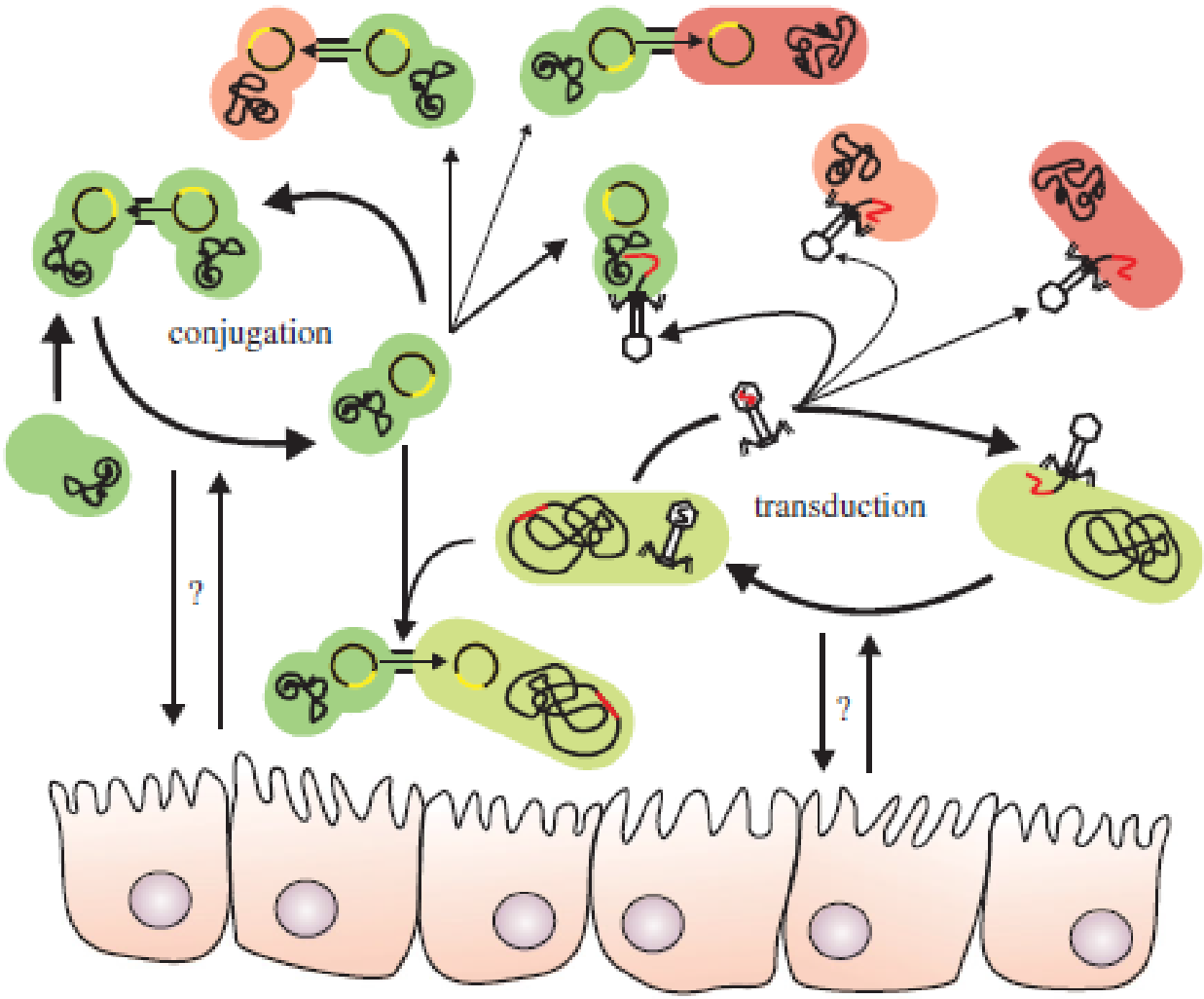
Transformation

Transduction

Conjugation



Gut microbiome - the marketplace of gene information

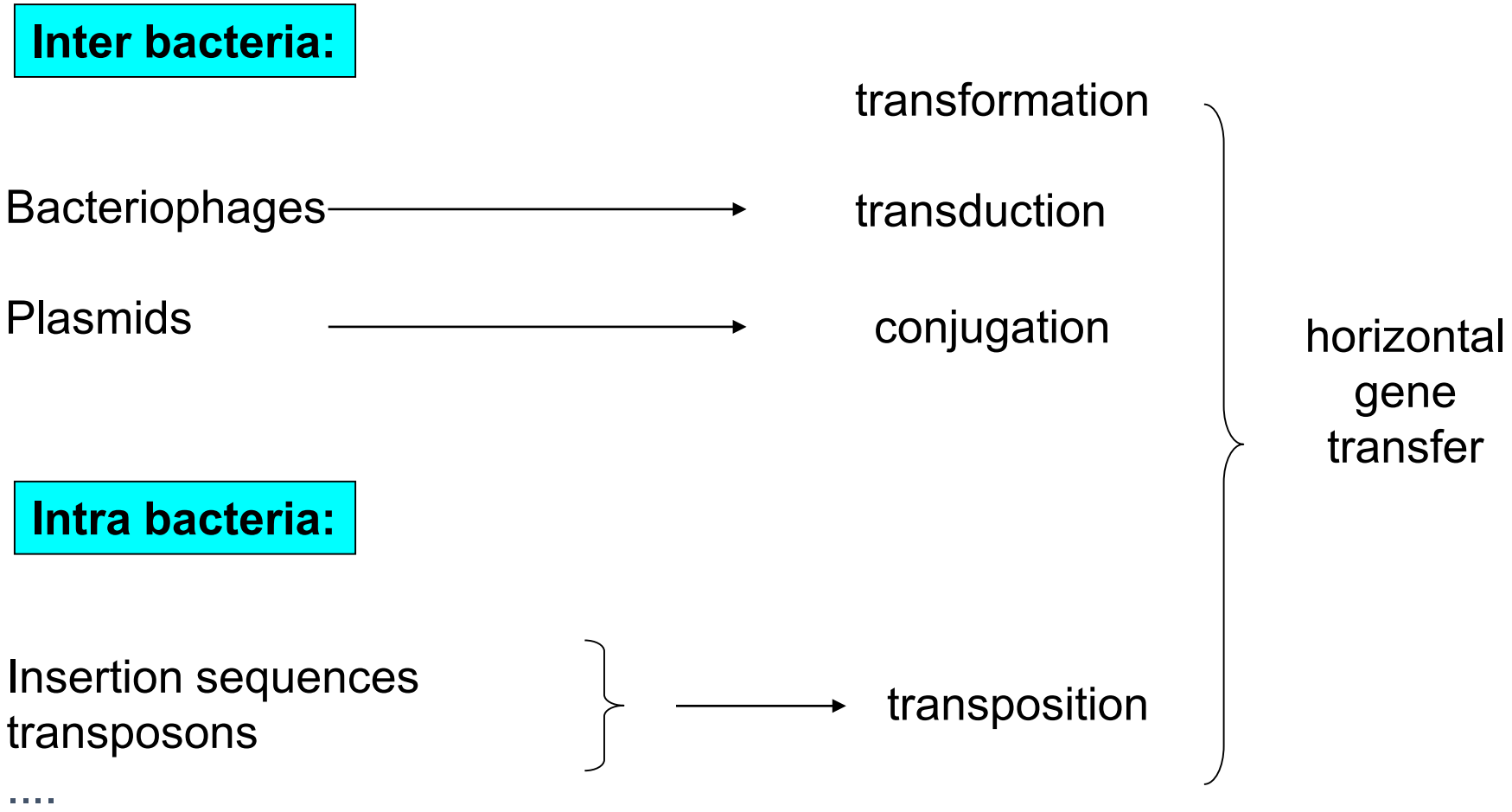


Schaik: The human gut resistome. 2015.

Commensals:
anaerobes as donors of antibotic resistence genes

