A study material for M.Sc. Biochemistry (Semester: IV) Students
on the topic (EC-1; Unit I)

History and Scope of Microbiology

The story of invisible organisms

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MICROBIOLOGY

1. WHAT IS A MICROBIOLOGY?

Micro means very small and **biology** is the study of living things, so microbiology is the study of very small living things normally too small that are usually unable to be viewed with the naked eye.

Need a microscope to see them

Virus - 10 → 1000 nanometers
Bacteria - 0.1 → 5 micrometers
(Human eye) can see 0.1 mm to 1 mm

Microbiology has become an umbrella term that encompasses many sub disciplines or fields of study. These include:

- **Bacteriology: The study of bacteria**
- **Mycology: Fungi**
- **Protozoology: Protozoa**
- **Phycology: Algae**
- **Parasitology: Parasites**
- **Virology: Viruses**

WHAT IS THE NEED TO STUDY MICROBIOLOGY

- Genetic engineering
- Recycling sewage
- Bioremediation: use microbes to remove toxins (oil spills)
- Use of microbes to control crop pests
- Maintain balance of environment (microbial ecology)
- Basis of food chain
- Nitrogen fixation
- Manufacture of food and drink
- Photosynthesis: Microbes are involved in photosynthesis and accounts for >50% of earth's oxygen

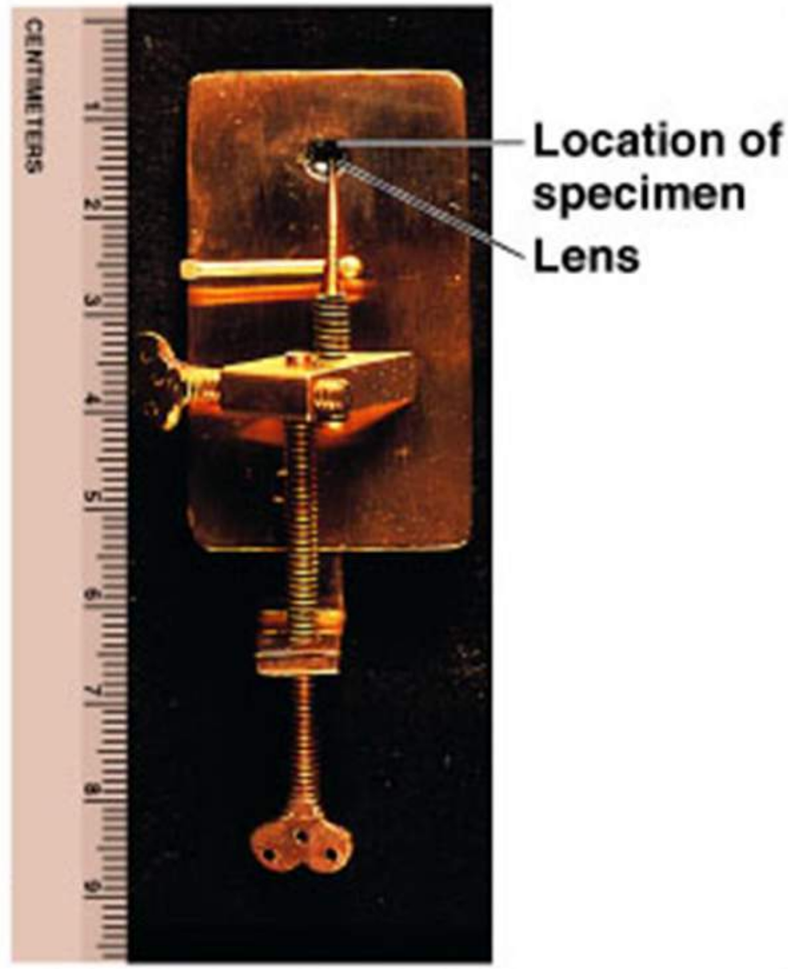
History of Microbiology

Anton van Leeuwenhoek (1632-1723)
(Dutch Scientist)

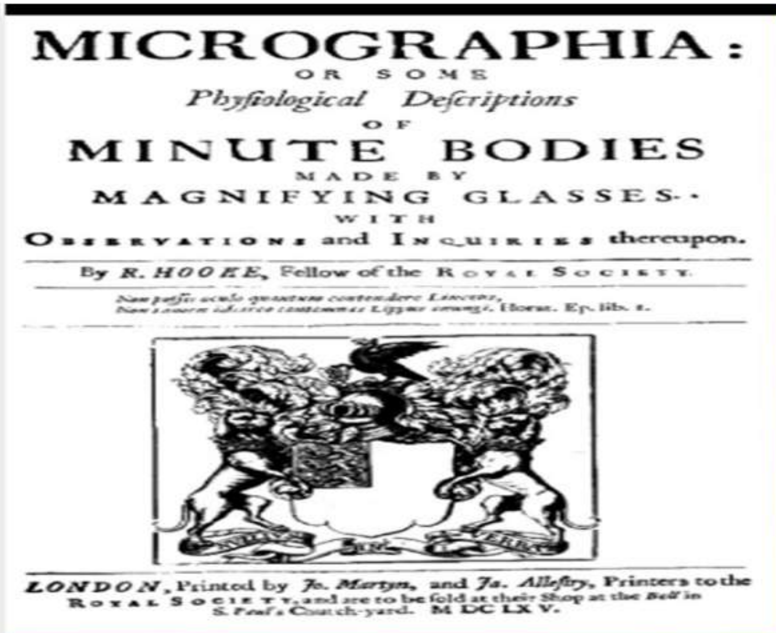
- The credit of discovery of microbial world goes to **Anton van Leeuwenhoek**. He made careful observations of microscopic organisms, which he called **animalcules (1670s).**

- Antoni van Leeuwenhoek described live microorganisms that he observed in teeth scrapings and rain water.

