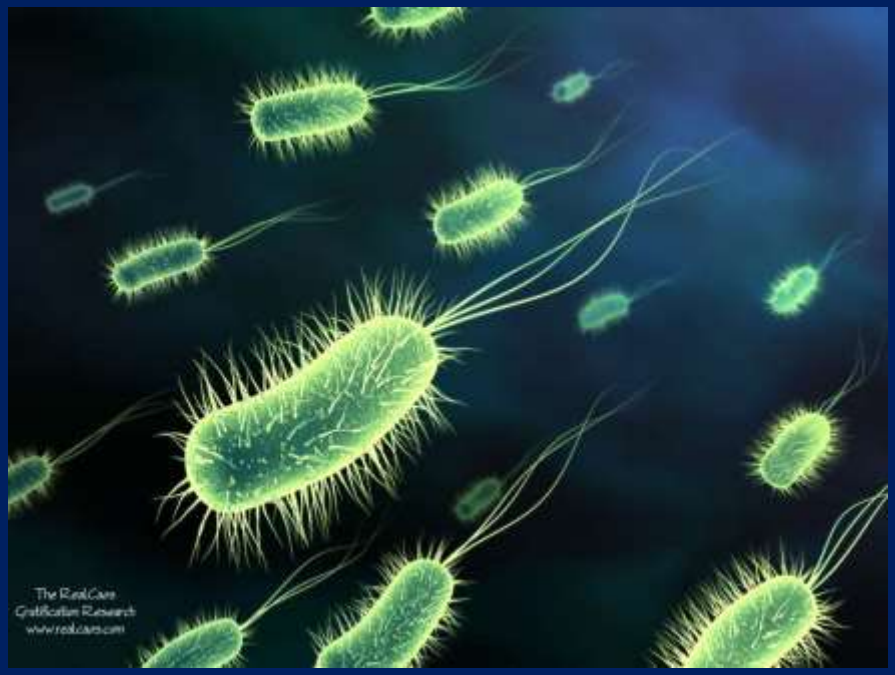
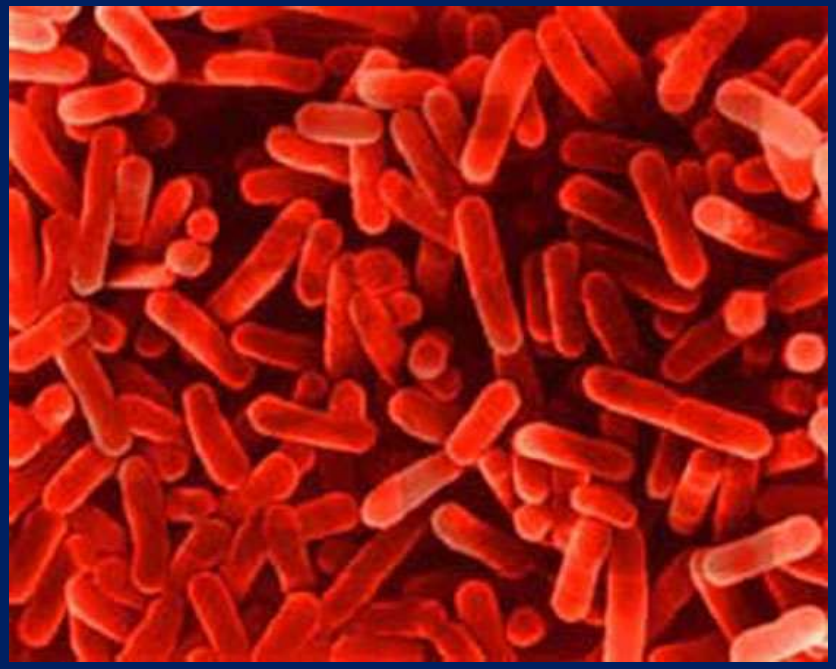
General Microbiology
Bio 127

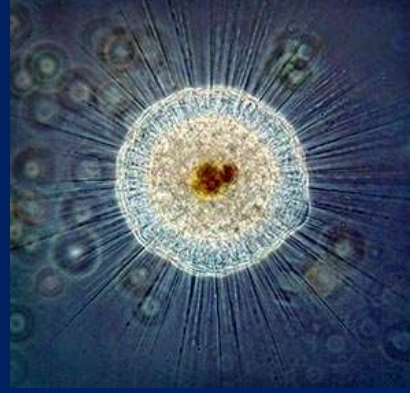




I. Introduction

A. The Science of Microbiology
B. History of Microbiology
C. Scope of Microbiology
D. Microbial world Defined

Microbiology

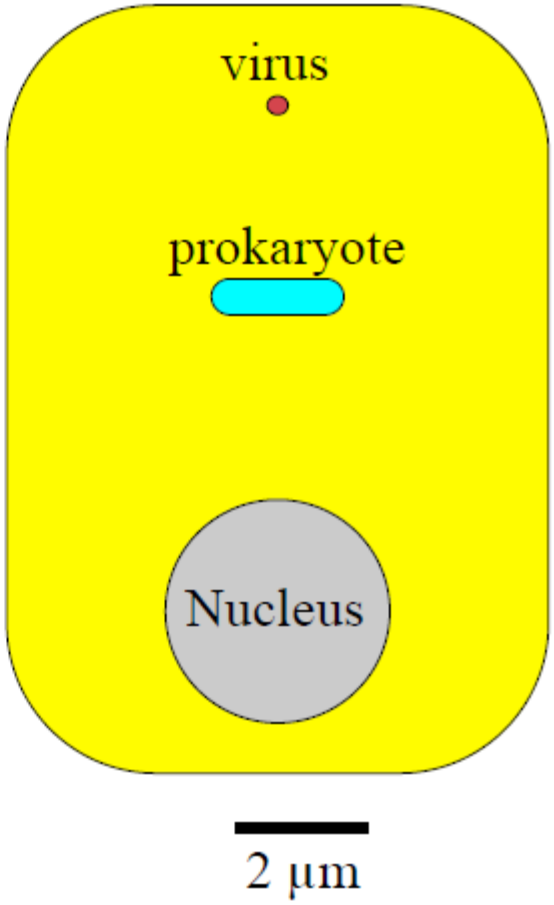


- the field of science that studies microorganisms- viruses, archaebacteria, eubacteria, fungi, algae and protozoa.

-derived its name from three Greek words: *mikros* (‘small’), *bios* (‘life’) and *logos* (‘science’)

Let's define a "microorganism"

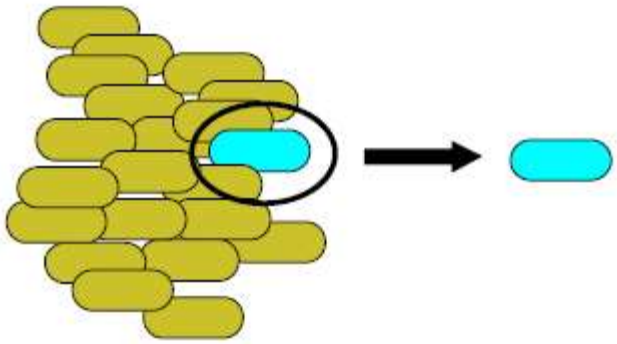
- Microorganism:
  - Can be eukaryotic, archaeal, or bacterial.
- Prokaryotes:
  - Lack membrane-bound nucleus
  - Self replicate
- We will focus is on the Prokaryotes
  - Bacteria and Archaea



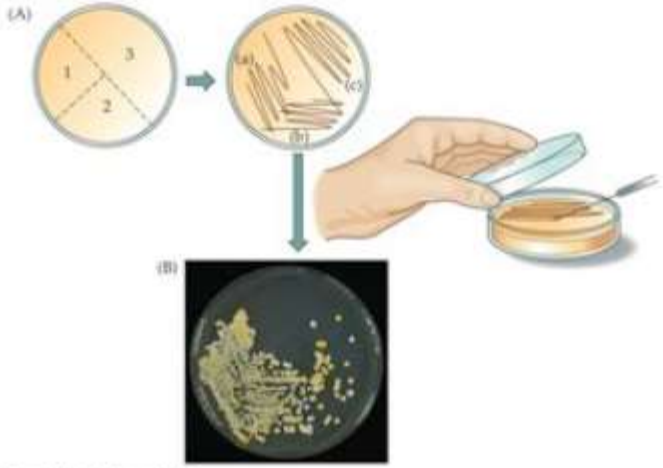
What is Microbiology

- Study of life too small to be seen unaided by eye
  - Need a microscope to see them

