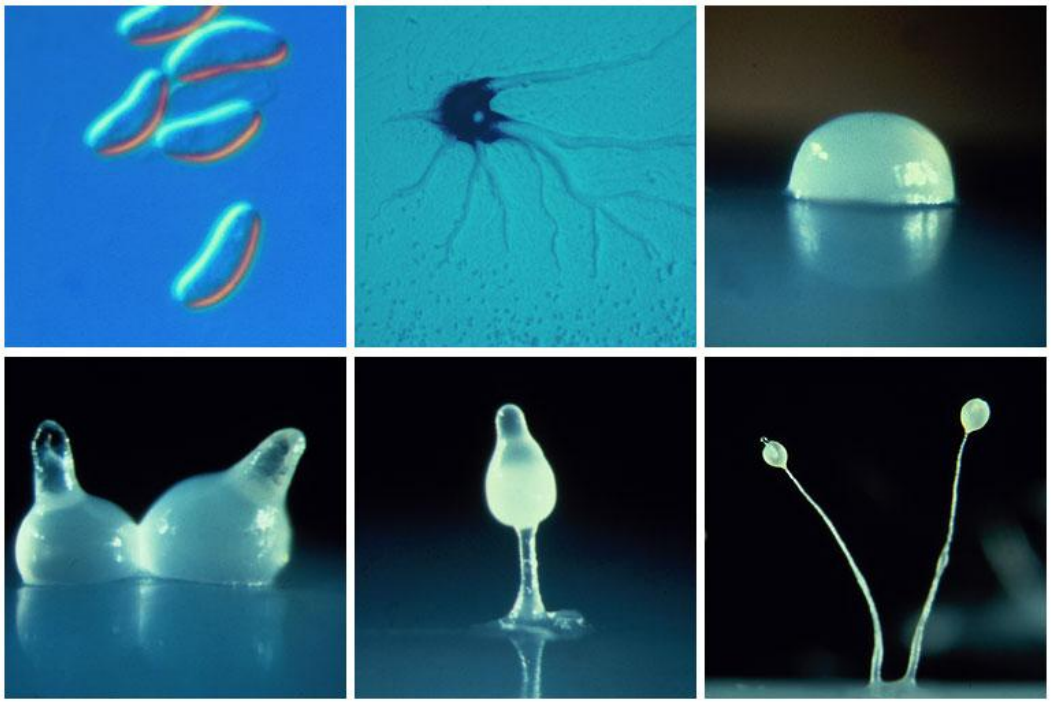
CHAPTER 4

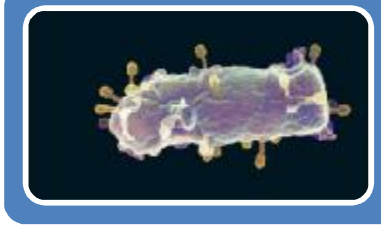
Viruses , Bacteria and Archea



Bui Tan Anh – College of Natural Sciences

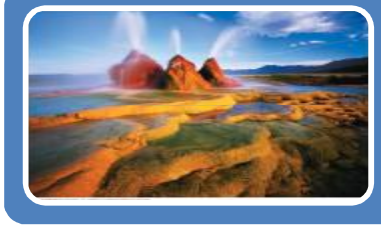
Contents in brief

Introduction to Taxonomy



Viruses

Bacteria



Archaea

Contents in brief

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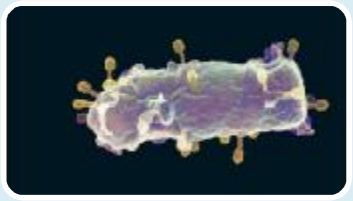


Viruses

Bacteria

Archaea

Overview

- Phylogeny(phát triển chủng loài) is the evolutionary(tiến hóa) history of a species or group of related species.
- The discipline(quy tắc) of systematics(phân loại) classifies organisms and determines their evolutionary relationships.
- Systematists use fossil, molecular, and genetic data to infer evolutionary relationships.
- Taxonomy(sự phân loại) is the ordered division and naming of organisms.

Naming species

- Common names
  - can cause confusion(lẫn lộn).
  - do not accurately reflect the type of organism.
- For example:
  - jellyfish (a cnidarian)
  - crayfish (a small lobster-like crustacean)
  - silverfish (an insect).

Binomial Nomenclature

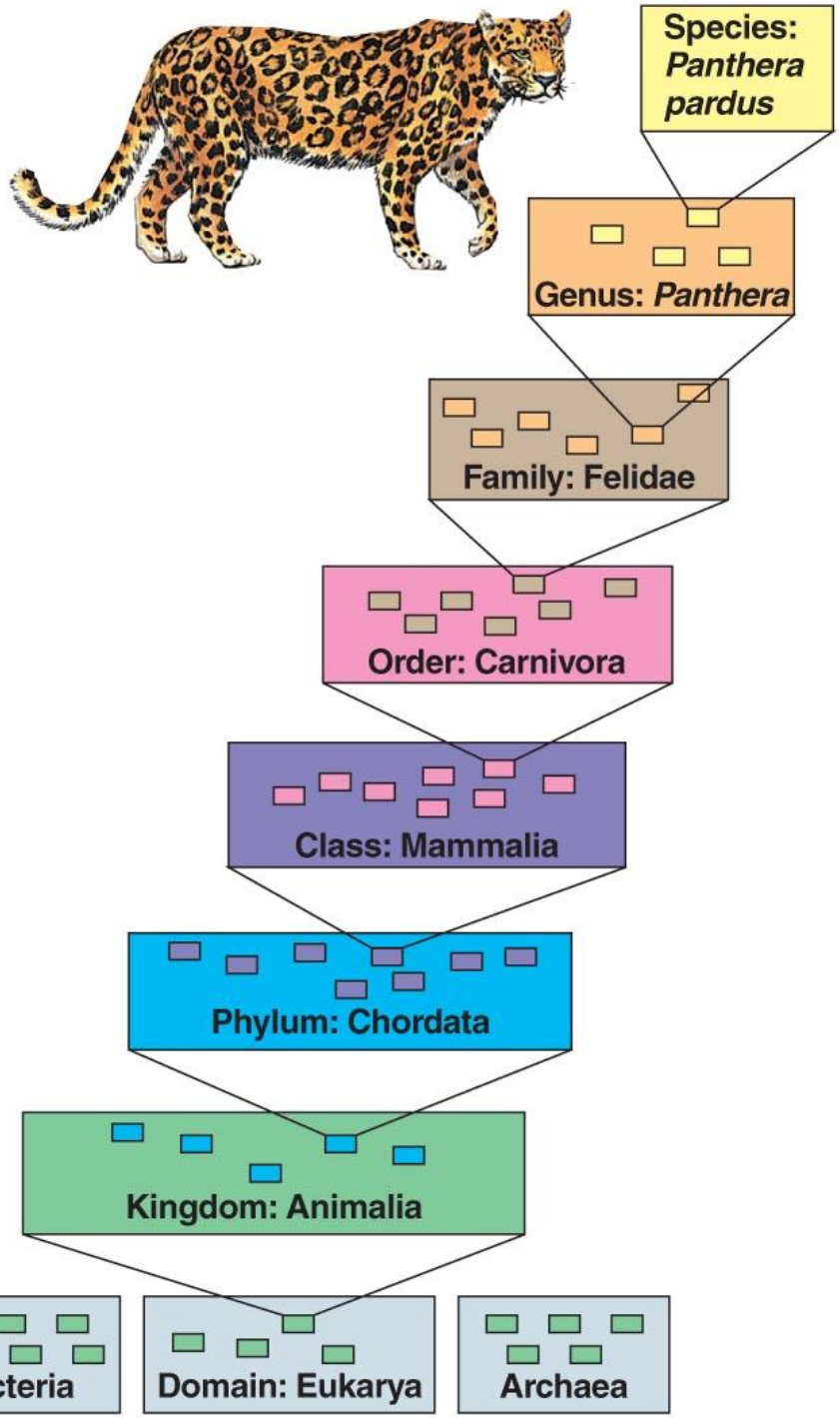
- In the 18th century, Carolus Linnaeus published a system of taxonomy based on resemblances(sự giống nhau).
- Two key features of his system remain useful today:
  - two-part names for species
  - hierarchical classification.

- The two-part scientific name of a species is called a binomial(tên sinh vật có 2 thuật ngữ).
- The first part of the name is the genus(chi)
- The second part refers to one species within the genus.
- The first letter of the genus is capitalized, and the entire species name is italicized.
- Both parts together name the species. Scientific names are "latinized"

Hierarchical Classification

- Linnaeus introduced a system for grouping species in increasingly broad categories.
- The taxonomic groups from broad to narrow are:

  Domain **ð** kingdom **ð** phylum **ð** class **ð** order **ð** family **ð** genus **ð** species

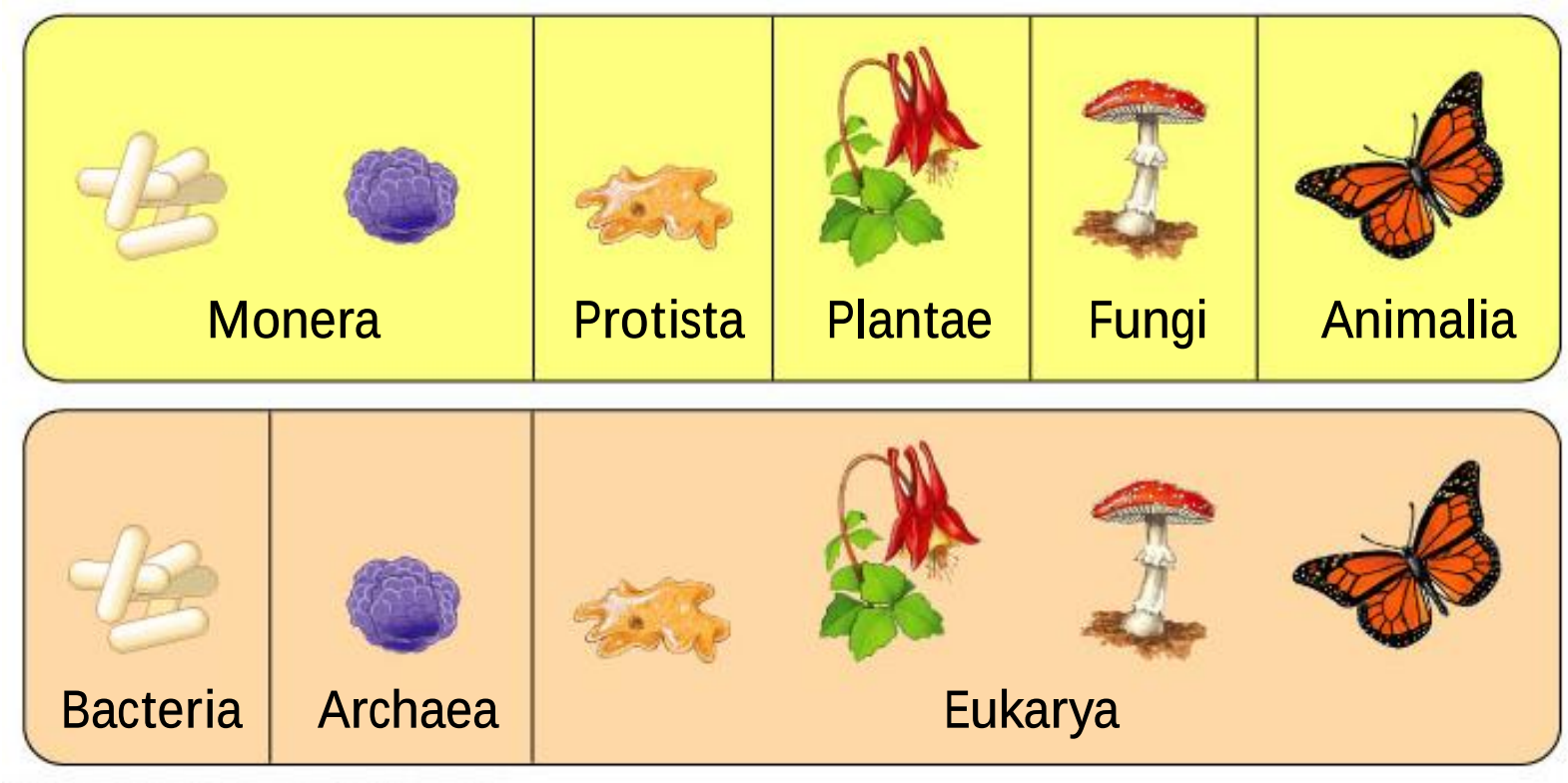

Species: Panthera pardus
Genus: Panthera
Family: Felidae
Order: Carnivora
Class: Mammalia
Phylum: Chordata
Kingdom: Animalia
Bacteria
Domain: Eukarya
Archaea

- The named taxonomic unit at any level is called a taxon(đơn vị phân loại) (plural, *taxa).*
  - For example, *Panthera* is a taxon at the genus level, and Mammalia is a taxon at the class level that includes all the many orders of mammals.
- Taxa broader(rộng) than the genus level are not italicized, though they are capitalized.

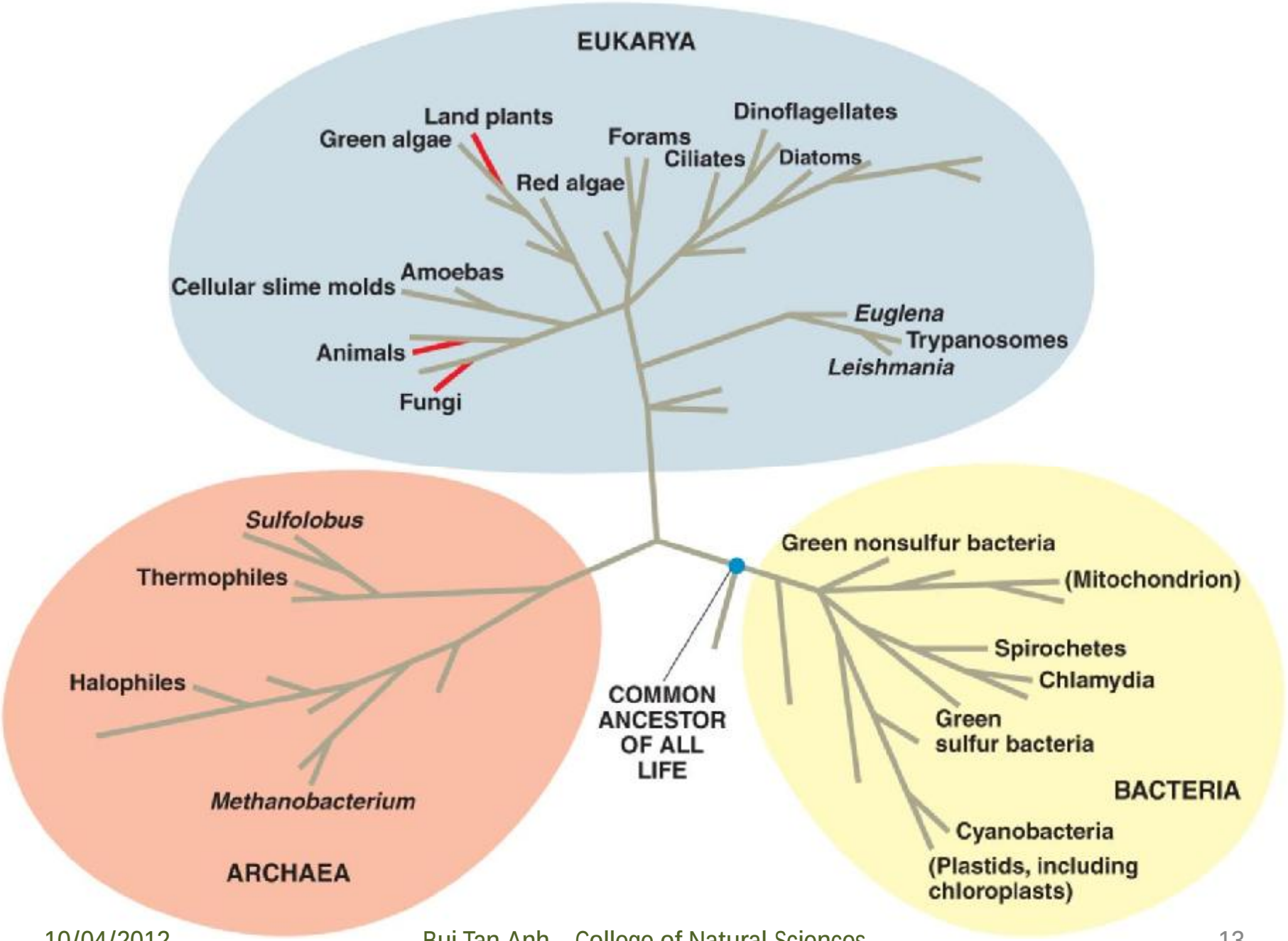
From Two Kingdoms to Three Domains

- Early taxonomists classified all species as either plants or animals.
- Later, five kingdoms were recognized: Monera (Prokaryotes), Protista, Plantae, Fungi, and Animalia.
- More recently, the three-domain system has been adopted: Bacteria, Archaea, and Eukarya.

Five kingdoms



Three domains


EUKARYA
Land plants
Green algae
Red algae
Forams
Ciliates
Dinoflagellates
Diatoms
Amoebas
Cellular slime molds
Animals
Fungi
Euglena
Trypanosomes
Leishmania
Sulfolobus
Thermophiles
Halophiles
Methanobacterium
ARCHAEA
COMMON ANCESTOR OF ALL LIFE
Green nonsulfur bacteria
(Mitochondrion)
Spirochetes
Chlamydia
Green sulfur bacteria
BACTERIA
Cyanobacteria
(Plastids, including chloroplasts)

Contents in brief

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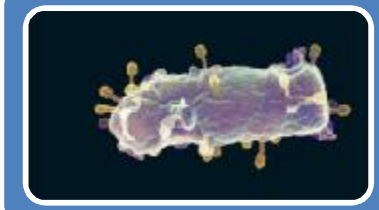
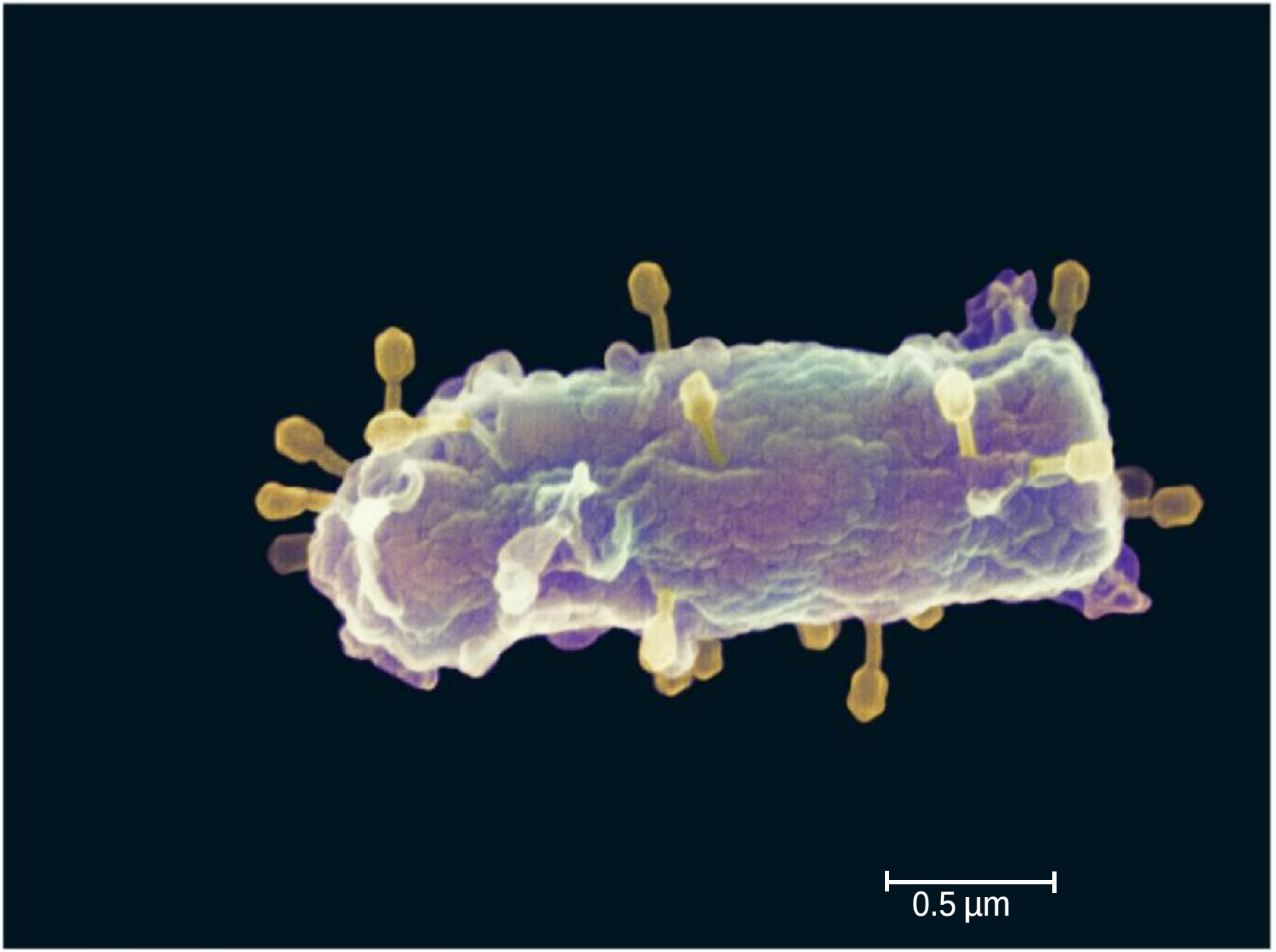