- Major contributions to the development of microbiology was the invention of the microscope (**50-300X magnification**) by Anton von Leuwenhoek and the implementation of the scientific method.



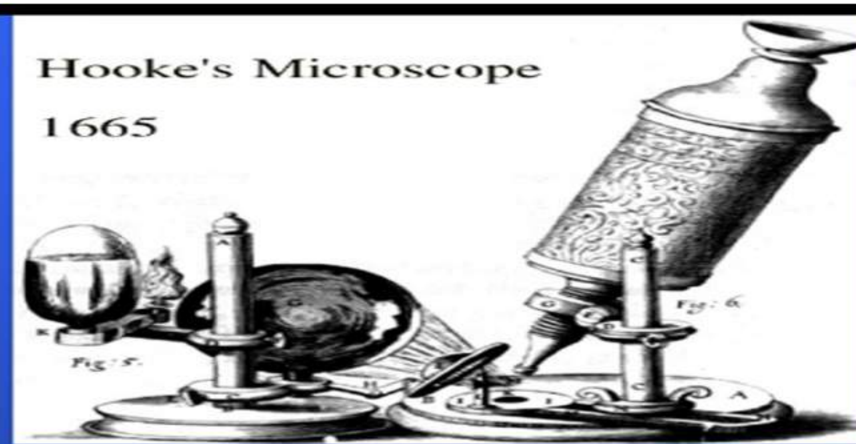
(b) Microscope replica


MICROGRAPHIA:
OR SOME
Physiological Descriptions
OF
MINUTE BODIES
MADE BY
MAGNIFYING GLASSES.
WITH
OBSERVATIONS and INQUIRIES thereupon.

By *R. HOOKE*, Fellow of the ROYAL SOCIETY.

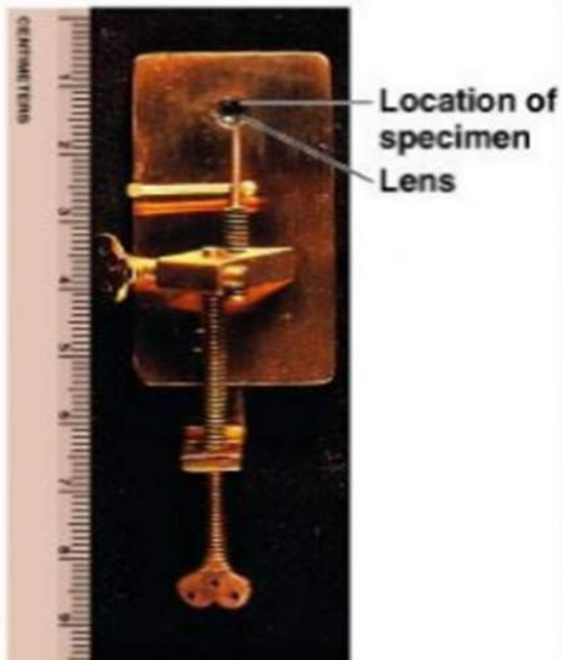
Non possis oculo quantum contendere Linceus,
Non tamen idcirco contemnas Lippus inungi. Horat. Ep. lib. 1.

LONDON, Printed by *Jo. Martyn*, and *Ja. Allestry*, Printers to the ROYAL SOCIETY, and are to be sold at their Shop at the *Bell* in S. *Paul's* Church-yard. M DC LX V.

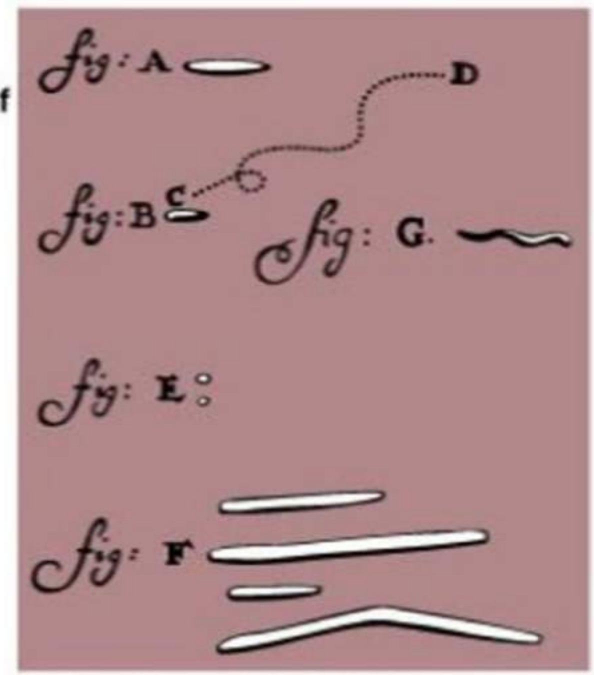


Antonie van Leeuwenhoek was inspired by this publication


(a) Van Leeuwenhoek using his microscope.



(b) Microscope replica



(c) Drawings of bacteria

Spontaneous generation versus biotic generation of life

Theory of Spontaneous generation

- Certain living things arose from vital forces present in non-living or decomposing matter. This ancient belief, known as **Spontaneous generation** (also known as abiogenesis)**.**

- The early Greeks believed that living things could originate from nonliving matter (abiogenesis) and that the goddess Gea could create life from stones. Aristotle discarded this notion, but he still held that animals could arise spontaneously from dissimilar organisms or from soil. His influence regarding this concept of spontaneous generation was still felt as late as the 17th century, but toward the end of that century a chain of observations, experiments, and arguments began that eventually refuted the idea. This advance in understanding was hard fought, involving series of events, with forces of personality and individual will often obscuring the facts.

