General Microbiology

(22ZOOC31)

Introduction to Microbial History

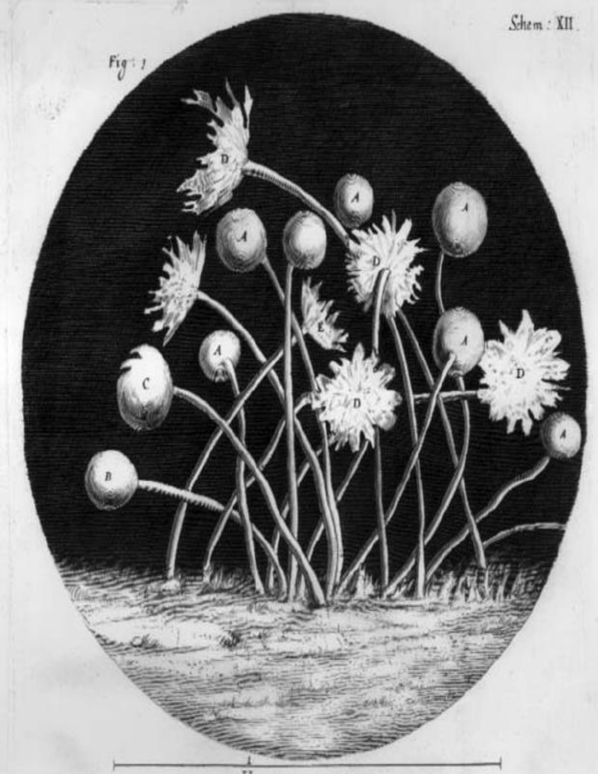
Fundamentals of microbiology

- Microbiology deals with study of microorganisms, like bacteria, archaea, algae, fungi, protozoa, and viruses.
- The field is concerned with the structure, function, and classification of such organisms and with ways of both exploiting and controlling their activities.

Scientist who paved Microbial study

Discovery of Microorganisms

- **Robert Hooke (1635–1703)**
  - First known publish the description of microorganisms.
  - The English mathematician and natural historian -an excellent microscopist.
  - In his book **Micrographia (1665),** Hooke illustrated the first microscopic observations of the **fruiting structures of molds.**
  - He observed organisms as diverse as **insects, sponges, bryozoans, foraminifera, and bird feathers.**
  - Hooke who coined the term **"cells".**


Schem : XII
Fig: 1
A
B
C
D

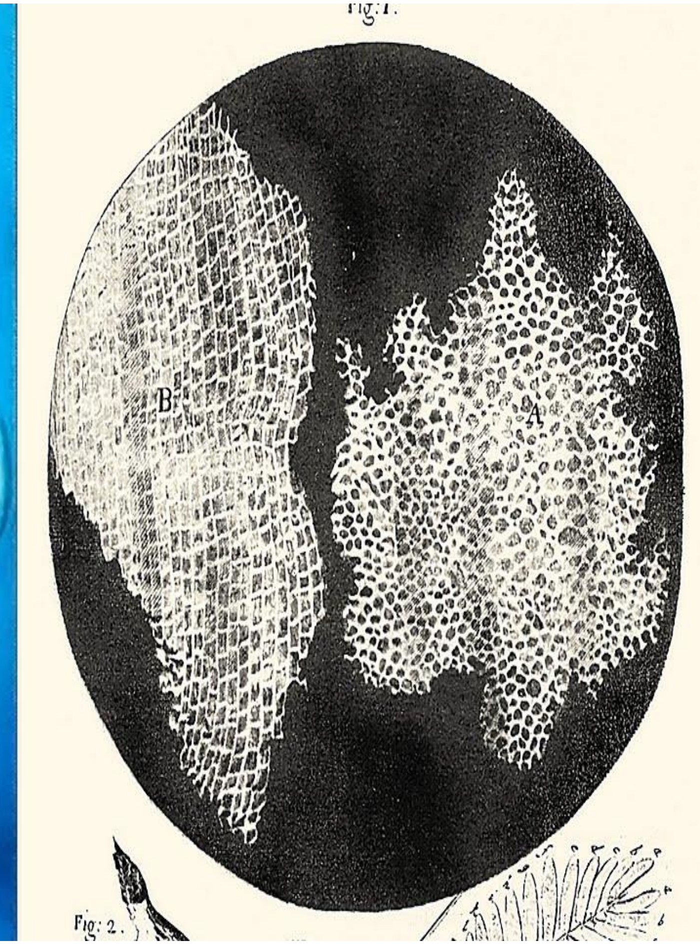
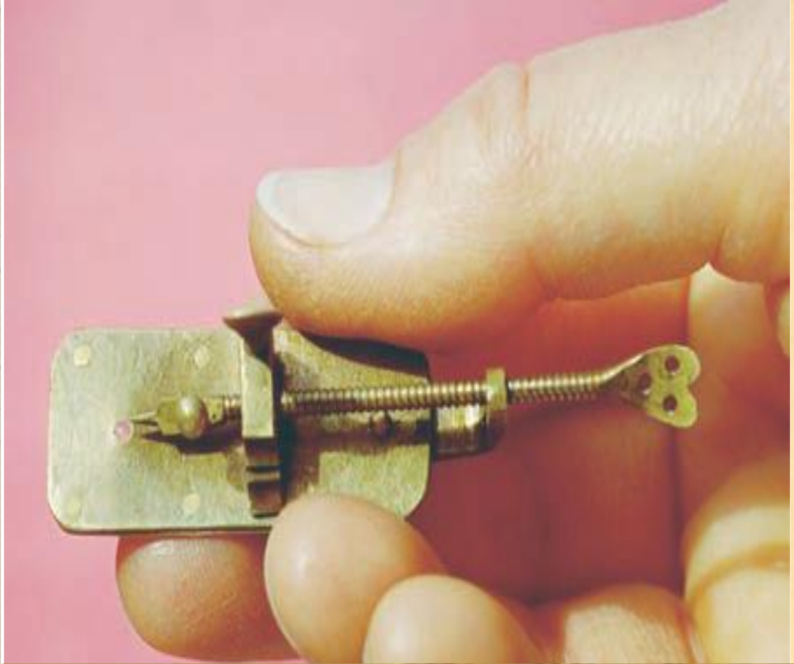
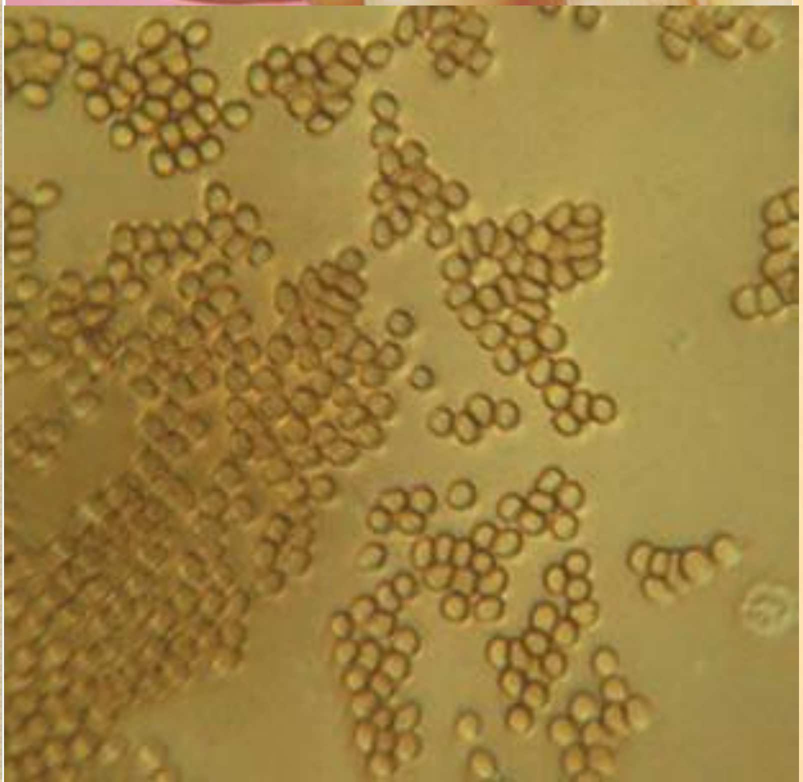


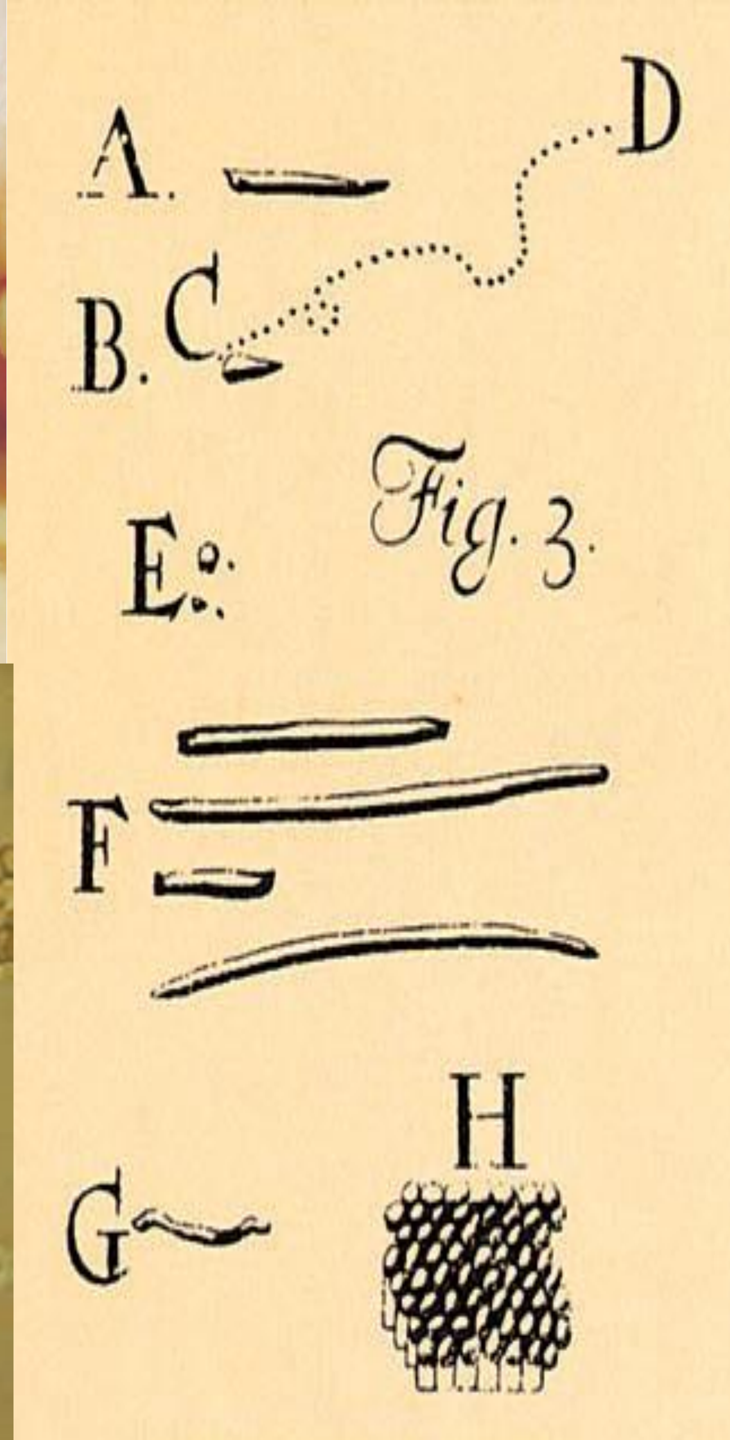
Fig: 1.
B
A
Fig: 2.