Viruses

Bacteria

Archaea

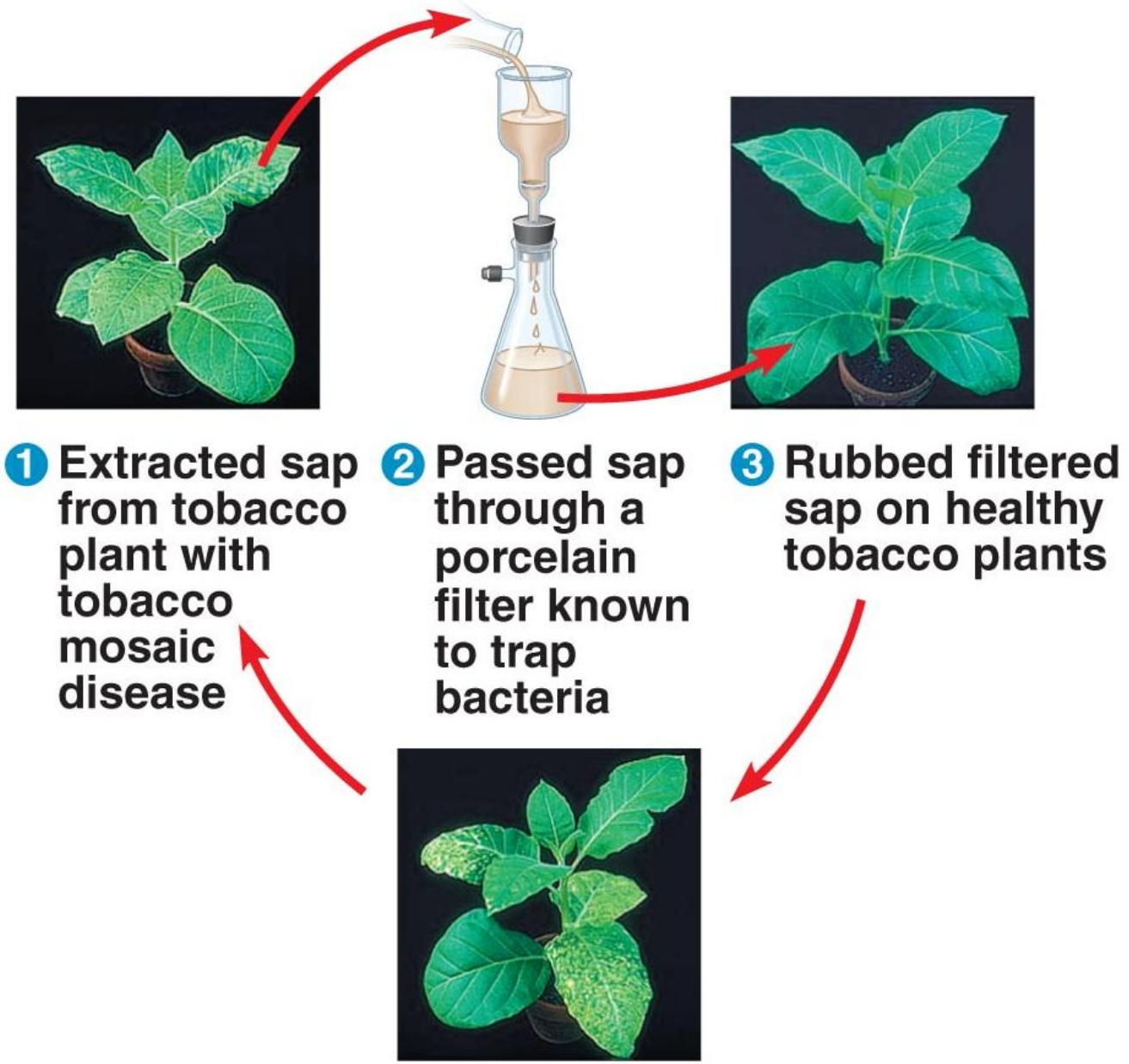


Overview

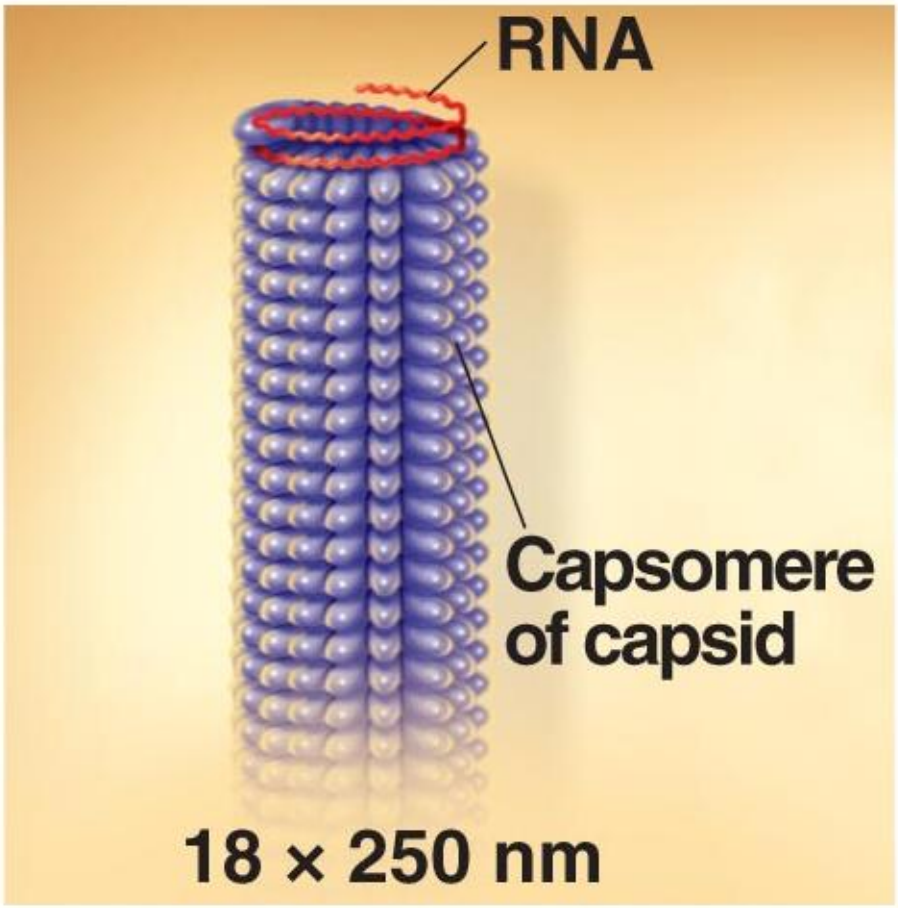
- Viruses called bacteriophages can infect and set in motion a genetic takeover of bacteria, such as *Escherichia coli.*
- Viruses lead “a kind of borrowed life” between life-forms and chemicals.
- The origins of molecular biology lie in early studies of viruses that infect bacteria.

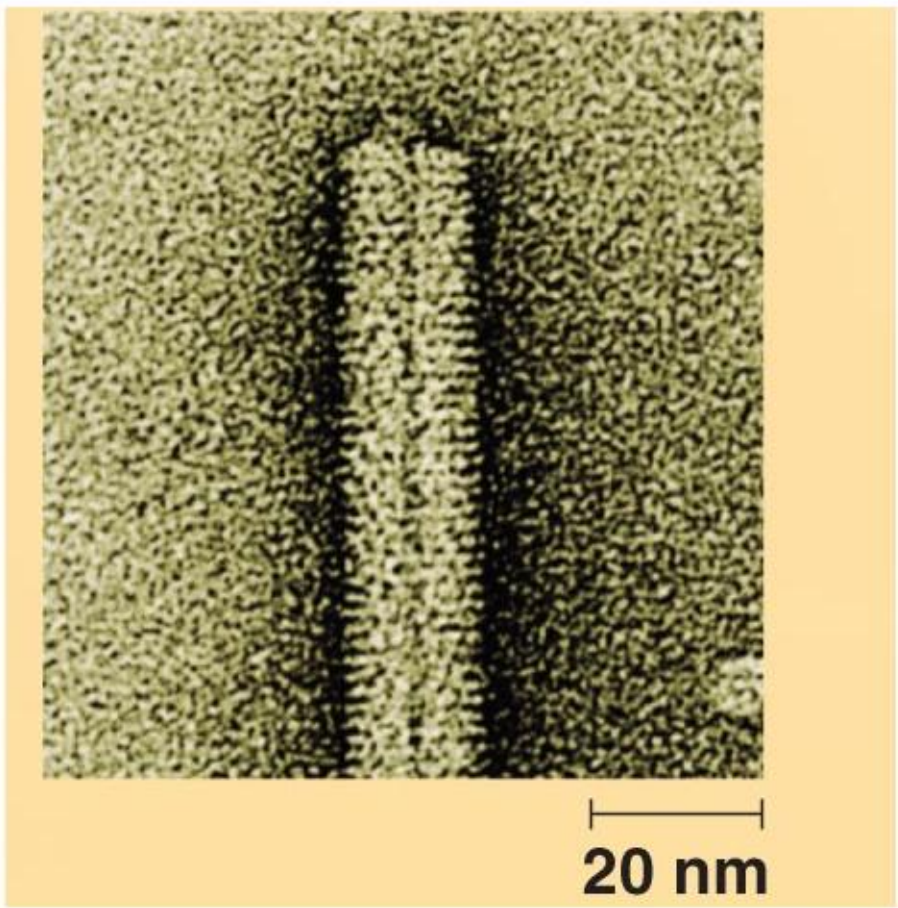
The Discovery of Viruses

- *Tobacco mosaic disease* stunts growth of tobacco plants and gives their leaves a mosaic coloration.
- In the late 1800s, researchers hypothesized that a particle smaller than bacteria caused the disease.
- In 1935, Wendell Stanley confirmed this hypothesis by crystallizing the infectious particle, now known as tobacco mosaic virus (TMV).


1 Extracted sap from tobacco plant with tobacco mosaic disease
2 Passed sap through a porcelain filter known to trap bacteria
3 Rubbed filtered sap on healthy tobacco plants
4 Healthy plants became infected

Tobacco Mosaic Virus





Structure of Viruses

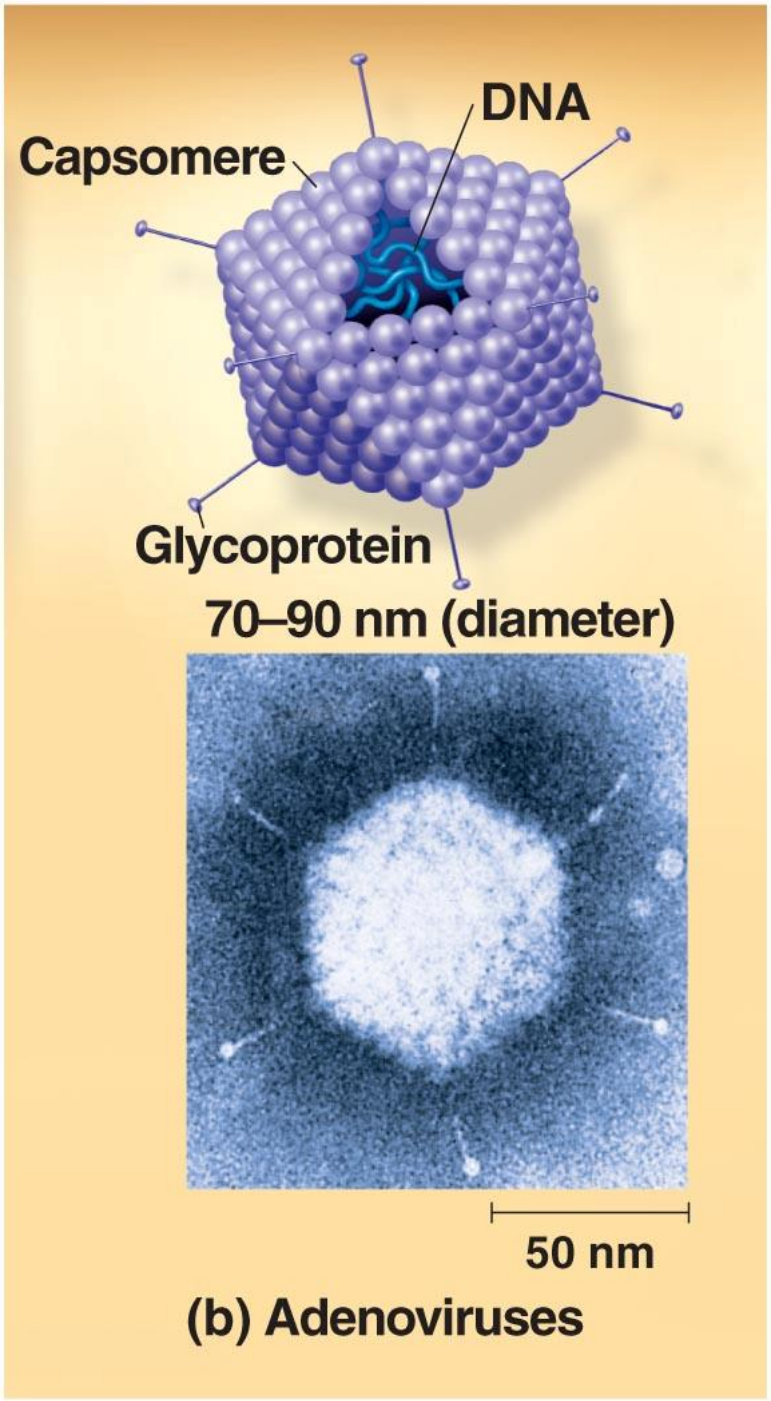
- Viruses are not cells.
- Viruses are very small infectious particles consisting of nucleic acid enclosed in a protein coat and, in some cases, a membranous envelope.

Viral genomes

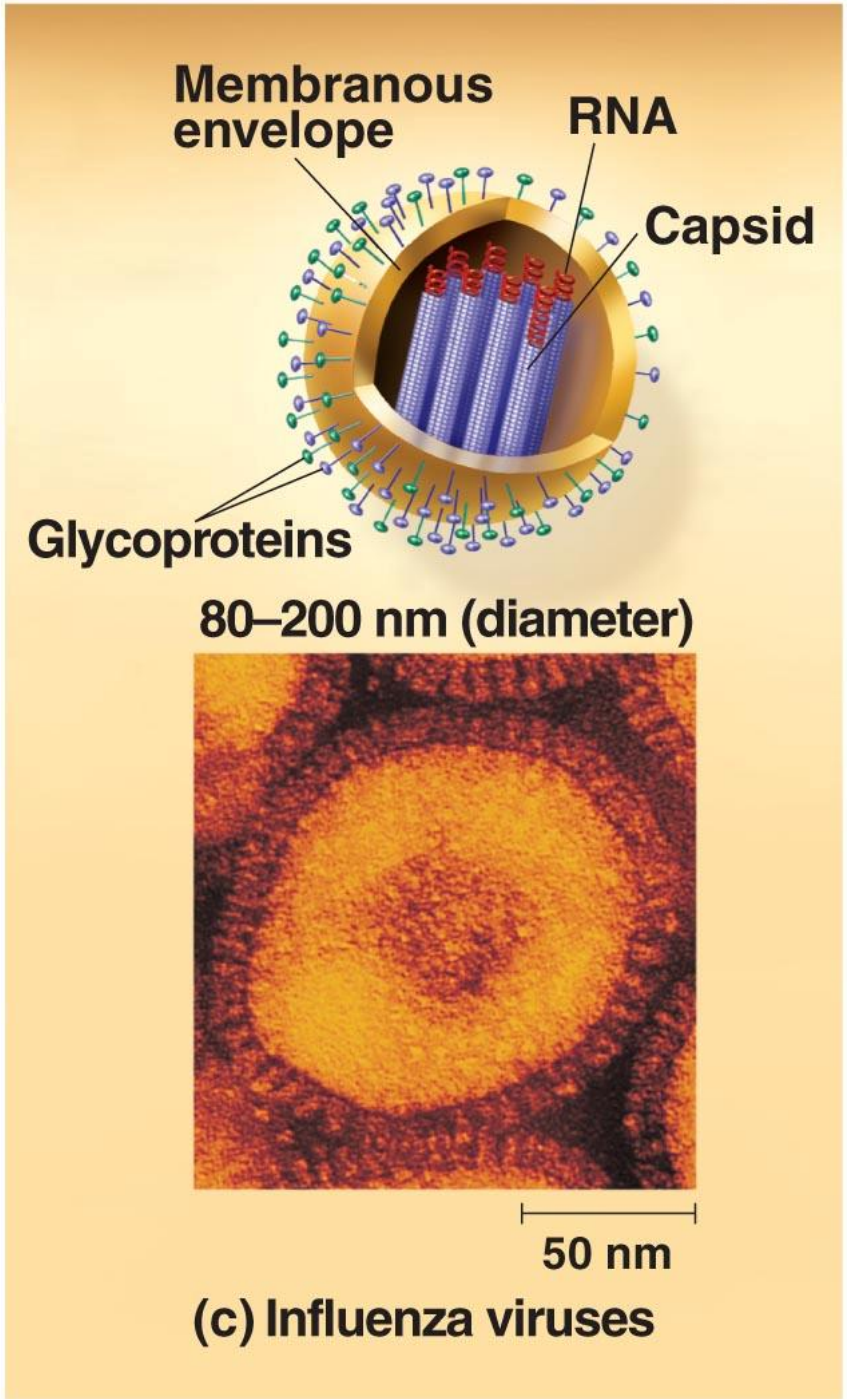
- Viral genomes may consist of either
  - Double- or single-stranded DNA, or
  - Double- or single-stranded RNA
- Depending on its type of nucleic acid, a virus is called a DNA virus or an RNA virus.

Capsid and envelopes

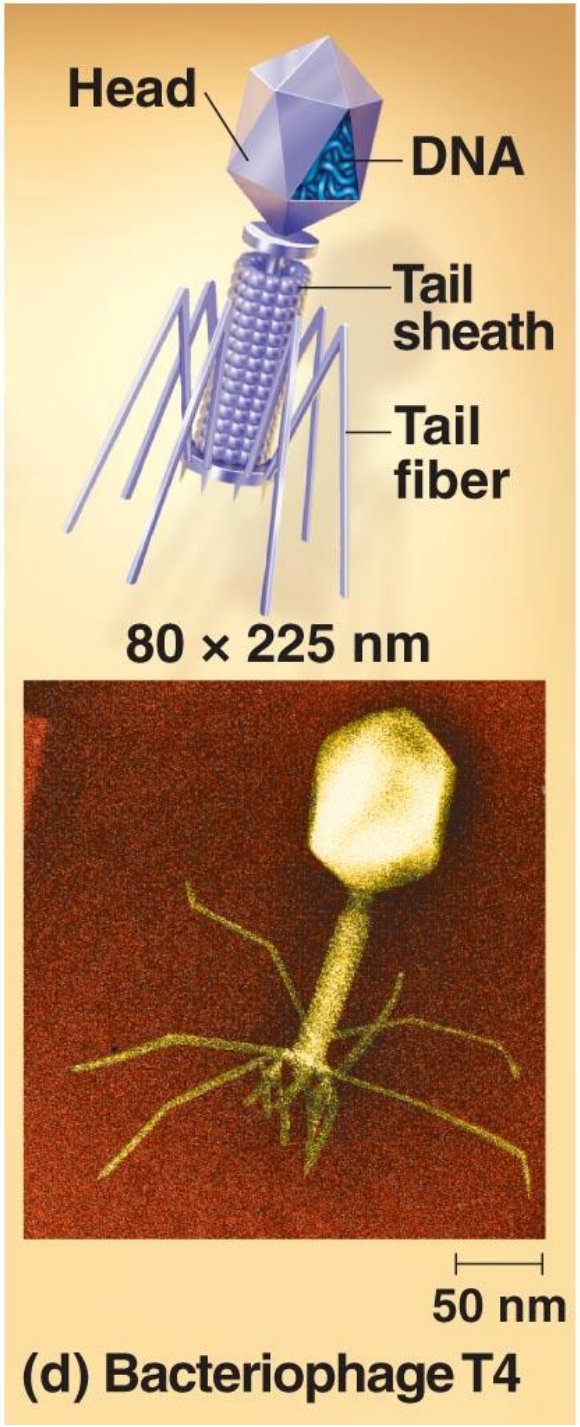
- A capsid is the protein shell(vỏ) that encloses the viral genome
- Capsids are built from protein subunits called *capsomeres*
- A capsid can have various structures

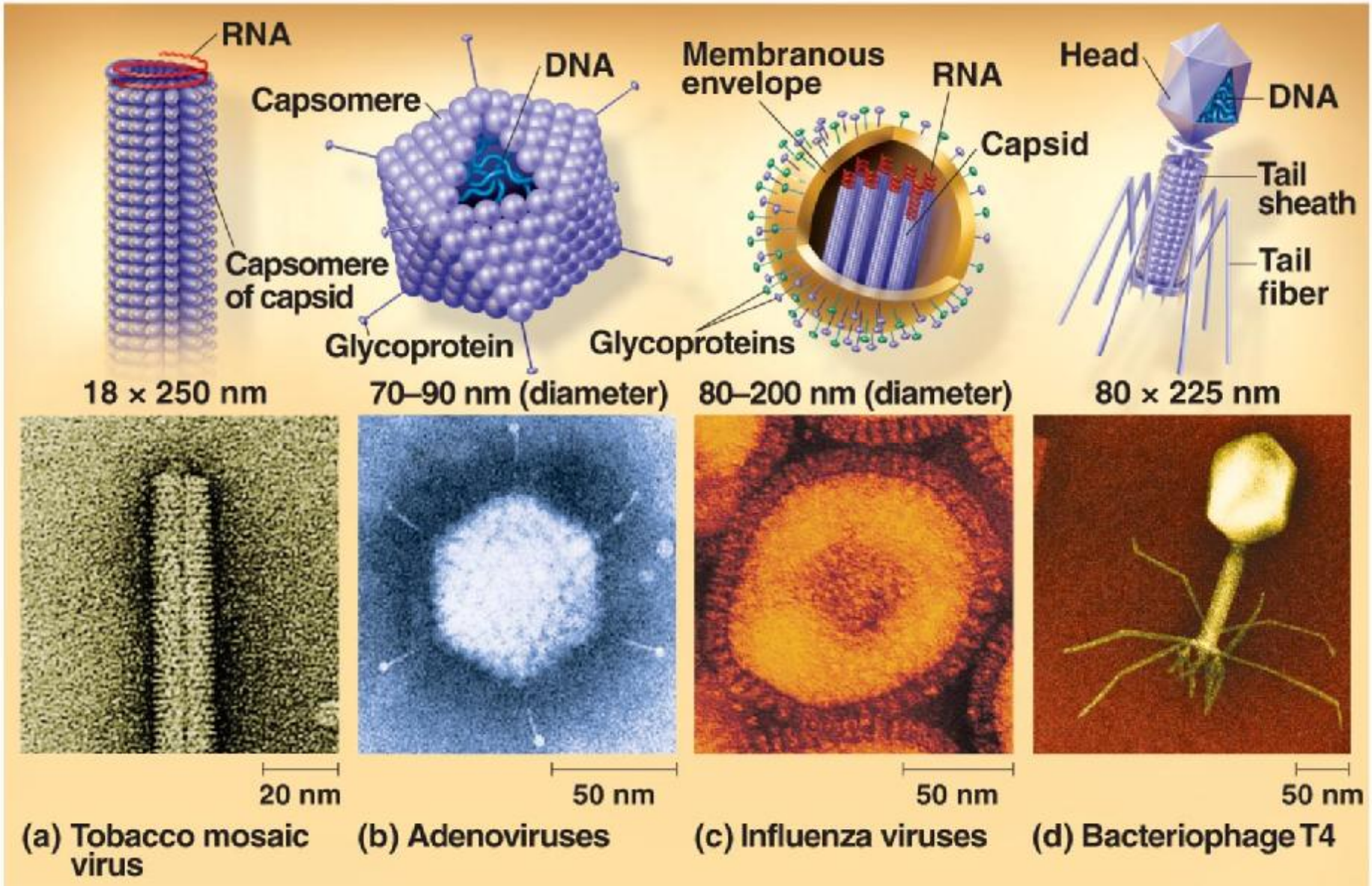

DNA
Capsomere
Glycoprotein
70–90 nm (diameter)
50 nm
(b) Adenoviruses

- Some viruses have membranous envelopes that help them infect hosts.
- These viral envelopes surround the capsids of influenza(bệnh cúm) viruses and many other viruses found in animals.
- Viral envelopes, which are derived(dẫn ra) from the host cell's membrane, contain a combination of viral and host cell molecules.