<0.1 mm too small to see



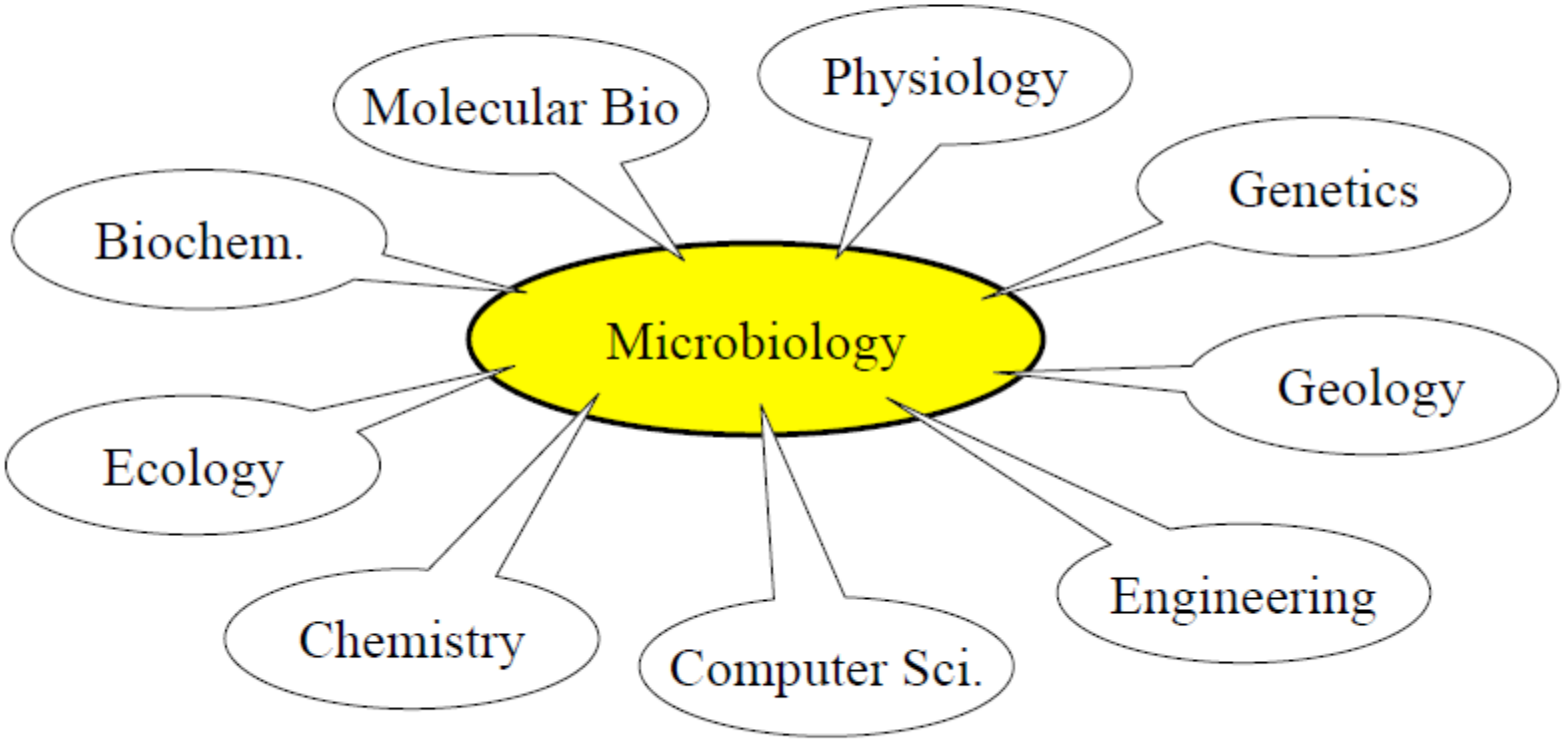
- Using techniques of microbiology
  - Isolate microorganisms
  - Study their characteristics



Microbial Life 2e, Figure 5.10

The science of microbiology

Microbiology can be highly interdisciplinary



Two Major areas in the field of microbiology

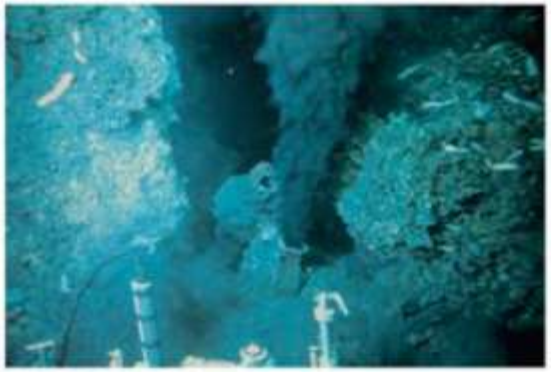
1. Basic Microbiology –where the fundamental nature and properties of microorganisms are studied

2. Applied Microbiology –where information learned from basic microbiology is employed to control and use microorganisms in beneficial ways

Why study microbiology?

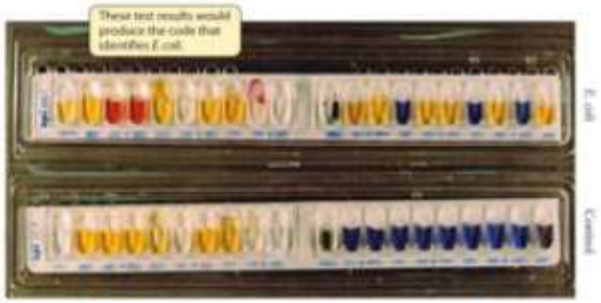
ENVIRONMENTAL

(A)



Microbial Life 2e, Figure 24.21 (Part 1)

MEDICAL

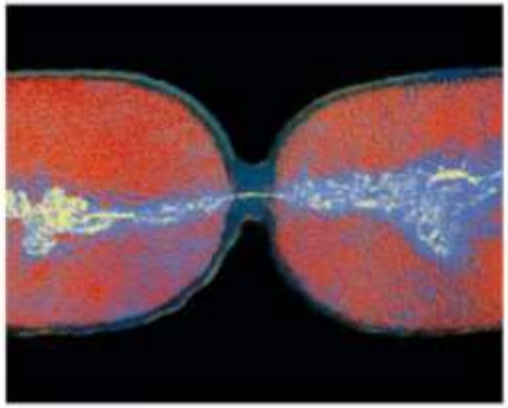


Microbial Life 2e, Figure 30.4

APPLIED SCIENCE

Microbial Life 2e, Part 8 Opener

BASIC SCIENCE



Microbial Life 2e, Part 4 Opener

Basic Microbiology

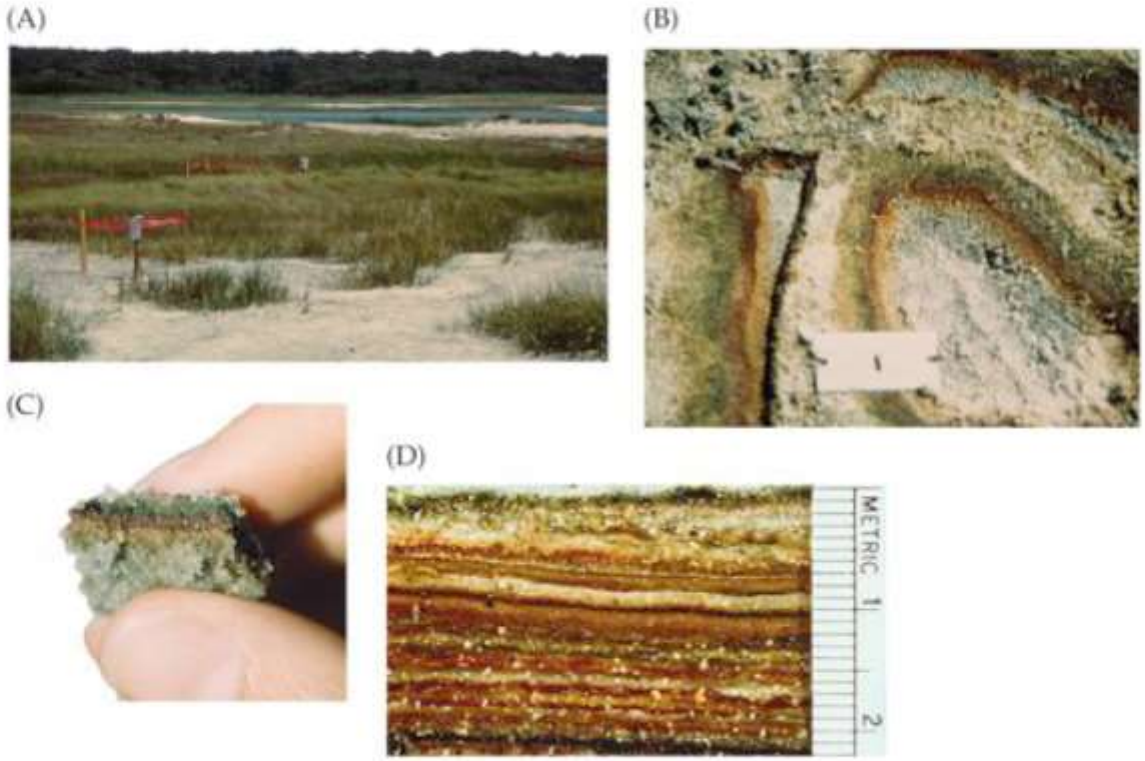
1. Morphological characteristics- the shape and size of cells, the chemical composition and fxns of internal structures
2. Physiological characteristics-the specific nutritional requirements and physical conditions needed for growth and reproduction
3. Biochemical activities-how the microbe breakdowns nutrients to obtain energy for synthesis of cellular components
4. Genetic characteristics-inheritance and variability of characteristic
5. Disease-causing potential-study of host-resistance to infection
6. Ecological characteristics-occurence in the environment and their relationships with other organisms
7. Classification

Applied Microbiology

1. Medical Microbiology
2. Immunology
3. Agricultural Microbiology
   Dairy Microbiology
   Soil Microbiology
   Food Microbiology
4. Industrial/Biotechnology Microbiology
   Sewage disposal
   Water Sanitation
5. Virology

Where to find microbes?

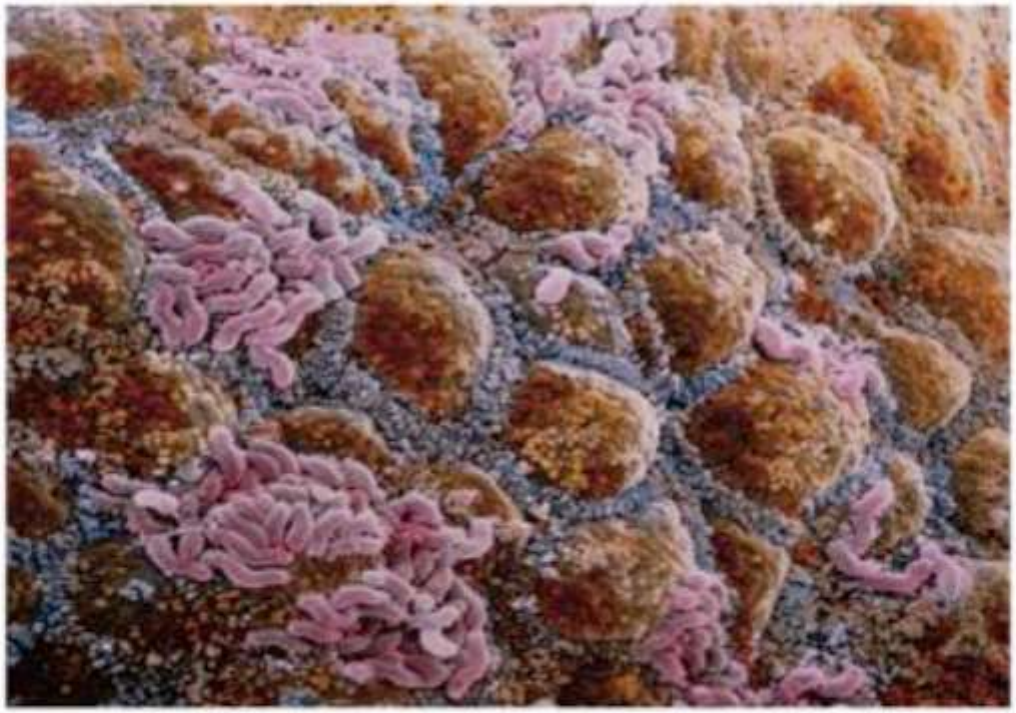
Ex. 1. In nature:



***Microbial Life 2e*, Figure 1.3**

Where to find microbe?