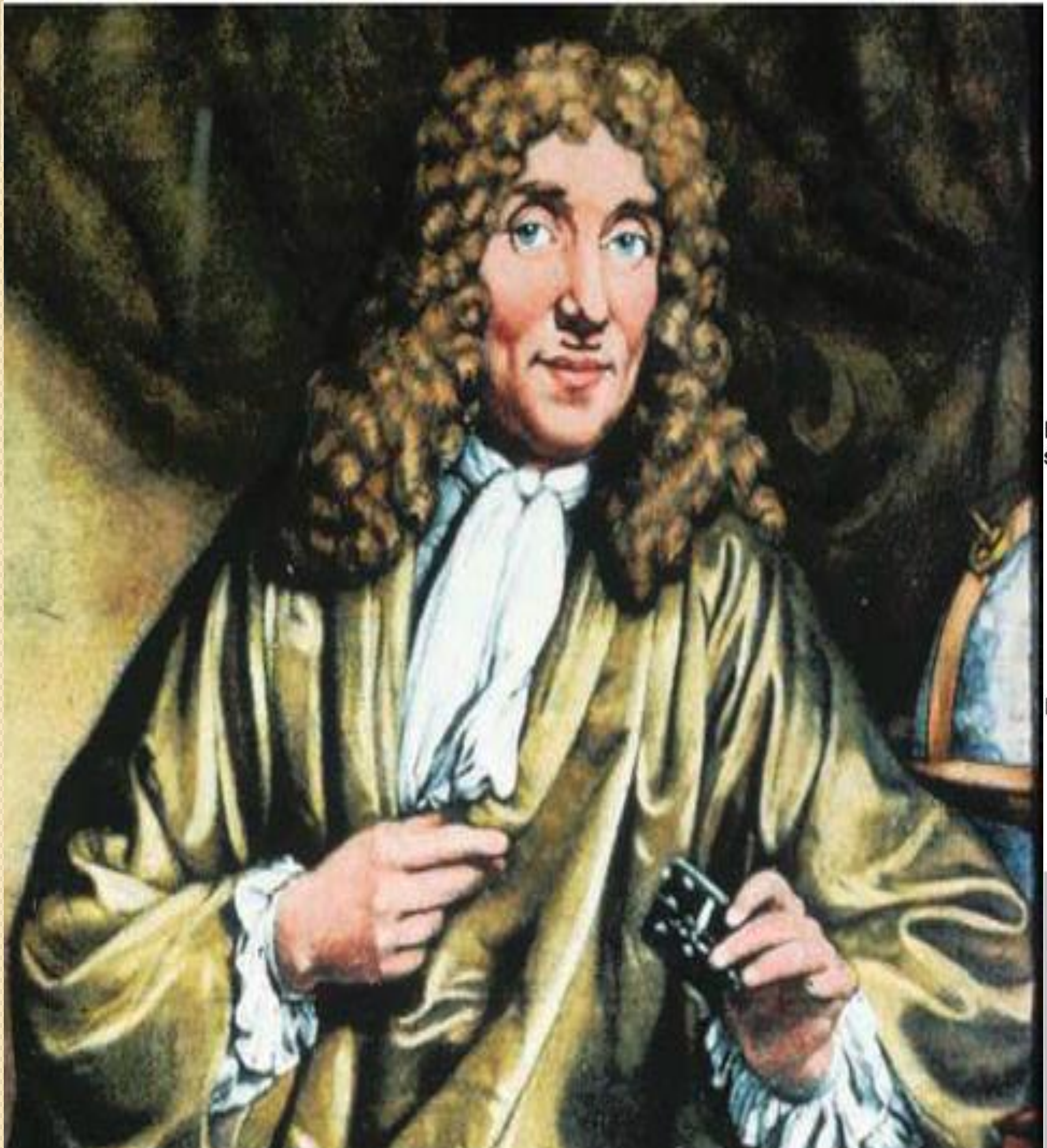
Anton van Leeuwenhoek (1632–1723).

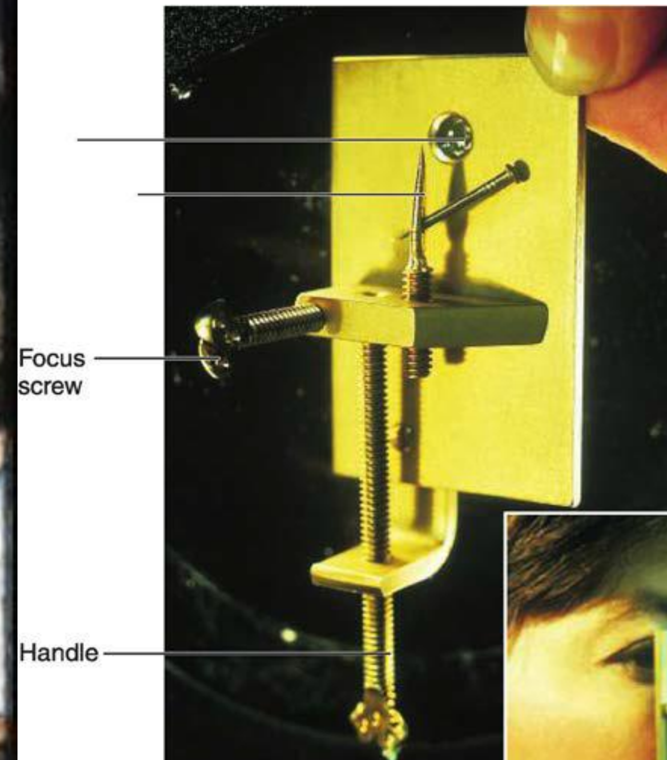
- A draper, the first person to see bacteria.
- Constructed extremely simple microscopes with a single lens to examine microorganisms.
- He discovered bacteria in **1676 -** pepper–water infusions.
- Reported his observations to Royal Society of London later published in 1684.
- van Leeuwenhoek's called it as "wee animalcules"

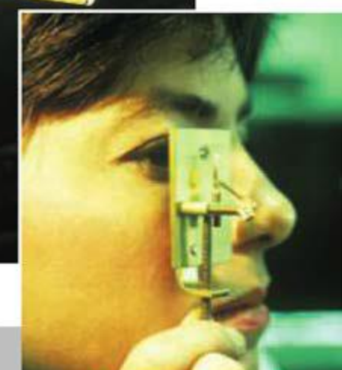





A.
D
B. C
Fig. 3.
E.
F
G
H




Focus screw
Handle



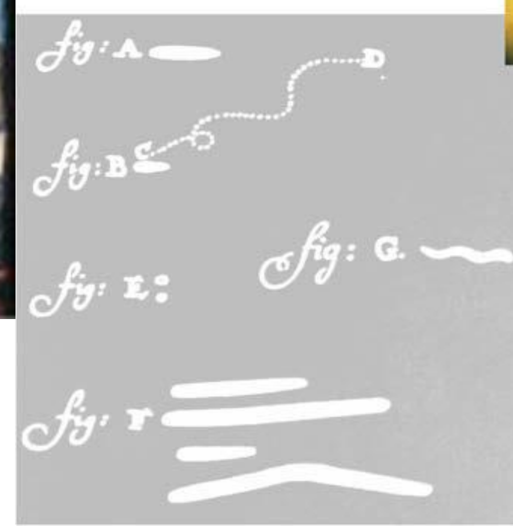


fig: A
D.
fig: B C
fig: G.
fig: E
fig: F

Ferdinand Cohn (1828–1898)

- German–Polish scientist, a botanist.

- Studied unicellular algae and later to bacteria(large sulfur bacterium *Beggiatoa*.
- Cohn interested in heat resistance in bacteria - led to his discovery of *endospores*.
- He described the life cycle of the endospore-forming bacterium *Bacillus* by boiling kills bacteria but not endospores
- Laid to a system of bacterial classification

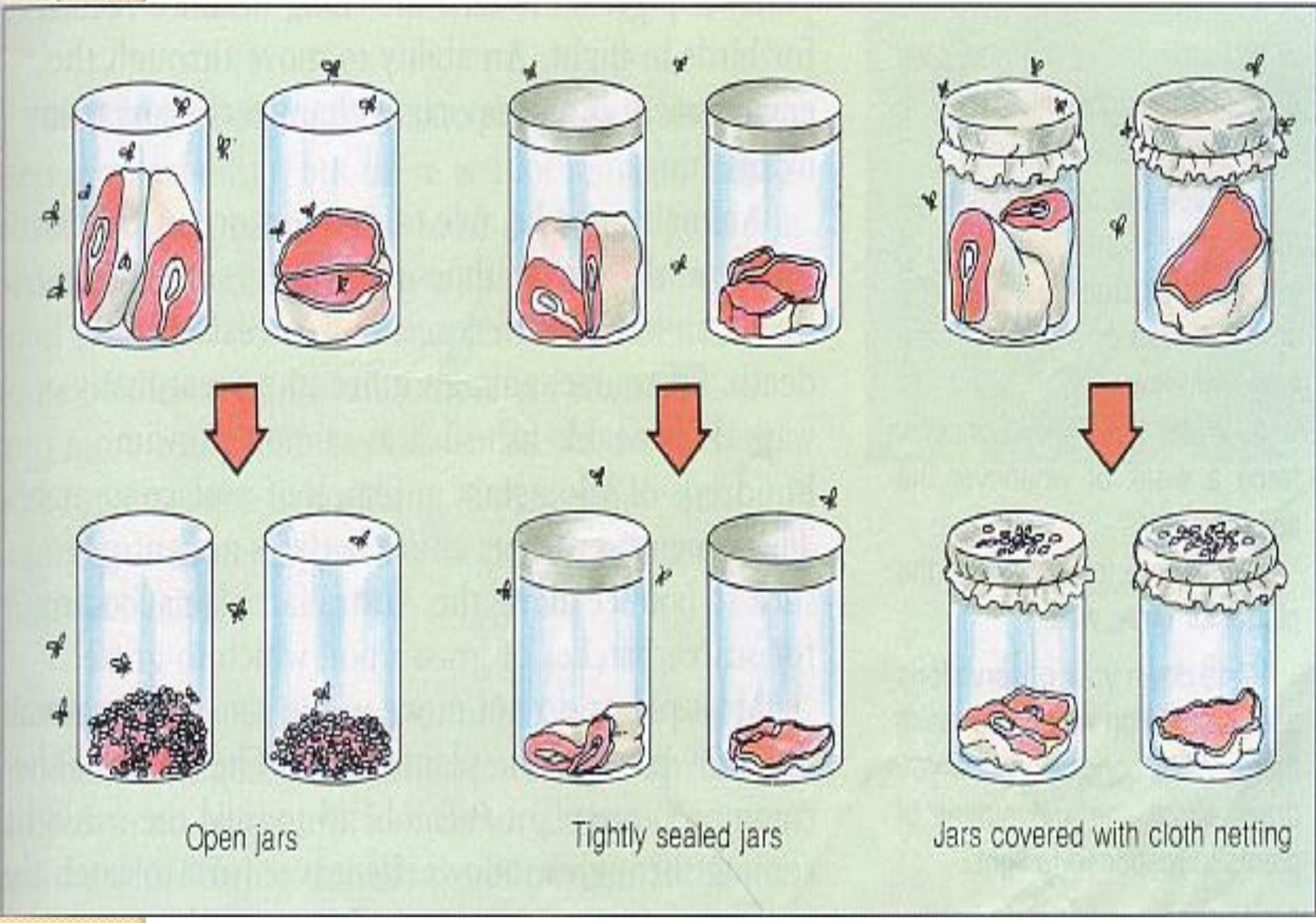
- **Ferdinand Cohn (1828–1898)**
- German−Polish scientist, a botanist.
  - Devised highly effective methods for preventing the contamination of culture media, by the use of cotton for closing flasks and tubes.
  - These methods later adopted by Robert Koch (the first medical microbiologist)
  - allowed him to make rapid progress in the isolation and characterization of several disease-causing bacteria.