Membranous envelope
RNA
Capsid
Glycoproteins
80–200 nm (diameter)
50 nm
(c) Influenza viruses

- Bacteriophages, also called phages, are viruses that infect(lây nhiễm) bacteria.
- They have the most complex capsids found among viruses.
- Phages have an elongated capsid head that encloses their DNA.
- A protein tail piece attaches the phage to the host and injects the phage DNA inside.


Head
DNA
Tail sheath
Tail fiber
80 × 225 nm
50 nm
(d) Bacteriophage T4

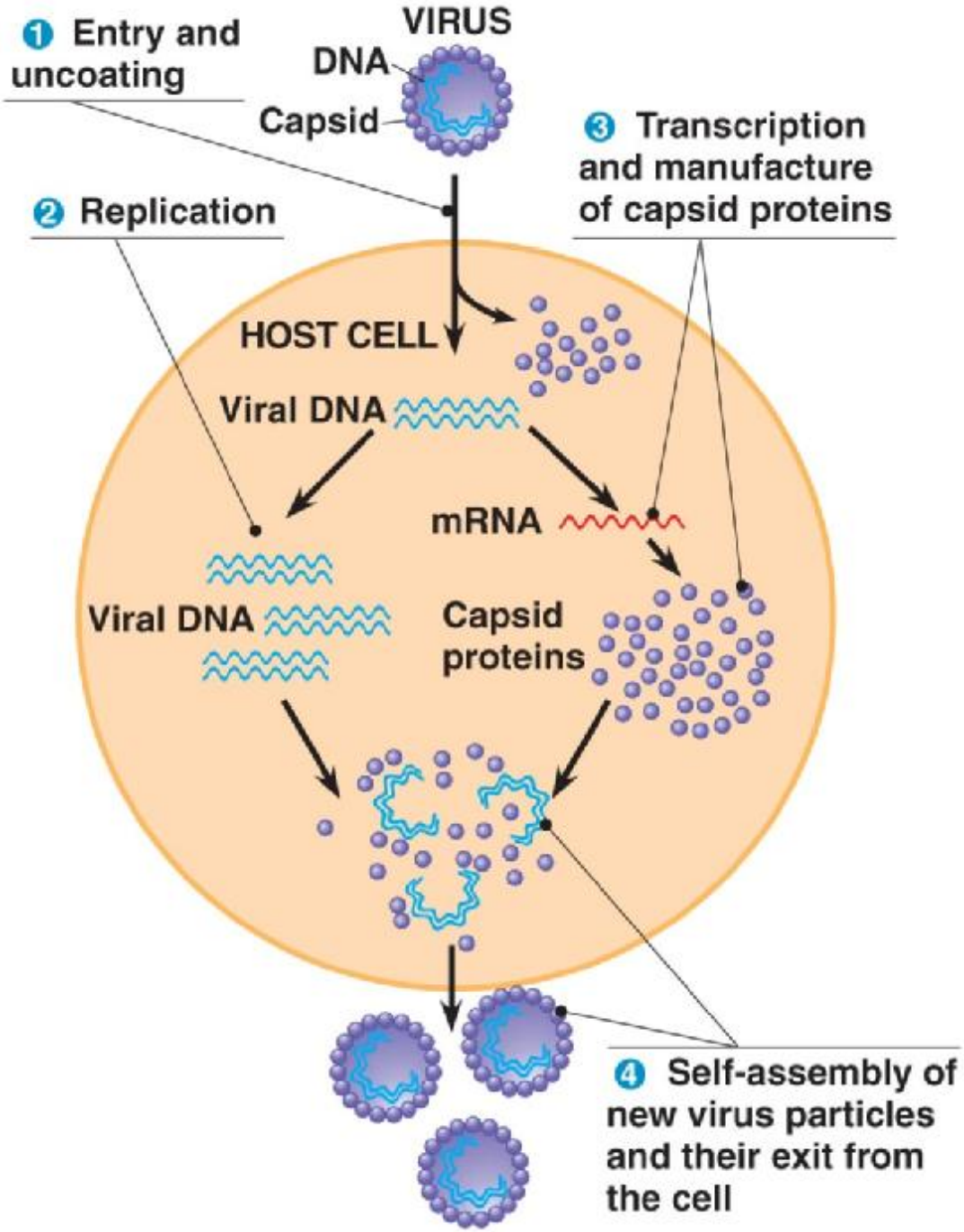

RNA
Capsomere of capsid
18 × 250 nm
20 nm
(a) Tobacco mosaic virus
DNA
Capsomere
Glycoprotein
70–90 nm (diameter)
50 nm
(b) Adenoviruses
Membranous envelope
RNA
Capsid
Glycoproteins
80–200 nm (diameter)
50 nm
(c) Influenza viruses
Head
DNA
Tail sheath
Tail fiber
80 × 225 nm
50 nm
(d) Bacteriophage T4

Viral reproduction

- Viruses are obligate(bắt buộc) intracellular (nội bào)parasites(vật kí sinh), which means they can reproduce only within a host cell.
- Each virus has a host range, a limited number of host cells that it can infect.

General Features of Viral Reproductive Cycles

- Once a viral genome has entered a cell, the cell begins to manufacture viral proteins.
- The virus makes use of host enzymes, ribosomes, tRNAs, amino acids, ATP, and other molecules.
- Viral nucleic acid molecules and capsomeres spontaneously self-assemble(tự tổng hợp) into new viruses.


1 Entry and uncoating
VIRUS
DNA
Capsid
3 Transcription and manufacture of capsid proteins
2 Replication
HOST CELL
Viral DNA
mRNA
Viral DNA
Capsid proteins
4 Self-assembly of new virus particles and their exit from the cell

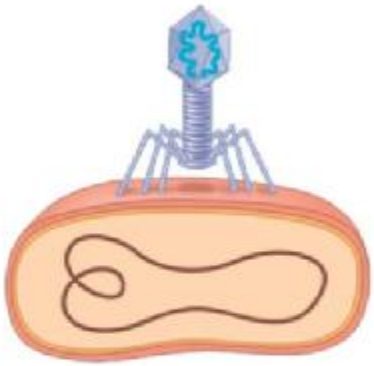
Reproductive cycle of phages

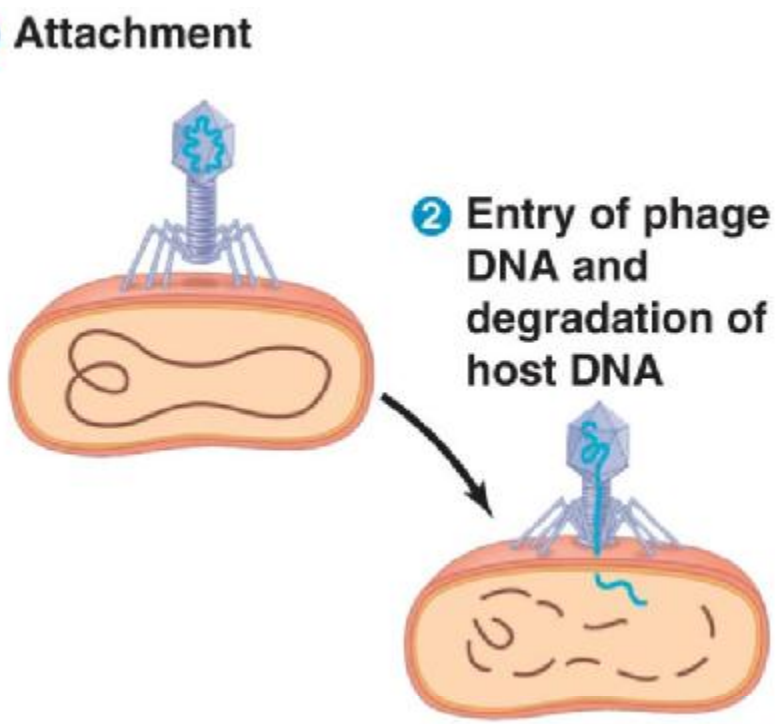
- Phages are the best understood of all viruses.
- Phages have two reproductive mechanisms:
  - the lytic cycle
  - the lysogenic cycle.

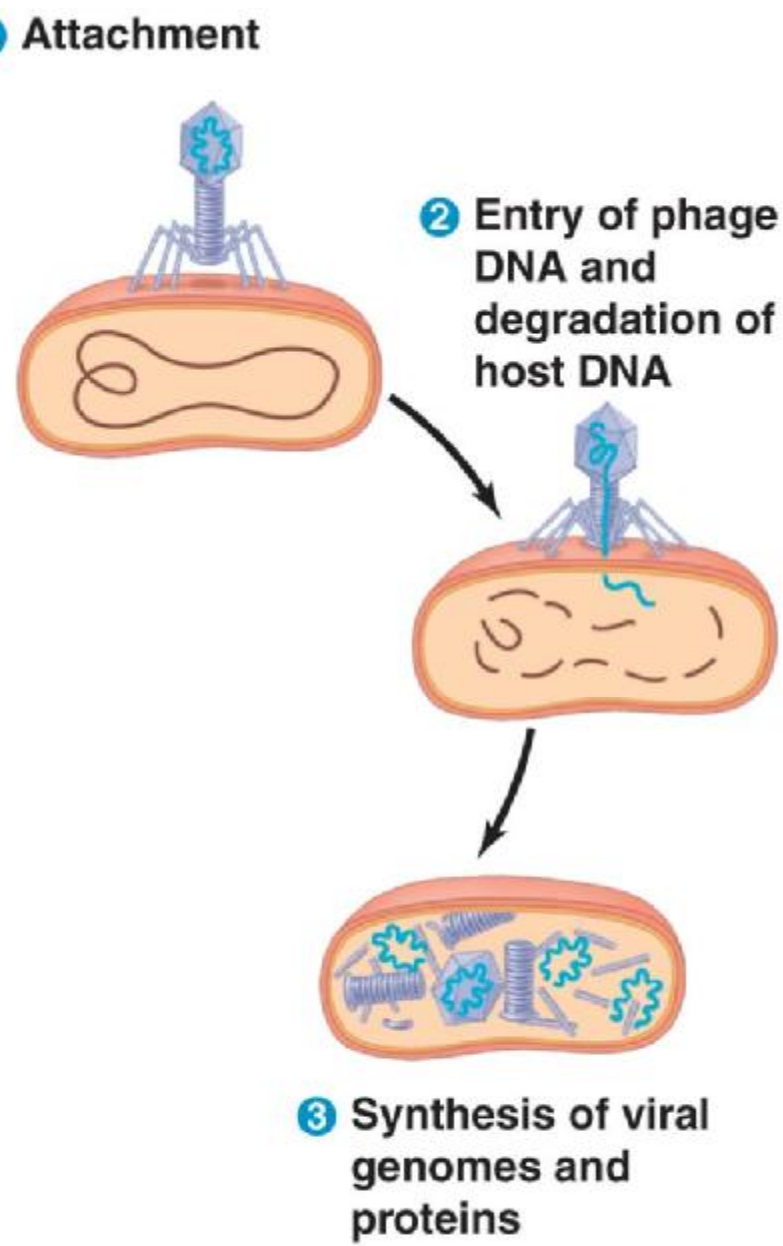
The lytic cycle

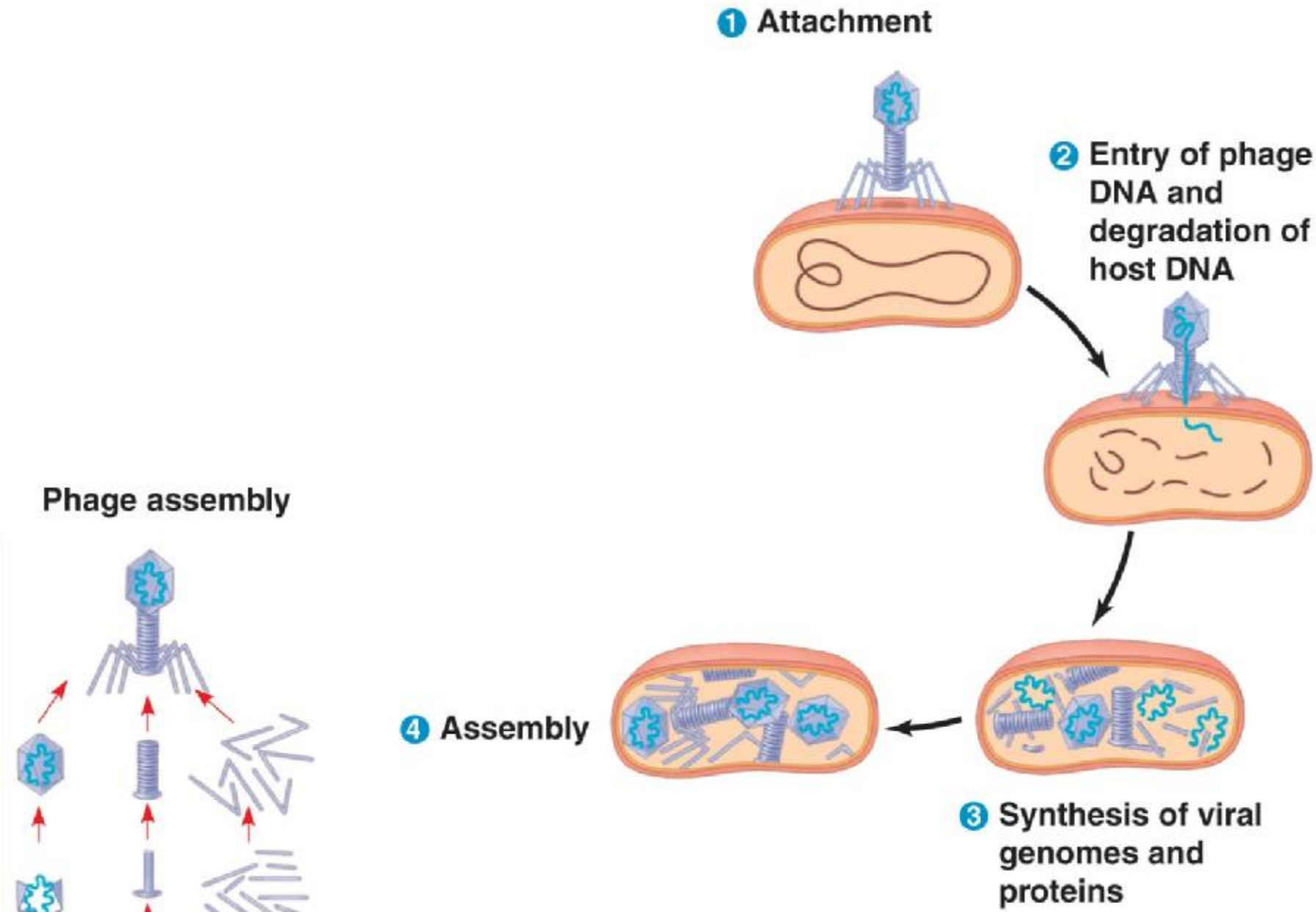
- The lytic cycle is a phage reproductive cycle that culminates in the death of the host cell.
- The lytic cycle produces new phages and digests the host's cell wall, releasing the progeny viruses.
- A phage that reproduces only by the lytic cycle is called a virulent phage.
- Bacteria have defenses against phages, including restriction enzymes that recognize and cut up certain phage DNA.

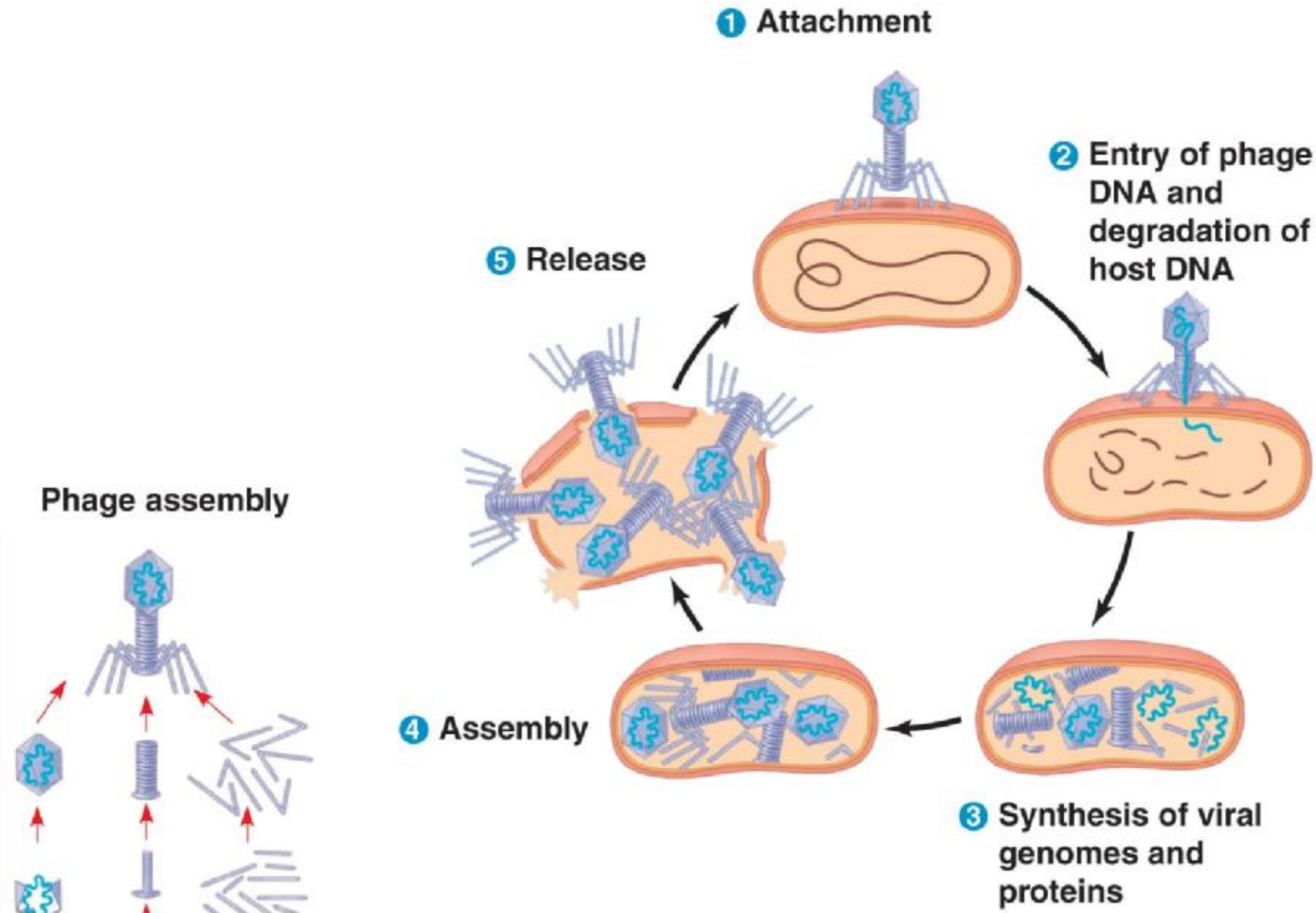
1 Attachment







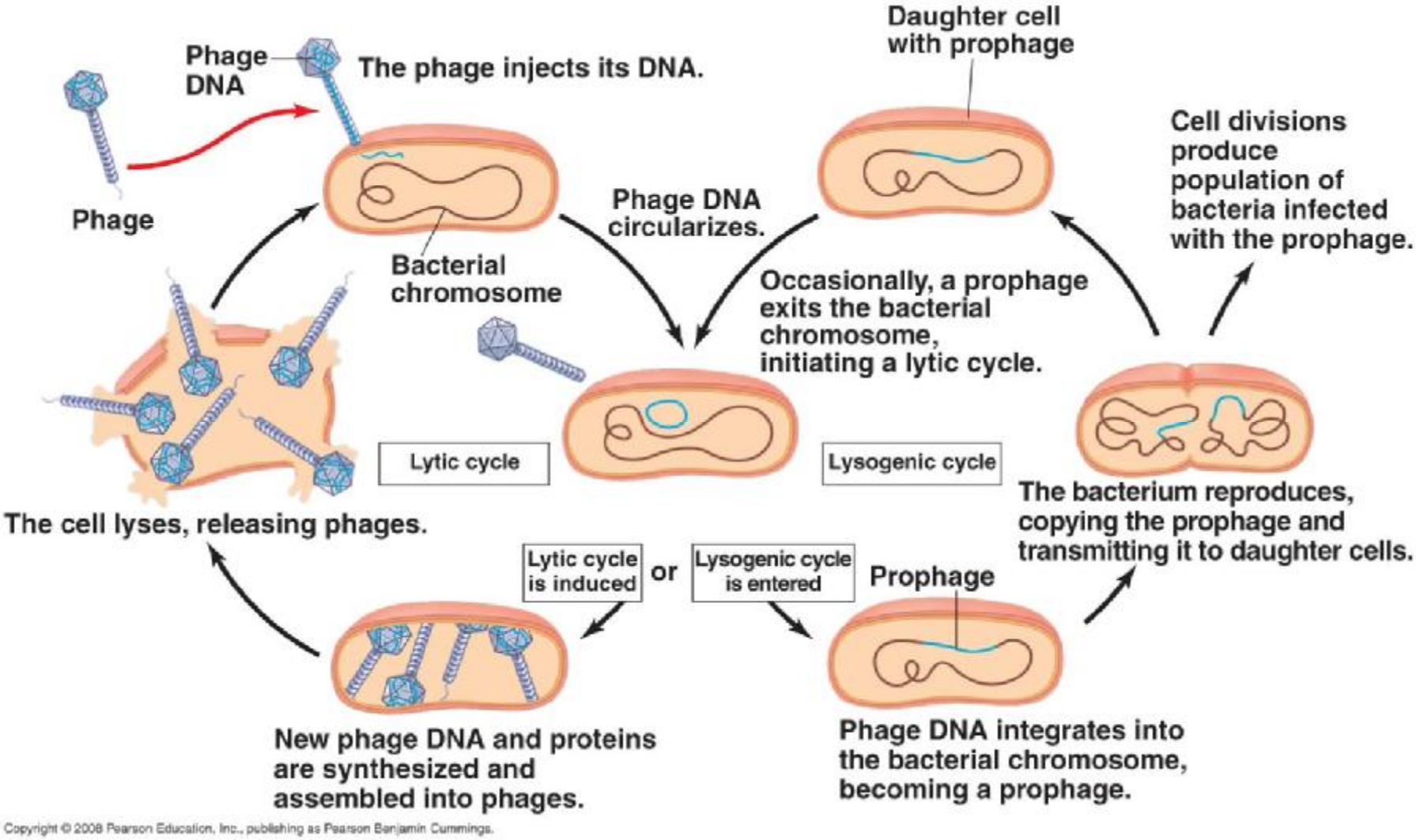




The lysogenic cycle

- The lysogenic cycle replicates the phage genome without destroying the host.
- The viral DNA molecule is incorporated into the host cell's chromosome.
- This integrated(hợp nhất) viral DNA is known as a prophage.
- Every time the host divides, it copies the phage DNA and passes the copies to daughter cells.

