

Principles of Microbiology for Engineers

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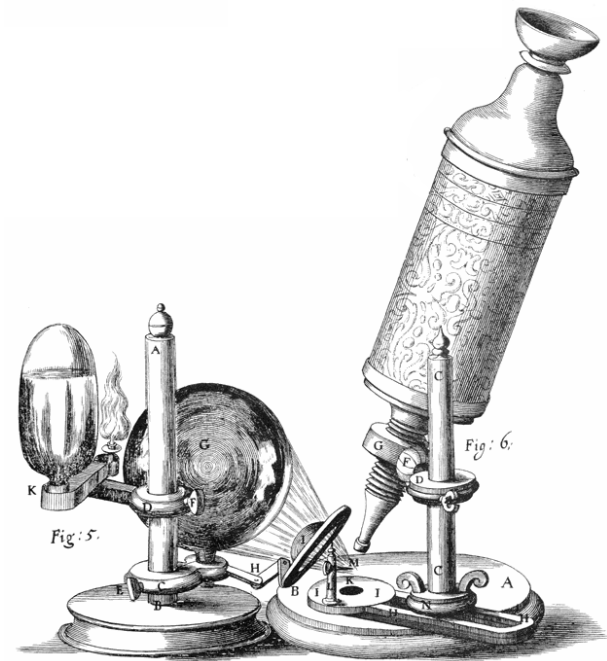
- Introduction / History (evolution) of microbiology
- Cell biology
- Genetics
- Biosynthesis & metabolism
- Enzymes
- Redox
- Population & community dynamics
- Aquatic & soil microbiology
- Biotechnology and bioremediation

History

- Three periods of thought
 - Observation
 - Pure culture
 - Molecular biology
- Main themes
 - “small critters”
 - Food safety
 - Public health
 - Biotechnology

History – observation

- Robert Hooke (1644)
 - Described the fruiting structure of fungi and some protozoa
 - “cell”



History - observation

- Antoni van Leeuwenhoek (1674)
 - Less ornate microscope
 - Described individual 'sperm'
 - Larger bacteria of the mouth
 - Muscle fibers
 - Vacuoles of cells

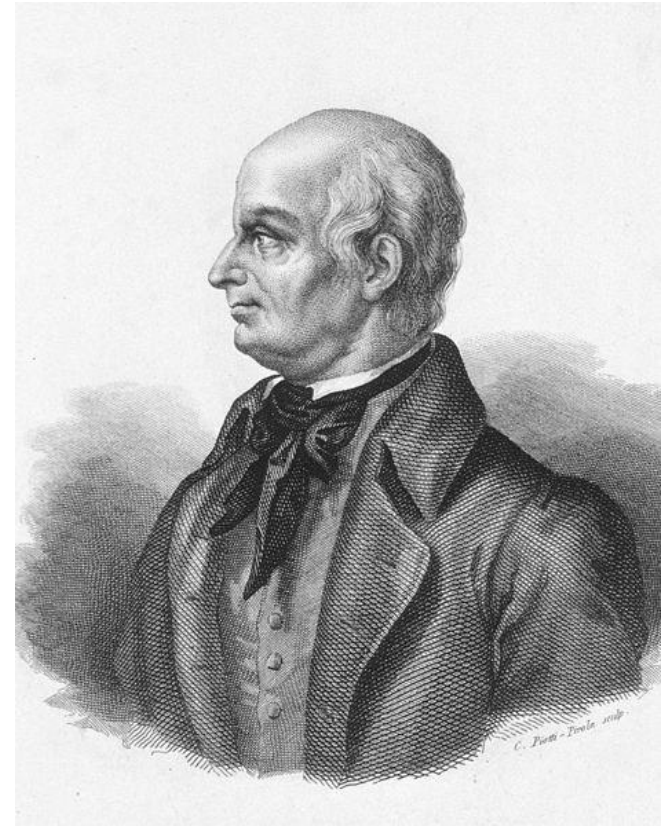


History - observation

- Theory of spontaneous generation
 - Microorganisms did not replicate – just appeared
 - Foul smelling products would form over time
 - Putrefaction resulted from breakdown of protein
 - Alcohol resulted from breakdown of carbohydrates
- Experiments continued but focused on food safety
- Cagnaird-Latour, Schwann and Kützing proposed that yeast formed alcohol (1837)

History - observation

- Lazzaro Spallanzani (1729 – 1799)
 - Demonstrated that meat, which was heated, did not putrefy (with some variability of results)
 - Lead to food canning practices