Support of Spontaneous generation:

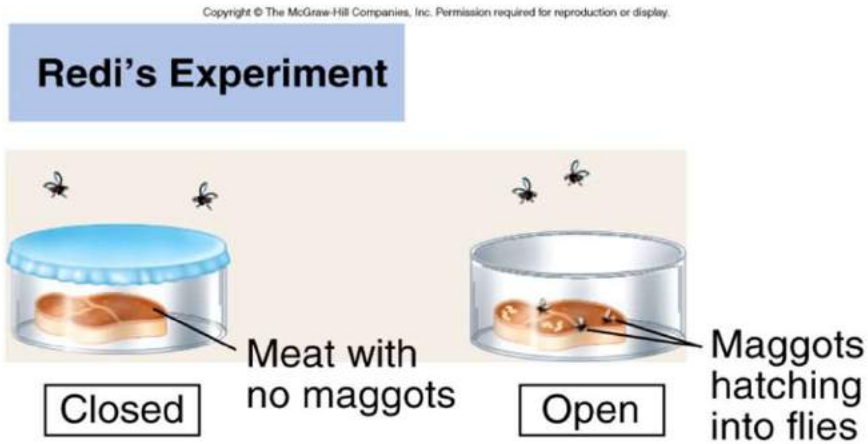
John Needham experiment

Needham theorized that if he took chicken broth and heated it, all living things in it would die. After heating some broth, he let a flask cool and sit at a constant temperature. The development of a thick turbid solution of microorganisms in the flask was strong proof to Needham of the existence of spontaneous generation.

Challenge of Spontaneous generation

1. Francesco Redi's Experiments (late 1600s)

Francesco Redi was able to disprove the theory that maggots could be spontaneously generated from meat using a controlled experiment.

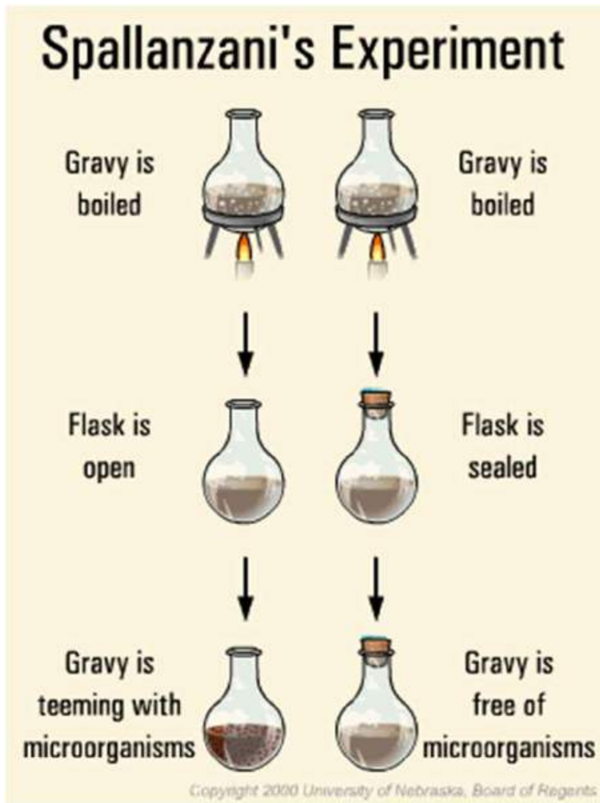


Redi concluded that the flies laid eggs on the meat in the open jar which caused the maggots. Because the flies could not lay eggs on the meat in the covered jar, no maggots were produced. Redi therefore proved that decaying meat did not produce maggots.