- An environmental signal can trigger the virus genome to exit the bacterial chromosome and switch to the lytic mode.
- Phages that use both the lytic and lysogenic cycles are called temperate phages.

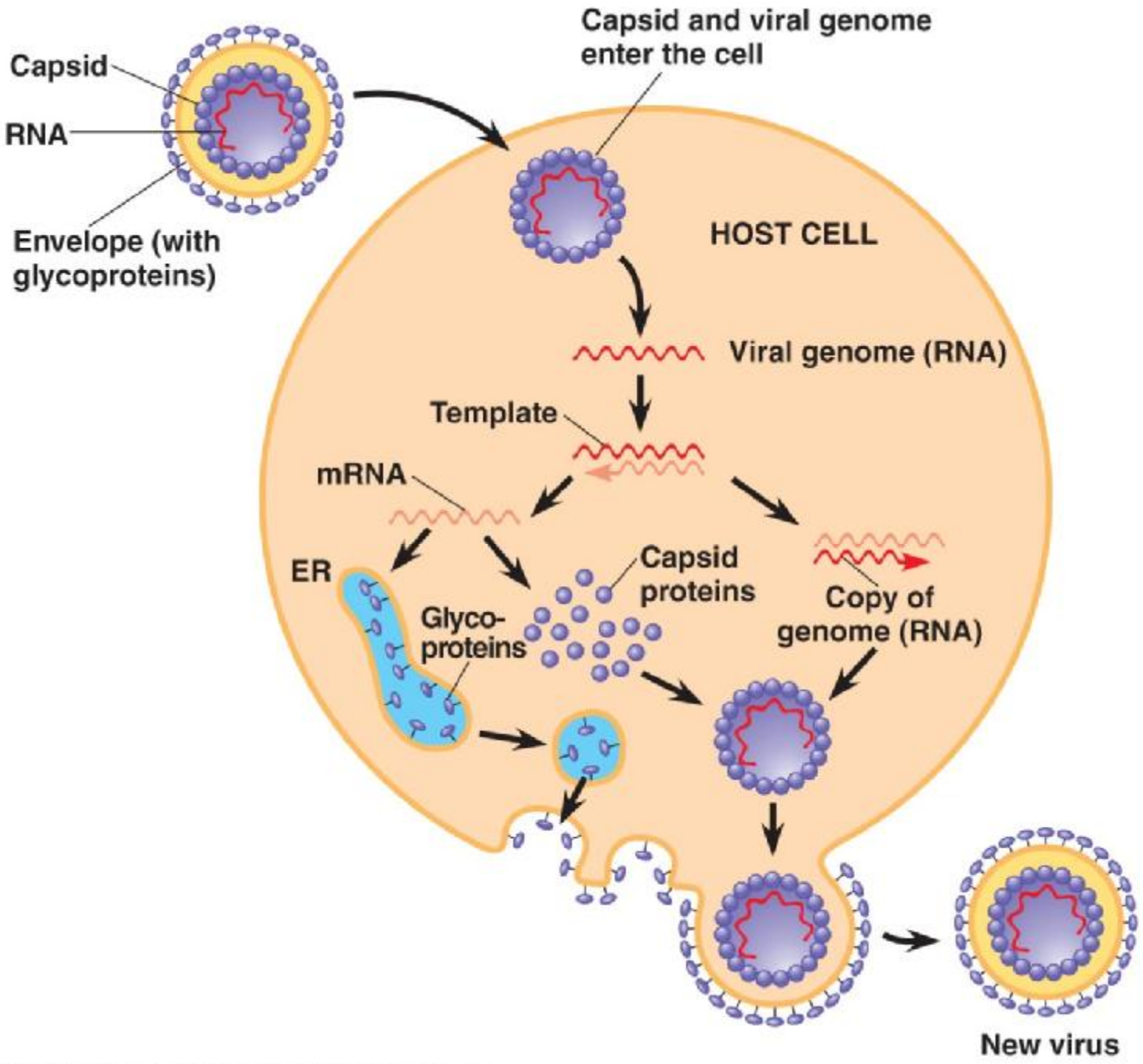


Reproductive Cycles of Animal Viruses

- There are two key variables used to classify viruses that infect animals:
  - DNA or RNA?
  - Single-stranded or double-stranded?

- Many viruses that infect animals have a membranous envelope.
- Viral glycoproteins on the envelope bind to specific receptor molecules on the surface of a host cell.

- Some viral envelopes are formed from the host cell's plasma membrane as the viral capsids exit.
- Other viral membranes form from the host's nuclear envelope and are then replaced by an envelope made from Golgi apparatus membrane.

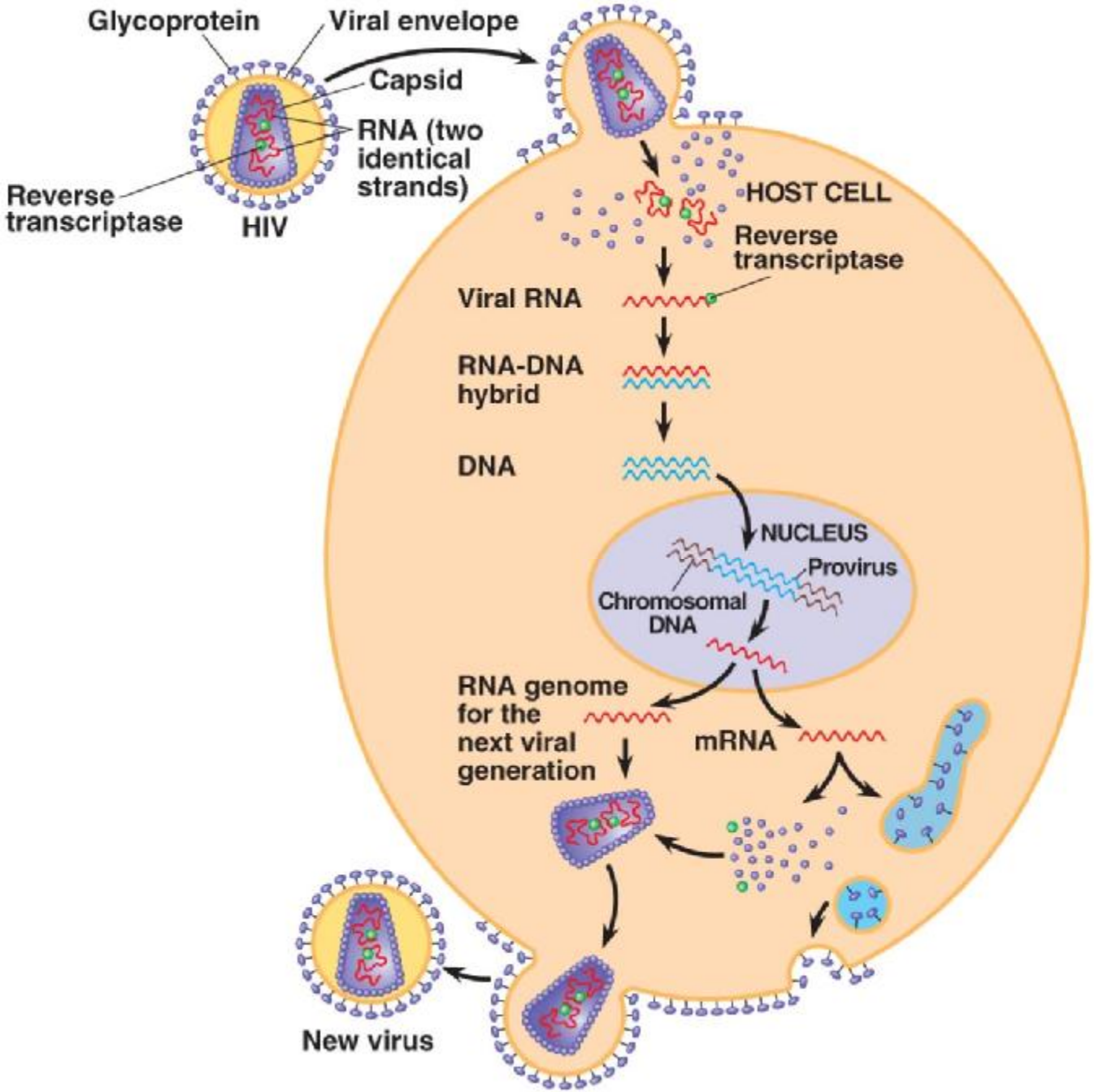


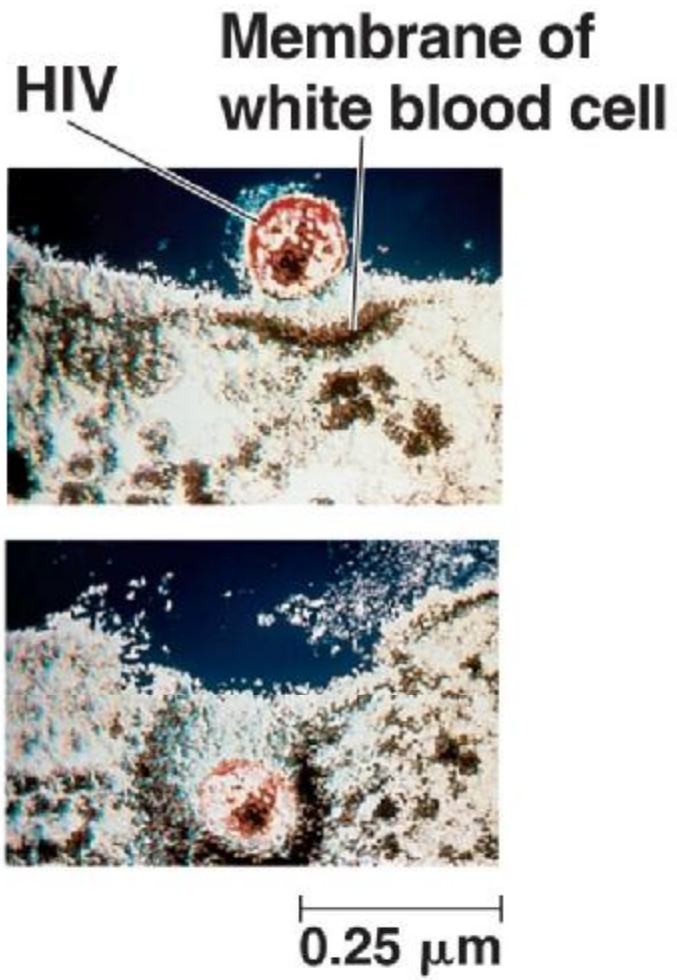
RNA as Viral Genetic Material

- The broadest variety of RNA genomes is found in viruses that infect animals.
- Retroviruses use reverse transcriptase to copy their RNA genome into DNA.
- HIV (human immunodeficiency virus) is the retrovirus that causes AIDS (acquired immunodeficiency syndrome).

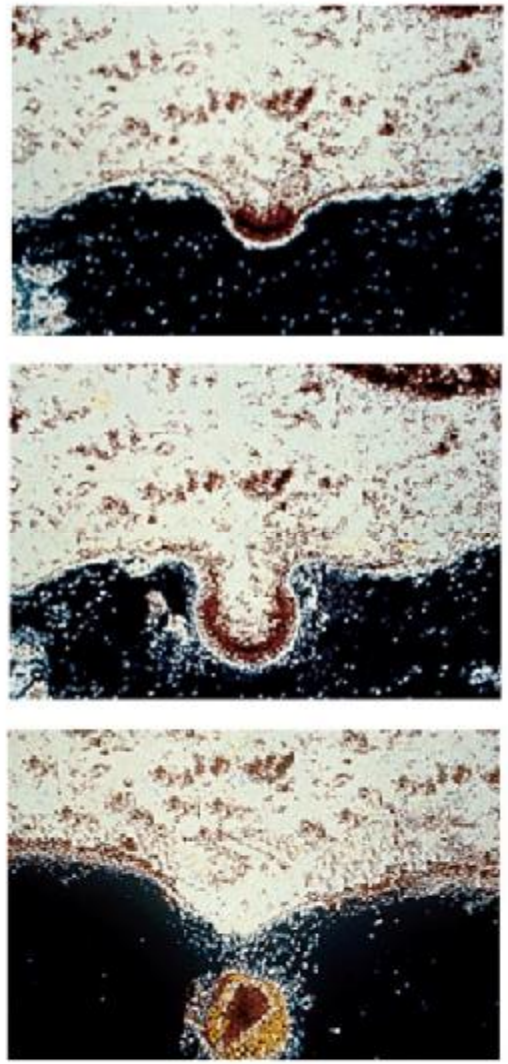
RNA as Viral Genetic Material

- The viral DNA that is integrated into the host genome is called a provirus.
- Unlike a prophage, a provirus remains a permanent resident of the host cell.
- The host's RNA polymerase transcribes the proviral DNA into RNA molecules.
- The RNA molecules function both as mRNA for synthesis of viral proteins and as genomes for new virus particles released from the cell.





HIV entering a cell



New HIV leaving a cell

Viral Diseases

- Diseases caused by viral infections affect humans, agricultural crops, and livestock(vật nuôi) worldwide.
- Smaller, less complex entities called viroids and prions also cause disease in plants and animals, respectively.

Viral Diseases in Animals

- Viruses may damage or kill cells by causing the release of hydrolytic enzymes from lysosomes
- Some viruses cause infected cells to produce toxins that lead to disease symptoms
- Others have envelope proteins that are toxic

- Vaccines are harmless derivatives(vật liệu tái sinh) of pathogenic(gây bệnh) microbes(vi khuẩn) that stimulate the immune(miễn dịch) system to mount defenses against the actual pathogen.
- Vaccines can prevent certain viral illnesses
- Viral infections cannot be treated by antibiotics(kháng sinh).
- Antiviral drugs can help to treat, though not cure, viral infections.

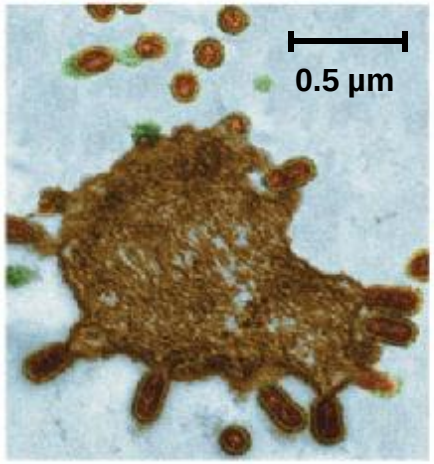
Emerging Viruses

- Emerging viruses are those that appear suddenly or suddenly come to the attention of scientists
- Severe acute respiratory syndrome (SARS) recently appeared in China
- Outbreaks of “new” viral diseases in humans are usually caused by existing viruses that expand their host territory

- Flu epidemics(lây nhiễm) are caused by new strains of influenza(bệnh cúm) virus to which people have little immunity(miễn dịch).
- Viral diseases in a small isolated population can emerge and become global.
- New viral diseases can emerge when viruses spread(lan rộng) from animals to humans.
- Viral strains(sự căng) that jump species can exchange genetic information with other viruses to which humans have no immunity.

- These strains can cause pandemics(dịch lớn), global epidemics.
- The “avian flu”(cúm gia cầm) is a virus that recently appeared in humans and originated in wild birds.

(a) The 1918 flu pandemic



(b) Influenza A H5N1 virus

(c) Vaccinating ducks

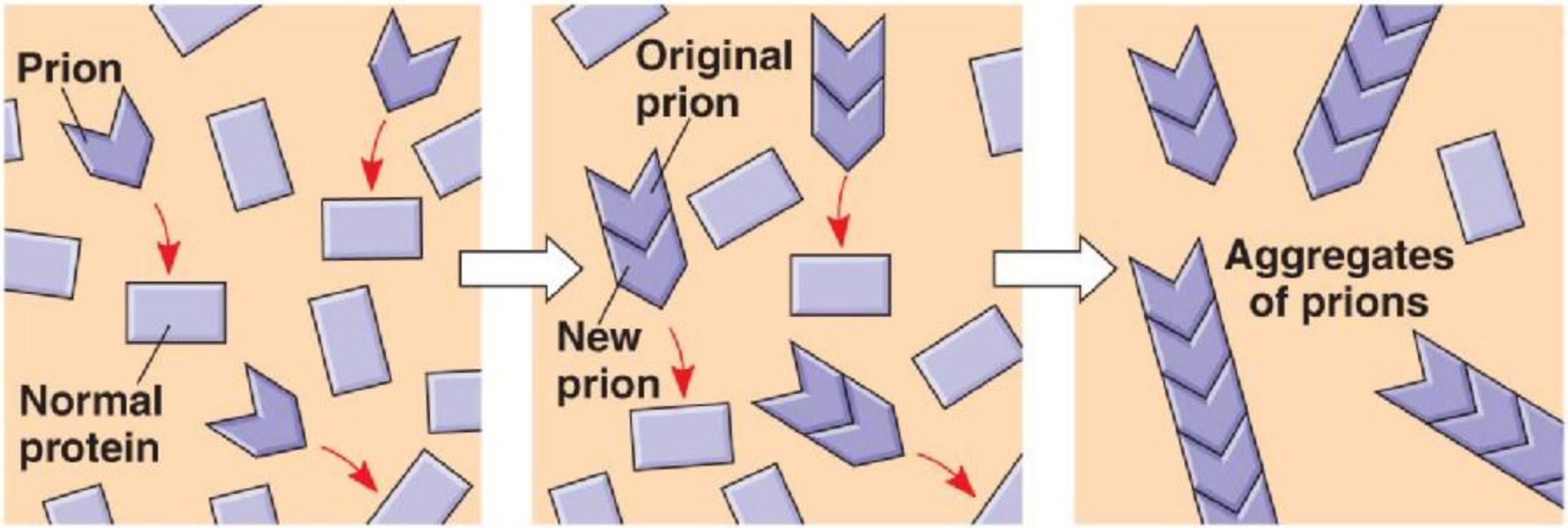
Viral Diseases in Plants

- More than 2,000 types of viral diseases of plants are known and cause spots on leaves and fruits, stunted growth, and damaged flowers or roots
- Most plant viruses have an RNA genome

- Plant viruses spread disease in two major modes:
  - Horizontal transmission, entering through damaged cell walls
  - Vertical transmission, inheriting(thừa kế) the virus from a parent

Viroids and Prions: The Simplest Infectious Agents

- Viroids are circular(vòng tròn) RNA molecules that infect plants and disrupt(phá vỡ) their growth
- Prions are slow-acting, virtually(hầu như) indestructible (ko thể phá hủy được) infectious(lây nhiễm) proteins that cause brain(não) diseases in mammals(đv có vú)
- Prions propagate(truyền) by converting normal proteins into the prion version(dịch)
- Scrapie in sheep, mad cow disease, and Creutzfeldt-Jakob disease in humans are all caused by prions



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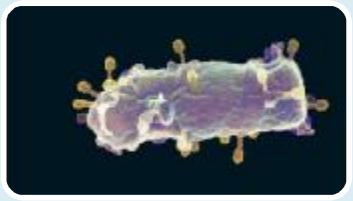