Ex. 2. In your intestines:



Microbial Life 2e, Figure 26.4

The Impact of Microorganisms on Humans

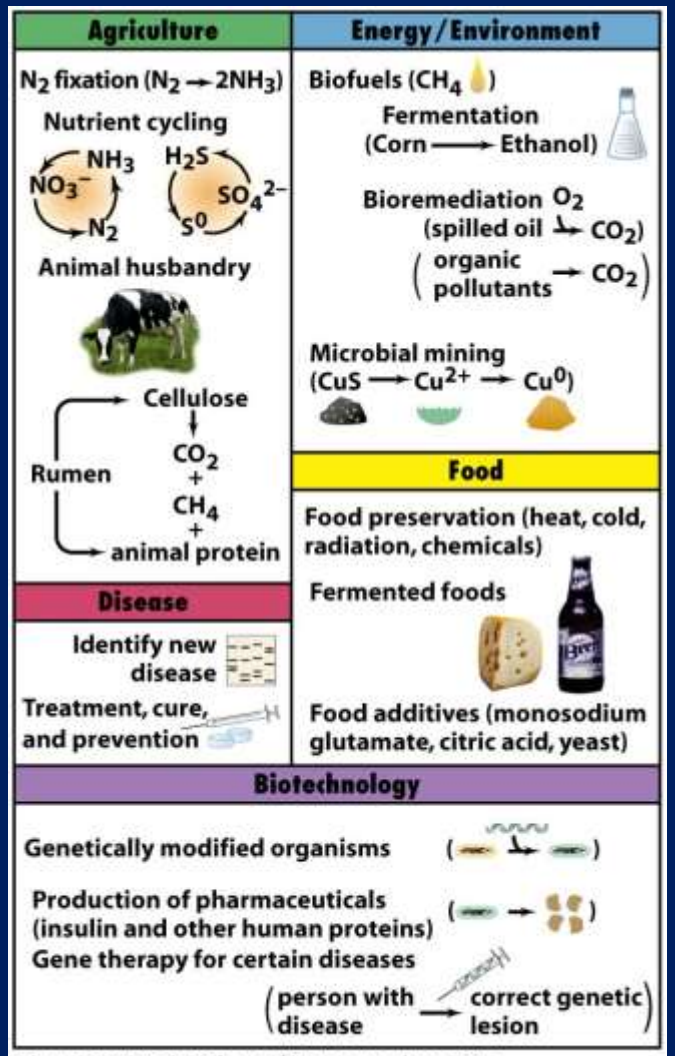


Figure 1-6 Brock Biology of Microorganisms 11/e

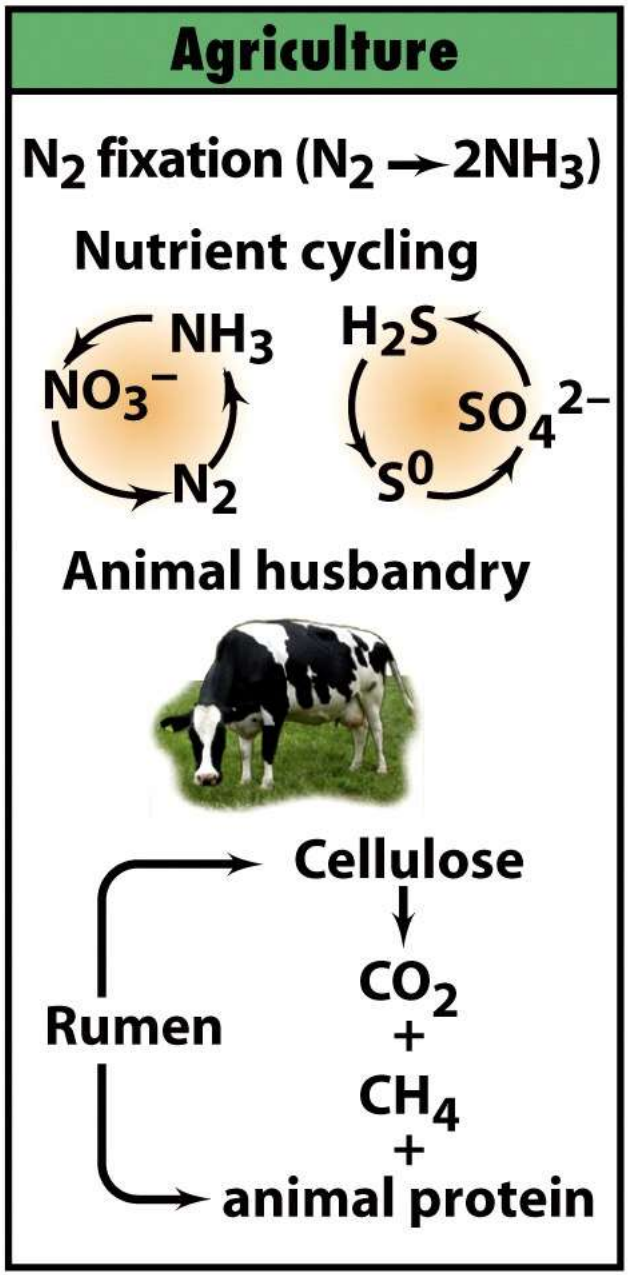


Figure 1-6 part 1 Brock Biology of Microorganisms 1

Energy / Environment

Biofuels (CH_4)

Fermentation

(Corn $\longrightarrow$ Ethanol)

Bioremediation O_2

(spilled oil $\rightarrow$ CO_2)

(organic pollutants $\rightarrow$ CO_2)

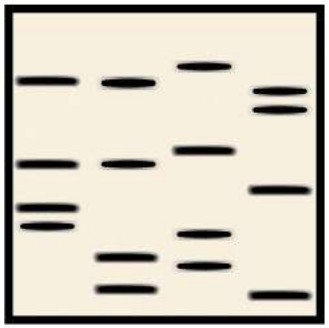
Microbial mining

($CuS \longrightarrow Cu^{2+} \longrightarrow Cu^0$)

Figure 1-6 part 2 Brock Biology of Microorganisms 11/e

Disease

Identify new disease



Treatment, cure, and prevention

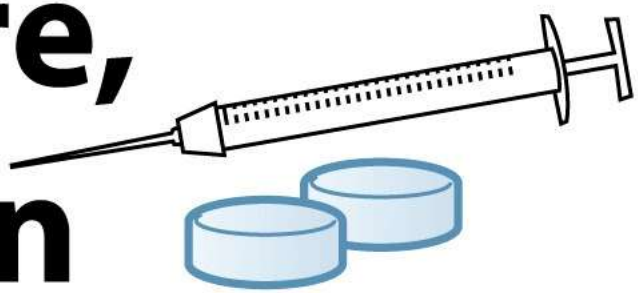


Figure 1-6 part 3 Brock Biology of Microorganisms 11/e

Food

Food preservation (heat, cold, radiation, chemicals)

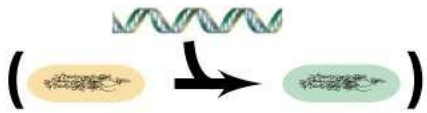
Fermented foods

Food additives (monosodium glutamate, citric acid, yeast)

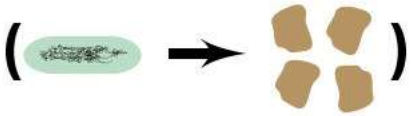
Figure 1-6 part 4 Brock Biology of Microorganisms 11/e

Biotechnology

Genetically modified organisms



Production of pharmaceuticals
(insulin and other human proteins)



Gene therapy for certain diseases

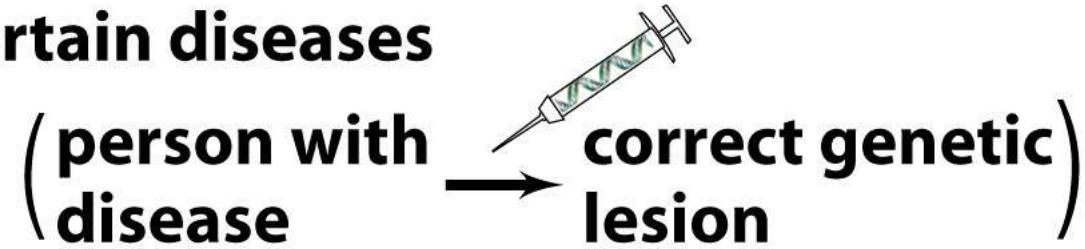


Figure 1-6 part 5 Brock Biology of Microorganisms 11/e

Historical Roots of Microbiology:

A. Hooke, van Leewenhoek and Cohn (discovery was linked to the invention of the microscope)

1. Robert Hooke – described the fruiting structures of molds in 1665
   - 1st person to describe microorganisms

2. Anton van Leewenhoek (1632-1723)
   - used primitive microscope to observe river water, pepper infusions, saliva and feces (see minute, moving objects which he called it 'animalcules')
   - discovered bacteria in 1676 where he made drawings and reported his observations to the Royal Society of London

Two schools of thought on the origin of microorganisms:

1. Abiogenesis – life arose from the non-living
   eg. Concept of Spontaneous Generation
   - started from the Greeks
   -John Needham in 1745 (used cooked meat and placed them in open flasks—eventually saw colonies of microorganisms on the surface)