Theory of Spontaneous Generation

- Earlier people believed living organisms develop from nonliving matter- spontaneous generation.
- People pointed out that boiled extracts of hay or meat gave rise to microorganisms.
- Later the extracts used to be the culture media in many microbiology laboratories today.

Francesco Redi (1626-1697)

- Carried out a series of experiments on decaying meat and its ability to produce maggots spontaneously.
- Redi placed meat in three containers to challenge spontaneous generation.


Open jars
Tightly sealed jars
Jars covered with cloth netting

John Needham (1713-1781)

Needham boiled mutton broth in flasks that and tightly sealed.

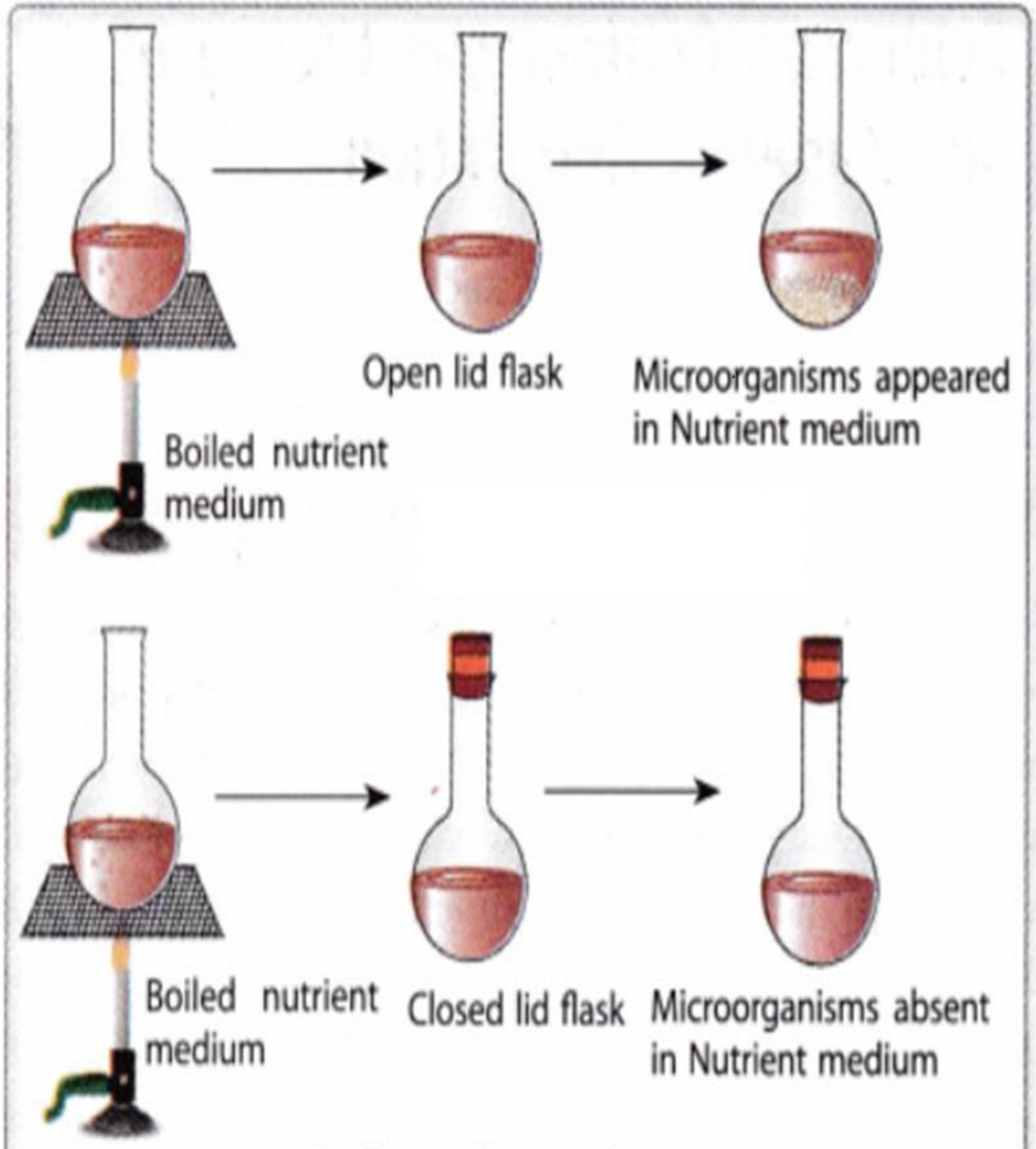
Many of the flasks became cloudy and contained microorganisms.

He thought organic matter contained a vital force that the new microbes must have arisen spontaneously.

But he did not boil the broth enough to kill all pre-existing microbes

Lazzaro Spallanzani (1729-1799)

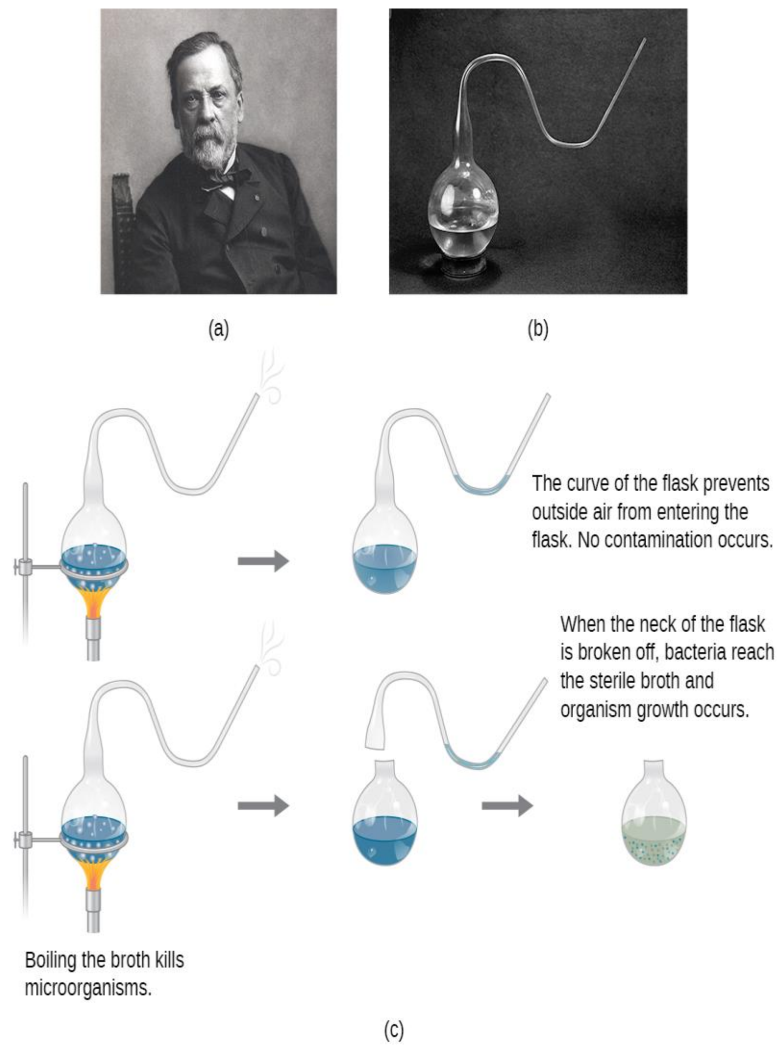
- Spallanzani (1729-1799) improved on Needham's experimental design.
- He first sealed the glass flasks that contained water and seeds.
- If the sealed flasks were placed in boiling water for about 45 minutes, no growth took place.
- If the flasks were subsequently opened to the air the microbes were introduced into these flasks from the air.



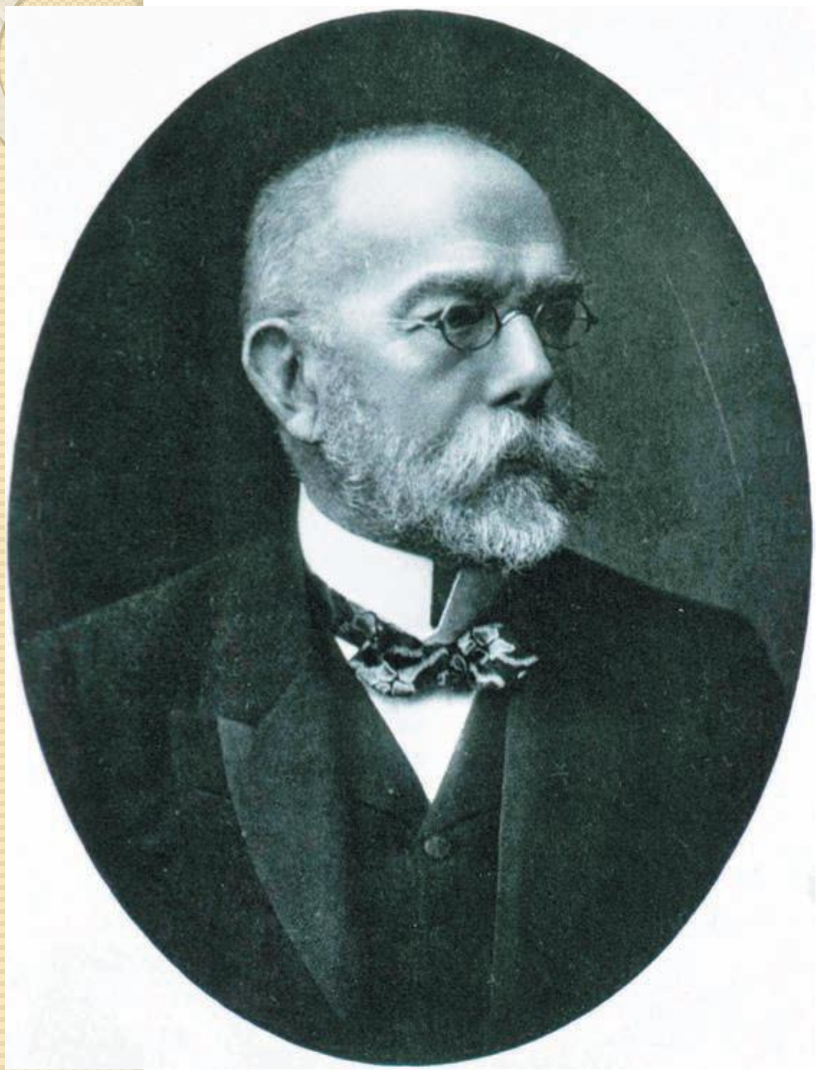
Spallanzani's experiment

Disproving Spontaneous Generation

- **Louis Pasteur (1822-1895)**
  - Pasteur was a chemist.
  - He proposed swan- neck experiment to settle spontaneous generation.