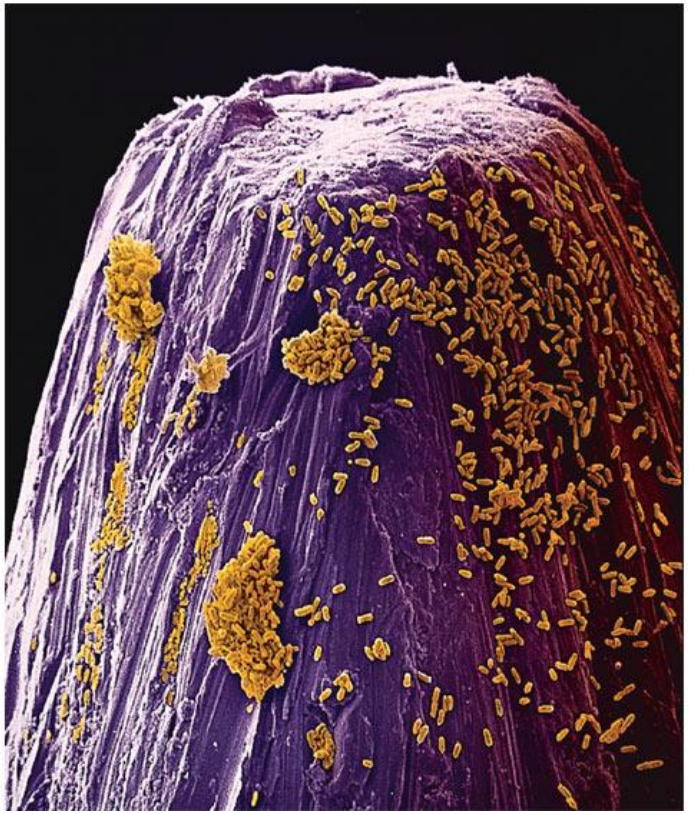
Viruses

Bacteria

Archaea

Prokaryotes

- Prokaryotes lived and evolved all alone on Earth for 2 billion years



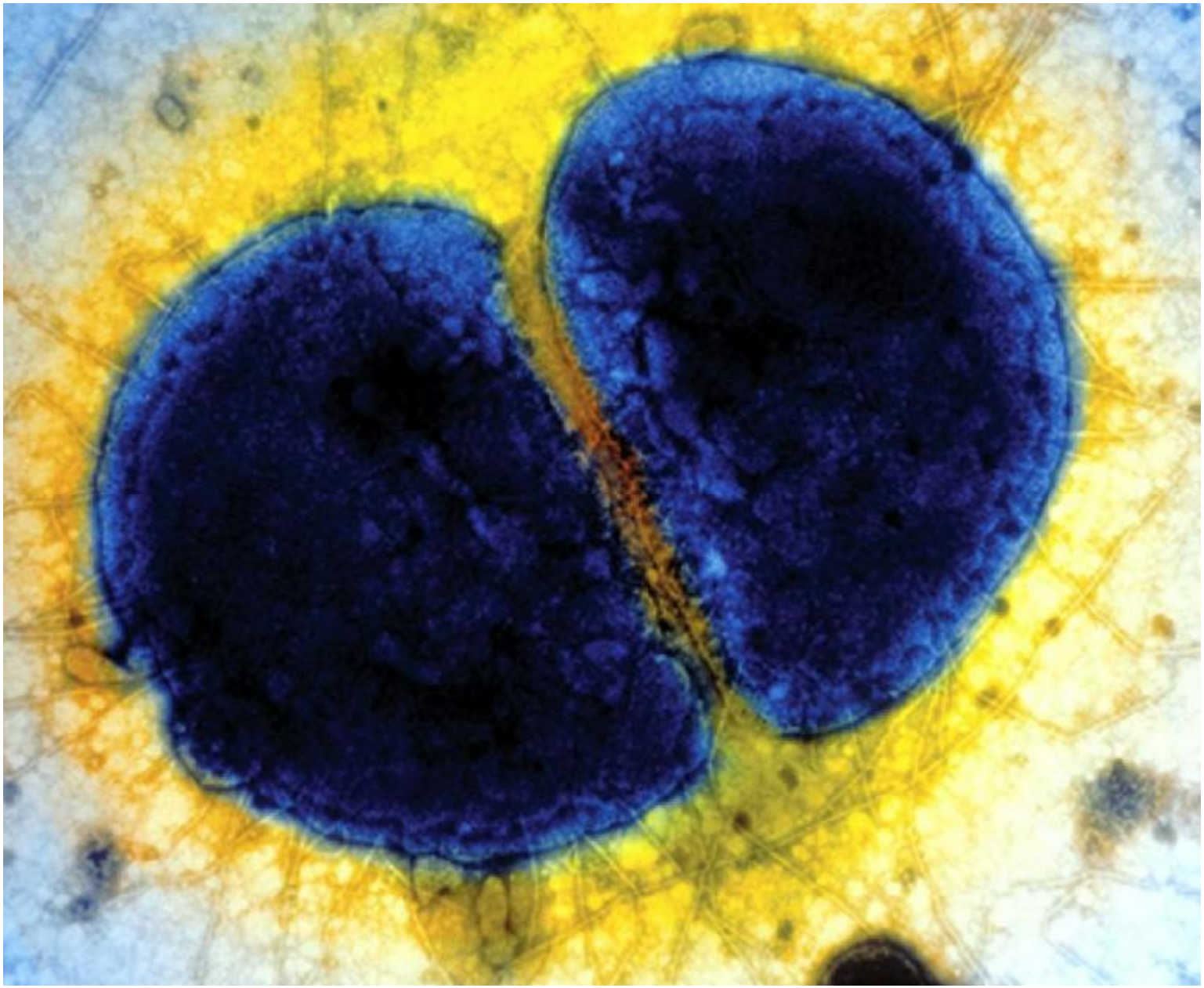
The Structure, Function, and Reproduction

- Prokaryotic cells
  - Lack nuclei
  - Lack other membrane-enclosed organelles
  - Have cell walls exterior(bên ngoài) to their plasma membranes
- Most prokaryotes are unicellular(đơn bào)
  - Although some species form colonies(tập đoàn)

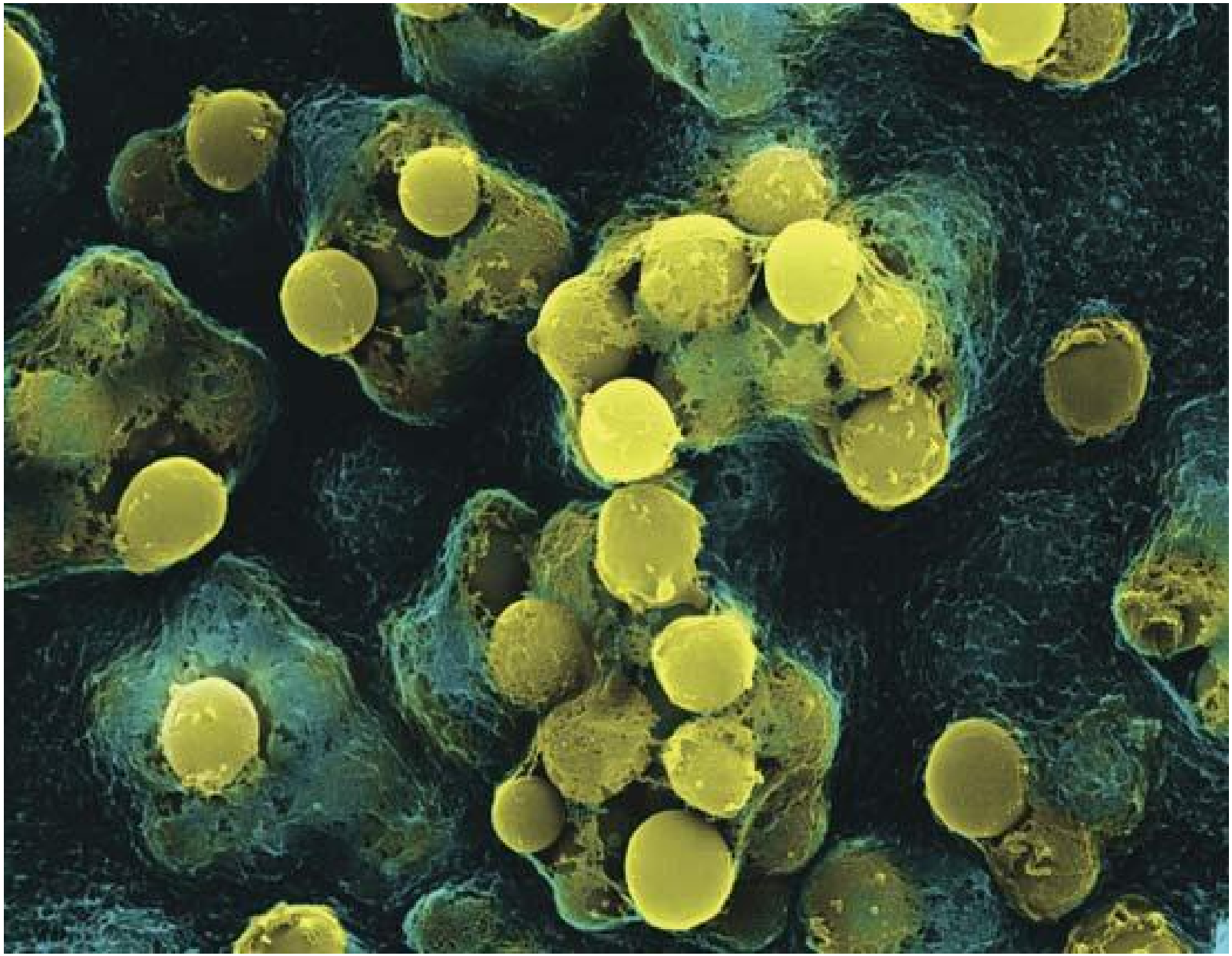
Cell shapes

- Cocci(khuẩn cầu) (Spherical shape):
  - Diplococcus
  - Streptococcus(khuẩn liên cầu)
  - Staphylococcus(khuẩn cầu chùm)
- Bacilli (Rod shape)
- Spirilla (Spiral shape)

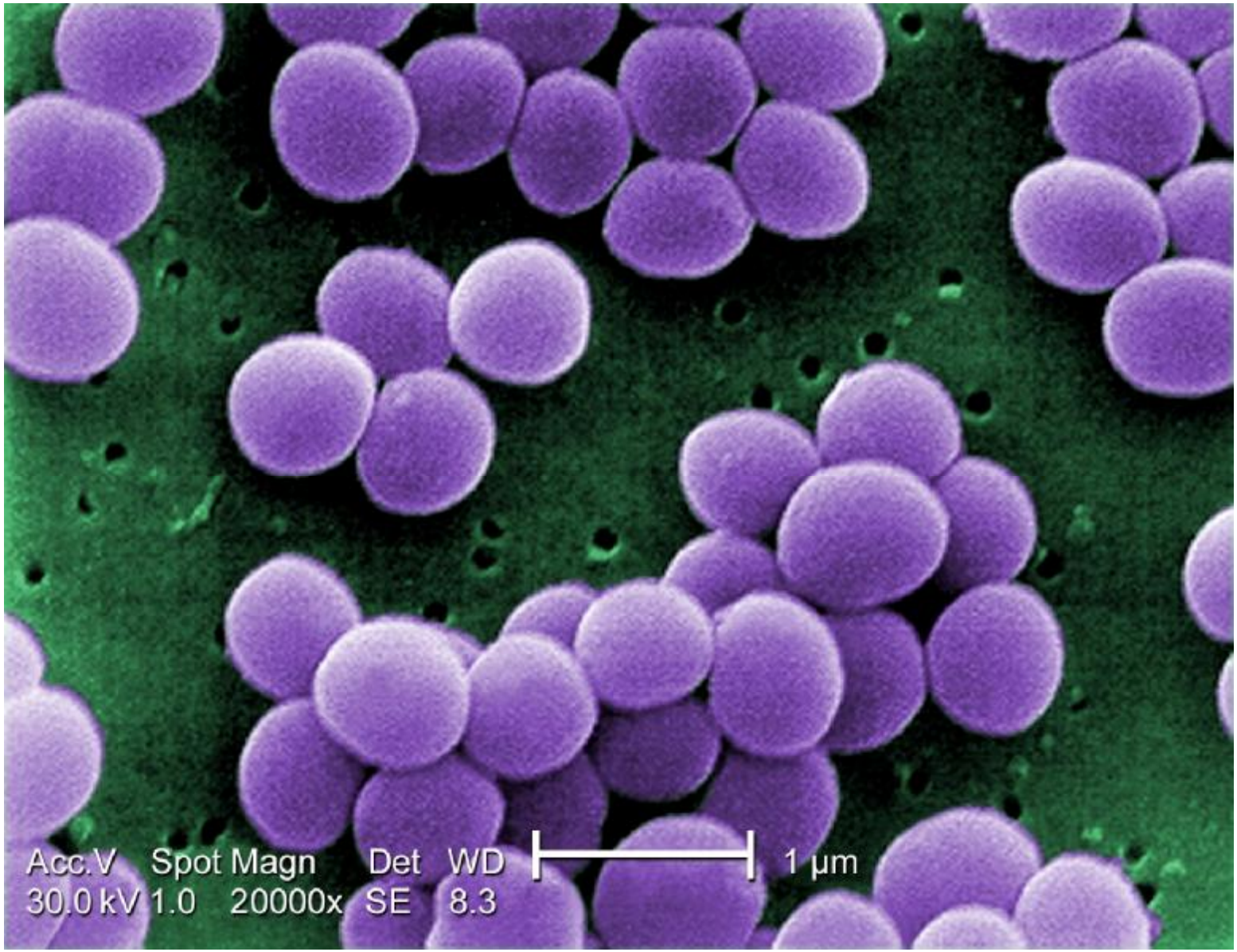
Diploccocus



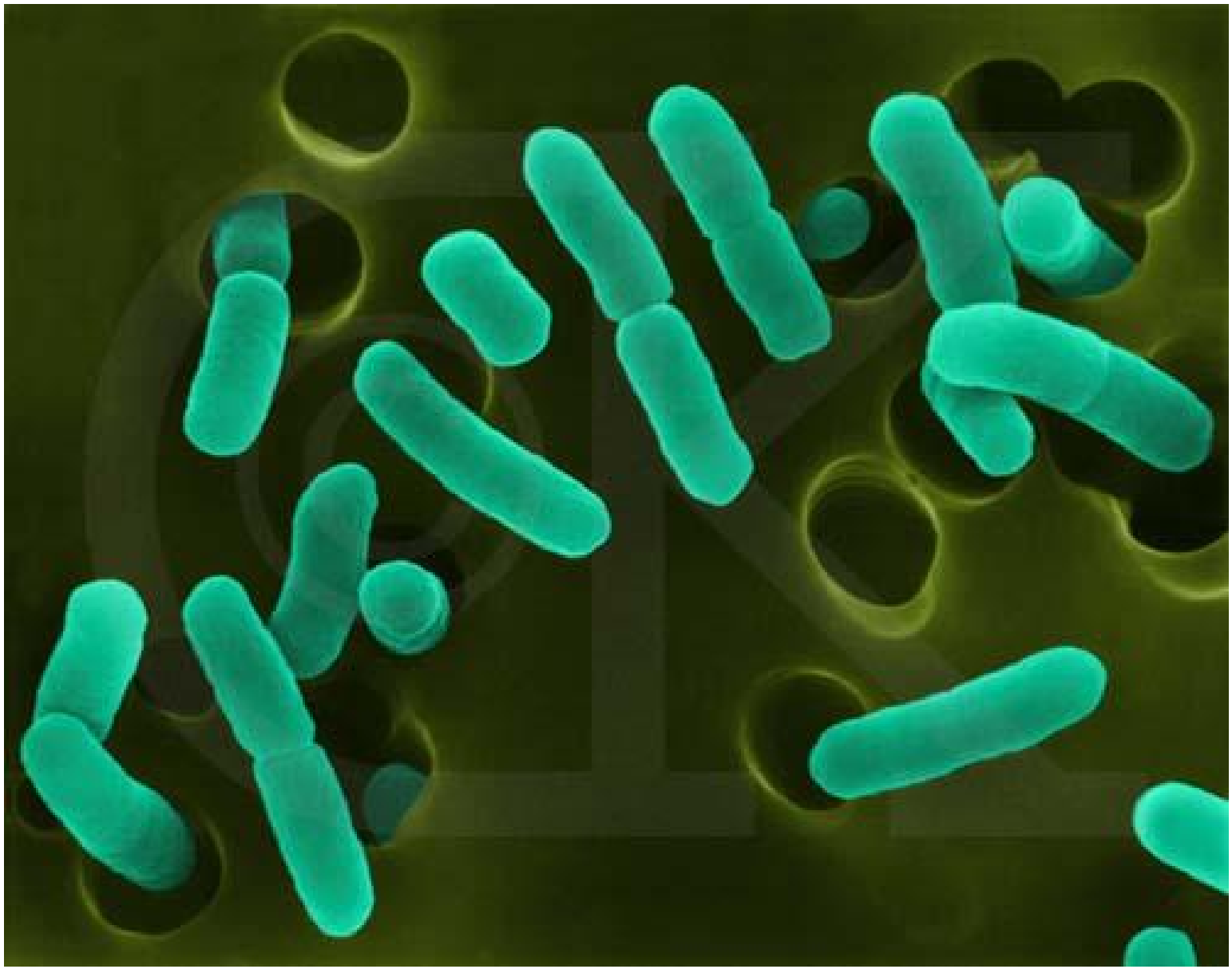
Streptoccocus pyogenes



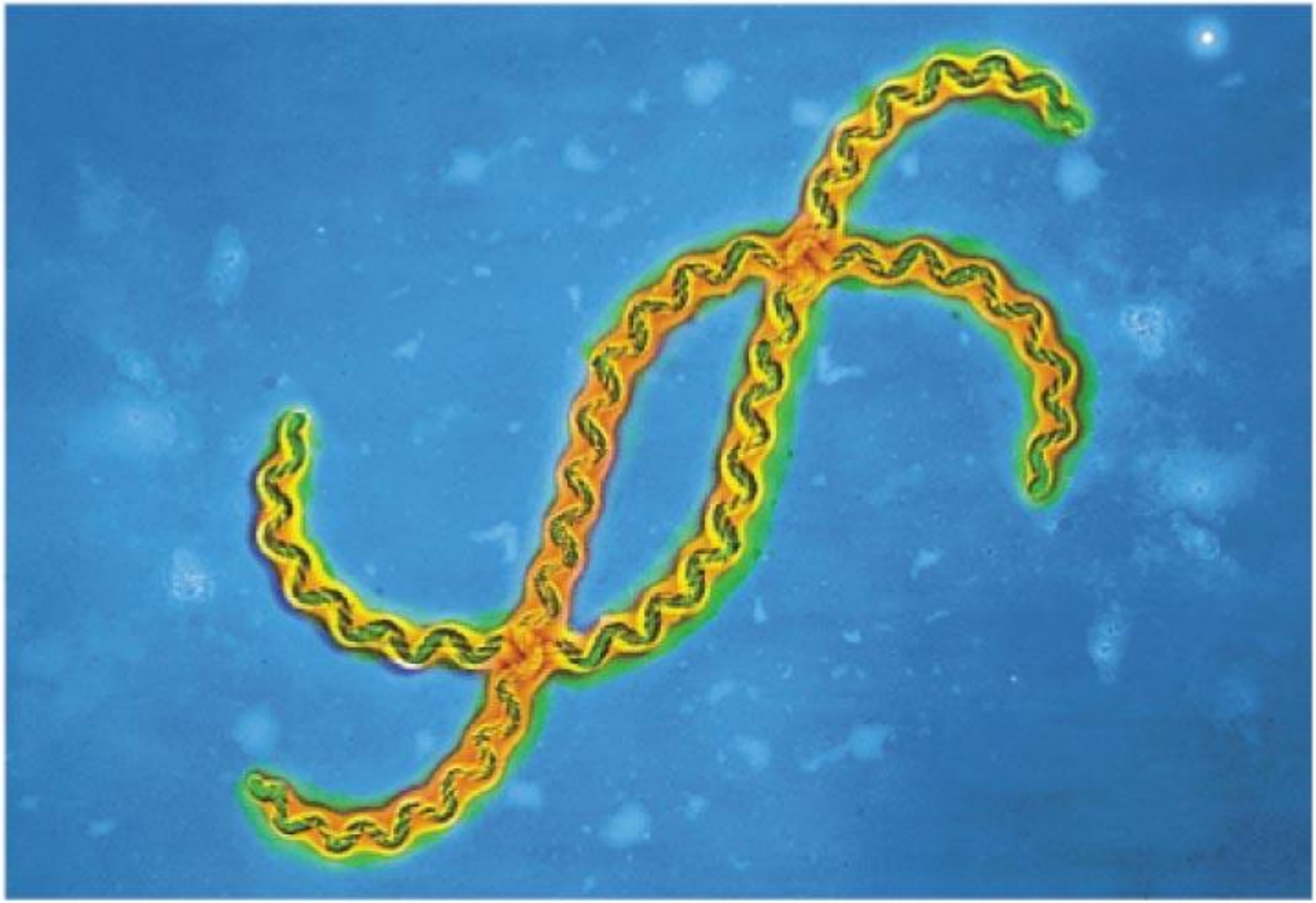
Staphyloccocus aureus



Bacillus sp.