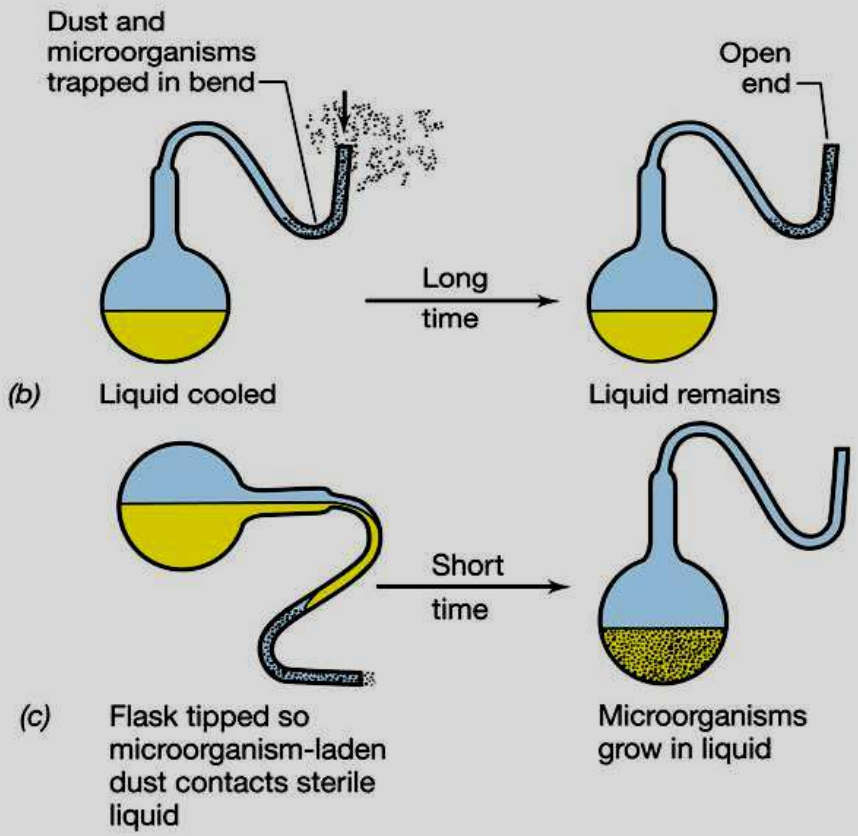
2. Biogenesis – life arose from living parents
   (All carried out expts that refuted spontaneous generation)
   - Francesco Redi
   - Lazzaro Spallanzani
   - Louis Pasteur
   - John Tyndall

3. Ferdinand Cohn (1828-1898)
   - trained as a botanist
   - founded the field of bacteriology and discovered bacterial endospores of *Bacillus*
   - credited for the used of cotton for closing flasks and tubes (simple method for preventing contamination of sterile culture media)

B. Pasteur, Koch and Pure Cultures

1. Louis Pasteur (1822-1895)
   - French chemist
   - disprove the theory of spontaneous generation using his swan-neck flask or Pasteur flask which was heated to eliminate contamination

* Sterilization –process of killing all the bacteria or microorganisms in or on objects.


Dust and microorganisms trapped in bend
Open end
Long time
(b)
Liquid cooled
Liquid remains
Short time
(c)
Flask tipped so microorganism-laden dust contacts sterile liquid
Microorganisms grow in liquid

BDJimenez

Germ Theory of Fermentation

Fermentation –occurs when grape juice is allowed to stand and thru a series of biochemical changes, alcohol and other substances are produced from grape sugar.

Wine making (Pasteur concluded that proper selection of microbes could ensure a consistently good product)

How?

1. Heating the grape juice
2. Cool and inoculate it with some high-quality wine (contained the desired kind of microbe)
3. Preserved the wine by heating it to 50-60° C (Pasteurization)
   -applied today in the canning and preservation of many foods

Establishment of Germ theory of disease

-Pasteur (silk industry) and Robert Koch (anthrax)

*Koch (1843-1910)

- German physician
- development of methods for study of bacteria in pure culture
- Koch postulates (criteria to prove a specific microbe causes a particular disease)

1. A specific microorganism can always be found associated with a given disease
2. The microorganism can be isolated and grown in pure culture in the laboratory
3. The pure culture of the microorganism will produce the disease when injected into a susceptible animal
4. It is possible to recover the injected microorganism from the experimentally infected animal

* the test of his postulate is his discovery of the causative agent of tuberculosis (1881)

KOCH'S POSTULATES:

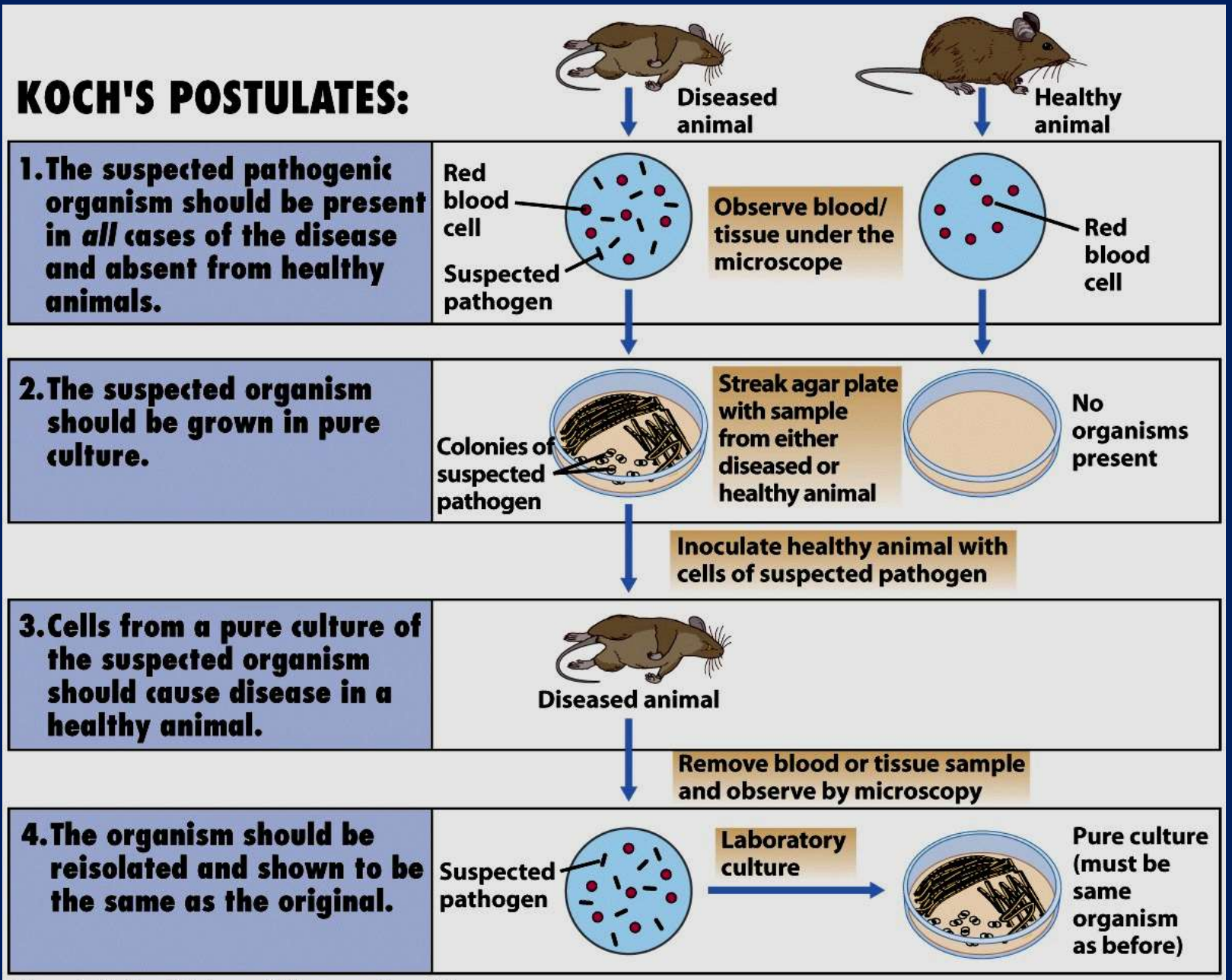


Figure 1-12 Brock Biology of Microorganisms 11/e

Pure Culture—that is, a culture containing a single kind of microorganism.

Joseph Lister (1827-1912)

-English surgeon

-development of the concept of asceptic technique

Developments in Nonmedical Microbiology

1. Martinus Beijerinck and the Enrichment Culture technique

- Dutch botanist (1851-1931)

* Enrichment culture- a procedure that greatly improves the possibility of isolating special kinds of microorganisms from soil and water (nutrient and incubation requirements)

e.g. Aerobic nitrogen-fixing bacteria, sulfate-reducing, sulfur-oxidixing bacteria, green algae

- concept of a virus (using selective filter techniques in his studies of tobacco mosaic virus)

2. Sergei Winogradsky and the concept of chemolithotropy

-Russian microbiologist (1856-1953)

- made fundamental observations on the role of microorganisms in performing chemical involving sulfur, iron and their compounds

* chemolithotropy –the oxidation of inorganic compounds linked to energy conservation

Some landmarks in microbiology in the past 65 years:

A. Early Days: discovery, Medical and General Microbiology

1687	van Leewenhoek
1864	Pasteur
1895	Koch, Winogradsky

B. Era of Molecular Biology/General Microbiology

1941	DNA is genetic material
1944	Streptomycin
1946	Bacterial Genetics
1953	Structure of DNA
1966	Genetic code
1977	1. DNA sequencing 2. Discovery of Archaea
1985	PCR