The Germ Theory



- German physician Robert Koch (1843–1910).
- Studied anthrax, caused by an endosporeforming bacterium called *Bacillus anthracis*.
- Discovery of the causative agent of tuberculosis (1881).

Postulates:	Laboratory tools:
1. The suspected pathogen must be present in *all* cases of the disease and absent from healthy animals.	Microscopy, staining
2. The suspected pathogen must be grown in pure culture.	Laboratory cultures
3. Cells from a pure culture of the suspected pathogen must cause disease in a healthy animal.	Experimental animals
4. The suspected pathogen must be reisolated and shown to be the same as the original.	Laboratory reisolation and culture

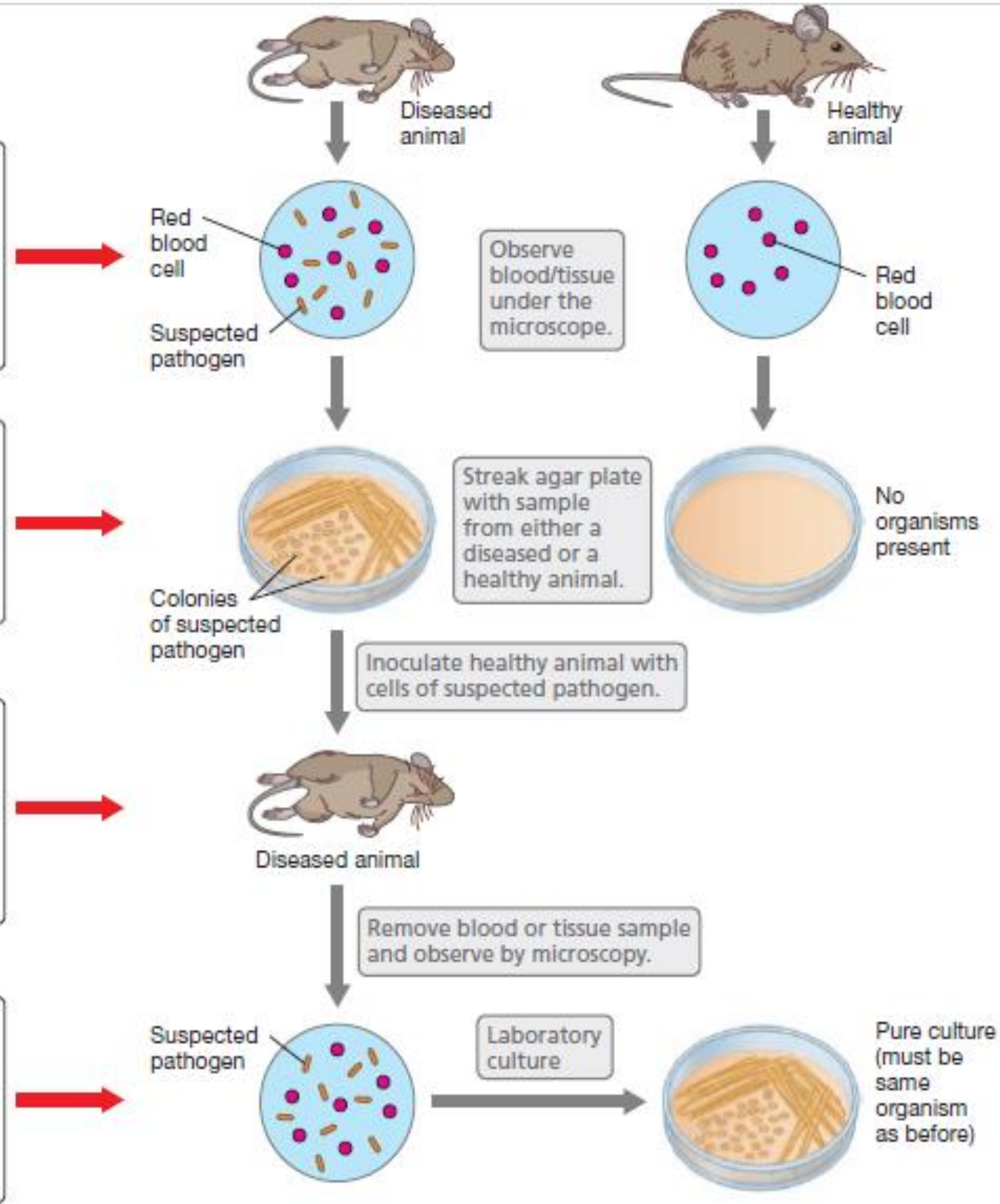


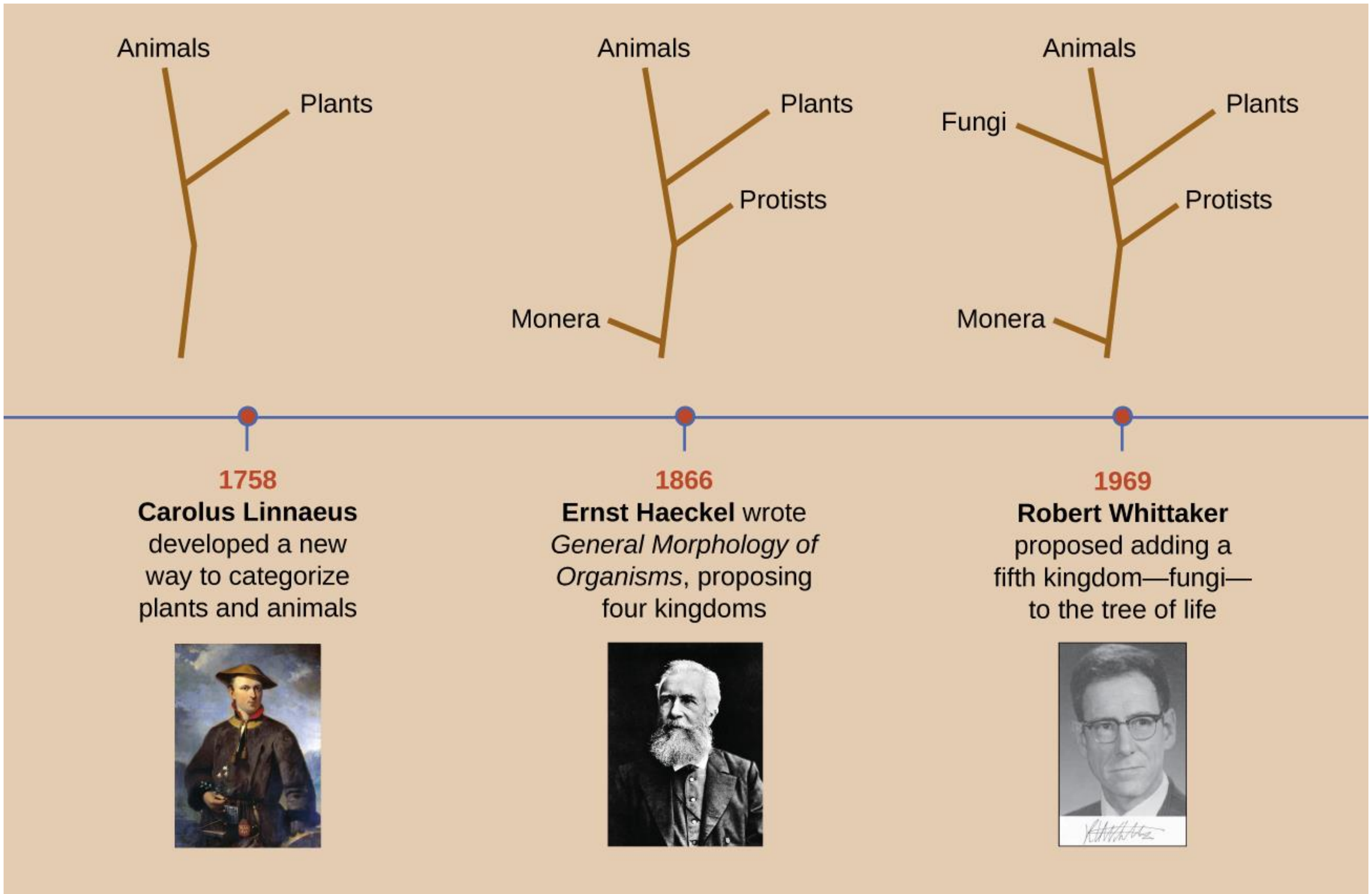
Figure 1.20 Koch's postulates for proving cause and effect in infectious diseases. Note that following isolation of a pure culture of the suspected pathogen, the cultured organism must both initiate the disease and be recovered from the diseased animal. Establishing the correct conditions for growing the pathogen is essential; otherwise it will be missed.