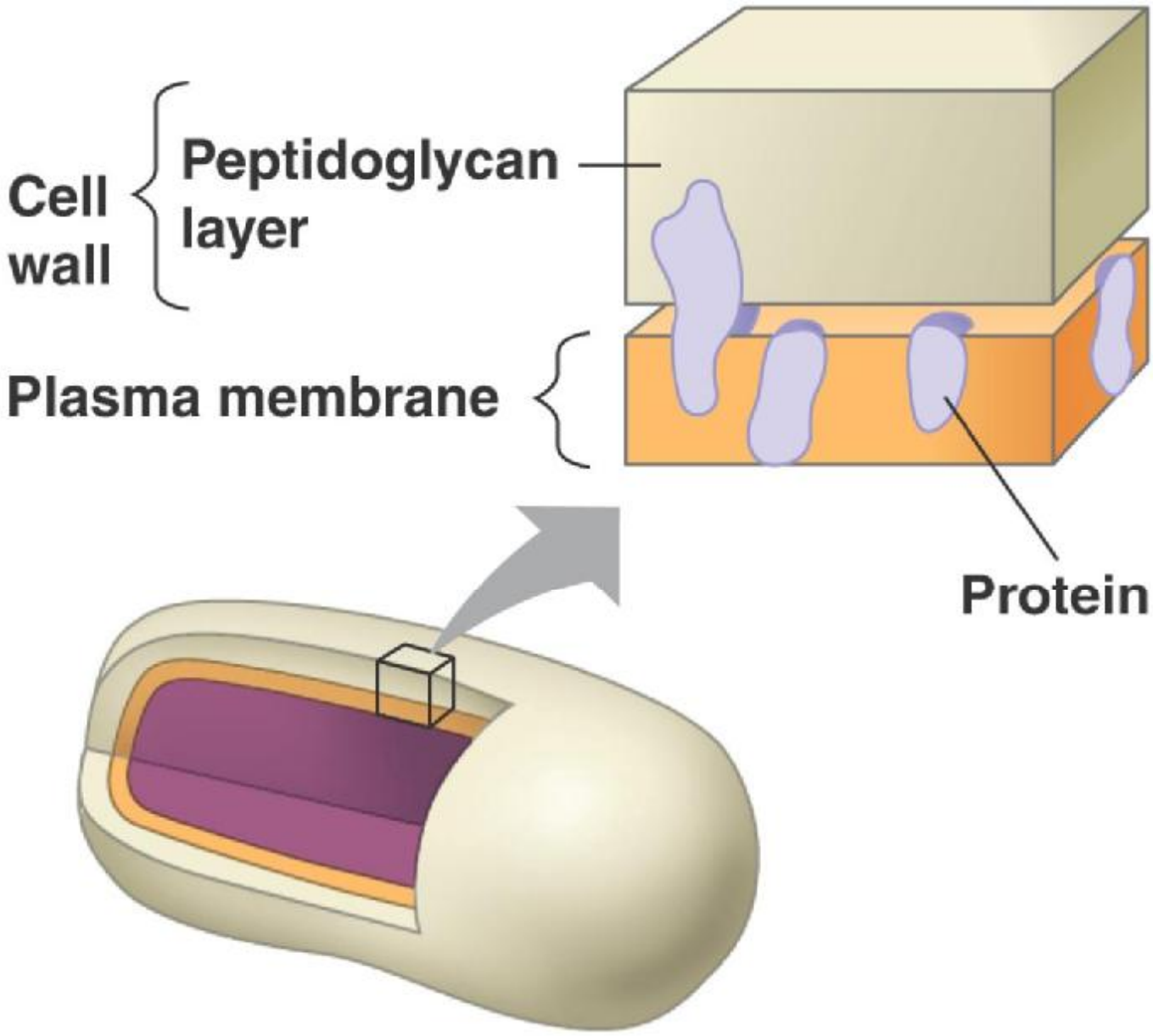
Leptospira



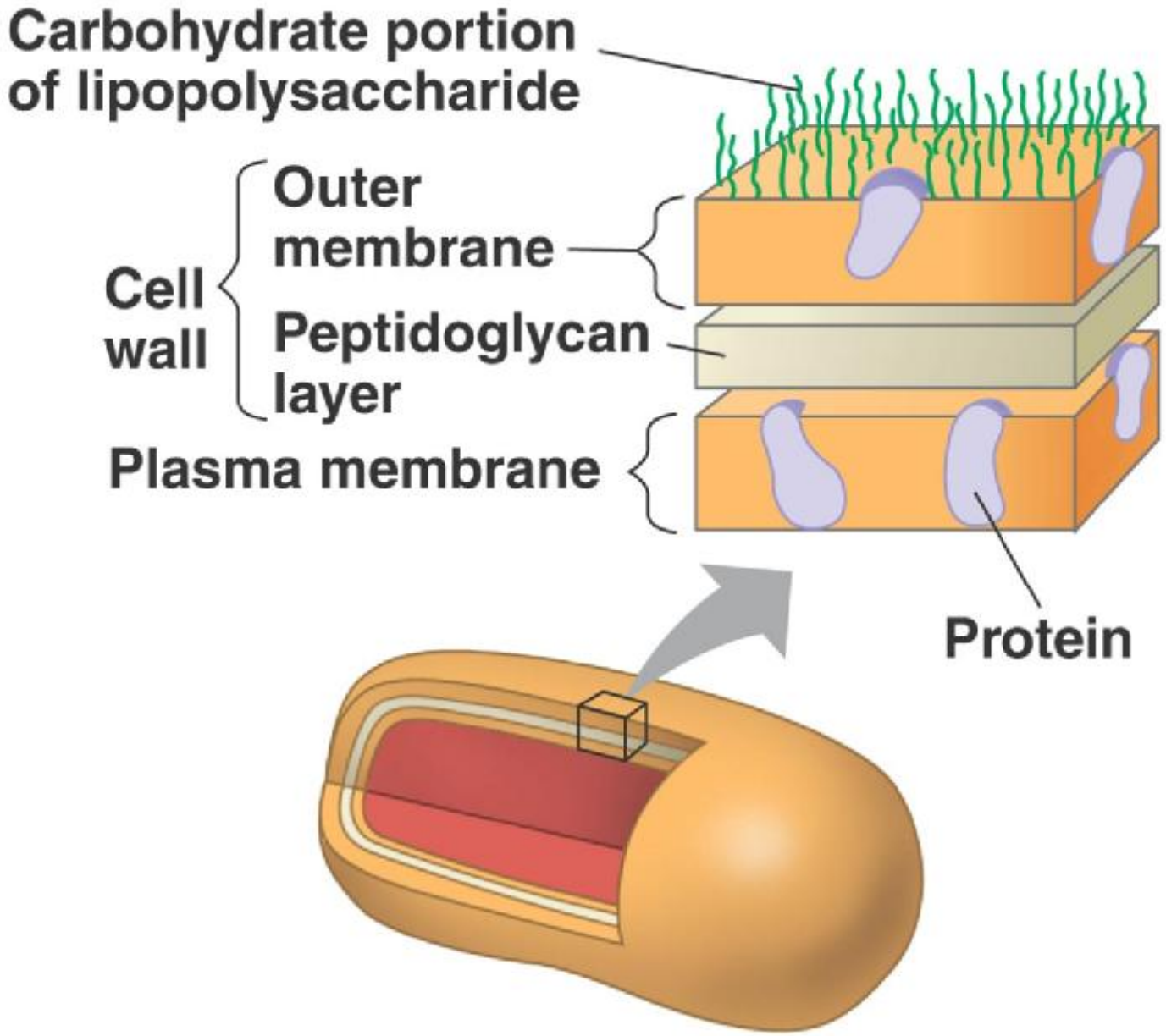
Cell-Surface Structures

- One of the most important features of nearly all prokaryotic cells is their cell wall:
  - maintains cell shape
  - provides physical protection
  - prevents the cell from bursting(tràn) in a hypotonic(nhược trương) environment

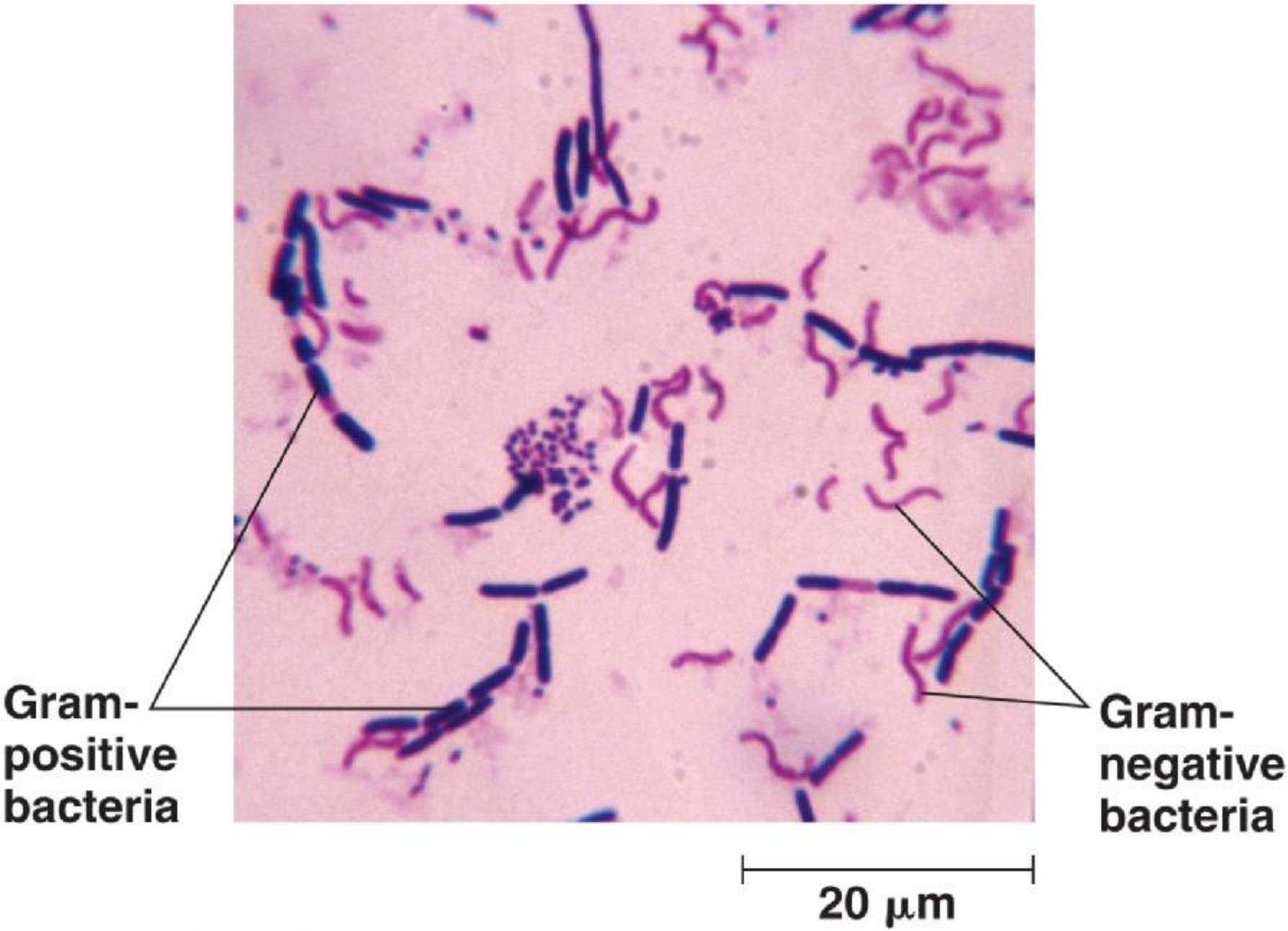
- Using a technique called the Gram stain, scientists can classify many bacterial species into two groups based on cell wall composition:
  - Gram-positive
  - Gram-negative



(a) Gram-positive: peptidoglycan traps crystal violet.

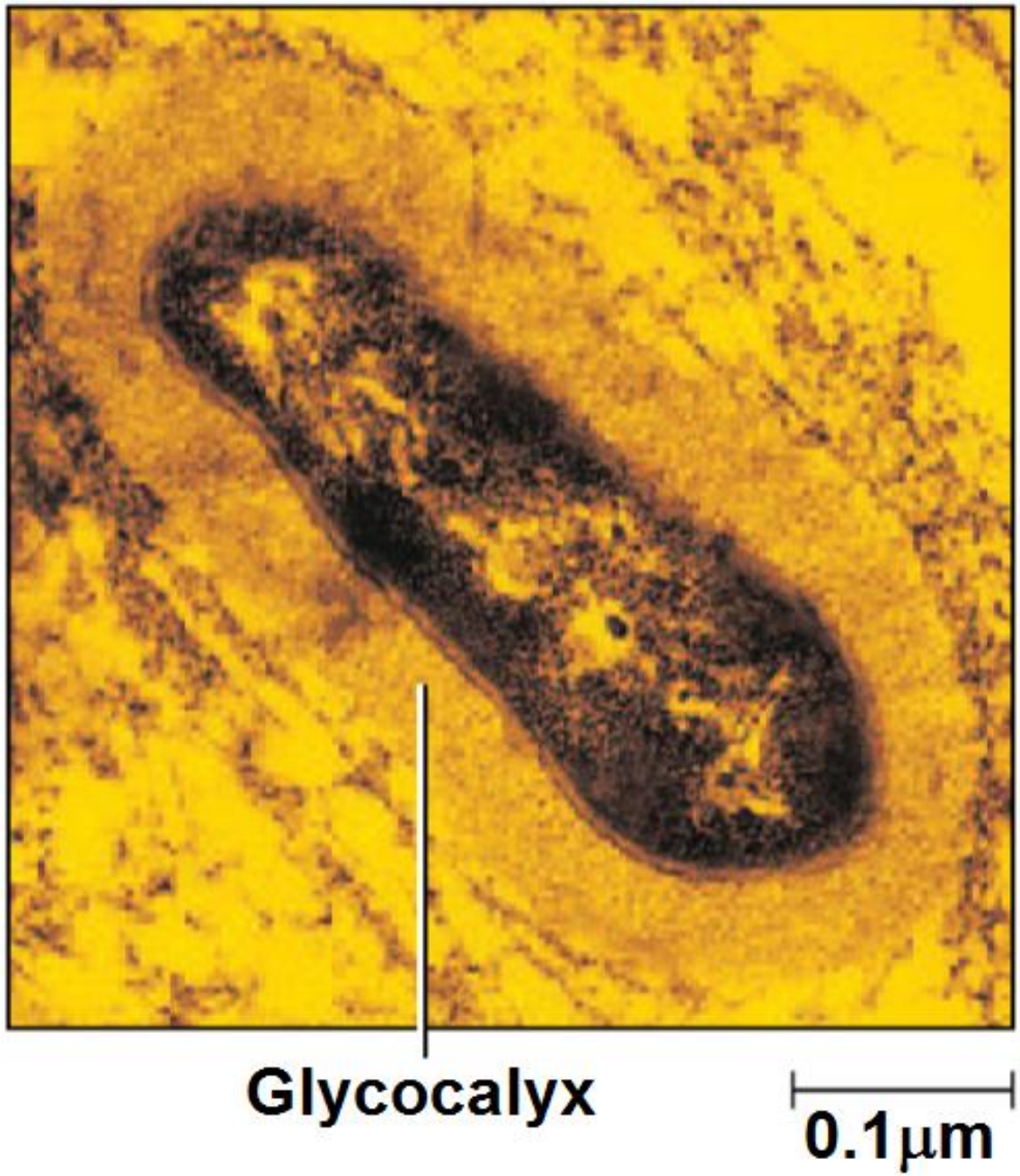


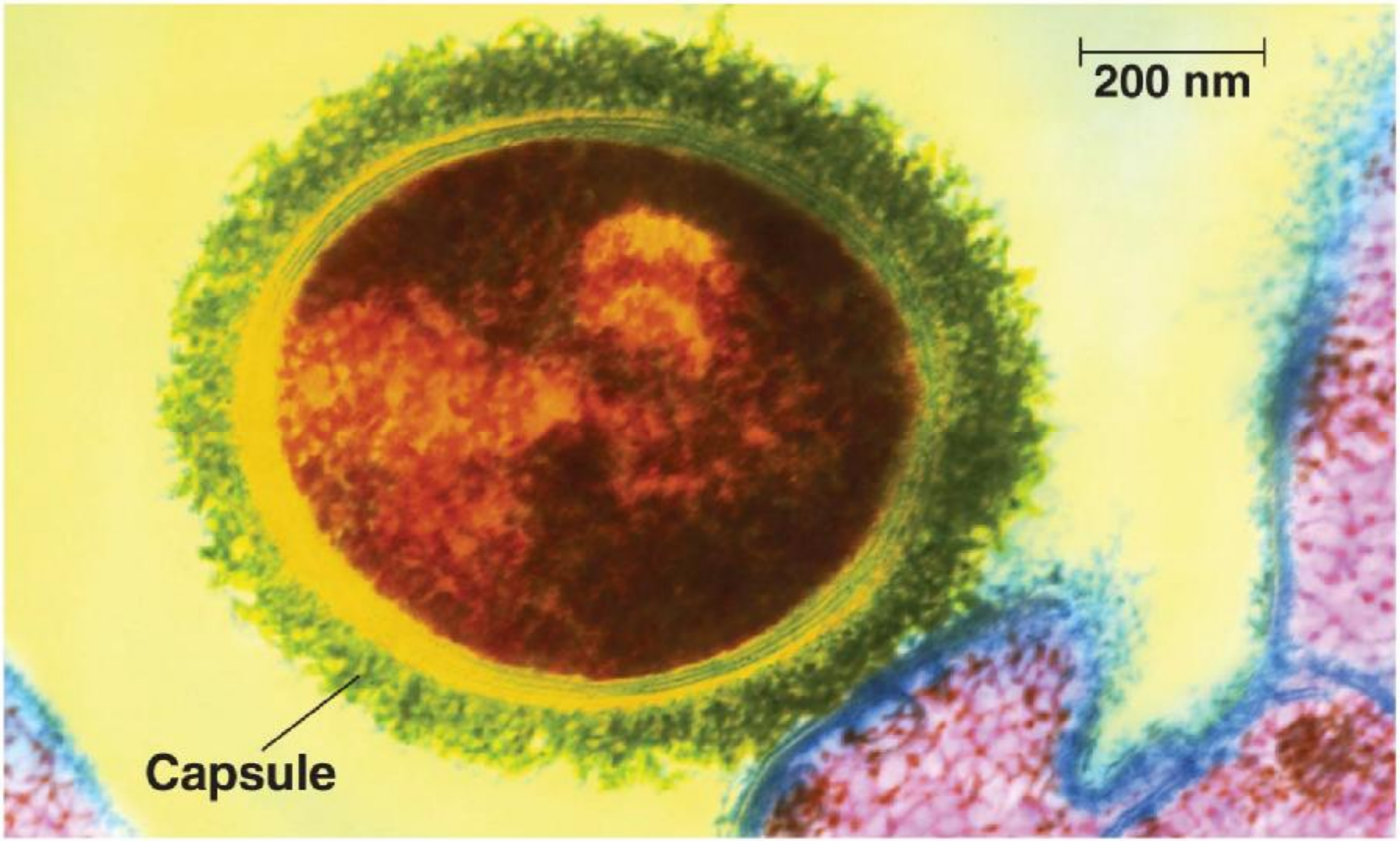
(b) Gram-negative: crystal violet is easily rinsed away, revealing red dye.


Gram-
positive
bacteria
Gram-
negative
bacteria
20 μm

Cell walls

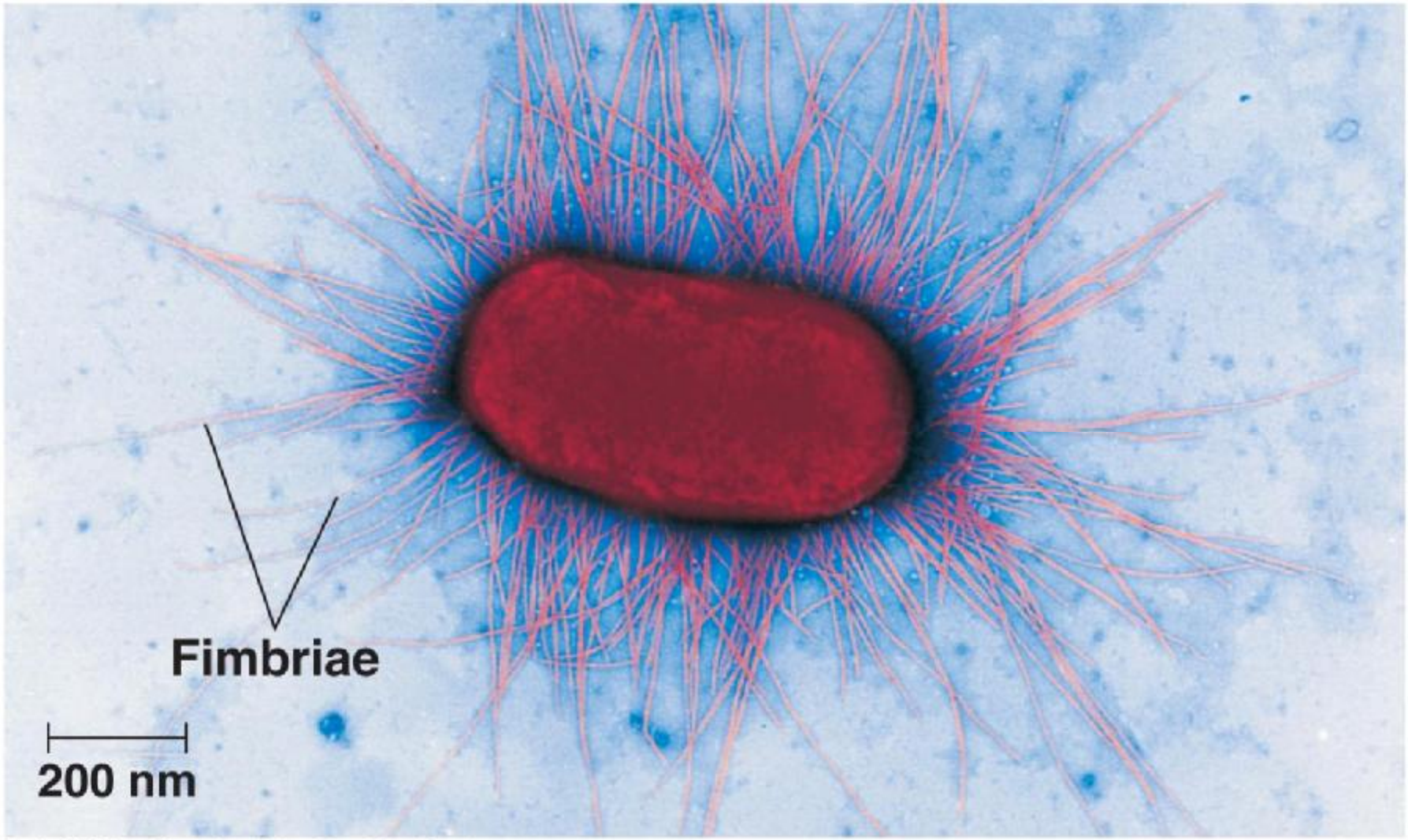
- Bacterial cell walls
  - contain a complex, cross-linked polysaccharide called peptidoglycan
  - may be surrounded by a thick or thin sticky layer called a glycocalyx, which is composed of proteins and/or polysaccharides
  - A loose(lõng) glycocalyx is called a slime layer, and a firm glycocalyx is a capsule