History - observation

- Louis Pasteur (1860s)
 - Showed that air contained microorganisms
 - Eliminated the “theory of spontaneous generation”
 - Also, proved that life existed without oxygen (while working for Carlsberg Brewery)



History - observation

- John Tyndall
 - Boiled hay solution for 5 ½ hours – did not ‘kill everything’
 - Found heat-resistant spores
 - Could kill microorganisms by discontinuous heating

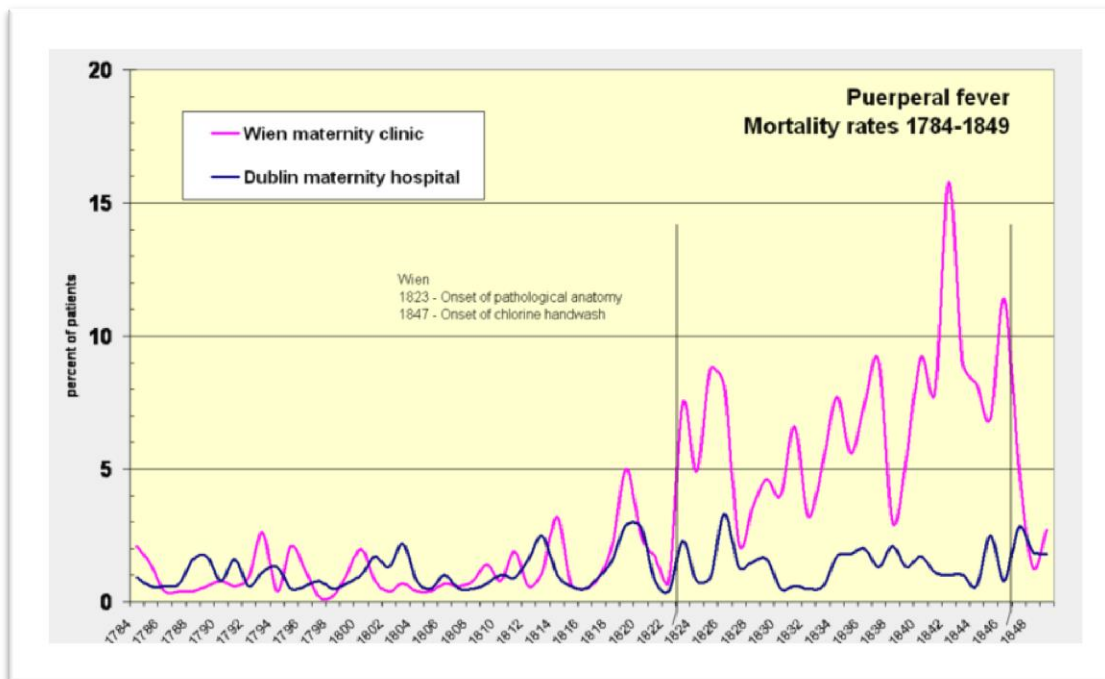
History - observation

- Microorganisms as source of disease
- Joseph Lister (1864)
 - Chemical sterilisation (phenolics)
 - Anaesthesia allowed for complicated procedures



History - observation

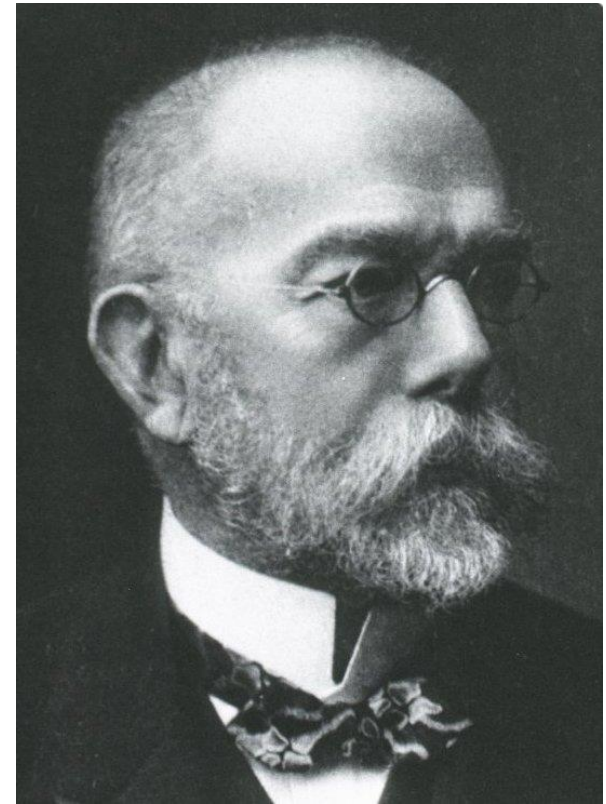
- Ignaz Semmelweis (1847)
 - Washing hands with chlorinated lime
 - Reduction of puerperal fever