C. Molecular Microbiology, Genomics and Proteomics

1986	Molecular microbial ecology
1987	First genome
1995	Over 500 genomes

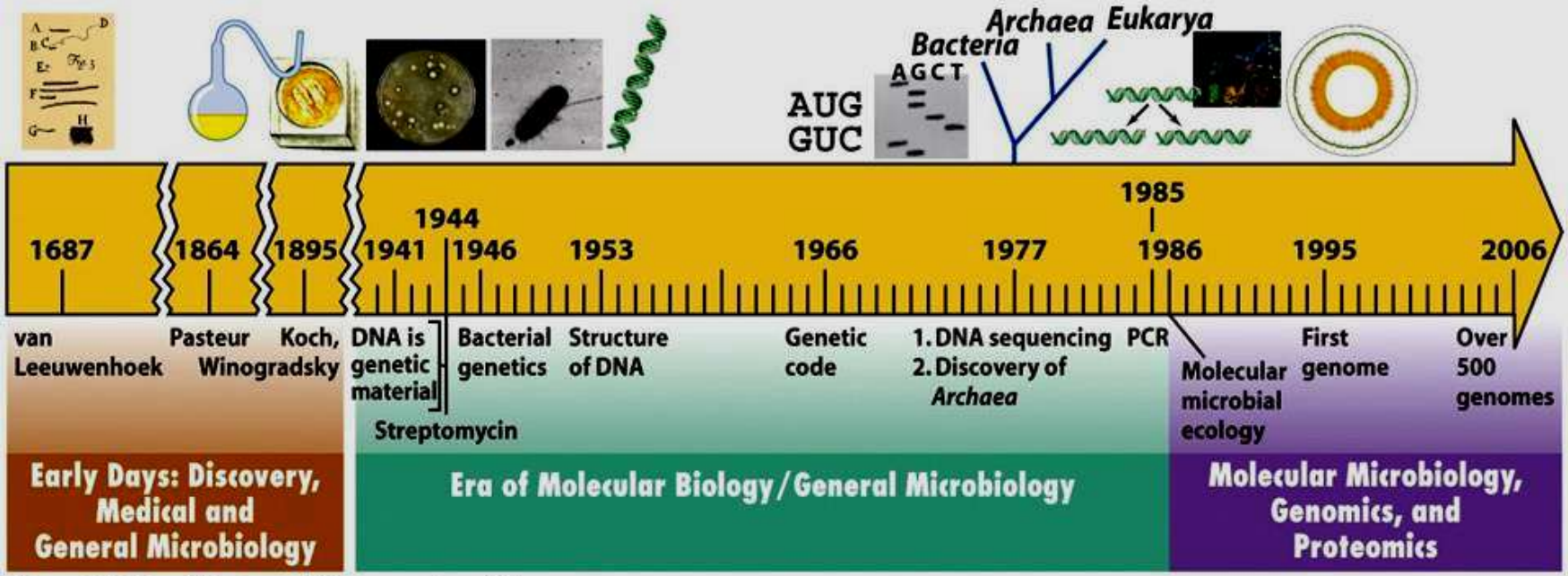


Figure 1-17 Brock Biology of Microorganisms 11/e

BDJimenez

Genomics

-the comparative analysis of the genes of different organisms.

Proteomics

-the study of protein expression in cell

Scope of Microbiology

Cell – basic unit of life structurally and functionally.

History:

a. Robert Hooke (1665)using his microscope discovers cells in cork

b. Schleiden ; Schwann and Virchow

Cell theory:

1. All organisms are composed of one or more cells

2. The cell is the structural unit of life

3. Cells can arise only by division from preexisting cells

Two Main Classes of Cells:

a. Prokaryotic cells – no nucleus
- simpler structure (bacteria and archaea)

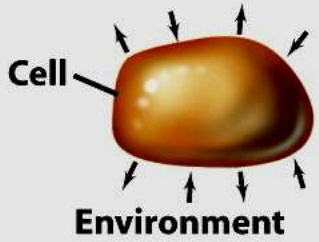
b. Eukaryotic cells - contain nucleus
-more complex structure(protists, fungi, plants & animals)

Basic Characteristics of organisms

1. They reproduce
2. They use food as a source of energy
3. They synthesize cell substances and structures
4. They excrete wastes
5. They respond to changes in the environment
6. They mutate, through infrequent sudden changes in their hereditary characteristics

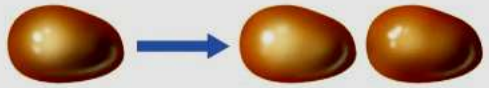
1. Metabolism

Uptake of nutrients from the environment, their transformation within the cell, and elimination of wastes into the environment. The cell is thus an *open* system.



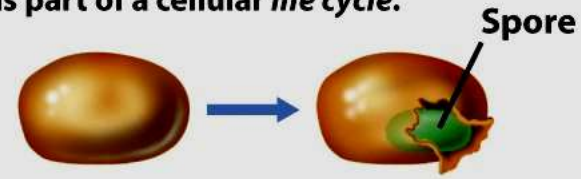
2. Reproduction (growth)

Chemicals from the environment are turned into new cells under the direction of preexisting cells.



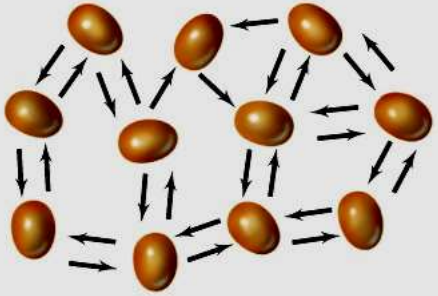
3. Differentiation

Formation of a new cell structure such as a spore, usually as part of a cellular *life cycle*.



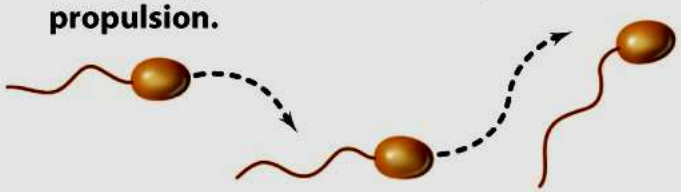
4. Communication

Cells *communicate* or *interact* primarily by means of chemicals that are released or taken up.



5. Movement

Living organisms are often capable of self-propulsion.



6. Evolution

Cells contain genes and *evolve* to display new biological properties. Phylogenetic trees show the evolutionary relationships between cells.

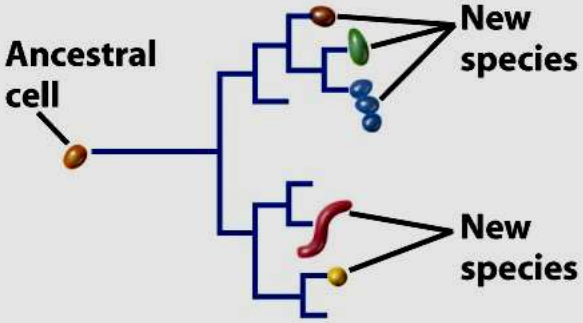
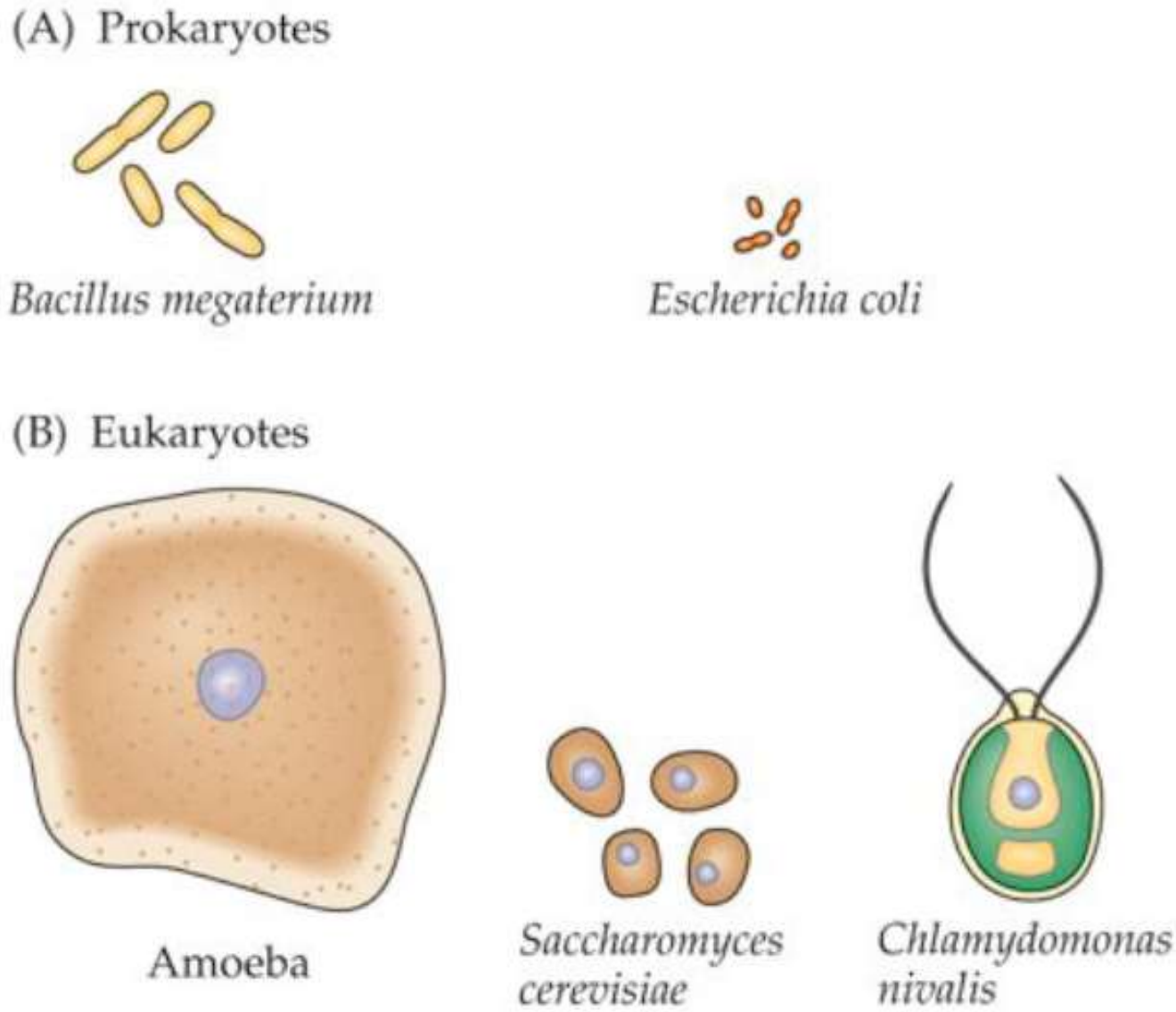