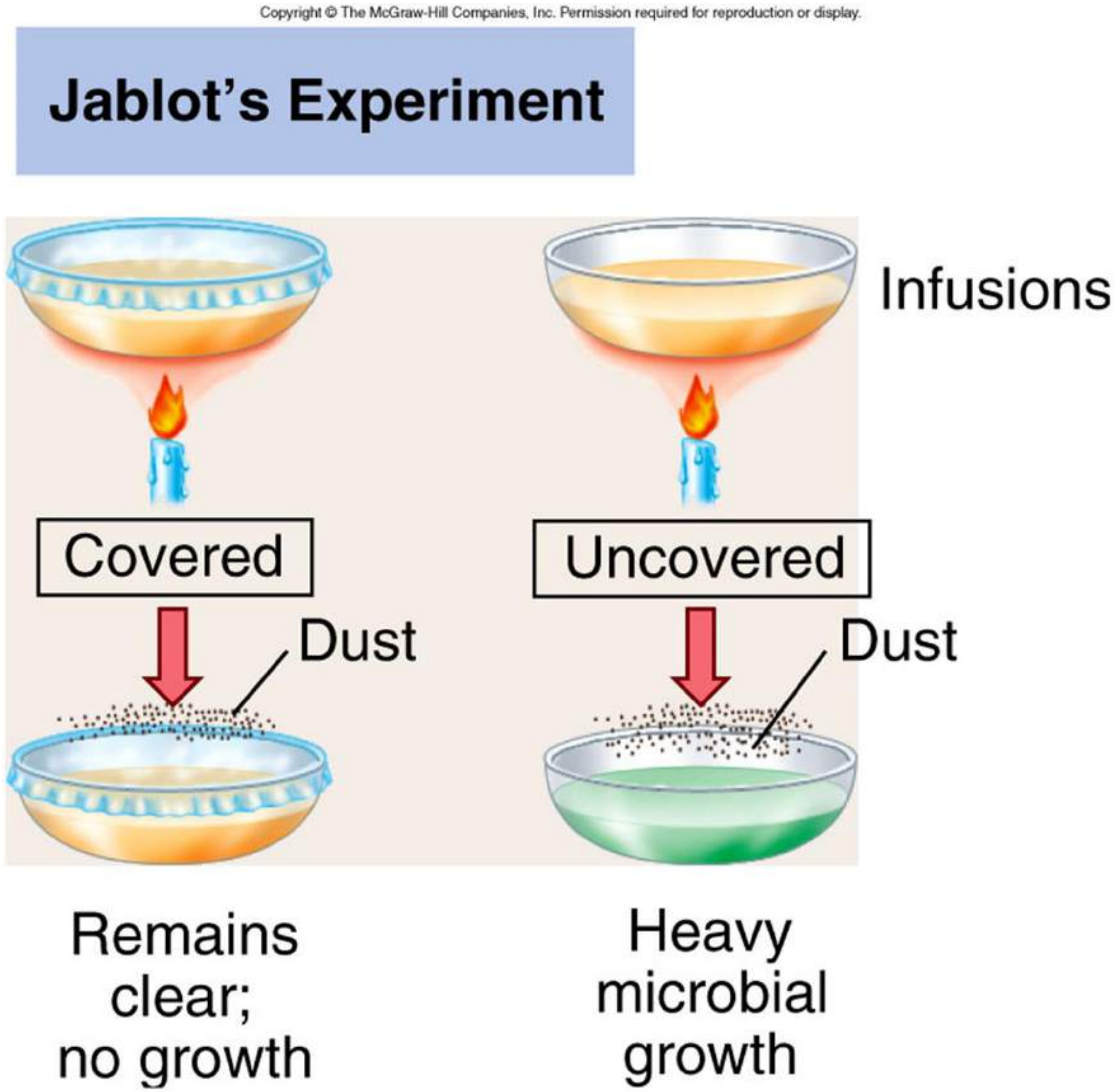
Redi successfully demonstrated that the maggots came from fly eggs and thereby helped to disprove spontaneous generation.

2. **Spallanzani's Experiment (**1770**)**

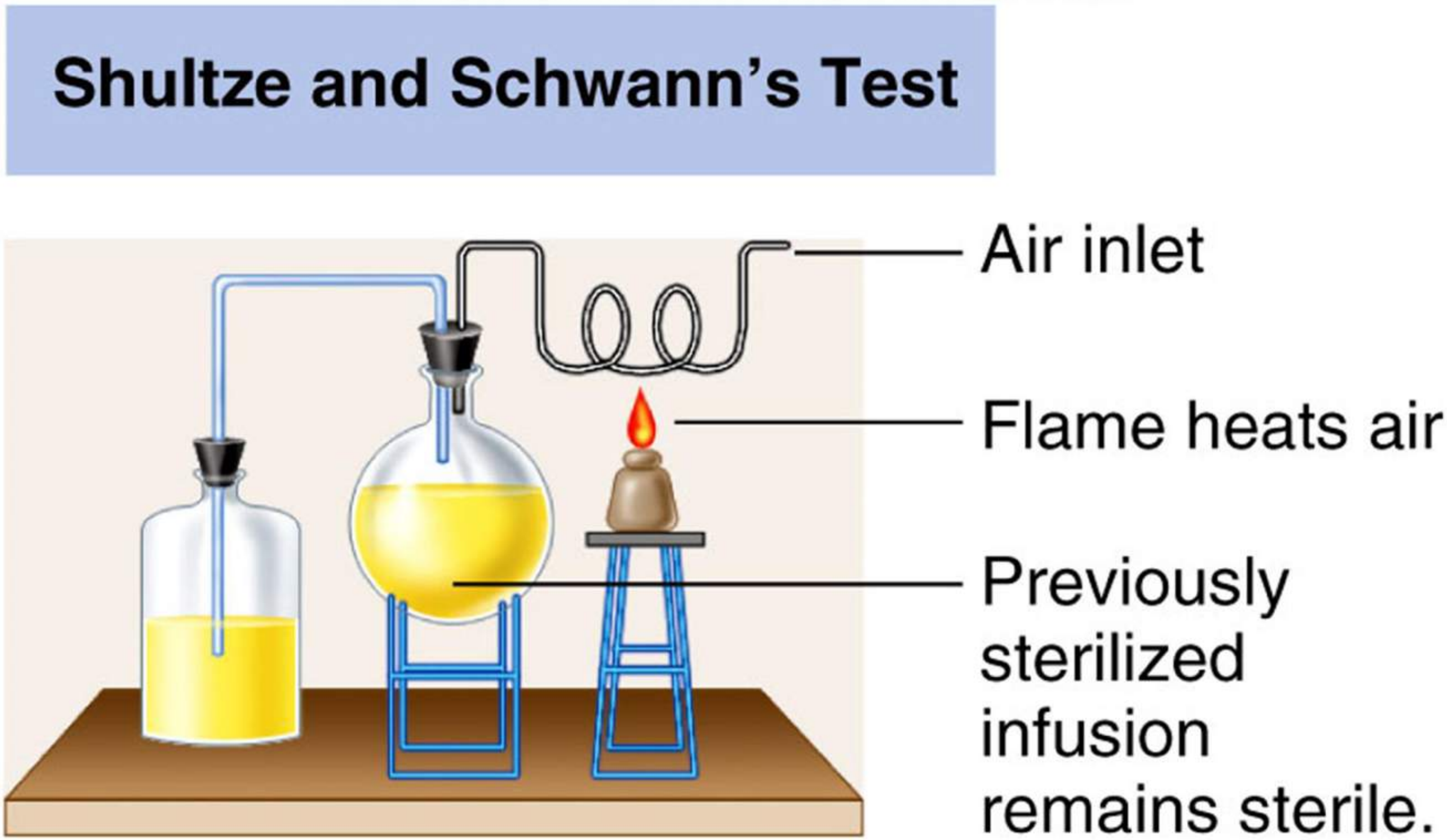
- Lazzaro Spallanzani, also an Italian scientist, reviewed both Redi's and Needham's data and experimental design and concluded that perhaps Needham's heating of the bottle did not kill everything inside.
- He constructed his own experiment by placing broth in each of two separate bottles, boiling the broth in both bottles, then sealing one bottle and leaving the other open. Days later, the unsealed bottle was teeming with small living things that he could observe more clearly with the newly invented microscope. The sealed bottle showed no signs of life. This certainly excluded spontaneous generation as a viable theory.