Opportunistic pathogens:
Enterobacteria and as grateful recipients

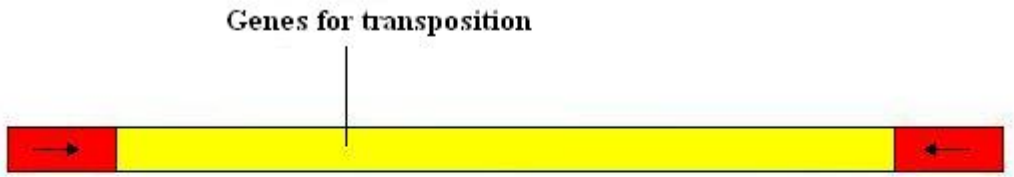
Mobile genetic elements



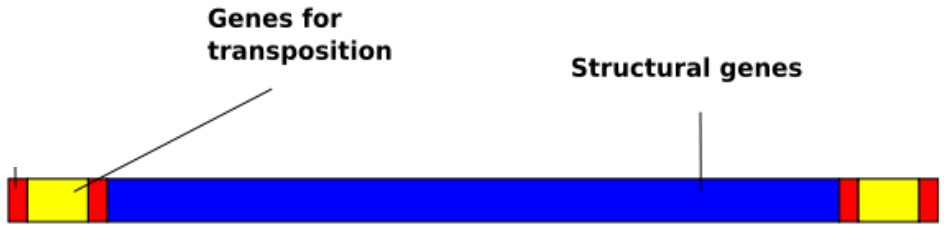
Transposable elements

DNA that is capable of movement within the genome

Insertion sequence
(0,8 - 2,5 kb)