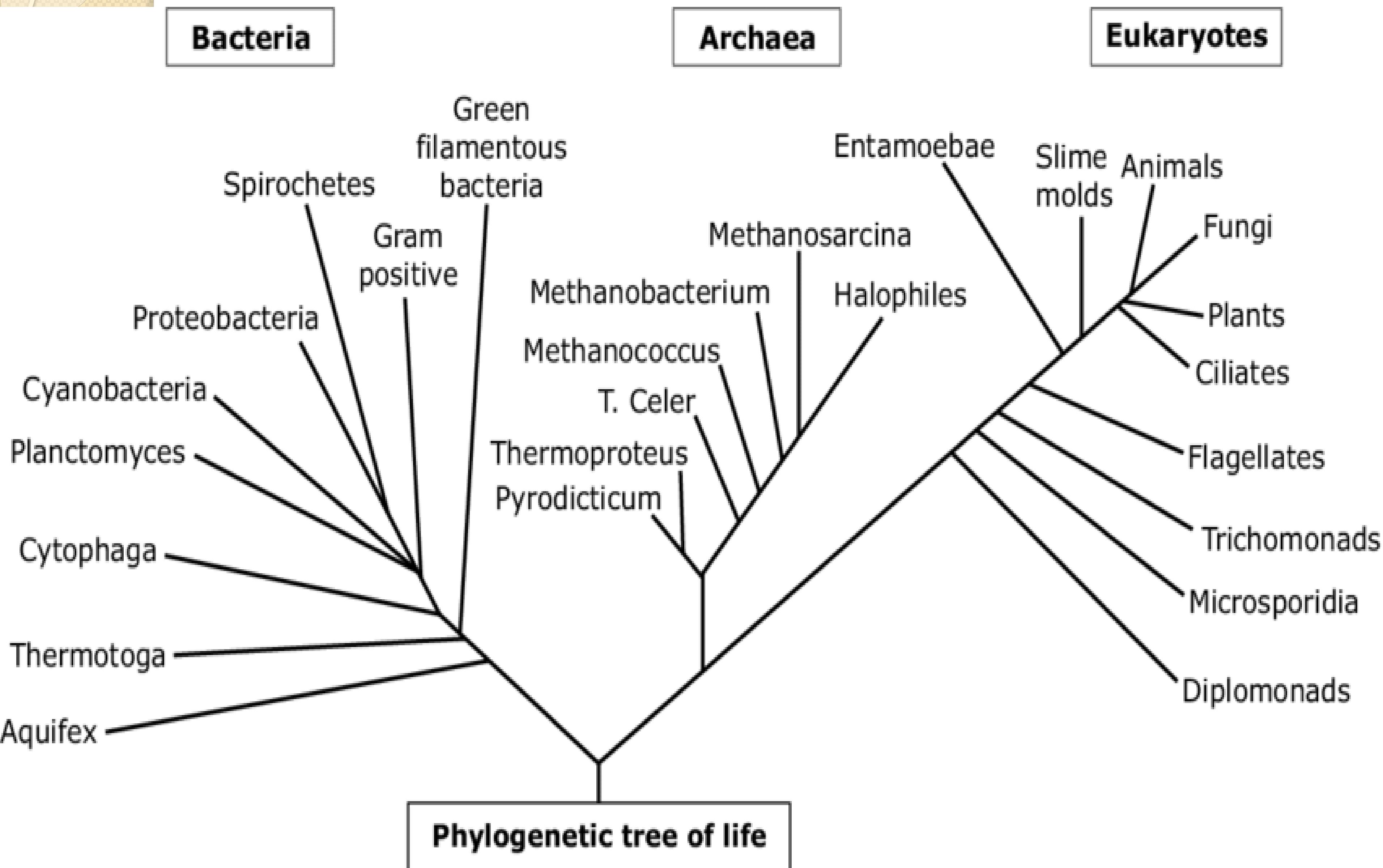
General Microbiology

22ZOOC31

Classification of Microbes
and
Microbial Structures

Classification of microorganism





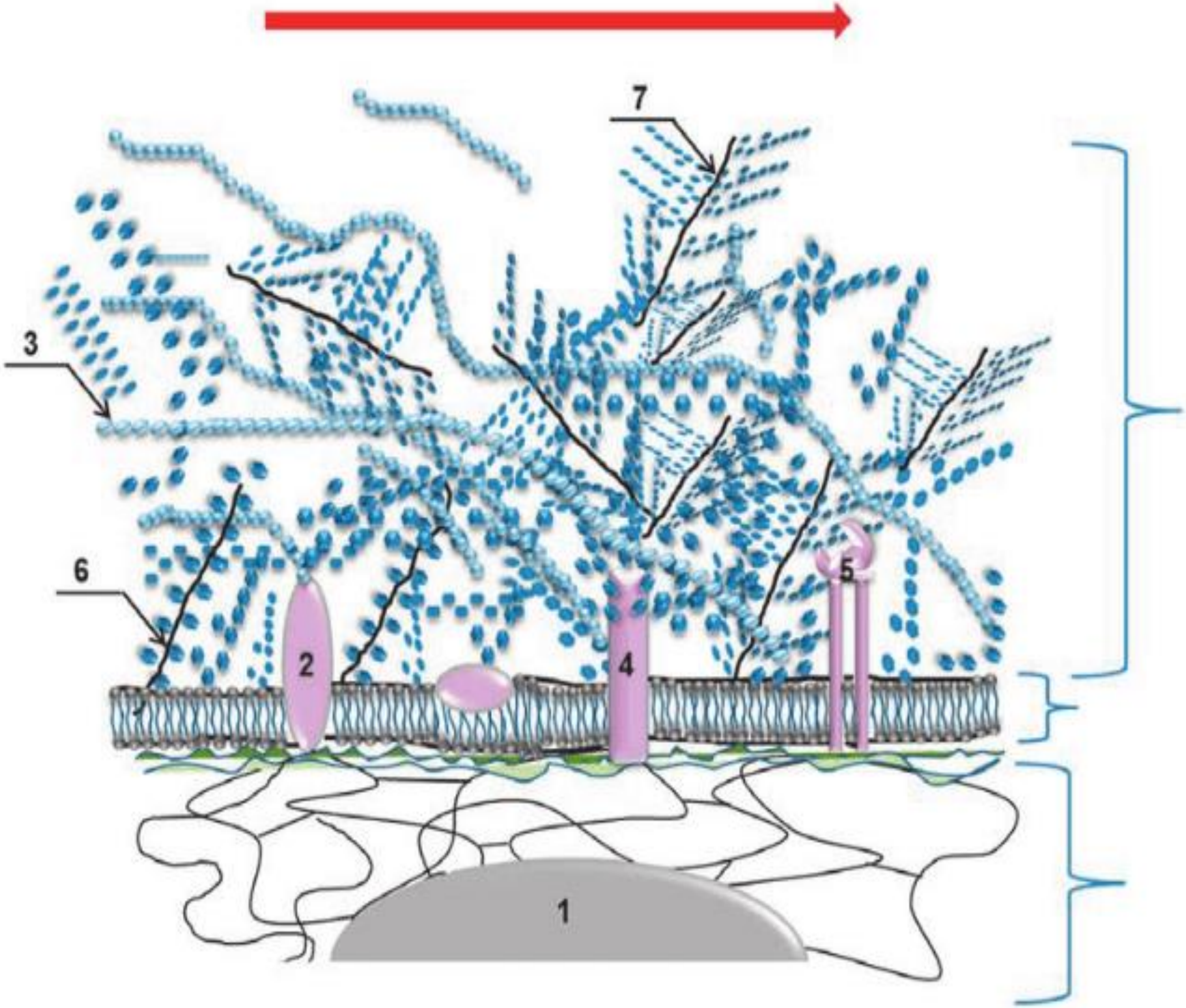
Bacteria
Archaea
Eukaryotes
Green filamentous bacteria
Spirochetes
Gram positive
Proteobacteria
Cyanobacteria
Planctomyces
Cytophaga
Thermotoga
Aquifex
Methanosarcina
Methanobacterium
Halophiles
Methanococcus
T. Celer
Thermoproteus
Pyrodicticum
Entamoebae
Slime molds
Animals
Fungi
Plants
Ciliates
Flagellates
Trichomonads
Microsporidia
Diplomonads
Phylogenetic tree of life

Carl Woese's Classification

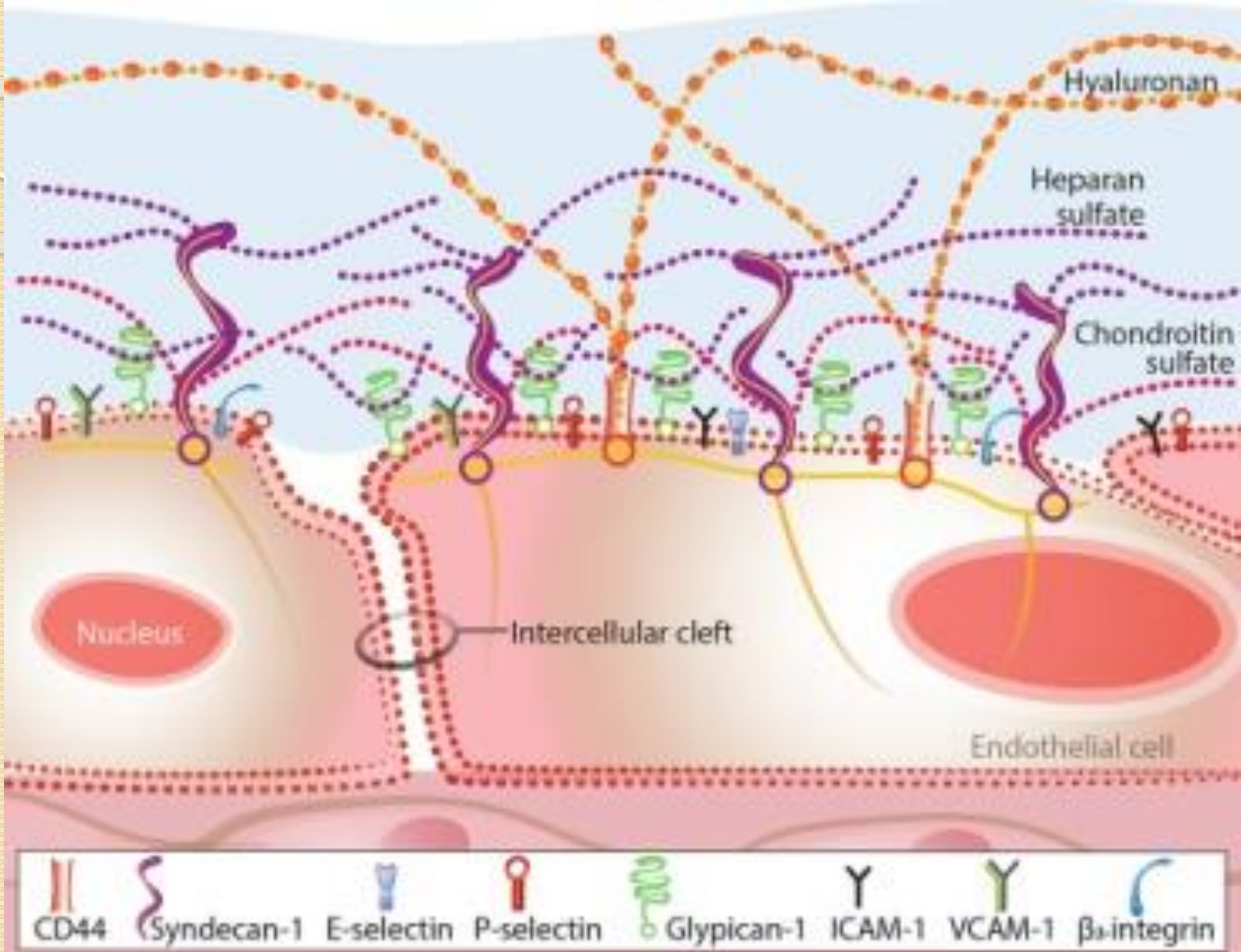
- The three-domain system was first introduced by **Carl Woese in 1990** called Carl Woese's Classification.
- This classification system also is known as the **Six Kingdoms and Three Domains Classification.**
- It divides the life forms into **three domains** and **six kingdoms**.
- The three-domains of **Carl Woese's Classification system** include **Archaea, Bacteria, Eukaryote,** and six kingdoms are **Archaebacteria (ancient bacteria), Eubacteria (true bacteria), Protista, Fungi, Plantae, Animalia.**