Ironically – he died of septicemia in a hospital

History – pure culture

- Robert Koch (1843 – 1910)
 - Demonstrated cause of Anthrax
 - Isolated, cultured and re-infected animals
 - Koch's postulates
 - Microorganisms are always present when disease is
 - Must be isolated from diseased animal
 - Must cause disease when re-inoculated into a healthy animal

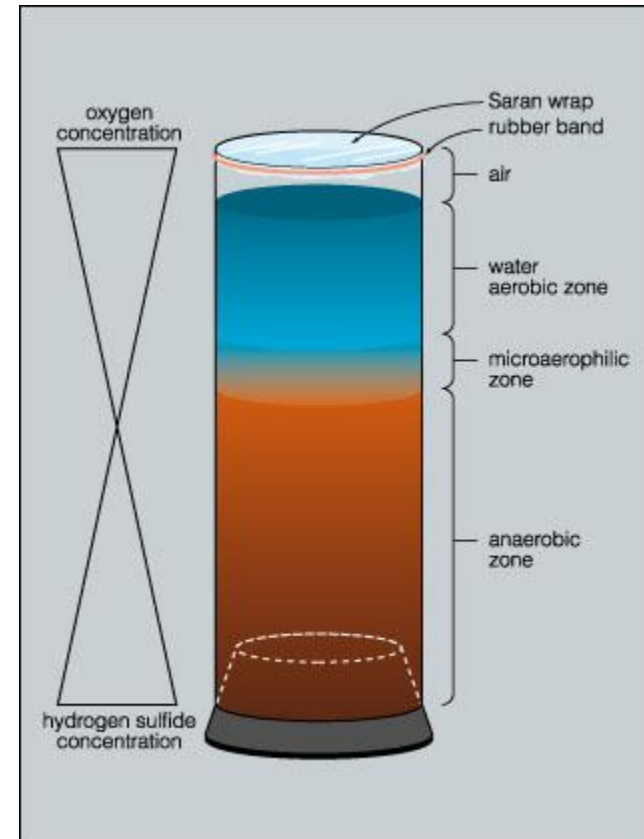


History - observation

- 1800s – beginning of environmental microbiology
 - Soil would oxidise H_2 gas, but ability will disappear with heating or acidification
 - Ammonia from sewage disappears when passed through sand, but stopped with treated with chloroform

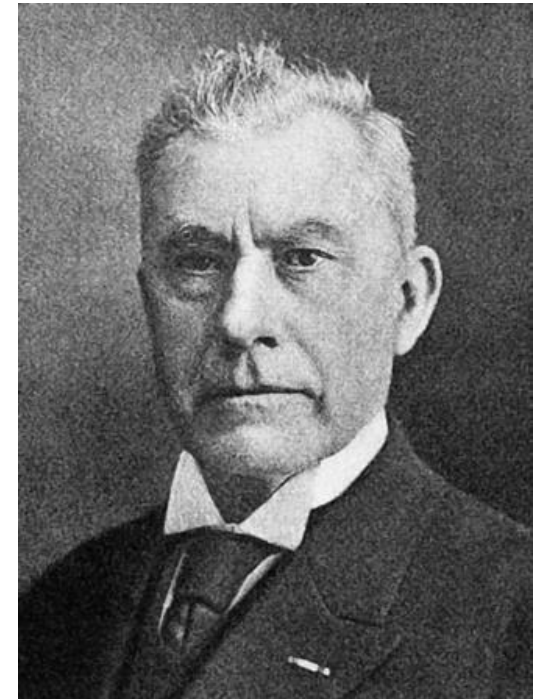
History – pure culture

- Sergei Winogradsky (1856–1953)
 - Isolated nitrifying bacteria (ammonia – nitrate)
 - Described the oxidation of iron and sulphide
 - Defined the idea of chemoautotrophy (using chemicals for energy)
 - Described nitrogen fixation



History – pure culture

- Martinus Beijerinck (1851–1931)
 - Isolated agents of symbiotic and aerobic nitrogen fixation
 - Believed microorganisms are everywhere, but required specialised culturing techniques



History – pure culture

- Great plate anomaly
 - Many microorganisms cannot grow on plates in the laboratory
 - Community vs. individual growth
 - 0.1% soil bacteria grow on Petri dishes
 - Severely limits what we can find out how these organisms function in the real world