Transposons
(3 - 30 kb)



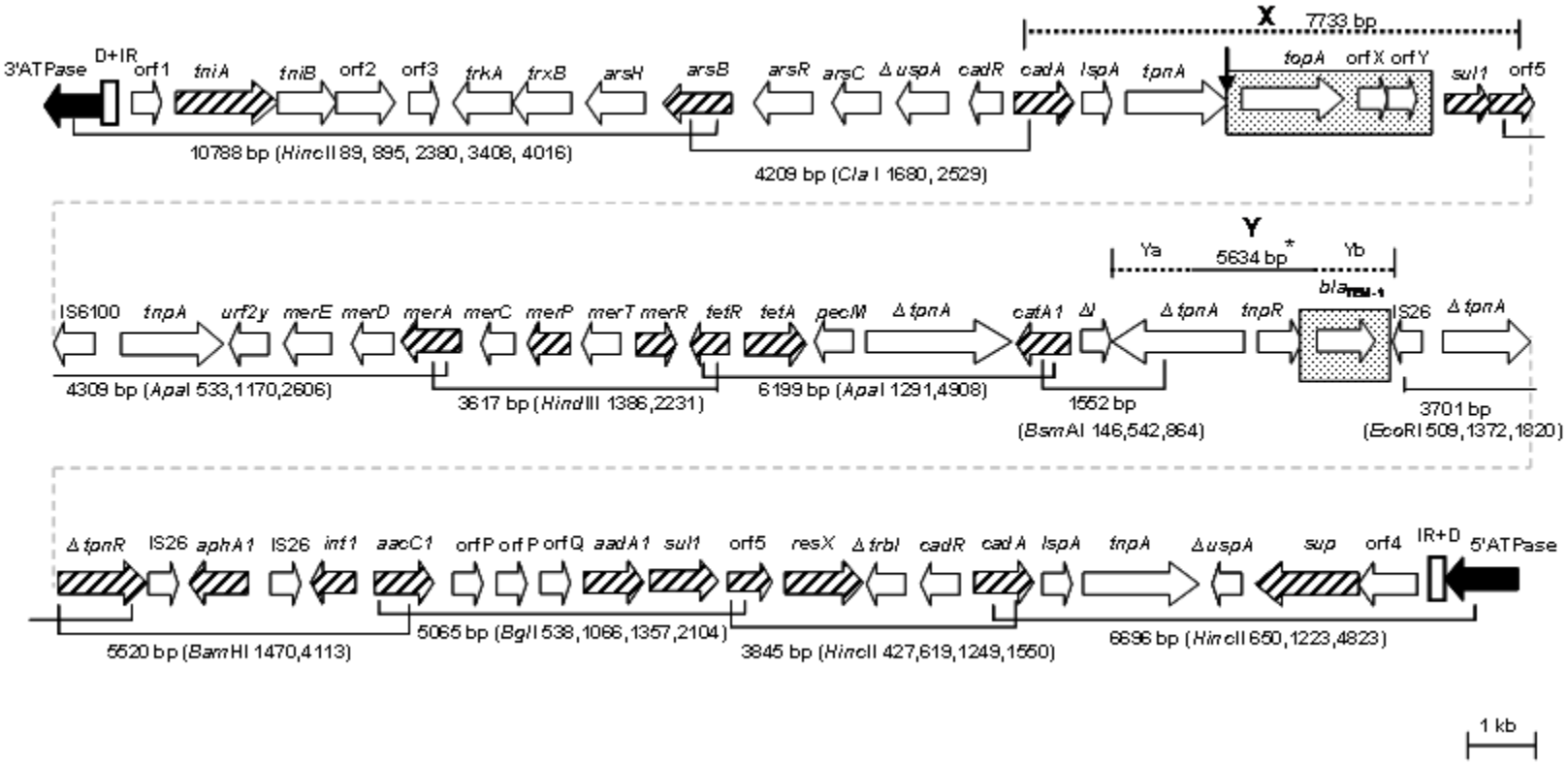
Genomic islands

transposition can end up with the creation of genomic islands
(10 - 200 kb)

- resistance islands (RI)
- pathogenicity island (PAI)
  (not present on avirulent strains of the same species)

Resistance island and *Acinetobacter baumannii*

64 kb in length
23 genes of resistance on various transposable elements disruption of a gene for ATPase
clone of *A. baumannii* with a **multiresistant phenotype**



Pathogenicity island and ...