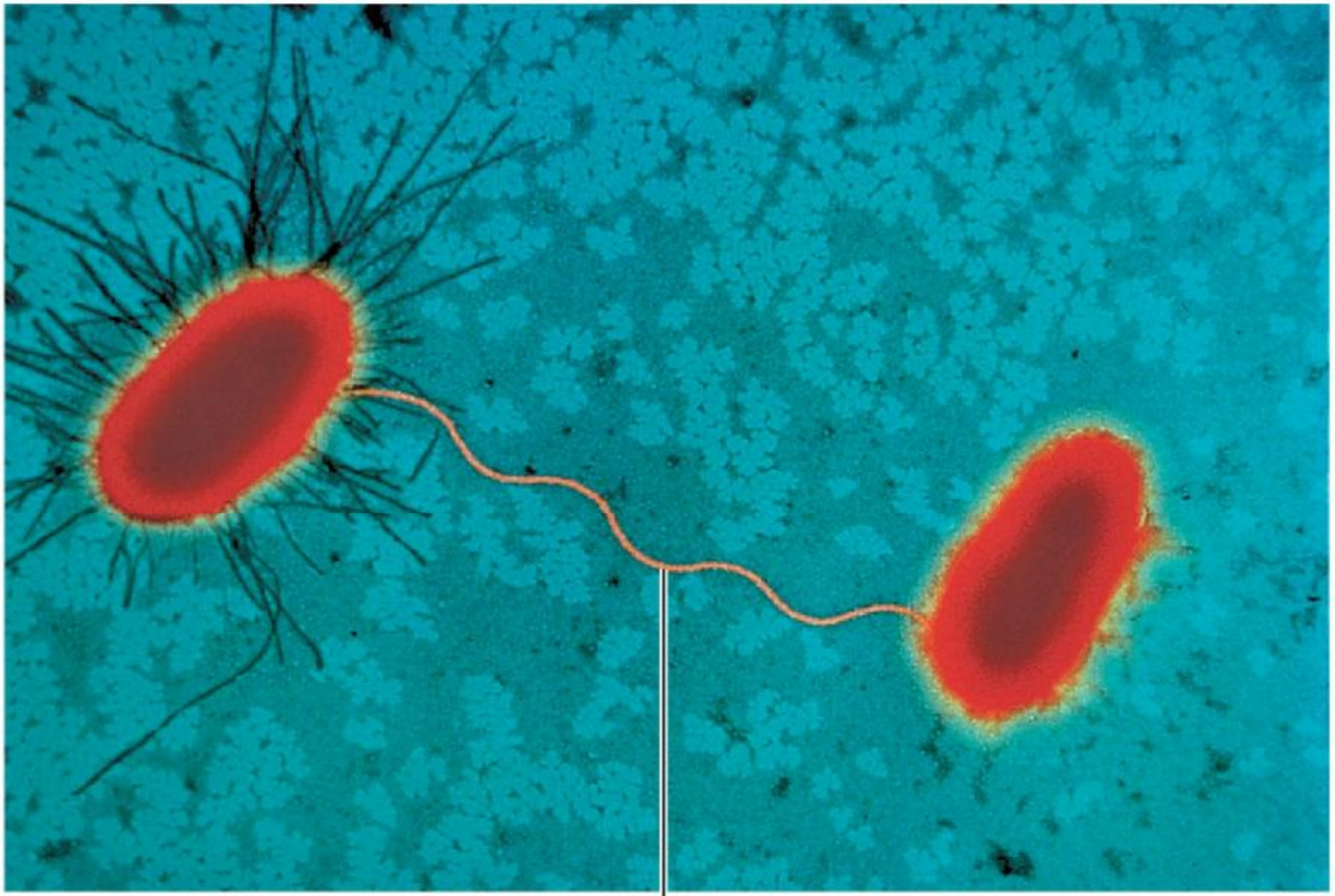

Glycocalyx
0.1μm



Cell walls

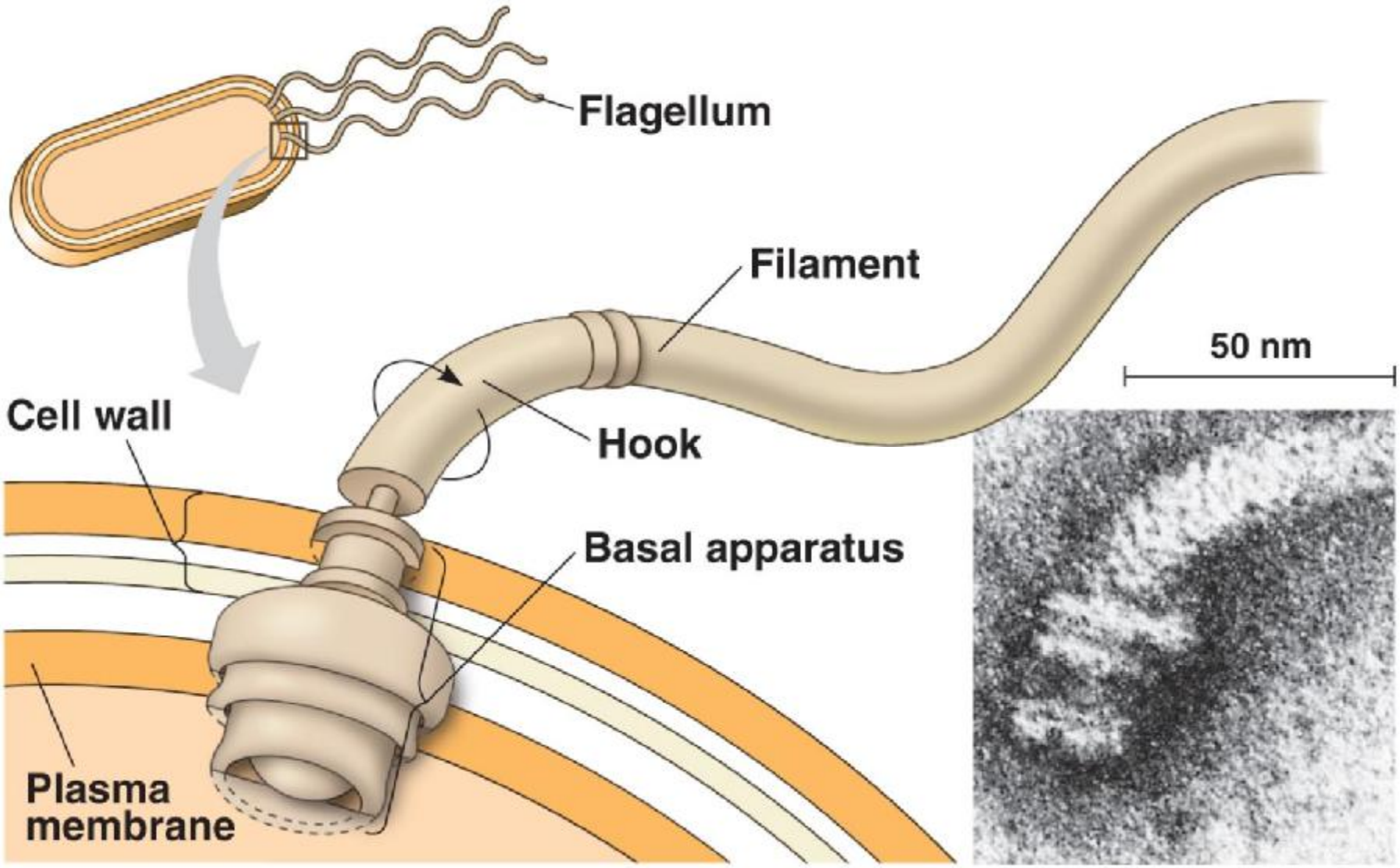
- Some prokaryotes have pili
  - Which allow them to stick to their substrate or other individuals in a colony(đàn)
  - Sex pili, which occur only in certain bacterial groups, can aid(giúp đỡ) in the transfer of DNA from cell to cell.





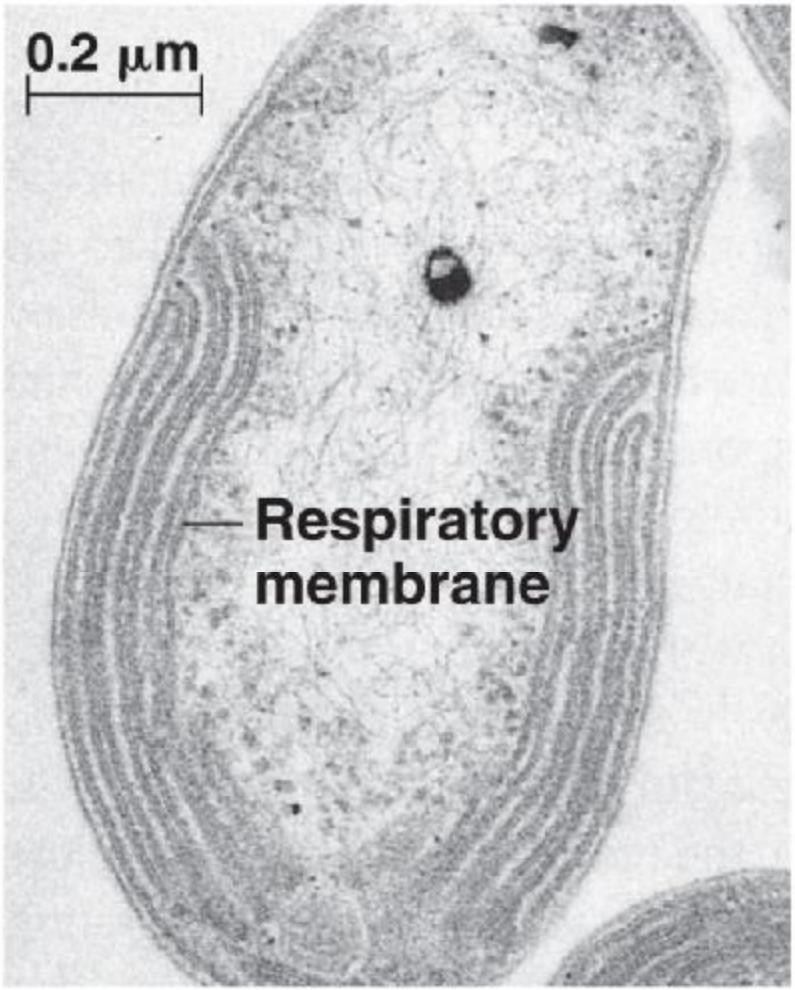
Motility(di động)

- Most motile bacteria propel(đẩy tới) themselves by flagella(roi)
  - Which are structurally and functionally different from eukaryotic flagella
- In a heterogeneous(hỗn tạp) environment, many bacteria exhibit(đưa ra) taxis
  - The ability to move toward or away from certain stimuli



Internal and Genomic(bộ gen) Organization

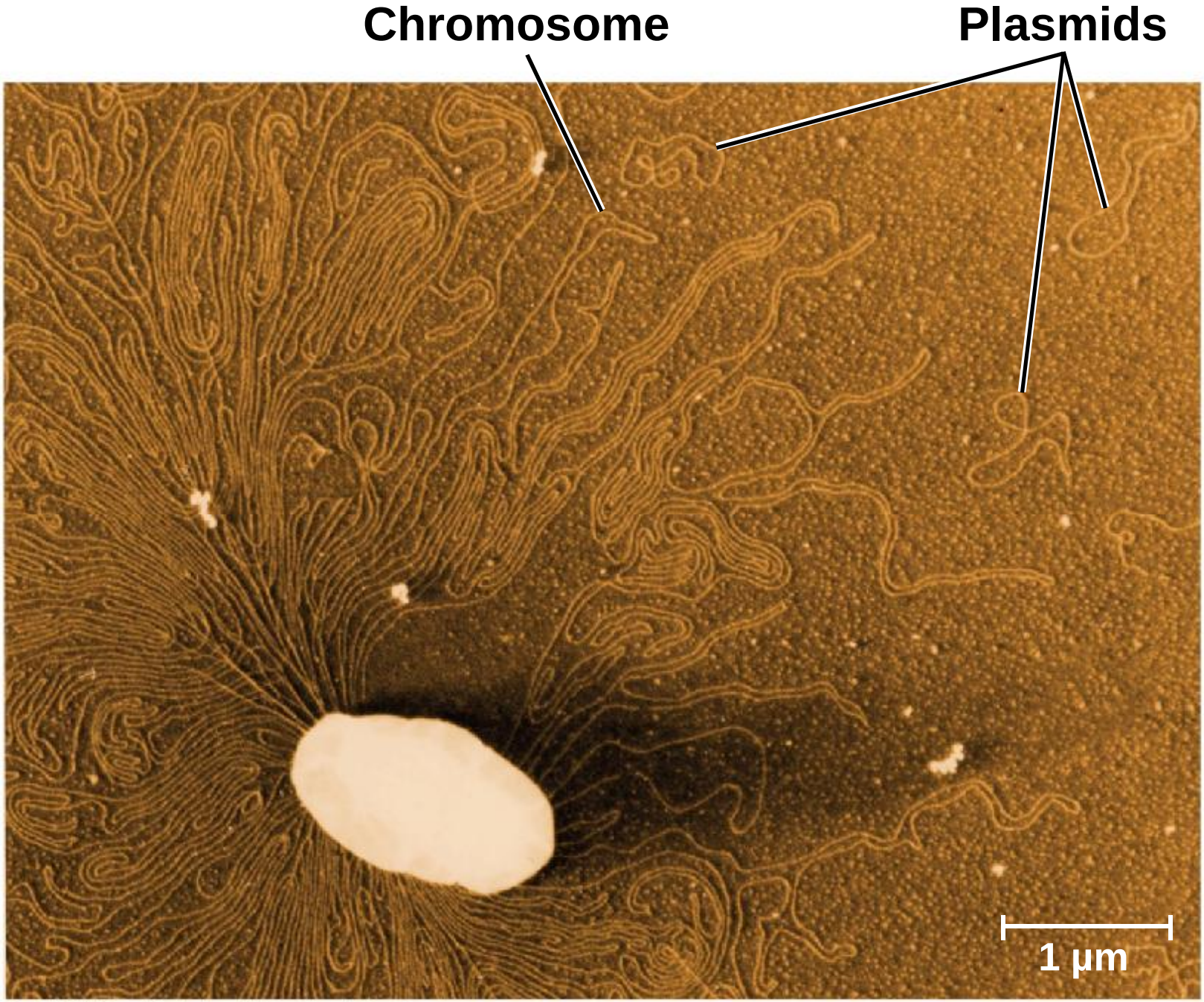
- Prokaryotic cells
  - Usually lack complex compartmentalization(chia thành ngăn)
- Some prokaryotes
  - Do have specialized membranes that perform metabolic functions



(a) Aerobic prokaryote

(b) Photosynthetic prokaryote

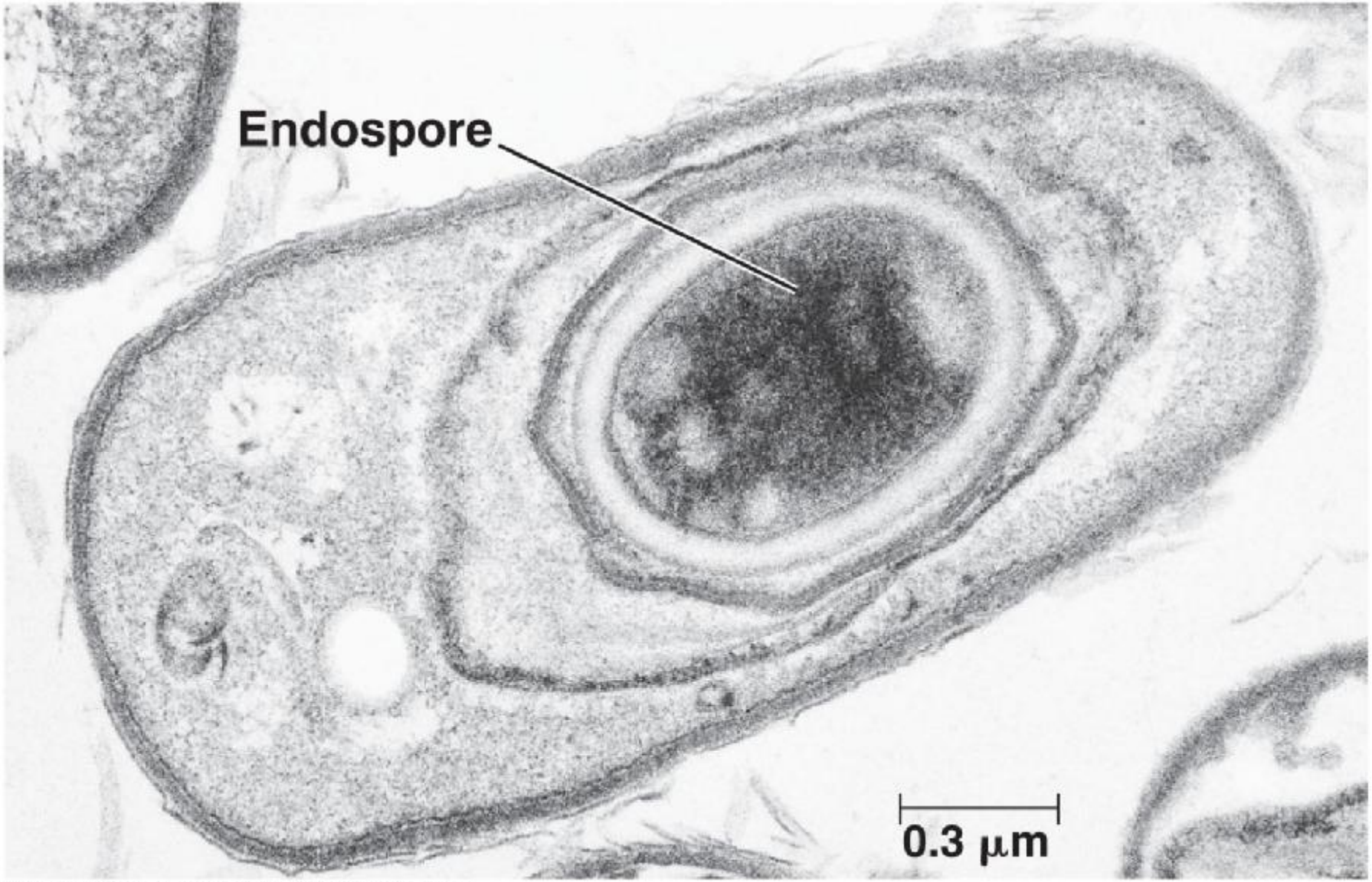
- The typical prokaryotic genome
  - Is a ring of DNA that is not surrounded by a membrane and that is located in a nucleoid region
- Some species of bacteria
  - Also have smaller rings of DNA called plasmids



Reproduction and Adaptation

- Prokaryotes reproduce quickly by binary fission(nguyên phân)
  - And can divide every 1–3 hours
- Many prokaryotes form endospores(nội bào tử)
  - Which can remain viable in harsh conditions for centuries

Binary fisson (SEM)



Nutritional modes in prokaryotes

Table 27.1 Major Nutritional Modes

Mode of Nutrition	Energy Source	Carbon Source	Types of Organisms
Autotroph			
Photoautotroph	Light	CO_2	Photosynthetic prokaryotes (for example, cyanobacteria); plants; certain protists (algae)
Chemoautotroph	Inorganic chemicals	CO_2	Certain prokaryotes (for example, *Sulfolobus*)
Heterotroph			
Photoheterotroph	Light	Organic compounds	Certain prokaryotes (for example, *Rhodobacter, Chloroflexus*)
Chemoheterotroph	Organic compounds	Organic compounds	Many prokaryotes (for example, *Clostridium*) and protists; fungi; animals; some plants

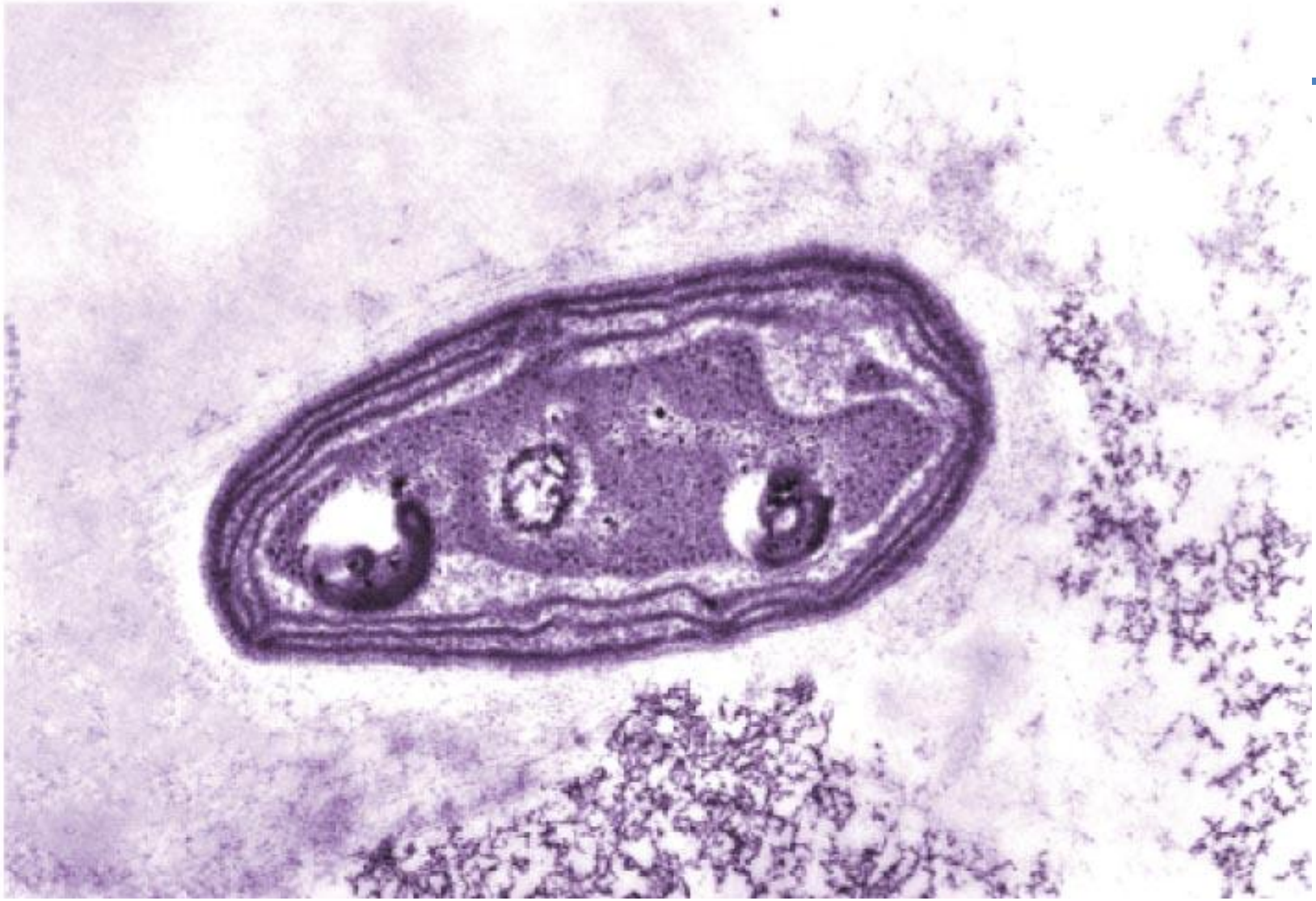
Metabolic Relationships to Oxygen

- Prokaryotic metabolism
  - Also varies with respect to oxygen
- Obligate aerobes
  - Require oxygen
- Facultative anaerobes
  - Can survive with or without oxygen
- Obligate anaerobes
  - Are poisoned by oxygen

Nitrogen Metabolism

- Prokaryotes can metabolize nitrogen
  - In a variety of ways
- In a process called nitrogen fixation
  - Some prokaryotes convert atmospheric nitrogen to ammonia