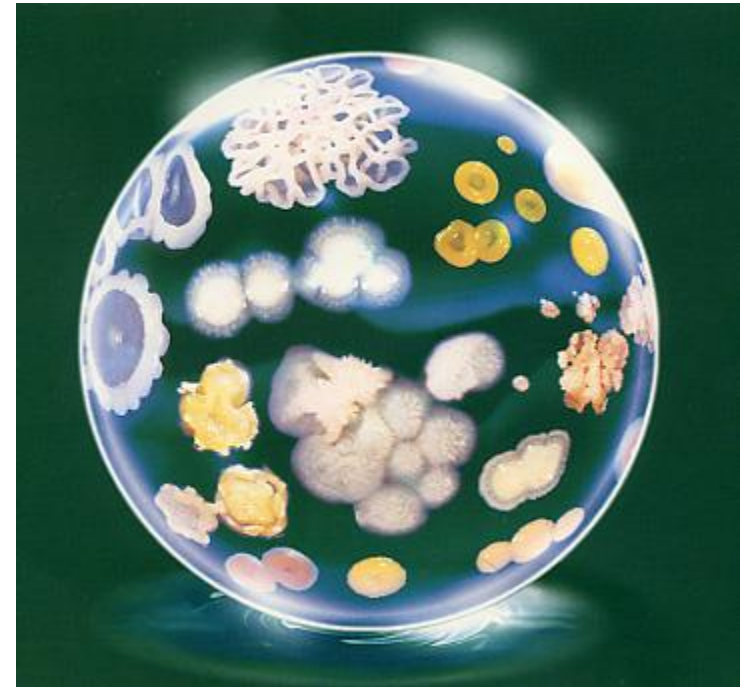
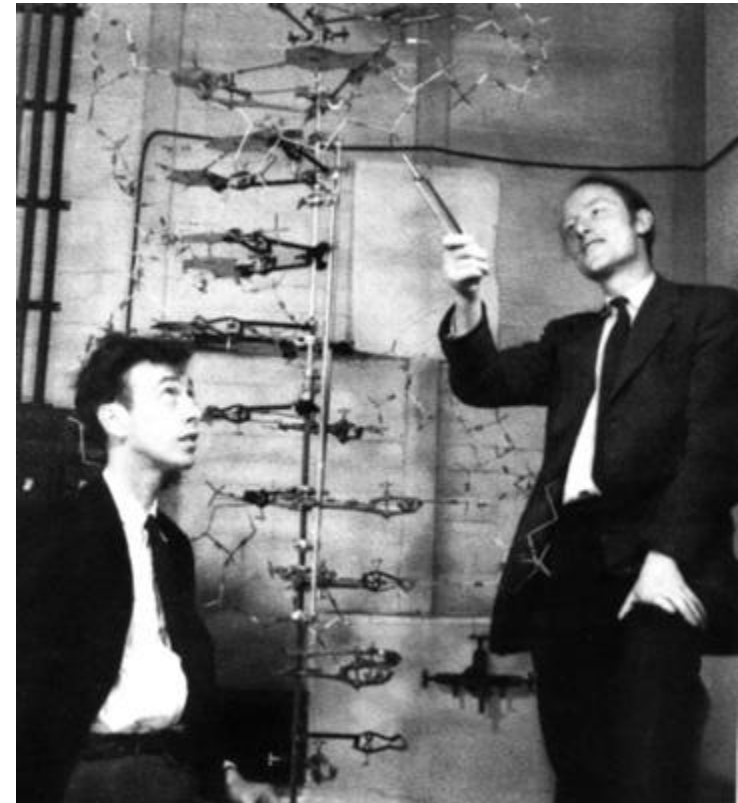