Black death

1. the Justinian plague (542 - 757)
2. Black Death (Europe, 1346 - 1352 and till 18th century)

The 2nd wave caused with the same clone of bacteria as the 1st wave (bugs remained endemic for centuries in central Asia); moved westward along the caravan routes (with rats)

Xenopsylla cheopis

- bubonic form
- septicemic
- pneumonic

Black death

1. the Justinian plague (542 - 757)
2. Black Death (Europe, 1346 - 1352 and till 18th century)
3. Third pandemics (China, 1860 - 1890s)

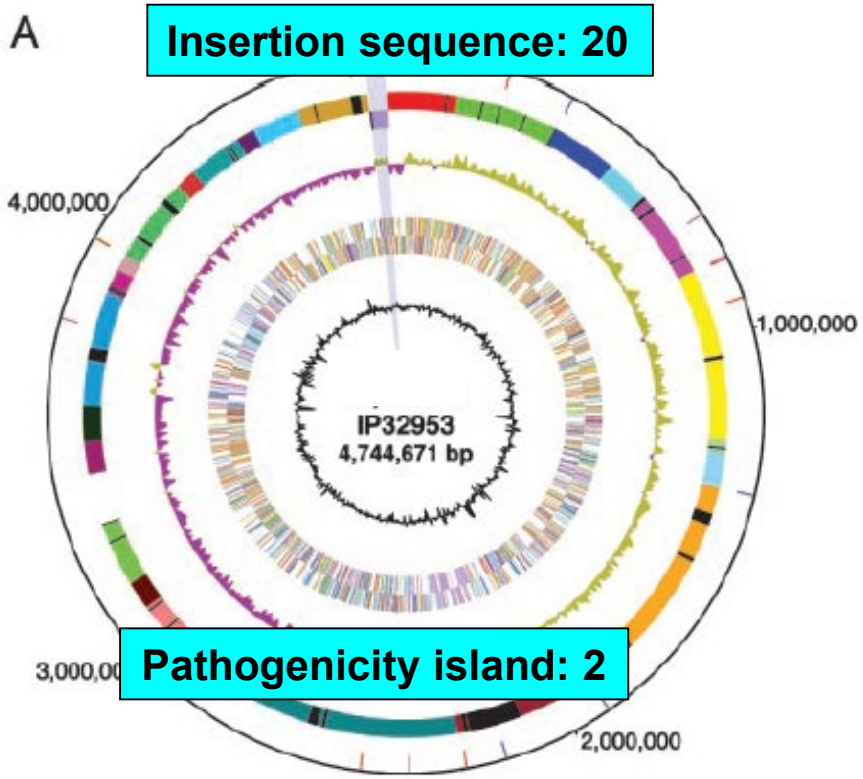
1894: Alexandre Yersin – discovered the cause: *Yersinia (Pasteurella) pestis*
1898: Paul-Louis Simond – discovered the route of transmission
(dead rats as a good hint)

Why pandemics?

- a dense human population cohabiting with infected rats
- low hygiene standards
- a large and susceptible rat population
- development of pneumonic form
- extremely low infectious dose