Microbial Structures

- Bacteria contains Capsule, Slime, S- Layer, Pili, Endospores, Cell wall
- Capsule or slime layer is used to describe glycocalyx ,
- The glycocalyx also known as the pericellular matrix and sometime cell coat.
- The capsule is considered a virulence factor - it enhances the ability of bacteria to cause disease.
- Capsule is found most commonly among Gram-negative bacteria
- for example:
  - *Escherichia coli*, *Neisseria meningitidis*, *Klebsiella pneumoniae*, *Haemophilus influenza*, and *Pseudomonas aeruginosa*



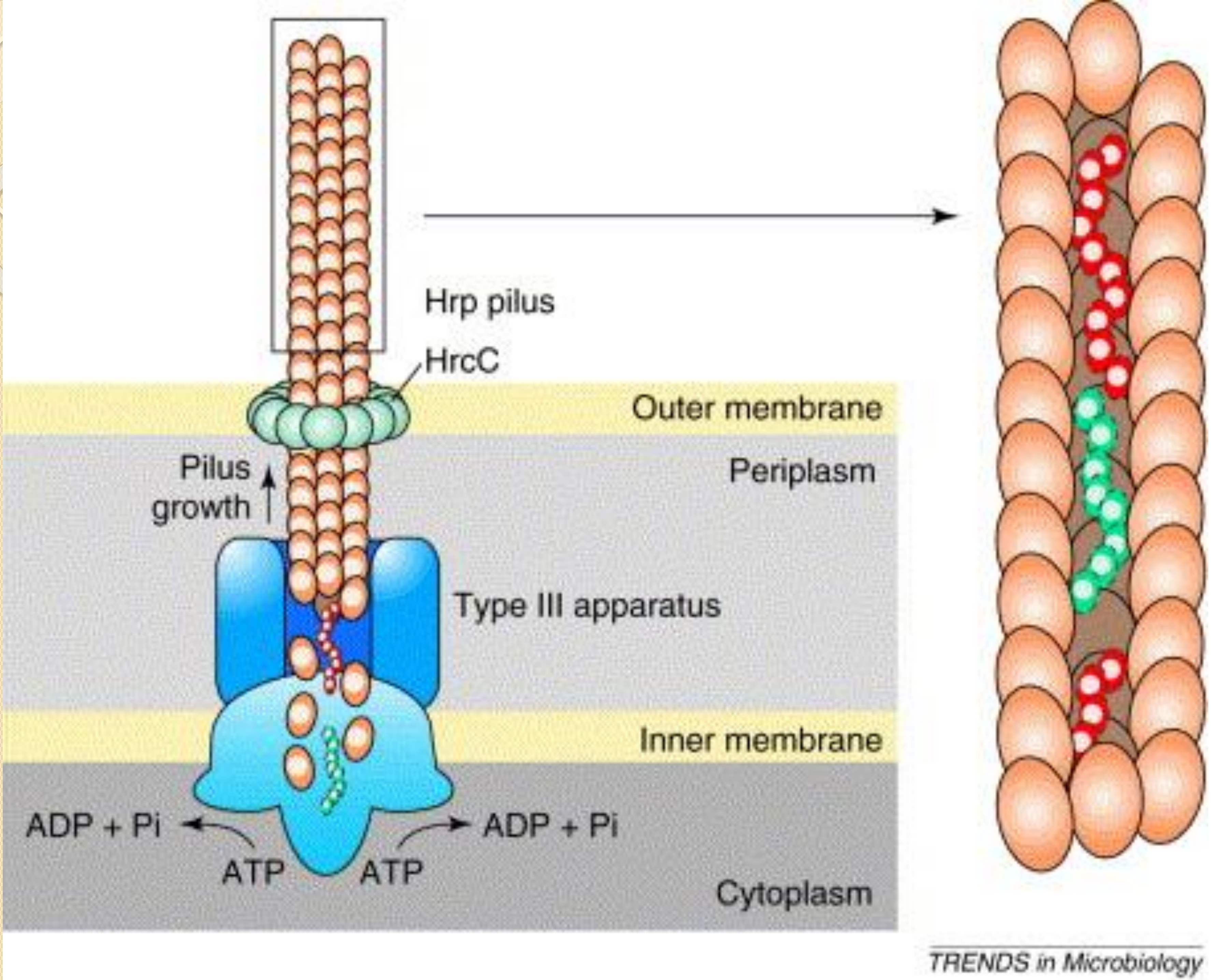
Composition and structure of endothelial glycocalyx* 1 -nucleus; 2 -hyaladherin; 3 -hyaluronic acid (HA); 4 -glycoprotein; 5 -integrin; 6 -syndecan; 7 -small soluble proteoglycan. *Glycocalyx is the external cell envelope associated with the plasma membrane that presents a polysaccharide gel. Glycocalyx executes receptor and protective functions, as well as the function of external signal transducer in circulating cells and cells in contact with biological fluids. Glycocalyx shedding leads to changes of cells receptors.

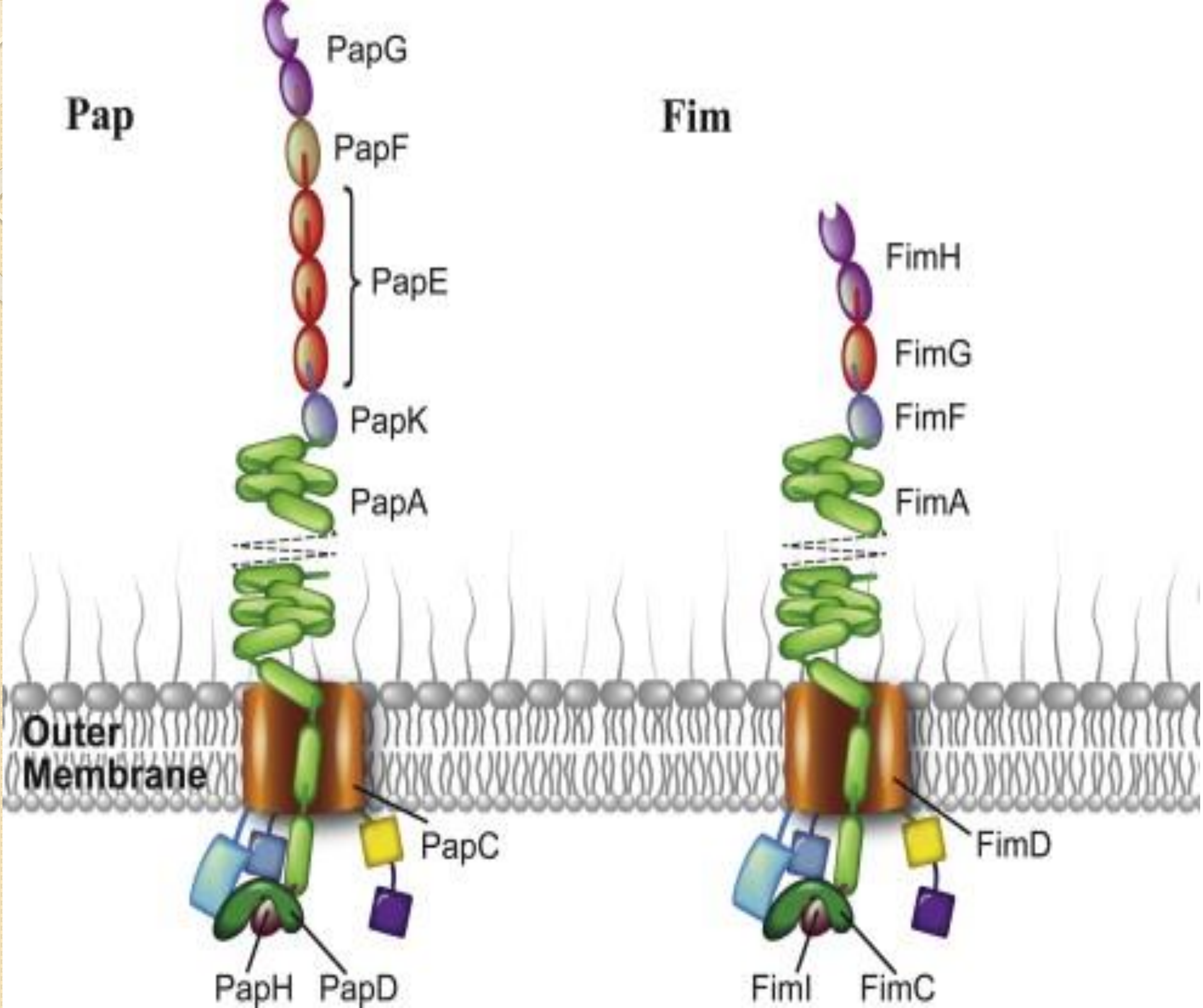


Hyaluronan
Heparan sulfate
Chondroitin sulfate
Nucleus
Intercellular cleft
Endothelial cell
CD44
Syndecan-1
E-selectin
P-selectin
Glypican-1
ICAM-1
VCAM-1
β₃ integrin

Pili or Fimbriae

- In Gram-negative bacteria, pili can be categorized into four groups depending on their assembly pathways.
- These groups are
  - chaperone-usher pathway pili,
  - type IV pili,
  - curli pili and
  - the CS1 pilus family.
- The pili of Gram-positive bacteria are fall into one of two groups: short, thin rods and longer, flexible pili.


Hrp pilus
HrcC
Outer membrane
Periplasm
Pilus growth
Type III apparatus
Inner membrane
ADP + Pi
ADP + Pi
ATP
ATP
Cytoplasm
TRENDS in Microbiology