Photo: Kenneth Todar, U. Wisconsin, 2008

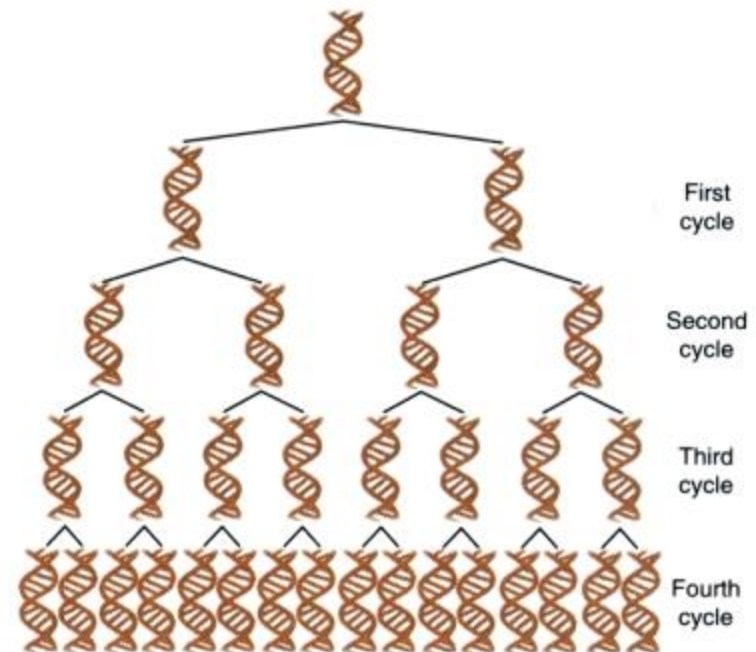
History – molecular

- DNA discovery
 - 19th century – isolation of DNA and RNA
 - 1869 – isolation of “nuclein” (DNA)
 - 1950 – helical structure of DNA
 - 1953 – Central Dogma Theory



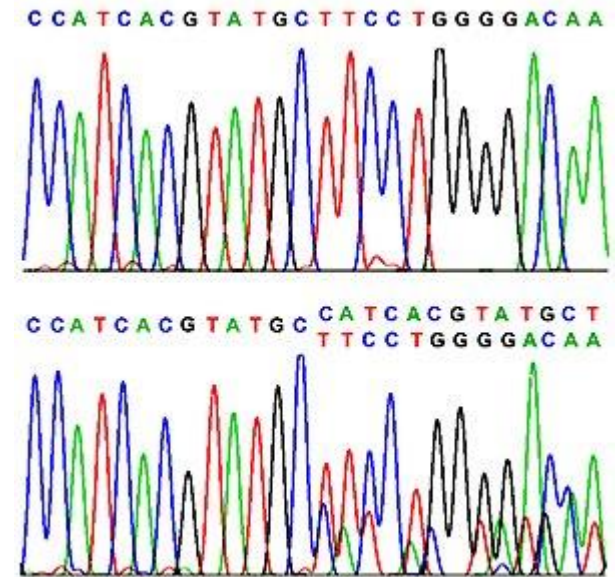
History – molecular

- Polymerase chain reaction (PCR)
 - Revolutionised the world of molecular biology
 - Automatic amplification of DNA
 - Provide quantity of DNA for analysis
 - 1983 – invented by Kary Mullis
 - 1999 – quantitative PCR



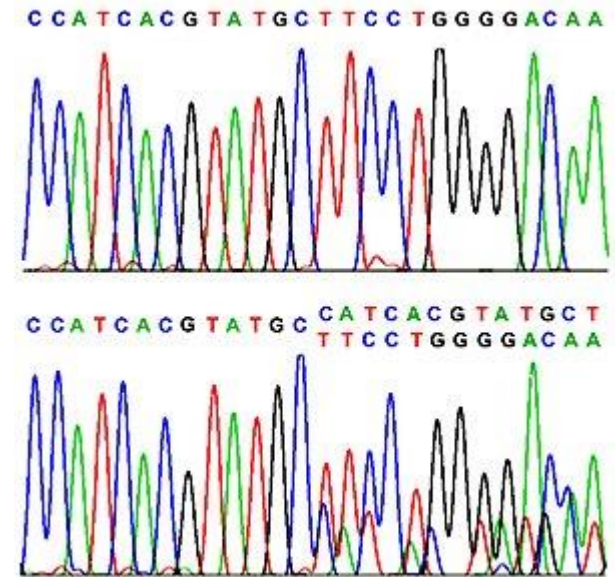
History - molecular

- DNA sequencing
 - 1977 Sanger sequencing
 - 1996 Pyrosequencing (454)
 - 2009 Third-generation sequencing
 - Ion Torrent
 - Illumina
 - Etc..