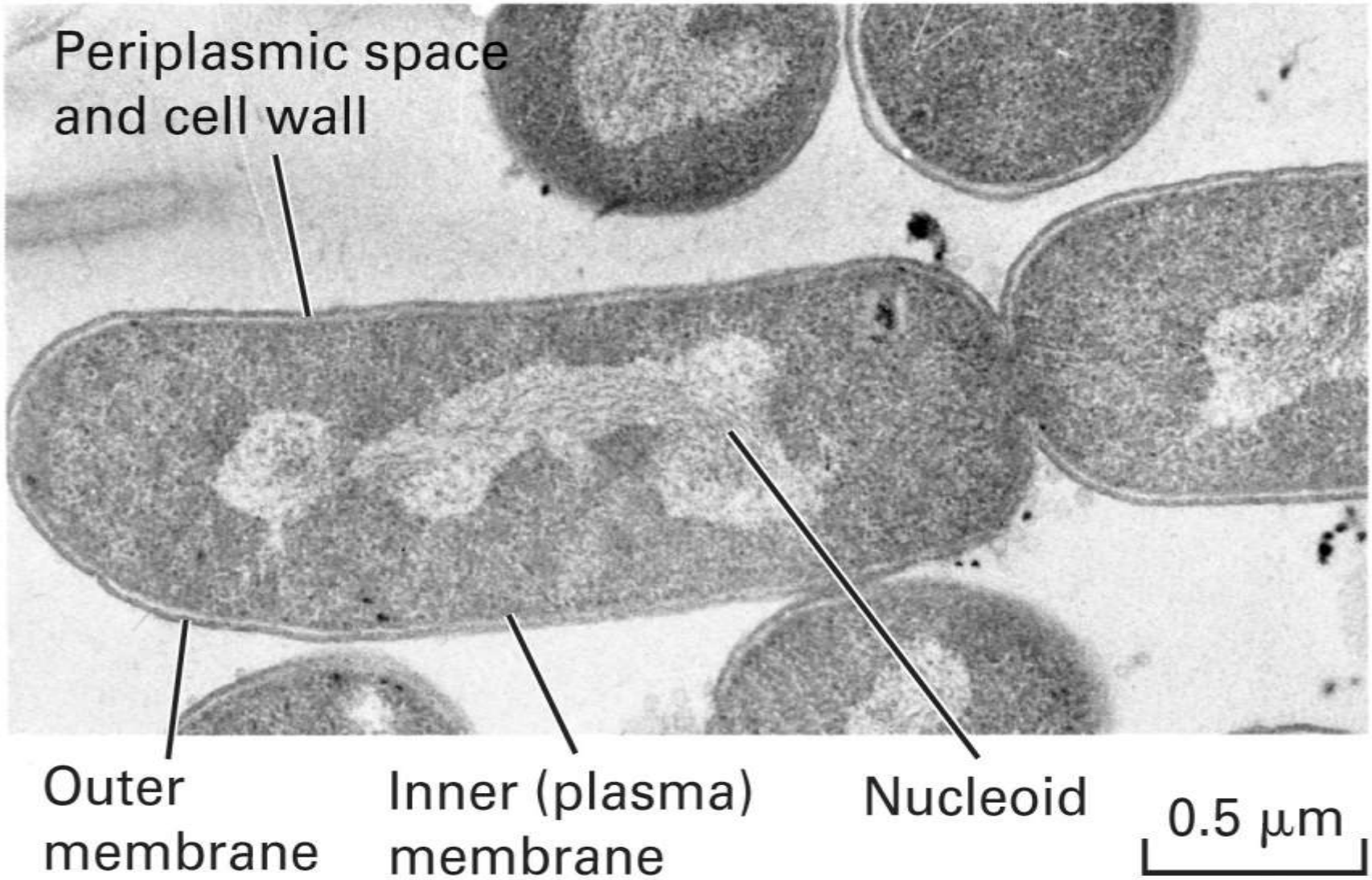
Figure 1-3 Brock Biology of Microorganisms 11/e

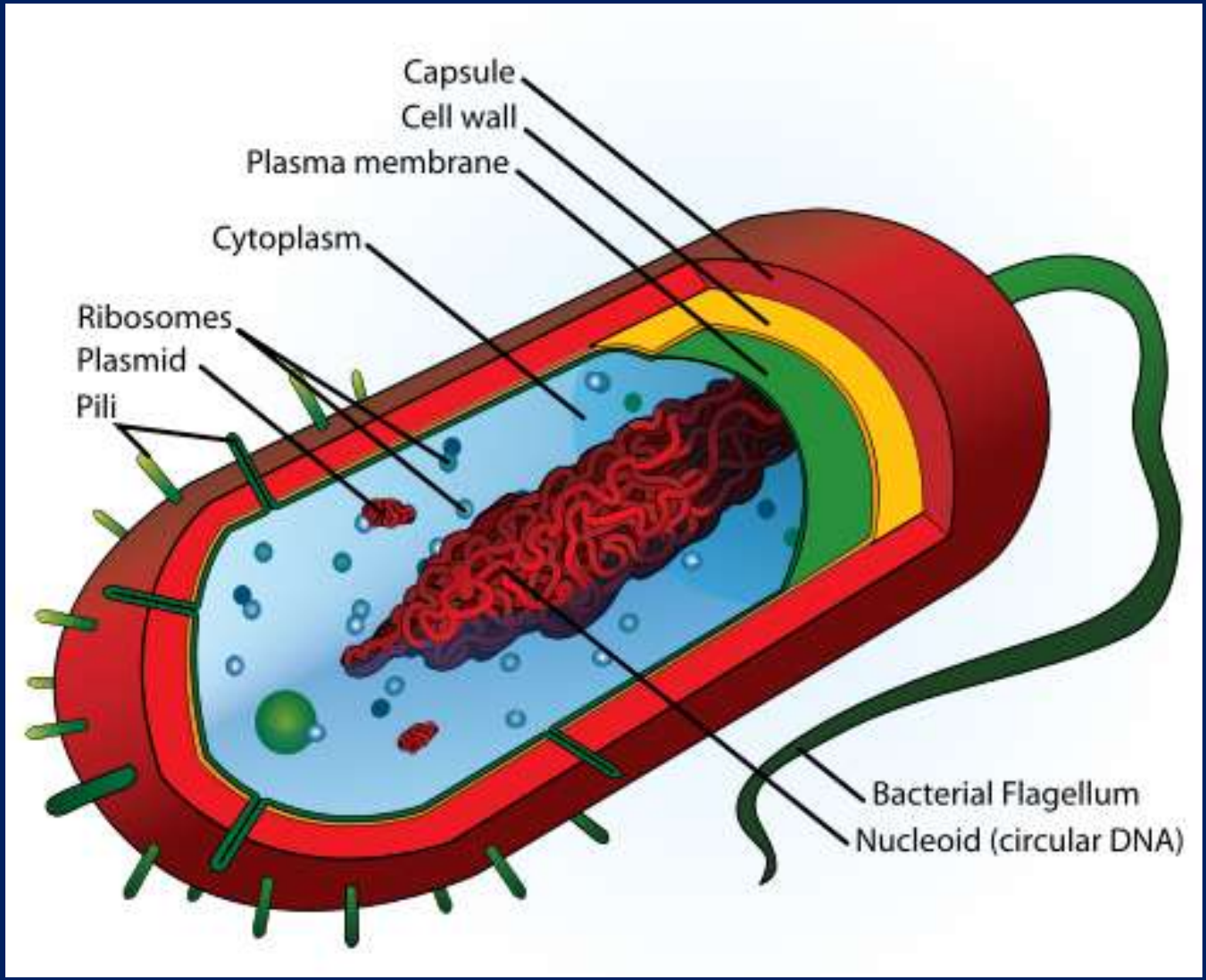
Figure 1.7 Drawings of representative microorganisms, as they appear by light microscopy



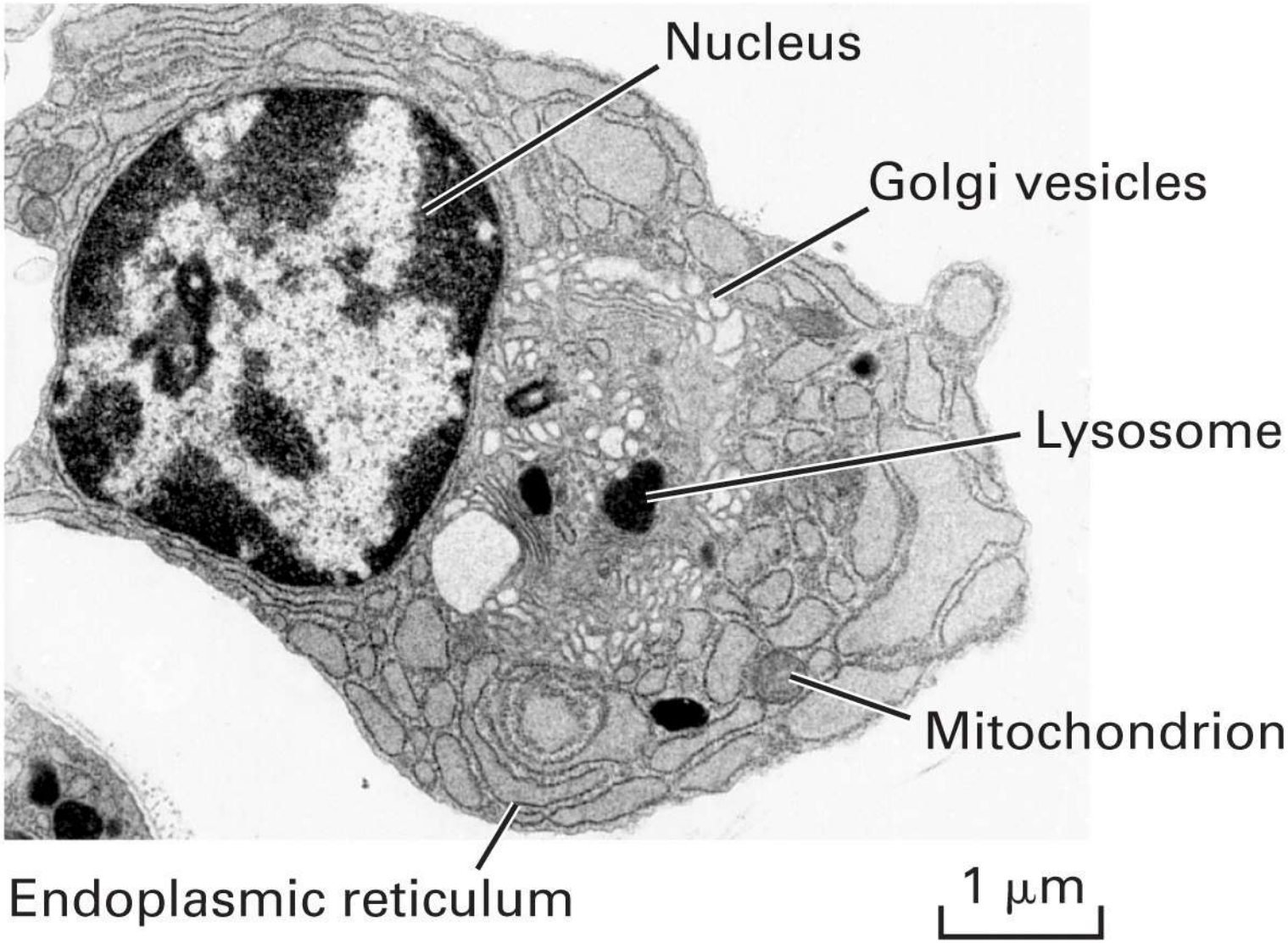
Microbial Life 2e, Figure 1.7

(a) Prokaryotic cell




Capsule
Cell wall
Plasma membrane
Cytoplasm
Ribosomes
Plasmid
Pili
Bacterial Flagellum
Nucleoid (circular DNA)