Pathogenicity island and ... *Yersinia pestis*

Yersinia pseudotuberculosis

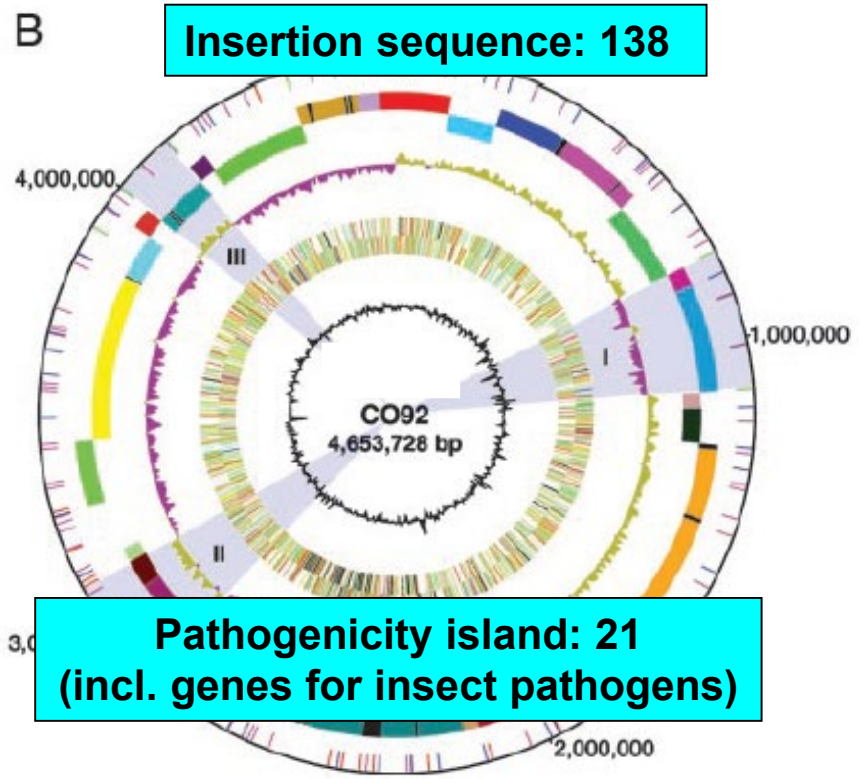


Insertion sequence: 20

Pathogenicity island: 2

Pseudogenes: 62

Yersinia pestis



Insertion sequence: 138

Pathogenicity island: 21
(incl. genes for insect pathogens)

Pseudogenes: 149

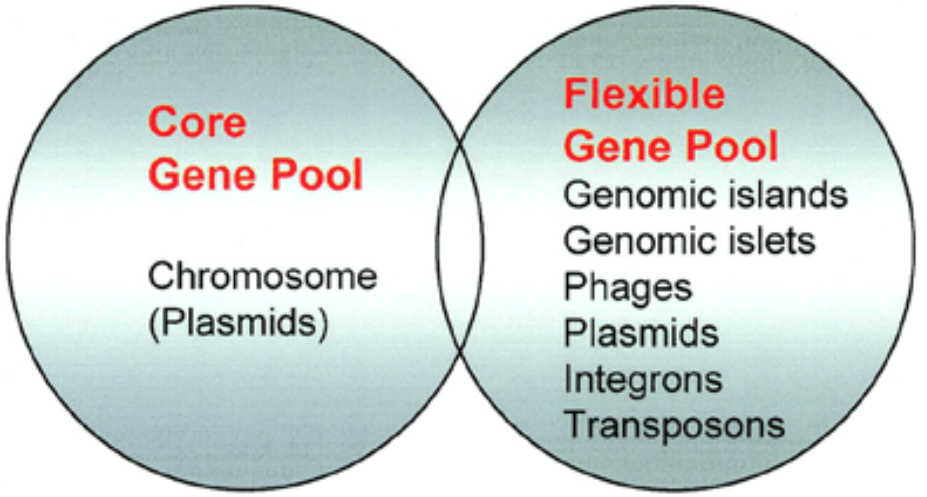
Chain et al: Insights into the evolution of Y. pestis ... 2004.

What happens to bacterial genome

- Its flexible part is really in motion

- adaptability of the organism to new conditions:

  - **horizontal gene transfer: acquisition, loss, gene inactivation or activation**
  - intragenomic recombination
  - random mutations



Bacterial genome

obligate intracellular pathogens

- *Yersinia pestis*

opportunistic extracellular pathogens

- *Acinetobacter baumannii*

Typhus (War Fever“, „Jail Fever“)

June 1812: Grand Army entering Russia; 500,000 troops

Napoleon. 2023.

Sept 7, 1812: battle at Borodino, 130,000 troops

Napoleon. 2023.

Sept 14, 1812: seizing Moscow, 90,000 troops

Napoleon. 2023.

Dec 1812: on retreat, 20,000 troops, just 1,000 fit for duty

Napoleon. 2023.

Typhus

1909: Charles Nicolle - discovered the transmission

1916: Henrique Da Rocha-Lima
- discovered the cause of the disease:

Rickettsia prowazekii

† Howard Ricketts (1871 – 1910)
† Stanislaus Von Prowazek (1875-1915)

Pediculus humanus (clothes louse)
contaminated faeces

Why epidemics?

overcrowded places
low hygiene
body lice

We already know at least 15 bacteria

G+

Staphylococcus aureus
Streptococcus poygenes
Bacillus anthracis
Clostridium tetani
Corynebacterium diphteriae

G-

Neisseria meningitidis
Acinetobacter baumannii
Bordetella pertussis
Escherichia coli
Yersinia pestis
Vibrio cholerae
Haemophilus influenzae

atypical

Treponema pallidum
Mycobacterium tuberculosis
Rickettia prowazekii