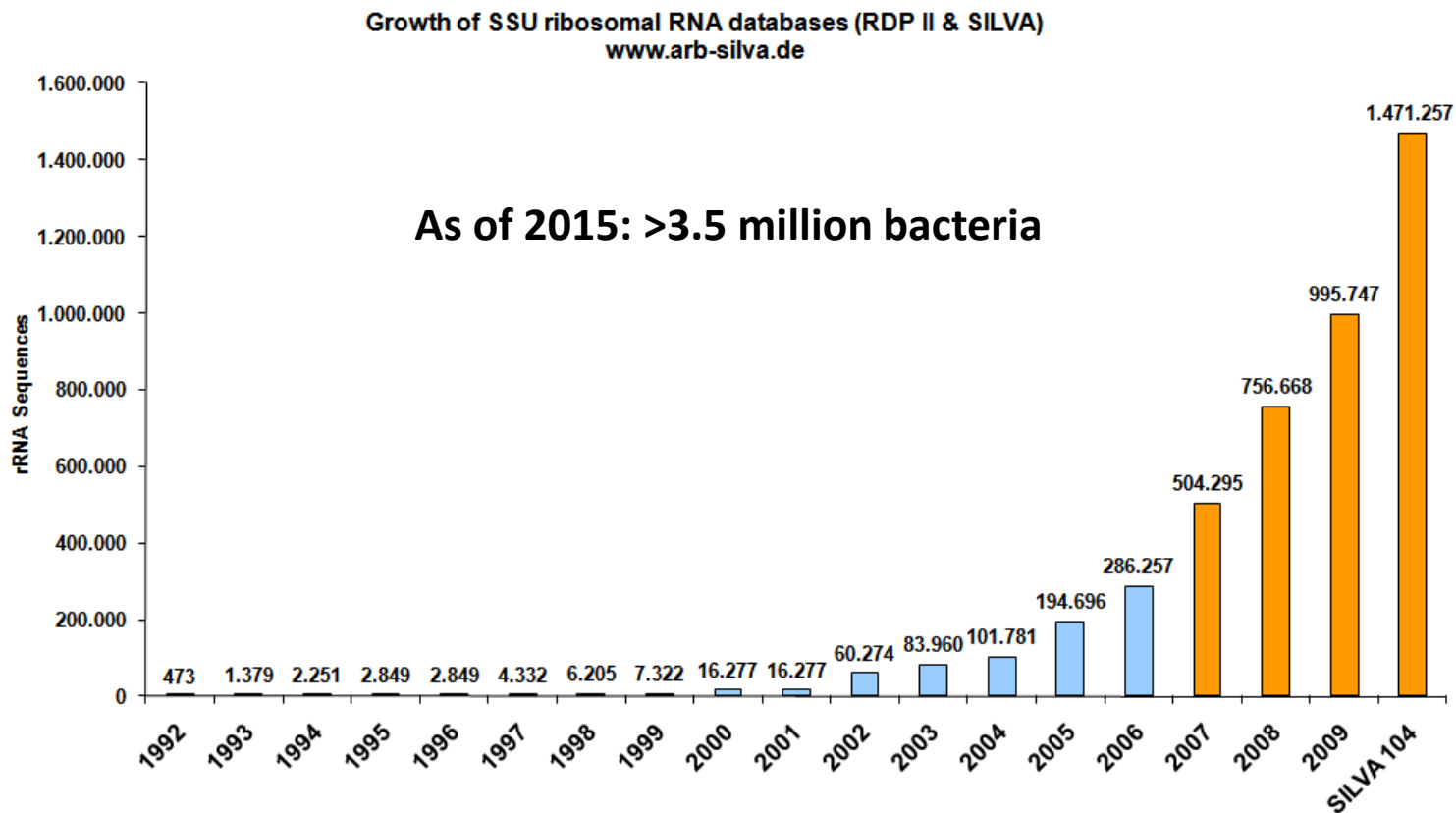
History - molecular

- DNA sequencing
 - 1976-1977, two virus genomes
 - Bacteriophage MS2 (RNA virus)
 - Phage ϕ -X174 (5385 bp)
 - *Haemophilus influenzae* (1995)
 - First bacterial genome
 - 1830 kbp
 - *Saccharomyces cerevisiae* (1995)
 - First eukaryotic (yeast) genome
 - Human genome project
 - Public Human Genome Project
 - 1986 – 2003
 - \$3 billion
 - Celero
 - 2000 initial publications
 - Faster & cheaper method