(b) Eukaryotic cell



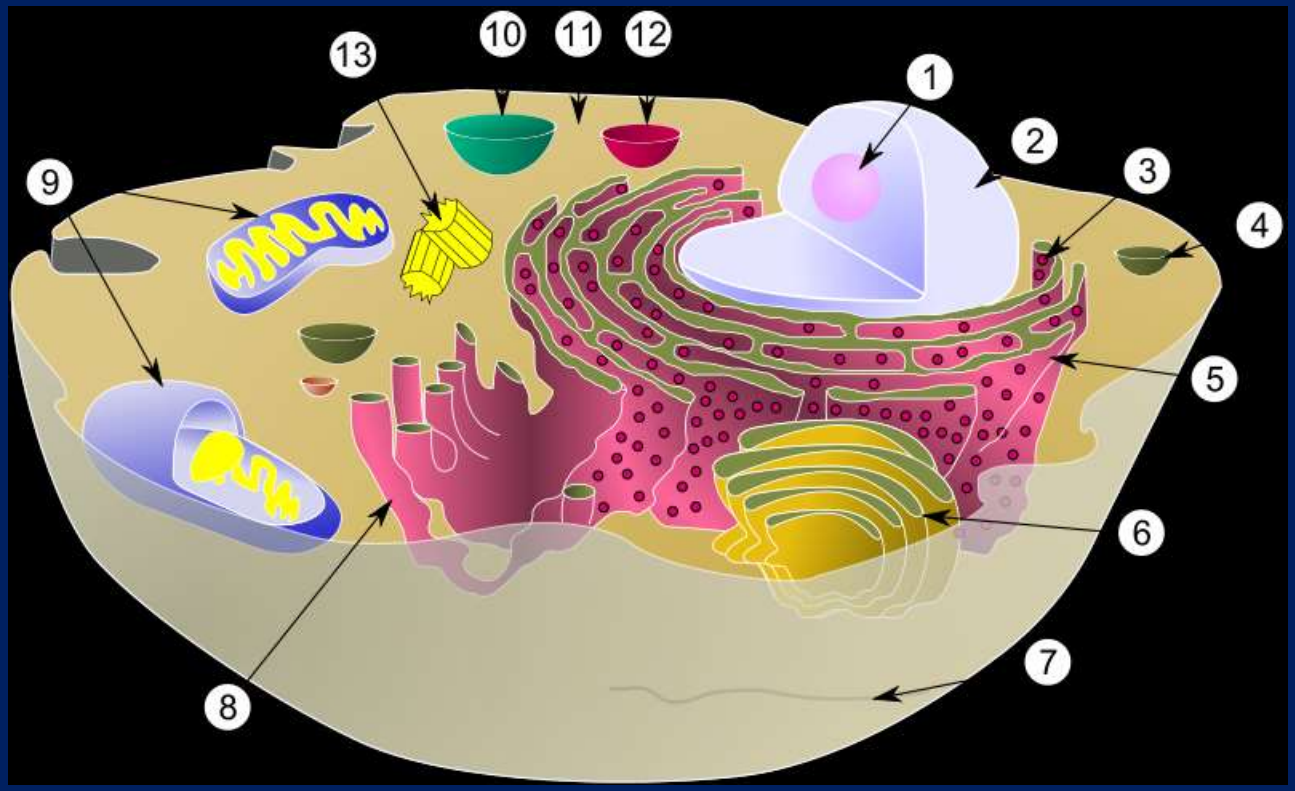


Fig1.2.Diagram of a typical animal (eukaryotic) cell, showing subcellular components.
Organelles:
(1) nucleolus
(2) nucleus
(3) ribosome
(4) vesicle
(5) rough endoplasmic reticulum (ER)
(6) Golgi apparatus
(7) Cytoskeleton
(8) smooth endoplasmic reticulum
(9) mitochondria
(10) vacuole
(11) cytoplasm
(12) lysosome
(13) centrioles within centrosome