3. Frenchman Louis Jablots experiment

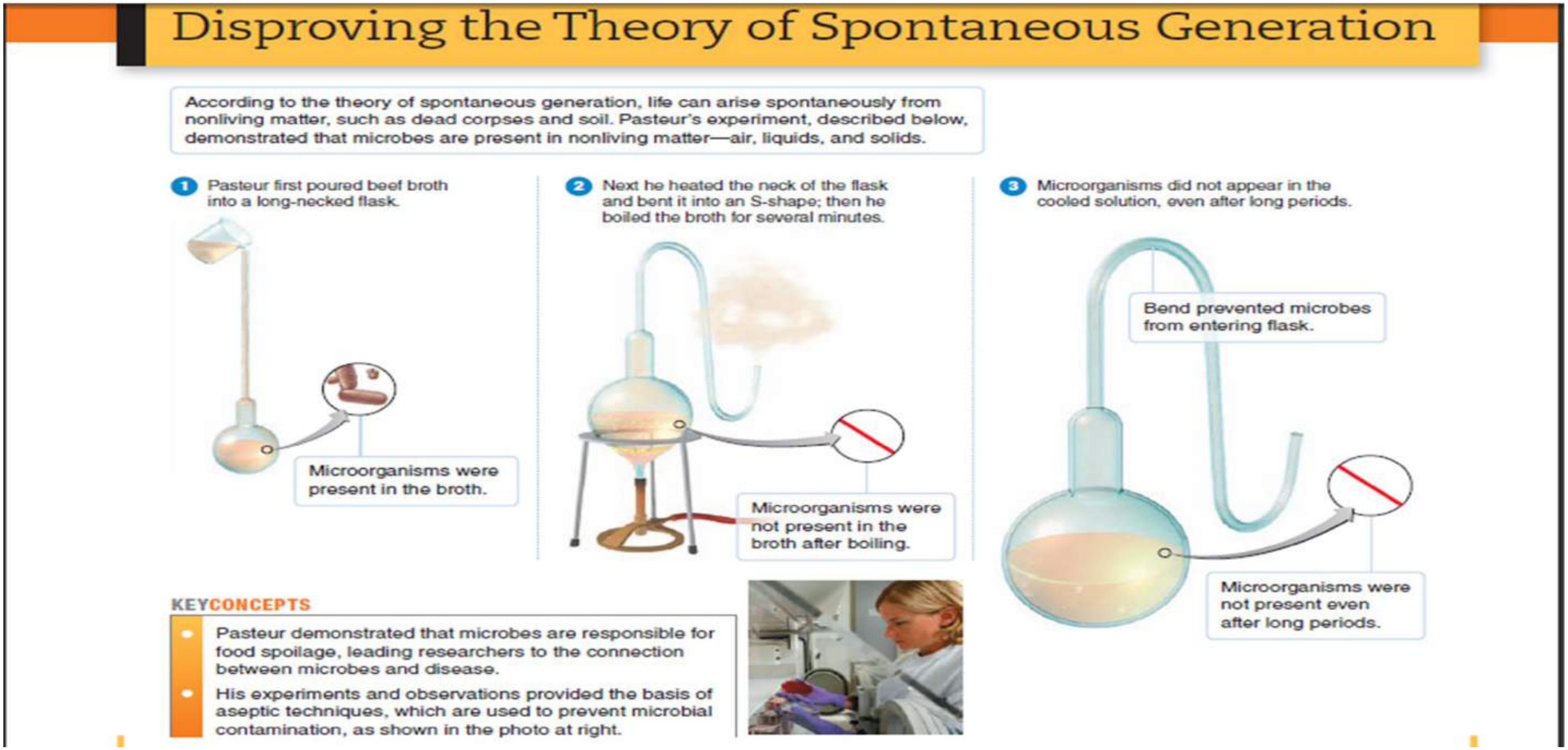


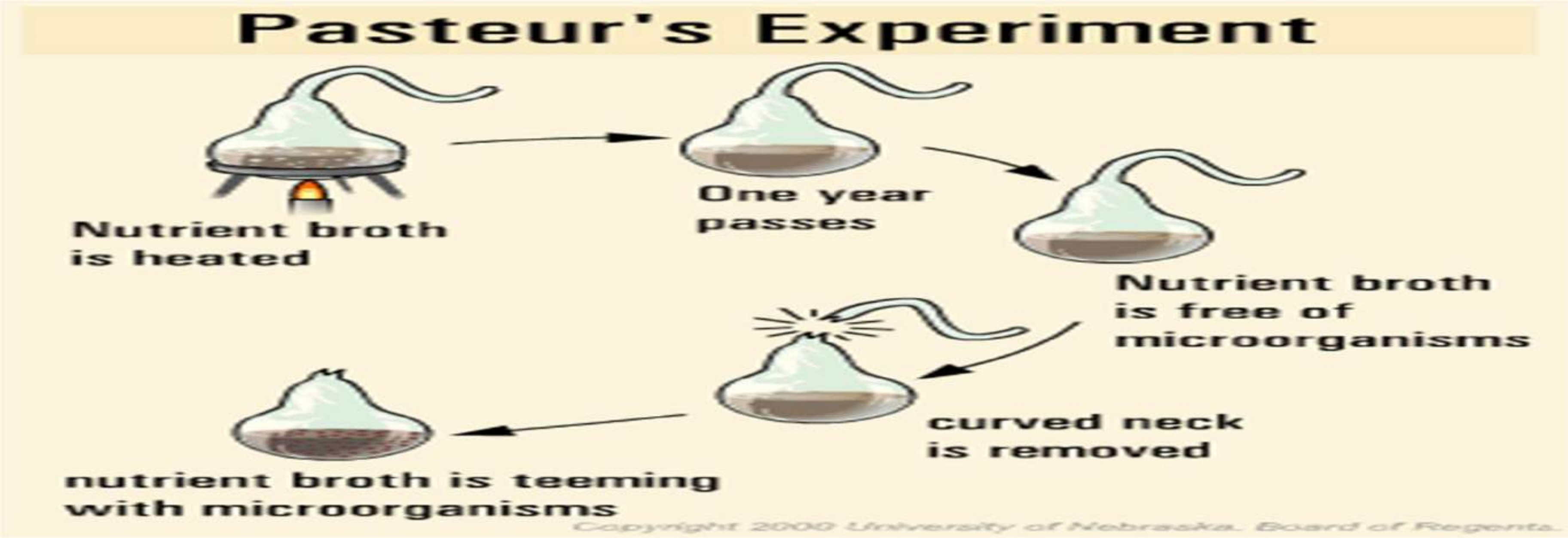
4. Shultze and Schwann's experiment



5. Louis pasteur's Experiment (1822 - 1895)

- trapped airborne organisms in cotton;
- he also heated the necks of flasks, drawing them out into long curves, sterilized the media, and left the flasks open to the air;
- no growth was observed because dust particles carrying organisms did not reach the medium, instead they were trapped in the neck of the flask; if the necks were broken, dust would settle and the organisms would grow; in this way Pasteur disproved the theory of spontaneous generation