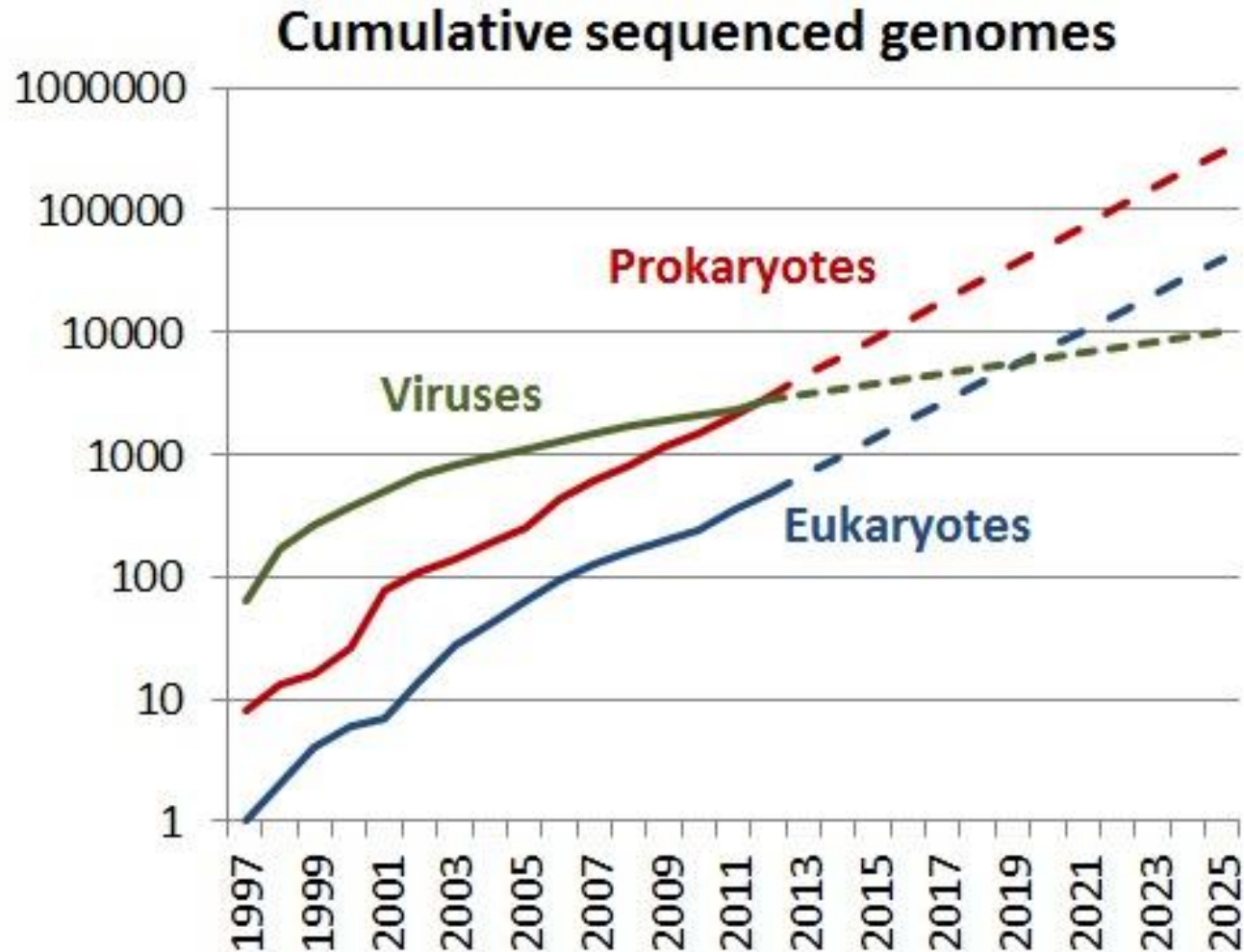


History - molecular

Growth of 16S-rRNA database



History - molecular



History - molecular

“We are now to the point where we can start to figure out how gene activity relates to the biochemistry of the earth.

Microbes drive it, we can just start to figure out how.”

-- Newman & Banfield, 2002, *Nature*

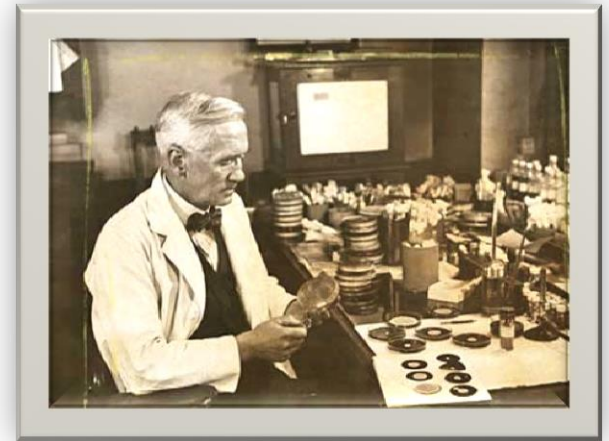
Growth of biotechnology

- 500BC: mouldy curds used as antibiotic (China)
- 100AD: insecticides, crushed Chrysanthemums
- 1761: Edward Jenner, small pox vaccine
- 1870: cotton cross-breeding (Mendelian genetics)
- 1911: Peyton Rous discovers “cancer virus”
- 1928: Alex Fleming discovers penicillin
- 1933: Hybrid corn
- 1942: Penicillin is mass produced
- 1950: First synthetic antibiotic produced