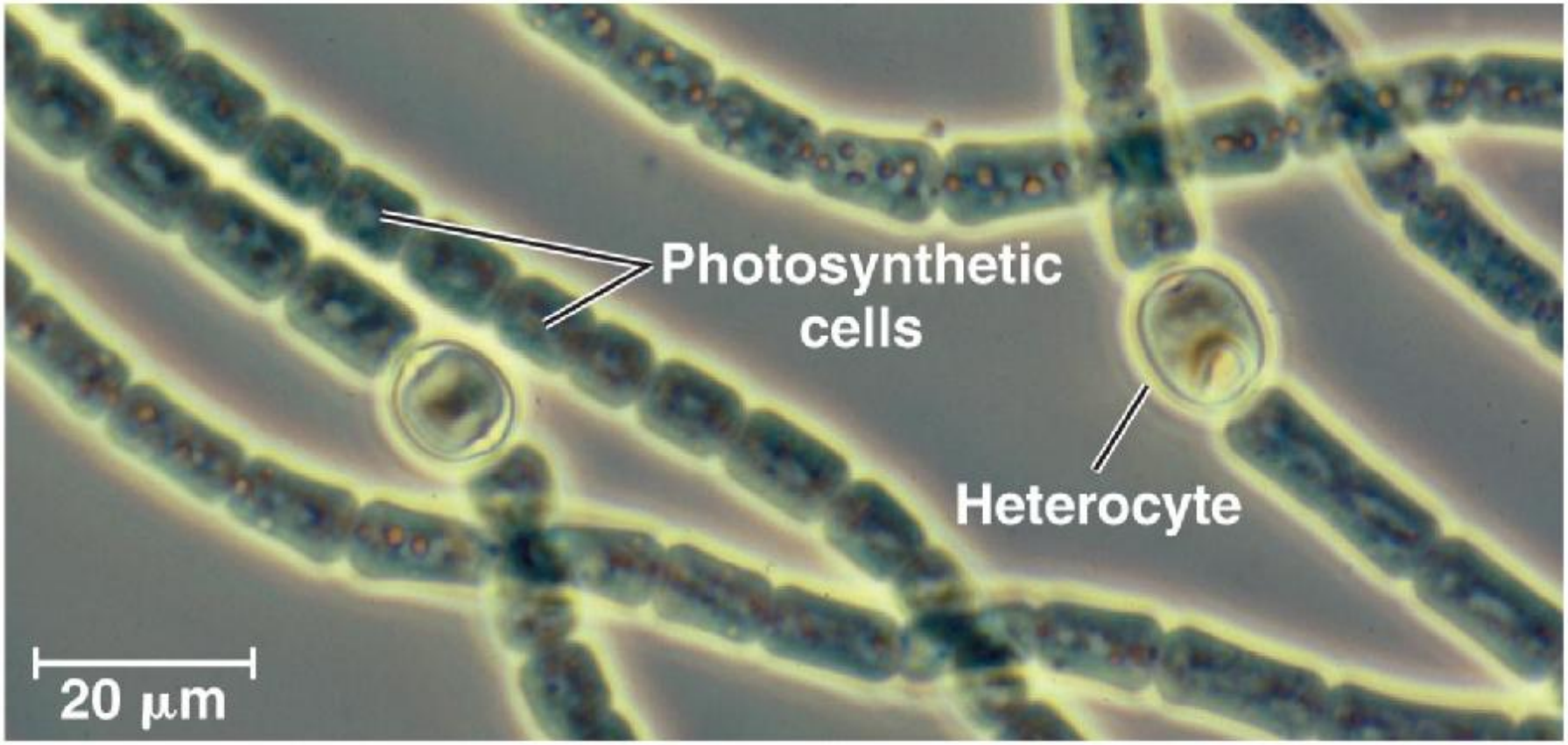
Rhizobium (arrows) inside a root cell of a legume (TEM)

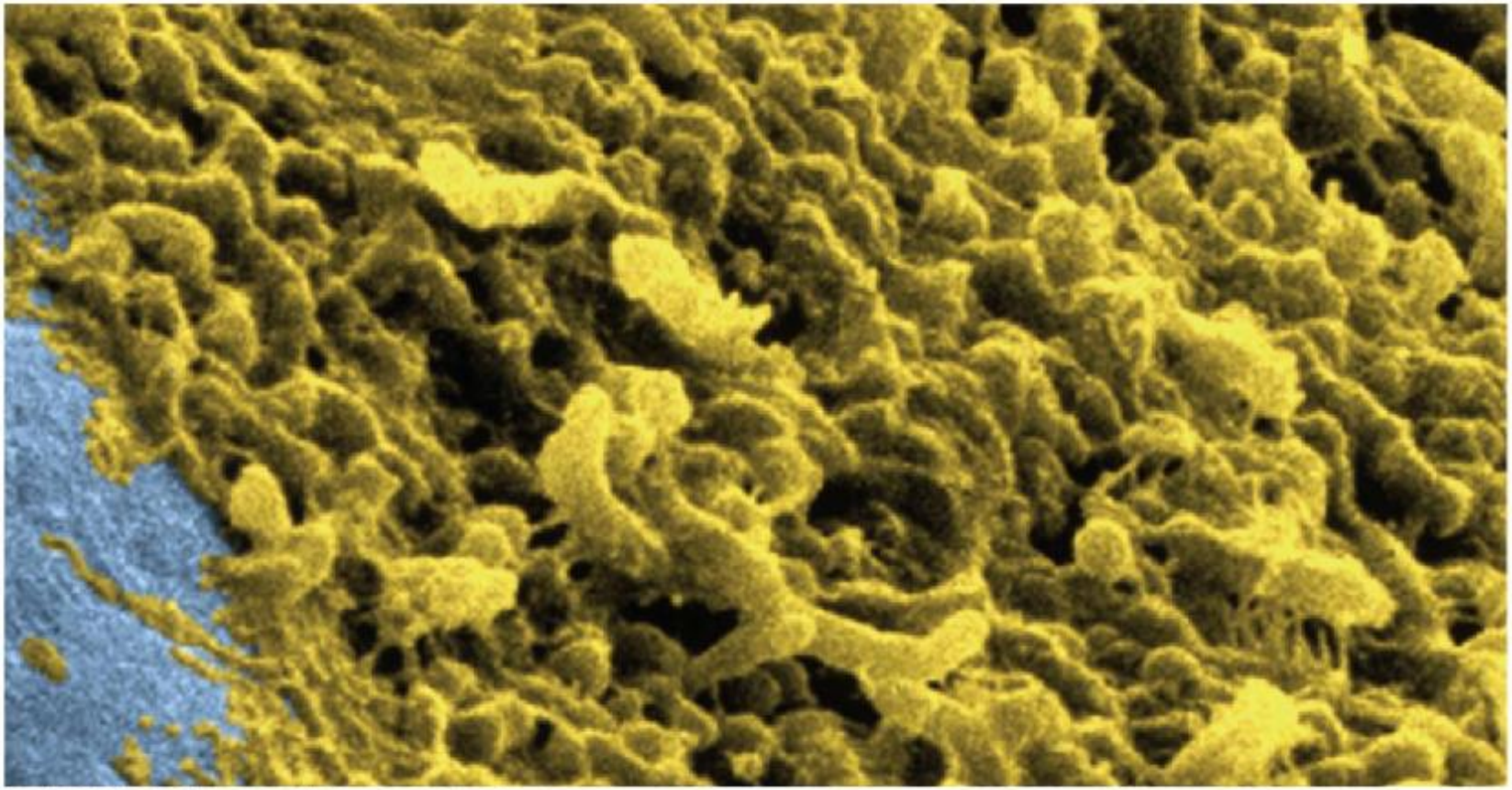


Nitrosomonas (colorized TEM)

Metabolic Cooperation

- Cooperation between prokaryotes
  - Allows them to use environmental resources they could not use as individual cells
- In the cyanobacterium *Anabaena*
  - Photosynthetic cells and nitrogen-fixing cells exchange metabolic products
- In some prokaryotic species
  - Metabolic cooperation occurs in surface-coating colonies called biofilms





Archaea

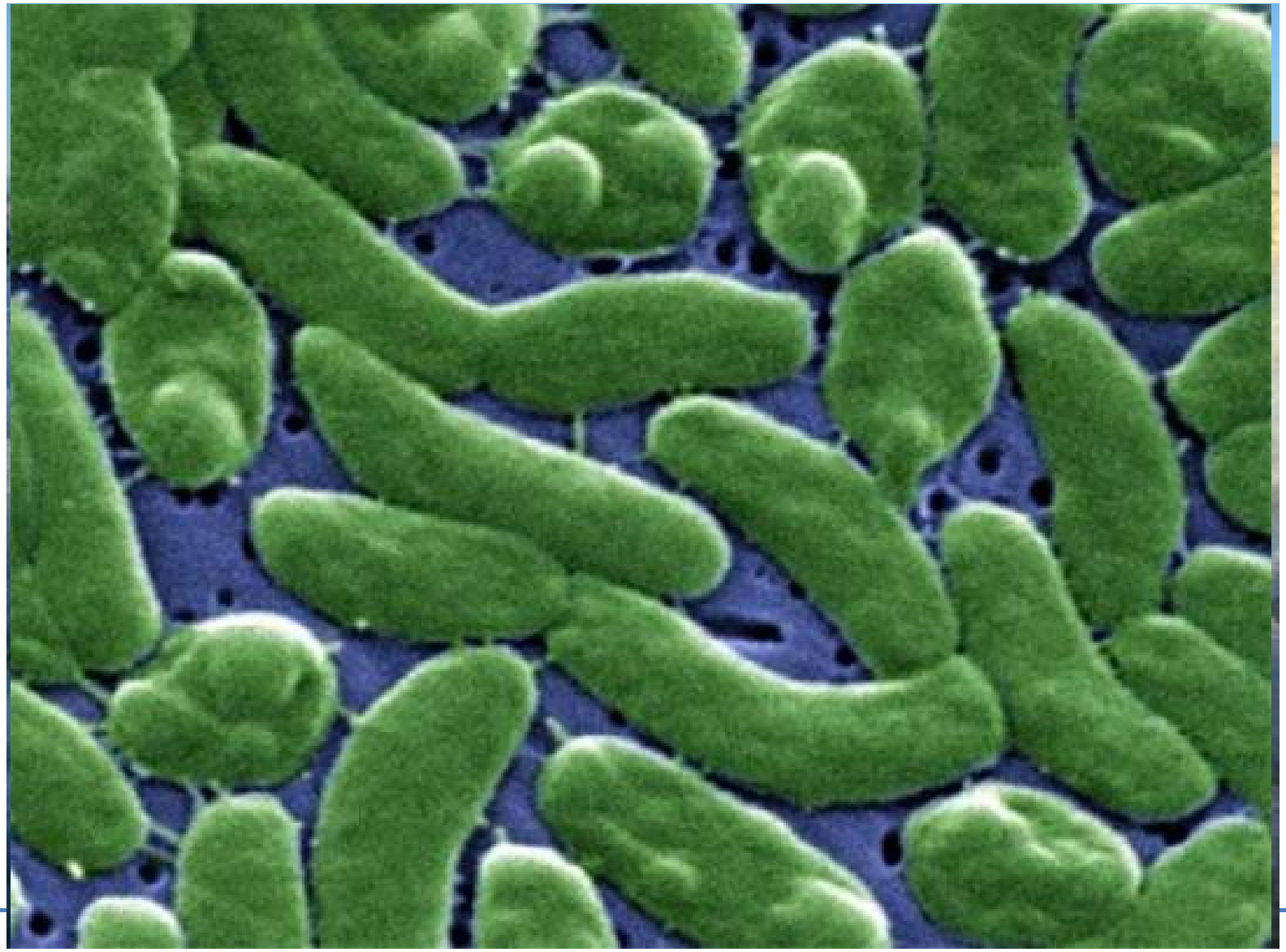
- Archaea share certaintraits with bacteria and other traits with eukaryotes

Table 27.2 A Comparison of the Three Domains of Life

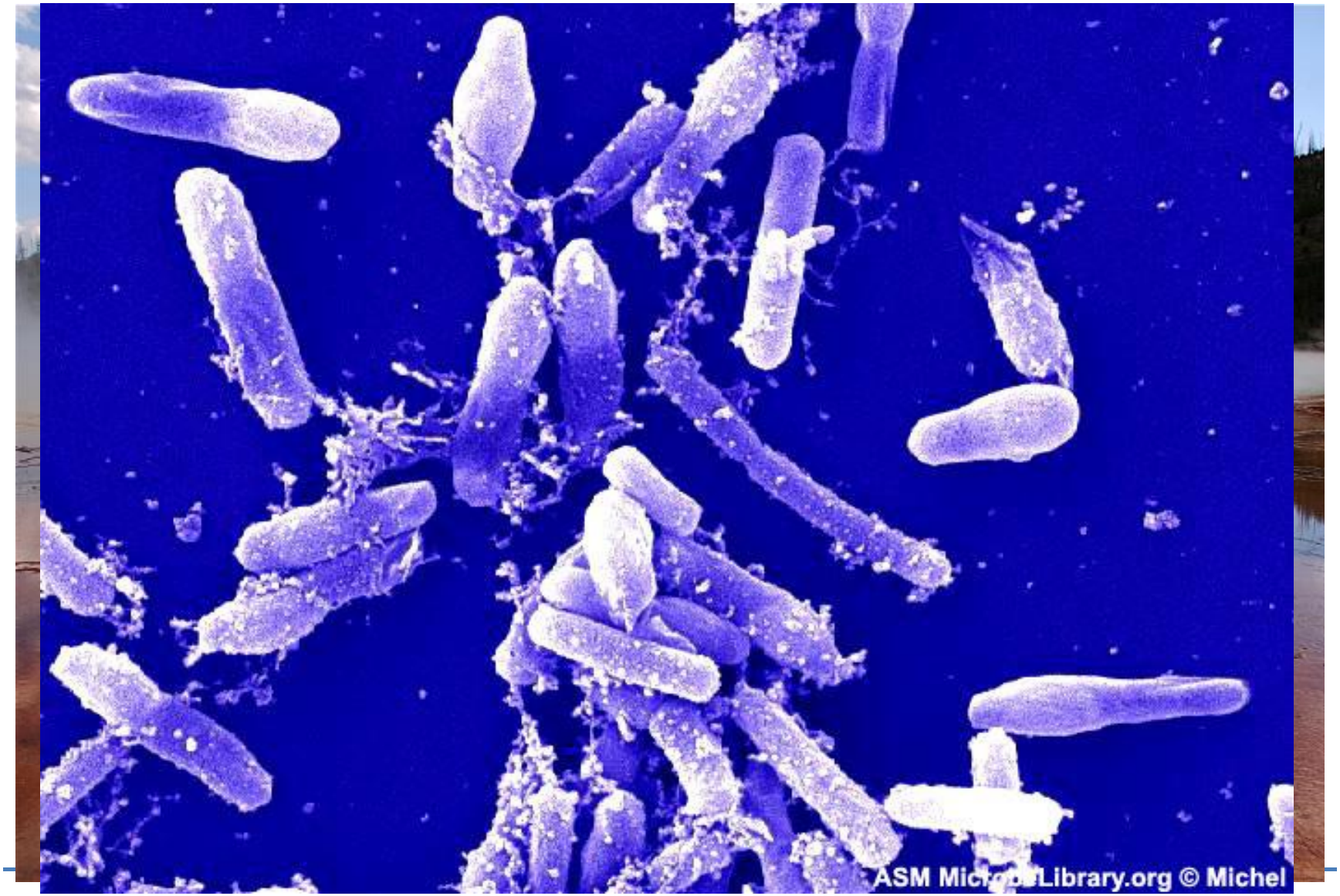
CHARACTER	DOMAIN		
	Bacteria	**Archaea**	**Eukarya**
Nuclear envelope	Absent	Absent	Present
Membrane-enclosed organelles	Absent	Absent	Present
Peptidoglycan in cell wall	Present	Absent	Absent
Membrane lipids	Unbranched hydrocarbons	Some branched hydrocarbons	Unbranched hydrocarbons
RNA polymerase	One kind	Several kinds	Several kinds
Initiator amino acid for protein synthesis	Formyl-methionine	Methionine	Methionine
Introns in genes	Very rare	Present in some genes	Present
Response to the antibiotics streptomycin and chloramphenicol	Growth inhibited	Growth not inhibited	Growth not inhibited
Histones associated with DNA	Absent	Present in some species	Present
Circular chromosome	Present	Present	Absent
Growth at temperatures > 100°C	No	Some species	No

- Archaea are described as “extremophiles” because they live in extreme environments: high temperatures, acidity, or salinity.
- There are three groups:
  - Thermophiles: thrive in very hot environments
  - Methanogens: live in swamps and marshes; produce methane as a waste product
  - Halophiles: live in very salty habitats such as seawater, evaporating ponds and salt flats

Halophiles



Thermophilic bacteria



Acidophilic bacteria

Deinococcus Radiodurans

The Ecological Impact of Prokaryotes

- Prokaryotes are so important to the biosphere that if they were to disappear
  - The prospects for any other life surviving would be dim

Chemical Recycling

- Prokaryotes play a major role
  - In the continual recycling of chemical elements between the living and nonliving components of the environment in ecosystems
- Chemoheterotrophic prokaryotes function as decomposers
  - Breaking down corpses, dead vegetation, and waste products
- Nitrogen-fixing prokaryotes
  - Add usable nitrogen to the environment

Symbiotic Relationships

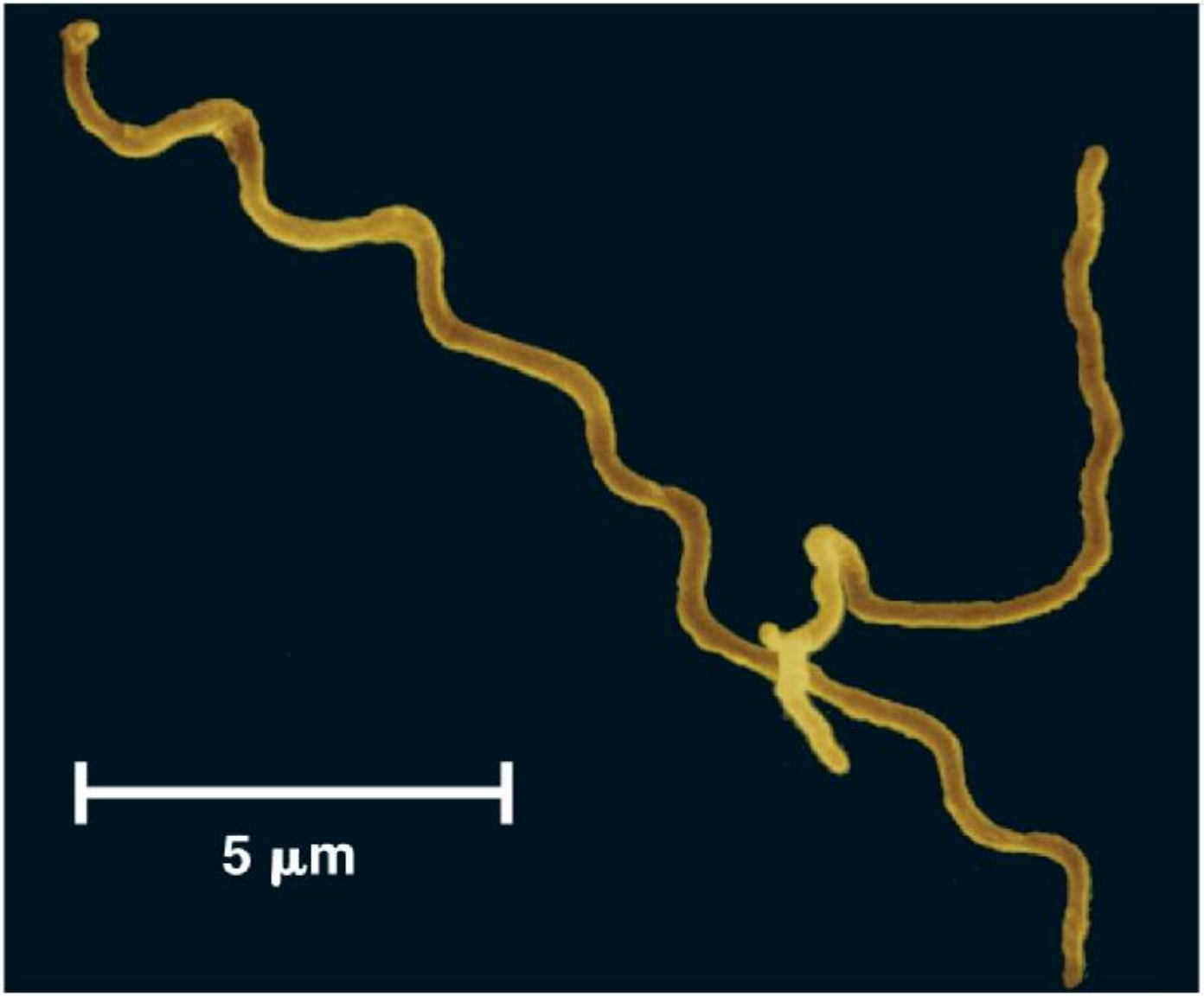
- Many prokaryotes
  - Live with other organisms in symbiotic relationships such as mutualism and commensalism
- Other types of prokaryotes
  - Live inside hosts as parasites

Harmful and beneficial impacts on humans

- Some prokaryotes are human pathogens
  - But many others have positive interactions with humans

Pathogenic Prokaryotes

- Prokaryotes cause about half of all human diseases
  - Lyme disease
    - Is caused by bacteria carried by ticks



***Borrelia burgdorferi* (SEM)**

- Pathogenic prokaryotes typically cause disease
  - By releasing exotoxins or endotoxins
  - Exotoxins are poisonous proteins secreted by bacterial cells
  - Endotoxins are chemical components of the cell walls of certain bacteria
- Many pathogenic bacteria
  - Are potential weapons of bioterrorism

Prokaryotes in Research and Technology

- Experiments using prokaryotes
  - Have led to important advances in DNA technology

Prokaryotes and Bioremediation

- Bioremediation is the use of organisms to remove pollutants from water, air, and soil
  - A familiar example is use of prokaryotic decomposers(phân li) in sewage treatment
  - Certain bacteria can decompose petroleum and are useful in cleaning up oil spills

- Prokaryotes are also major tools in
  - Mining(sự khai mỏ)
  - The synthesis of vitamins
  - Production of antibiotics, hormones, and other products

Streptomyces