- With the results from his experiment, Pasteur concluded that air alone was not sufficient to generate life.
- Pasteur definitively demonstrated that microorganisms are present in air but not created by air





- Beginning with Pasteur's work, discoveries included the relationship between microbes and disease, immunity, and antimicrobial drugs

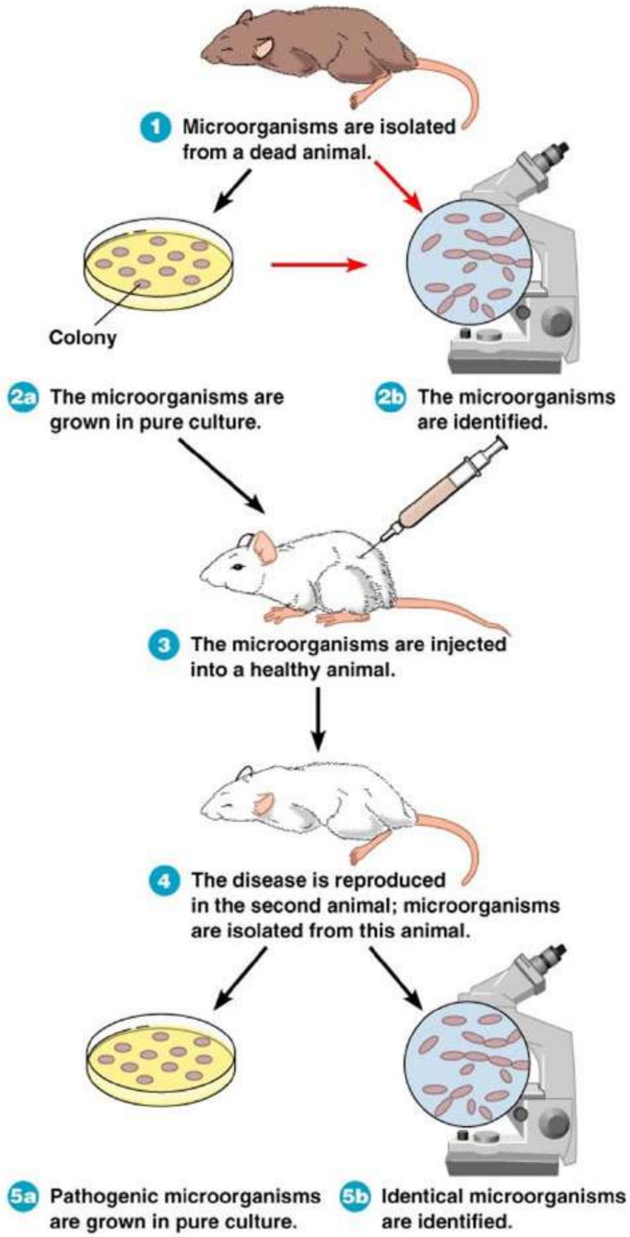
- Louis Pasteur is often referred to as the "Father of Microbiology" (along with scientist Robert Koch) for his contributions to discerning the cause and prevention of disease