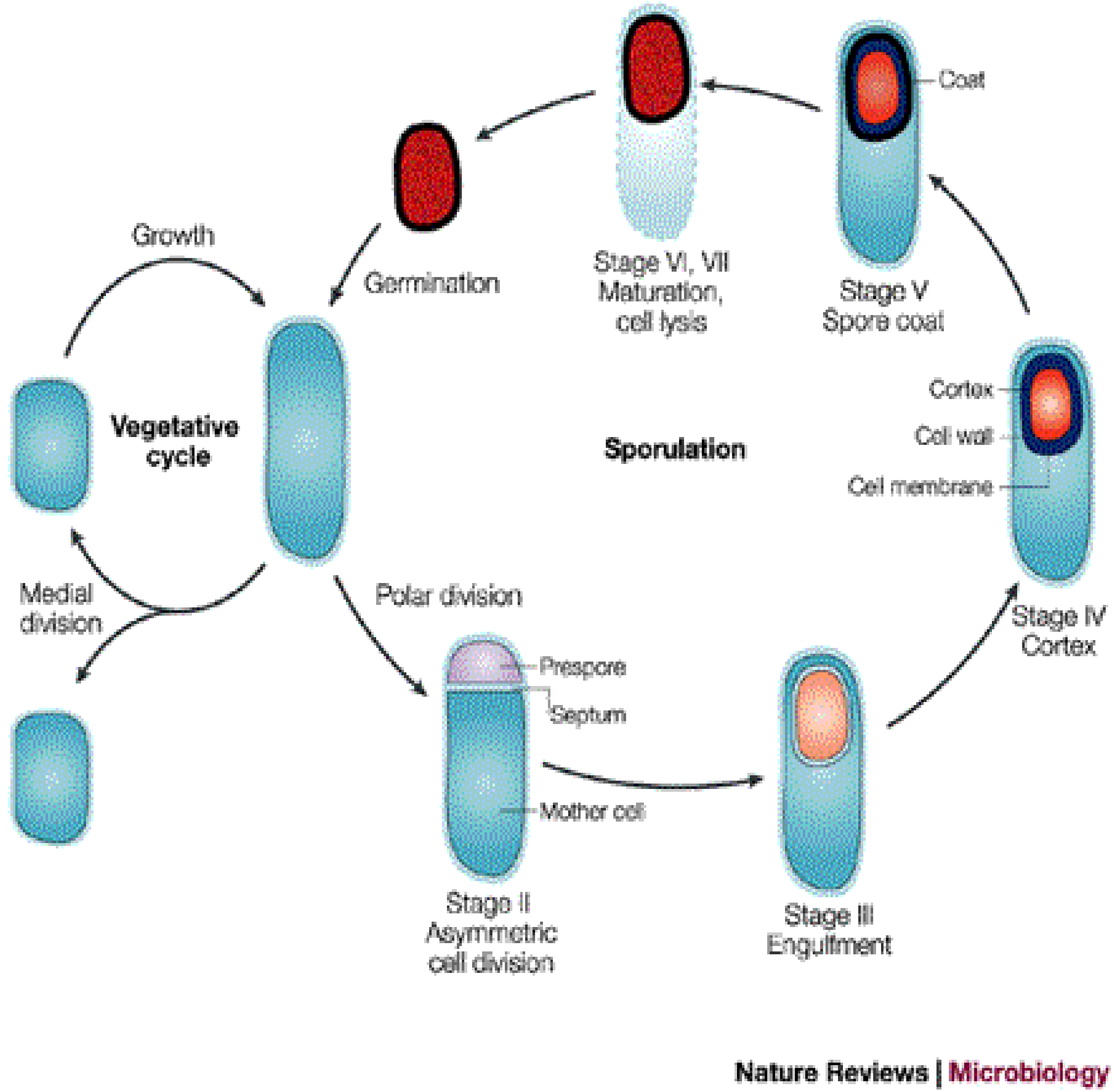


Pap
Fim
PapG
PapF
PapE
PapK
PapA
FimH
FimG
FimF
FimA
Outer
Membrane
PapC
FimD
PapH
PapD
FimI
FimC

Endospore

- A number of gram-positive bacteria can form a special resistant, dormant structure called an **endospore.**
- Endospores develop
- within vegetative bacterial cells of several genera: *Bacillus and*
- *Clostridium (rods), Sporosarcina (cocci), and others.*
- These structures are extraordinarily resistant to environmental stresses such as heat, ultraviolet radiation, gamma radiation, chemical disinfectants,
- and desiccation.
- Some endospores have remained viable for around 100,000 years.

- Endospore formation, also called **sporogenesis or sporulation,** normally commences when growth ceases due to lack of nutrients.
- Endospore heat resistance probably is due to several factors:
  - calcium-dipicolinate and acid-soluble protein stabilization of DNA
  - protoplast dehydration
  - the spore coat
  - DNA repair enzymes


Growth
Germination
Stage VI, VII
Maturation,
cell lysis
Stage V
Spore coat
Coat
Vegetative
cycle
Sporulation
Cortex
Cell wall
Cell membrane
Medial
division
Polar division
Stage IV
Cortex
Prespore
Septum
Mother cell
Stage II
Asymmetric
cell division
Stage III
Engulfment
Nature Reviews | Microbiology

General Microbiology (22ZOOC31)

Microbial Interactions

Microbial interaction

- Biological interactions are the effects that the organisms in a community with one another.
- There are completely different kinds of microbial interactions which incorporates with different microbes,
- Plant-Germ interactions promoting plant growth, interaction with animals, interaction with humans, and interaction with water, etc.
- Microbial interactions are ubiquitous, diverse, critically important in the function of any biological community, and are crucial in global biogeochemistry.
- The most common cooperative interactions seen in microbial systems

- The term symbiosis ("together- life"), elaborates various interactions between microorganisms and also between higher organisms

- Its occurrence of these interactions is natural, it may cause disease.
- In various ways, microorganisms forms association with other higher organisms.
- Some are ectosymbiont; one organism can be found on the surface of the other organisms.
- Some are endosymbiont; one organism can be found within the other organisms.
- Usually, simple microbial interactions include a symbiont and a host.
- There is a number of hosts that have more than one symbiont, known as a consortium. e.g., Thiothrix spp, a sulfur bacteria, located on the mayfly larva's outer surface which contains a parasitic bacterium. These physical associations are either transient or permanent.
- In transient associations, pathogen-causing human diseases which include listeriosis, malaria, and leptospirosis are involved.
- In permanent associations, both the host and the symbiont are coevolved, and the symbiont benefits the host.

Positive Interaction	Negative Interaction
Mutualism	Predation
Syntrophism	Parasitism
Commensalism	Competition
Proto-cooperation	Ammensalism

Microbial Interaction

1. Mutualism

- It is defined as the relationship in which each organism in interaction gets benefits
- from the association.
- It is an obligatory relationship in which mutualist and host are metabolically
- dependent on each other.
- A mutualistic relationship is very specific where one member of the association
- cannot be replaced by another species.
- Mutualism requires close physical contact between interacting organisms.
- The relationship of mutualism allows organisms to exist in a habitat that could not be occupied by either species alone.
- The mutualistic relationship between organisms allows them to act as a single organism.

Examples of mutualism:

- Lichens: Lichens are an excellent example of mutualism.

They are the association of specific fungi and certain genus of algae. In lichen, the fungal partner is called mycobiont and algal partner is called phycobiont is a

2. Syntrophism

- It is an association in which the growth of one organism either depends on or improved by the substrate provided by another organism.
- In syntrophism, both organisms in association get to benefit from each other.
- Compound A Utilized by population 1
- Compound B Utilized by population 2
- Compound C utilized by both Population 1+2 Products.
- In this theoretical example of syntrophism, population 1 is able to utilize and metabolize compound A, forming compound B but cannot metabolize beyond compound B without co-operation of population

2. Population 2is unable to utilize compound A but it can metabolize compound B forming compound C.

3. Protocooperation

- It is a relationship in which an organism in an association is mutually benefited with each other.
- This interaction is similar to mutualism but the relationships between the organisms in protocooperation are not obligatory as in mutualism.
- Examples of Protocooperation:
- a. Association of Desulfovibrio and Chromatium: It is a protocooperation between the carbon cycle and the sulfur cycle.
- b. Interaction between N2-fixing bacteria and cellulolytic bacteria

4. Commensalism

It is a relationship in which one organism (commensal) in the association is benefited while another organism (host) of the association is neither benefited nor harmed.

It is a unidirectional association and if the commensal is separated from the host, it can survive.

Examples of commensalism:

a. Non-pathogenic E. coli in the intestinal tract of humans: E. coli is a facultative anaerobe that uses oxygen and lowers the O2 concentration in the gut which creates a suitable environment for obligate anaerobes such as Bacteroides. E. coli is a host which remains unaffected by Bacteroides.

b. b. Flavobacterium (host) and Legionella pneumophila (commensal): Flavobacterium excretes cystine which is used by Legionella pneumophila and survives in the aquatic habitat

5. Amensalism (antagonism)

- When one microbial population produces substances that are inhibitory to other microbial population then this interpopulation relationship is known as Ammensalism or Antagonism.
- It is a negative relationship. The first population which produces inhibitory substances are unaffected or may gain competition and survive in the habitat while other populations get inhibited. This chemical inhibition is known as antibiosis. Examples of the antagonism (amensalism):
- a. Lactic acid produced by lactic acid bacteria in the vaginal tract: Lactic acid produced by many normal floras in the vaginal tract is inhibitory to many pathogenic organisms such as Candida albicans.
- b. Skin normal flora: Fatty acid produced by skin flora inhibits many pathogenic bacteria in the skin
- c. Thiobacillus thiooxidant: Thiobacillus thioxidant produces sulfuric acid by oxidation of sulfur

6. Competition

- The competition represents a negative relationship between two microbial populations in which both the population are adversely affected with respect to their survival and growth.
- Competition occurs when both populations use the same resources such as the same space or same nutrition, so, the microbial population achieves lower maximum density or growth rate. Microbial population competes for any growth-limiting resources such as carbon source, nitrogen source, phosphorus, vitamins, growth factors etc.
- Competition inhibits both populations from occupying exactly the same ecological niche because one will win the competition and the other one is eliminated.
- **Examples of competition**: a. Competition between Paramecium caudatum and Paramecium aurelia: Both species of Paramecium feeds on the same bacteria population when these protozoa are placed together. P. aurelia grow at a better rate than P. caudatum due to competition.

7. Parasitism

It is a relationship in which one population (parasite) get benefited and derive its nutrition from other population (host) in the association which is harmed. The host-parasite relationship is characterized by a relatively long period of contact which may be physical or metabolic.

- Some parasite lives outside the host cell, known as ectoparasite while other parasite lives inside the host cell, known as endoparasite.
- **Examples of parasitism:** a. Viruses: Viruses are an obligate intracellular parasite that exhibits great host specificity. There are many viruses that are parasite to bacteria (bacteriophage), fungi, algae, protozoa etc. b. Bdellovibrio: Bdellavibrio is ectoparasite to many gram-negative bacteria.

8. Predation

It is a widespread phenomenon when one organism (predator) engulf or attack other organisms (prey).

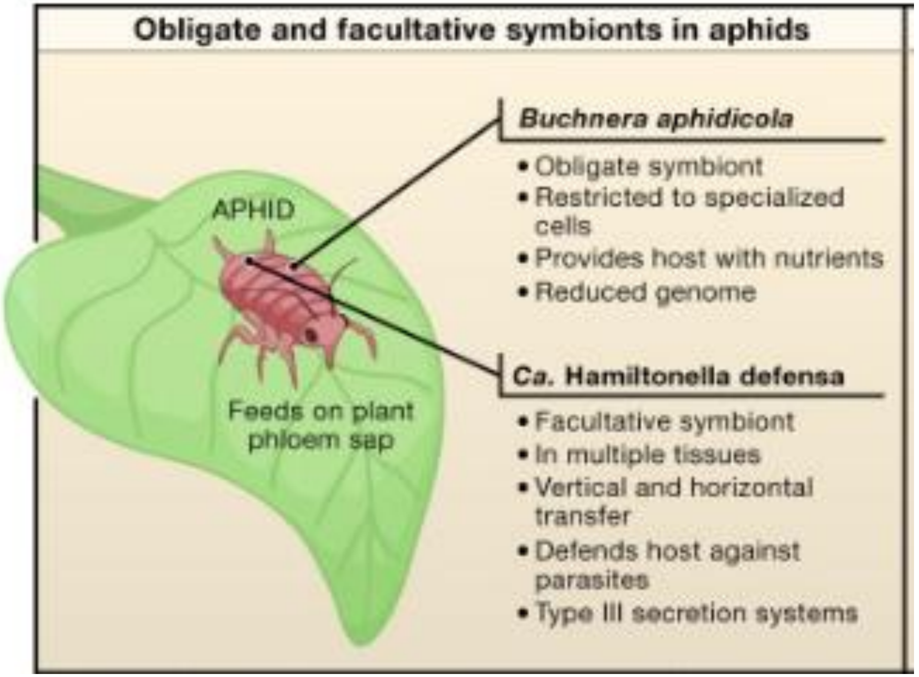
The prey can be larger or smaller than the predator and this normally results in the death of the prey.