Growth of biotechnology

- 1958: DNA artificially synthesised
- 1978: recombinant insulin
- 1979: synthetic growth hormones
- 1980: small pox “eradicated”
- 1980: first patent for “oil eating” bacterium
- 1981: first transgenic animal
- 1982: recombinant DNA vaccine for livestock
- 1982: genetically modified bacteria make insulin
- 1988: pest-resistant corn
- 1990: gene therapy



Growth of biotechnology

- 1986: anticancer drug
- 1992: increased milk production
- 1994: gene therapy against cancer
- 1996: GM crops
- 1997: “Dolly” –first cloned animal
- 1998: anticancer drug
- 1999: BSE detection (prions)
- 2000: Kenya field tests GM crops
- 2000’s litany of Health & Agricultural patents

- 2005: incentives for bioethanol production (USA)
- 2009: global biotech crop acreage = 330 million acres



Wastewater Treatment



- 400AD: Roman sewer systems
- 1850: “Punch” satire on English situation
- 1868: Sulfide odours in drinking water (Virchow)
- 1869: Self-purification = biological process (Muller)
- 1890: Biological oxidation of carbon and nitrogen
- 1890: cholera illness... soil or bacteria?
- 1960s:shouldn't rely on rivers for self-purification

Wastewater Treatment

- 1860: irrigation strategies
- 1890: intermittent soil filtration
- 1903: trickling filters
- 1960: high-rate trickling filters



Wastewater Treatment

- Previous – “air” treated sewage
- 1913 – first aeration experiments
- 1920 – activated sludge (enhance biological process)



Wastewater treatment

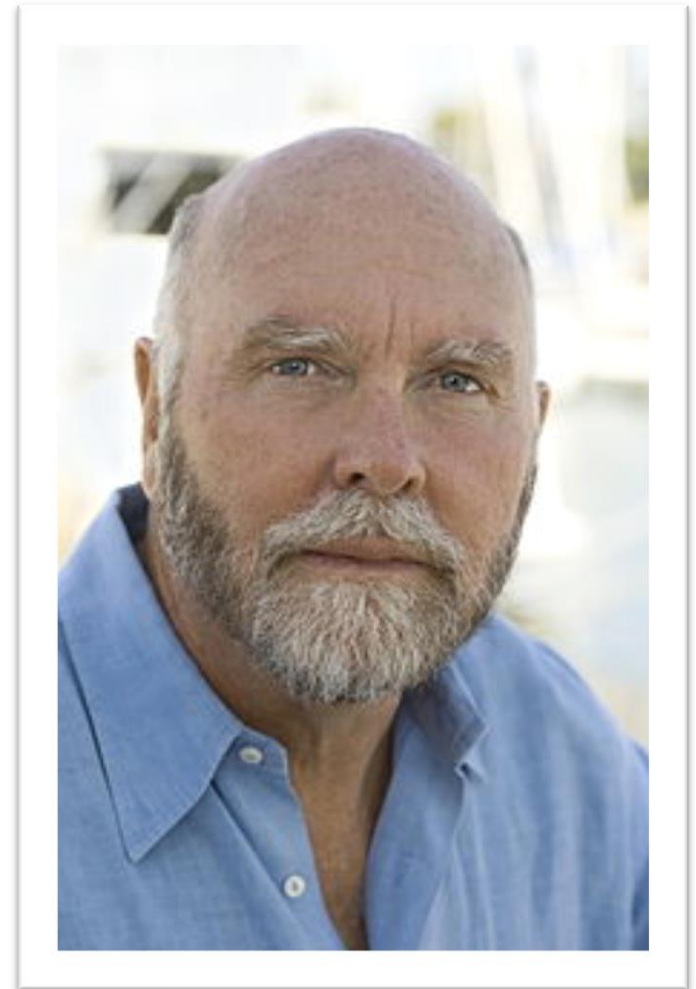
- 1990: phosphorus accumulating organisms
- 1999: Anammox – anaerobic ammonia oxidation
- 2000: SHARON process
- 2015: Comammox - processes

Geomechanics and geotechnics?

- Ceramic and pottery
- Soil / clay properties (e.g., chemical and physical properties)
- Particle aggregation
- Bio-cementation / grouting / bio-mineral formation
- Bio-weathering / bio-corrosion
- Bio-extraction (e.g., metal chelation)
- Bio-clogging

It is not the end...

- Human genome
- Sequencing the bio-diversity of entire sea
- First fully synthetic organism
- Bio-fuel production



Craig Venter

What is next?