Contribution of Pasture:

- Pasteurization:
- Discovery of Germ-Disease Relationship: Germ theory of Diseases
- The Rabies Vaccine:
- Microorganisms responsible for fermentation

Robert Koch: (1843 – 1910**)**

- He was a German Physician.
- He became famous for isolating *Bacillus anthracis* (1877), the *Tuberculosis bacillus* (1882) and *Vibrio cholerae* (1883) and for his development of Koch's postulates
- He was awarded the Nobel Prize in Physiology or Medicine in 1905 for his tuberculosis findings
- Probably as important as his work on tuberculosis, for which he was awarded a Nobel Prize in 1905, are *Koch's postulates*, which say that *to establish that an organism is the cause of a disease.*



Koch's postulates are as follows:

- The suspected causative agent of a disease must be found in every case, and absent in healthy individuals.
- The agent must then be isolated and grown outside the host (i.e. cultivated in a laboratory environment).
- When a healthy, susceptible host is inoculated with the agent, the host must develop the same disease.
- That same agent must then be re-isolated from the experimental host.

However, Koch's postulates have their limitations and so may not always be the last word. They may not hold if:

- The particular bacteria (such as the one that causes leprosy) cannot be "grown in pure culture" in the laboratory.
- There is no animal model of infection with that particular bacteria.
- Two or more organism work in synergy to cause a disease
- **A harmless bacteria may cause disease if:**

  It has acquired extra virulence factors making it pathogenic.

  It infects an immunocompromised patient.

  Not all people infected by a bacteria may develop disease

Despite such limitations, Koch's postulates are still a useful benchmark in judging whether there is a cause-and-effect relationship between a bacteria (or any other type of microorganism) and a clinical disease.

1665 Hooke—First observation of cells
1673 van Leeuwenhoek—First observation of live microorganisms
1735 Linnaeus—Nomenclature for organisms
1798 Jenner—First vaccine
1835 Bassi—Silkworm fungus
1840 Semmelweis—Childbirth fever
1853 DeBary—Fungal plant disease

GOLDEN AGE OF MICROBIOLOGY

1857 Pasteur—Fermentation
1861 Pasteur—Disproved spontaneous generation
1864 Pasteur—Pasteurization
1867 Lister—Aseptic surgery
1876 *Koch—Germ theory of disease
1879 Neisser—*Neisseria gonorrhoeae*
1881 *Koch—Pure cultures
Finley—Yellow fever
1882 *Koch—*Mycobacterium tuberculosis*
Hess—Agar (solid) media
1883 *Koch—*Vibrio cholerae*
1884 *Metchnikoff—Phagocytosis
Gram—Gram-staining procedure
Escherich—*Escherichia coli*
1887 Petri—Petri dish
1889 Kitasato—*Clostridium tetani*
1890 *von Bering—Diphtheria antitoxin
*Ehrlich—Theory of immunity
1892 Winogradsky—Sulfur cycle
1898 Shiga—*Shigella dysenteriae*
1908 *Ehrlich—Syphilis
1910 Chagas—*Trypanosoma cruzi*
1911 * Rous—Tumor-causing virus (1966 Nobel Prize)

1928 *Fleming, Chain, Florey—Penicillin
Griffith—Transformation in bacteria
1934 Lancefield—Streptococcal antigens
1935 *Stanley, Northrup, Sumner—Crystallized virus
1941 Beadle and Tatum—Relationship between genes and enzymes
1943 *Delbrück and Luria—Viral infection of bacteria
1944 Avery, MacLeod, McCarty—Genetic material is DNA
1946 Lederberg and Tatum—Bacterial conjugation
1953 *Watson and Crick—DNA structure
1957 *Jacob and Monod—Protein synthesis regulation
1959 Stewart—Viral cause of human cancer
1962 *Edelman and Porter—Antibodies
1964 Epstein, Achong, Barr—Epstein-Barr virus as cause of human cancer
1971 *Nathans, Smith, Arber—Restriction enzymes (used for recombinant DNA technology)
1973 Berg—Genetic engineering
1975 Dulbecco, Temin, Baltimore—Reverse transcriptase
1978 Woese—Archaea
*Mitchell—Chemiosmotic mechanism
1981 Margulis—Origin of eukaryotic cells
1982 *Klug—Structure of tobacco mosaic virus
1983 *McClintock—Transposons

1988 *Deisenhofer, Huber, Michel—Bacterial photosynthesis pigments
1994 Cano—Reported to have cultured 40-million-year-old bacteria
1997 *Prusiner—Prions

Louis Pasteur (1822–1895)
Demonstrated that life did not arise spontaneously from nonliving matter.

Robert Koch (1843–1910)
Established experimental steps for directly linking a specific micr to a specific disease.

Joseph Lister (1827–1912)
Performed surgery under antiseptic conditions using phenol. Proved that microbes caused surgical wound infections.

Rebecca C. Lancefield (1895–1981)
Classified streptococci according to serotypes (variants within a species)

Figure 1.4 Milestones in microbiology, highlighting those that occurred during the Golden Age of Microbiology. An asterisk (*) indicates a Nobel laureate.