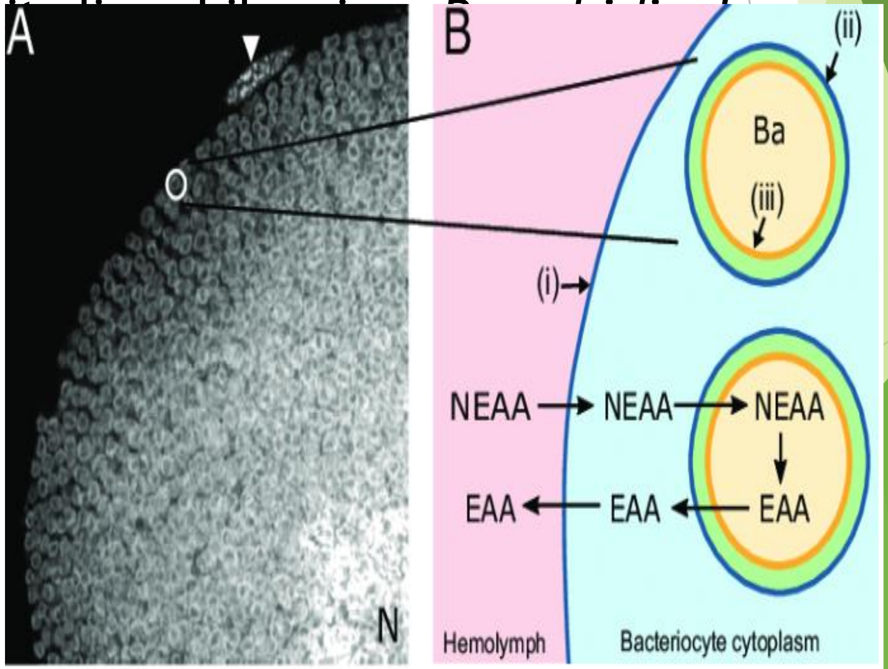
Normally predator-prey interaction is of short duration.

Examples of Predation: a. Protozoan-bacteria in soil: Many protozoans can feed on various bacterial population which helps to maintain the count of soil bacteria at optimum level b. Bdellovibrio, Vamparococcus, Daptobacter, etc are examples of predator bacteria that can feed on a wide range of the bacterial population.

Microorganism-Insect Mutualisms

- The aphid is an excellent example of this mutualistic relationship.
- This insect harbors the -proteobacterium *Buchnera aphidicola* in its cytoplasm, and a mature insect contains literally millions of these bacteria in its body.
- The *Buchnera* provides its host with 10 essential amino acids, and if





(a)

(b)

Figure 30.2 **Mutualism.** Light micrographs of **(a)** a worker termite of the genus *Reticulitermes* eating wood (×10), and **(b)** *Trichonympha*, a multiflagellated protozoan from the termite's gut (×135). Notice the many flagella that occur over most of its length. The ability of *Trichonympha* to break down cellulose allows termites to use wood as a food source.

The protozoan-termite relationship is another classic example of mutualism in which the flagellated protozoa live in the gut of termites and wood roaches

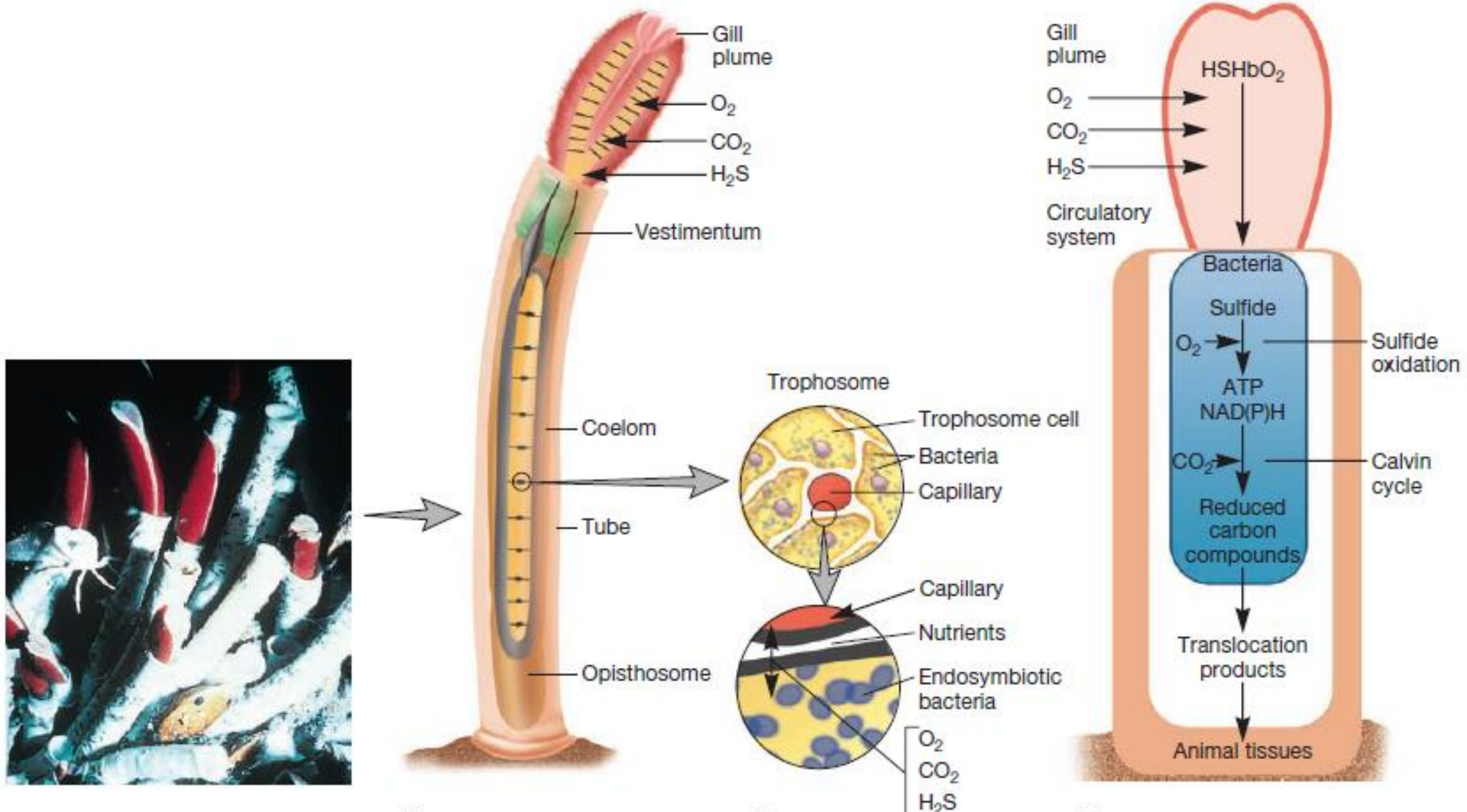


Figure 30.5 The Tube Worm–Bacterial Relationship. **(a)** A community of tube worms (*Riftia pachyptila*) at the Galápagos Rift hydrothermal vent site (depth 2,550 m). Each worm is more than a meter in length and has a 20 cm gill plume. **(b, c)** Schematic illustration of the anatomical and physiological organization of the tube worm. The animal is anchored inside its protective tube by the vestimentum. At its anterior end is a respiratory gill plume. Inside the trunk of the worm is a trophosome consisting primarily of endosymbiotic bacteria, associated cells, and blood vessels. At the posterior end of the animal is the opisthosome, which anchors the worm in its tube. **(d)** Oxygen, carbon dioxide, and hydrogen sulfide are absorbed through the gill plume and transported to the blood cells of the trophosome. Hydrogen sulfide is bound to the worm's hemoglobin ($HSHbO_2$) and carried to the endosymbiont bacteria. The bacteria oxidize the hydrogen sulfide and use some of the released energy to fix CO_2 in the Calvin cycle. Some fraction of the reduced carbon compounds synthesized by the endosymbiont is translocated to the animal's tissues.

Ruminants are the most successful and diverse group of mammals on Earth today.

Examples include cattle, deer, elk, bison, water buffalo, camels, sheep, goats, giraffes, and caribou.

These animals spend vast amounts of time chewing their cud—a small ball of partially digested grasses that the animal has consumed but not yet completely digested.

It is thought that the ruminants evolved an "eat now, digest later" strategy because their grazing can often be interrupted by predator attacks.

These herbivorous animals have stomachs that are divided into four chambers

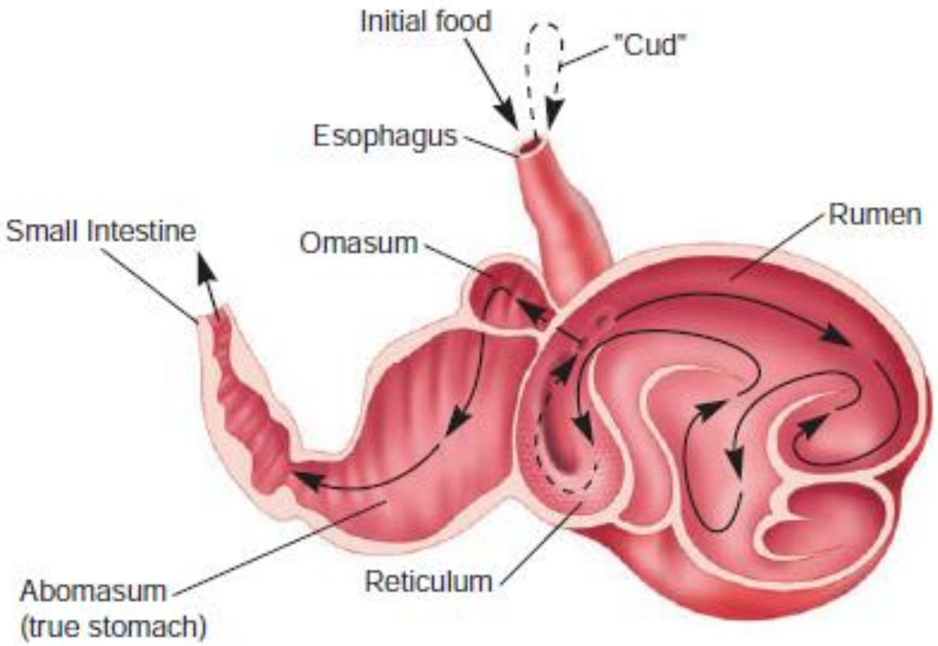


Figure 30.6 Ruminant Stomach. The stomach compartments of a cow. The microorganisms are active mainly in the rumen. Arrows indicate direction of food movement.