Scope of Microbiology

The advantageous fields of microbiology are essentially the ones enumerated below :

- Beverage Microbiology — making of beer, shandy, wine, and a variety of alcoholic bever ages e.g., whisky, brandy, rum, gin, vodka. etc.
- Exomicrobiology — to help in the exploration of life in the outer space.
- Food Microbiology — making of cheese, yogurt.
- Geochemical Microbiology — to help in the study of coal, mineral deposits, and gas formation ; prospecting the deposits of gas and oil, coal, recovery of minerals from low-grade ores.
- Industrial Microbiology — making of ethanol, acetic acid, lactic acid, citric acid, glucose syrup, high-fructose syrup.
- Medical Microbiology — helps in the diagnostic protocol for identification of causative agents of various human ailments, and subsequent preventive measures.
- Pharmaceutical Microbiology — making of life-saving drugs, 'antibiotics' e.g., penicillins, ampicillin, chloramphenicol, ciprofloxacin, tetracyclines, streptomycin.
- Soil and Agricultural Microbiology — helps in the maintenance of a good farm land by keeping and sustaining a reasonable and regular presence of microbes in it.
- Waste-Treatment Microbiology — treatment of domestic and industrial effluents or wastes.

Table 1.1: Major antibiotics and their microbial sources	
Antibiotic	**Microbial source**
Bacitracin	*Bacillus licheniformis*
Cephalosporin	*Cephalosporium acremonium*
Chloramphenicol	*Streptomyces venezuelae*
Cycloheximide	*Streptomyces griseus*
Cycloserine	*Streptomyces orchidaceus*
Erythromycin	*Streptomyces erythraeus*
Griseofulvin	*Penicillium griseofulvum*
Kanamycin	*Streptomyces kanamyceticus*
Lincomycin	*Streptomyces lincolnensis*
Neomycin	*Streptomyces fradiae*
Nystatin	*Streptomyces noursei*
Penicillin	*Penicillium chrysogenum*
Polymyxin B	*Bacillus polymyxa*
Streptomycin	*Streptomyces griseus*
Teicoplanin	*Actinoplanes teichomyceticus*
Tetracycline	*Streptomyces rimosus*
Vancomycin	*Streptomyces orientalis*

TABLE 1.2 Selected Nobel Prizes Awarded for Research in Microbiology

Nobel Laureates	Year of Presentation	Country of Birth	Contribution
Ronald Ross	1902	England	Discovered how malaria is transmitted
Selman A. Waksman	1952	Ukraine	Discovered streptomycin
Hans A. Krebs	1953	Germany	Discovered chemical steps of the Krebs cycle in carbohydrate metabolism
John F. Enders, Thomas H. Weller, and Frederick C. Robbins	1954	United States	Cultured poliovirus in cell cultures
Joshua Lederberg, George Beadle, and Edward Tatum	1958	United States	Described genetic control of biochemical reactions
Frank Macfarlane Burnet and Peter Brian Medawar	1960	Australia Great Britain	Discovered acquired immune tolerance
César Milstein, Georges J. F. Köhler, and Niels Kai Jerne	1984	Argentina Germany Denmark	Developed a technique for producing monoclonal antibodies (single pure antibodies)
Susumu Tonegawa	1987	Japan	Described the genetics of antibody production
J. Michael Bishop and Harold E. Varmus	1989	United States	Discovered cancer-causing genes called oncogenes
Joseph E. Murray and E. Donnall Thomas	1990	United States	Performed the first successful organ transplants by using immunosuppressive agents
Edmond H. Fisher and Edwin G. Krebs	1992	United States	Discovered protein kinases, enzymes that regulate cell growth
Richard J. Roberts and Phillip A. Sharp	1993	Great Britain United States	Discovered that a gene can be separated onto different segments of DNA
Kary B. Mullis	1993	United States	Discovered the polymerase chain reaction to amplify (make multiple copies of) DNA
Peter C. Doherty and Rolf M. Zinkernagel	1996	Australia Switzerland	Discovered how cytotoxic T cells recognize virus-infected cells prior to destroying them
Peter Agre and Roderick MacKirron	2003	United States	Discovered water and ion channels in plasma membranes
Aaron Ciechanover, Avram Hershko, and Irwin Rose	2004	Israel Israel United States	Discovered how cells dispose of unwanted proteins in proteasomes
Barry Marshall and J. Robin Warren	2005	Australia	Discovered that *Helicobacter pylori* causes peptic ulcers
Andrew Fire and Craig Mello	2006	United States	Discovered RNA interference (RNAi), or gene silencing, by double-stranded RNA
Harald zur Hausen	2008	Germany	Discovered that human papilloma viruses cause cervical cancer
Françoise Barré-Sinoussi and Luc Montagnier	2008	France	Discovered human immunodeficiency virus (HIV)
Venkatraman Ramakrishnan, Thomas A. Steitz, and Ada E. Yonath	2010	India United States Israel	Detailed study of the structure and function of ribosomes

In the future microbiologists will be:

1. Trying to better understand and control existing, emerging, and reemerging infectious diseases (Covid 19 has proved this)
2. Studying the association between infectious agents and chronic diseases
3. Learning more about host defenses and host-pathogen interactions
4. Developing new uses for microbes in industry, agriculture, and environmental control
5. Still discovering the many microbes that have not yet been identified and cultured
6. Trying to better understand how microbes interact and communicate
7. Analyzing and interpreting the ever-increasing amount of data from genome studies
8. Continuing to use microbes as model systems for answering fundamental questions in biology
9. Assessing and communicating the potential impact of new discoveries and technologies on society

Acknowledgement and Suggested Readings:

1. Microbiology, An Introduction; Tortora, Funke and Case; Pearson Publication
2. Microbiology; Prescott, Harley and Klein; The MacGraw-Hill Companies
3. Microbiology: Principles and Explorations; Jacquelyn G Black; John Wiley and Sons Inc.
4. Brock Biology of Microorganisms; Madigan, Martinko, Stahl and Clark; Benjamin Cummings (Pearson Publication)

Thanks