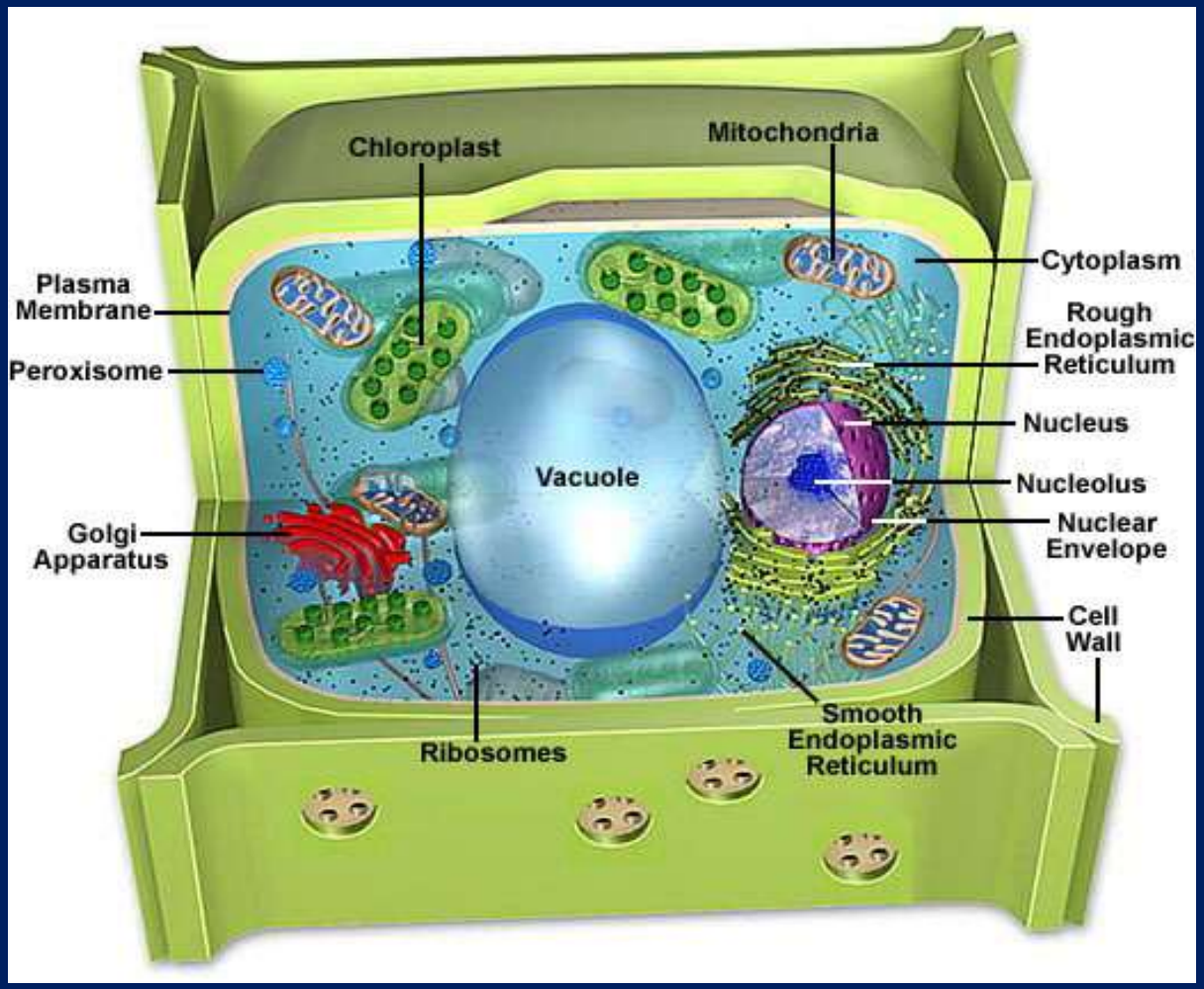


Fig.1.3.Diagram of a typical plant cell

Table 1. Some Differential characteristics of Procaryotes and Eukaryotes

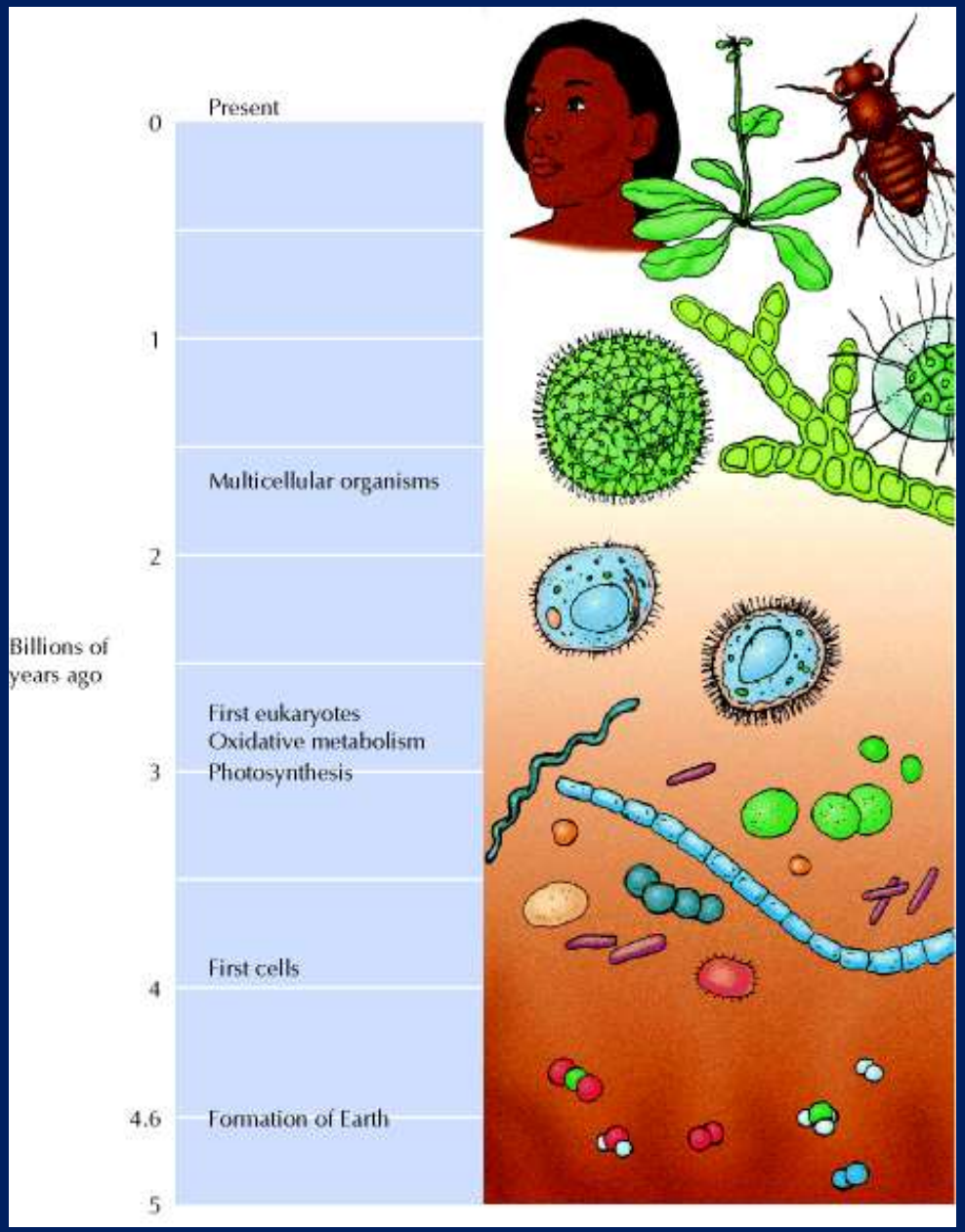
Characteristic	Procaryotes	Eucaryotes
Genetic matl separated from cytoplasm by a membrane	No	Yes
Usual cell width or diameter	0.2 to 2.0 um	>2.0 um
Mitochondria	Absent	Present
Chloroplasts(in photosynthetic species)	Absent	Present
Endoplasmic reticulum and Golgi complex	Absent	Present
Gas Vacuoles	Formed by some species	Absent
Poly-B-hdroxybutyrate inclusions	Formed by some species	Absent
Cytoplasmic streaming	Absent	Often present
Ability to ingest insoluble food particles	Absent	Present in some species

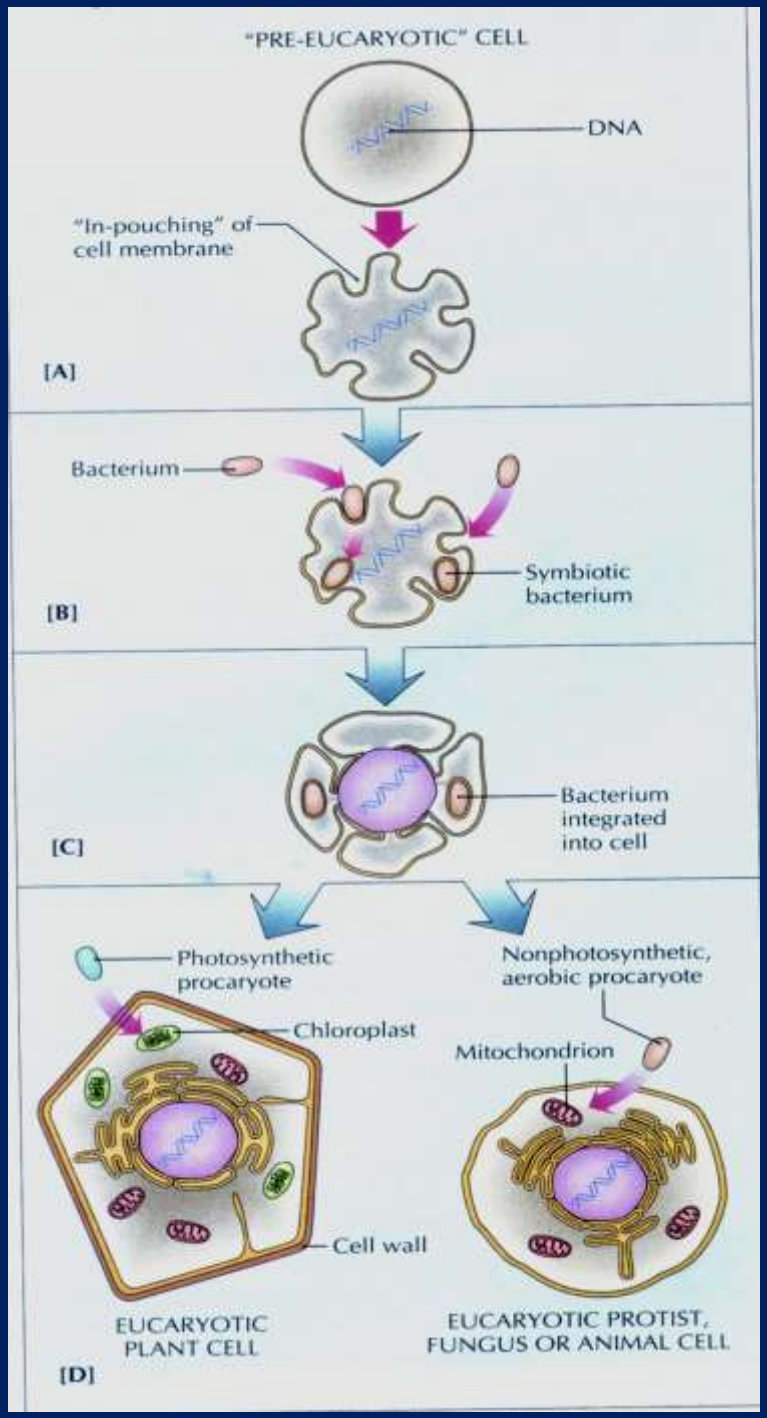
Con't

Flagella, if present: Diameter Cross section ("9+2" arrangement of microtubules)	0.01 to 0.02 um No	0.2 um Yes
Heat-resistant spores (endospores)	Formed by some species	Absent
Polyunsaturated fatty acids or sterols in membranes	Rare	Common
Muramic acid in cell walls	Common	Absent
Ability to use inorganic cpds as a sole energy source	Present in some species	Absent
Ability to fix atmospheric nitrogen	Present in some species	Absent
Ability to dissimilate nitrates to nitrogen gas	Present in some species	Absent
Ability to produce methane gas	Present in some species	Absent
Site of photosynthesis, if it occurs	Cytoplasmic membrane extensions; thylakoids	Grana of chloroplasts

Characteristic	Procaryotes	Eucaryotes
Cell division occurs by mitosis	No	Yes
Mechanisms of gene transfer and recombination, if they occur, involve gametogenesis and zygote formation	No	Yes
Chromosomes: Shape Number per cell	 Circular Usually 1	 Linear Usually>1
Ribosomes: Location in cell Sedimentation constant (in Svedberg units)	 Dispersed thruout cytoplasm 70S	 Attached to endoplasmic reticulum; found free in cytoplasm 80S

Discovering the Microbial World





Endosymbiont Theory

Classification of Living Organisms

- need to make order of these organisms since there about 10 M species including the thousands of microbial species

Taxonomy

-field of science which includes:

1. classification (arrangement)
2. nomenclature (naming)
3. and identification (description and characterization) of living organisms

Taxa – taxonomic groups where organisms are placed that share certain common characteristics

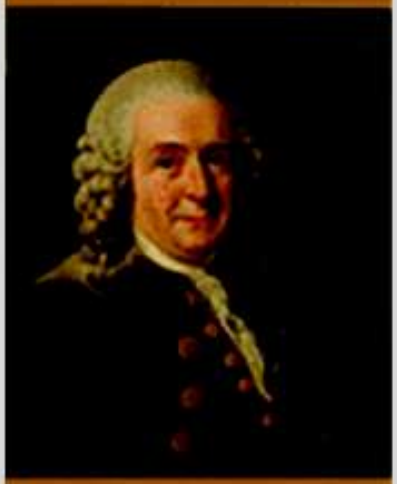
Species - basic taxon

- a collection of strains with similar characteristics-especially similarity in their hereditary material or other features like morphology and nutritional requirements

Strain - made up of the descendants of a single colony from a pure culture

Table 3. Some Examples of the classification of Organisms

Taxa (Categories)	ORGANISM Cat	Alga	Bacterium
Kingdom or major goup	Animal	Plant	Eubacteria
Division		Clorophyta	Gracilicutes
Phylum	Chordata		
Subphylum	Vertebrata		
Class	Mammalia	Chlorophycea	Scotobacteria
Subclass	Eutheria		
Order	Carnivora	Volvocales	Spirochae-tales
	Felidae	Chlamydo-monadaceae	Leptospira-ceae
Genus	***Felis***	***Chlamydomonas***	***Leptospira***
Species	***F. domesticus***	***C. eugametos***	***L.* interrogans**



Carolus von Linnaeus
(1707-1778)

Swedish scientist who laid the foundation for modern taxonomy

Binomial nomenclature

- Two word naming system
  - Genus
    - Noun, capitalized,
    - underlined or italicized
  - Species
    - Descriptive, lower case
    - Underlined or italicized

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Classification of Microorganisms

A. Carolus Linnaeus (1753)

Two Kingdom Scheme:

Plantae (Bacteria, fungi, algae, plants)
Animalia (Protozoa and higher animals)

B. Ernst Haeckel (1865)

Three-Kingdom Scheme:

Plantae (Multicellular algae and plants)
Animalia (Animals)
Protista (Microorganims like bacteria, protozoa, algae, molds and yeasts)

C. Whittaker (1969)

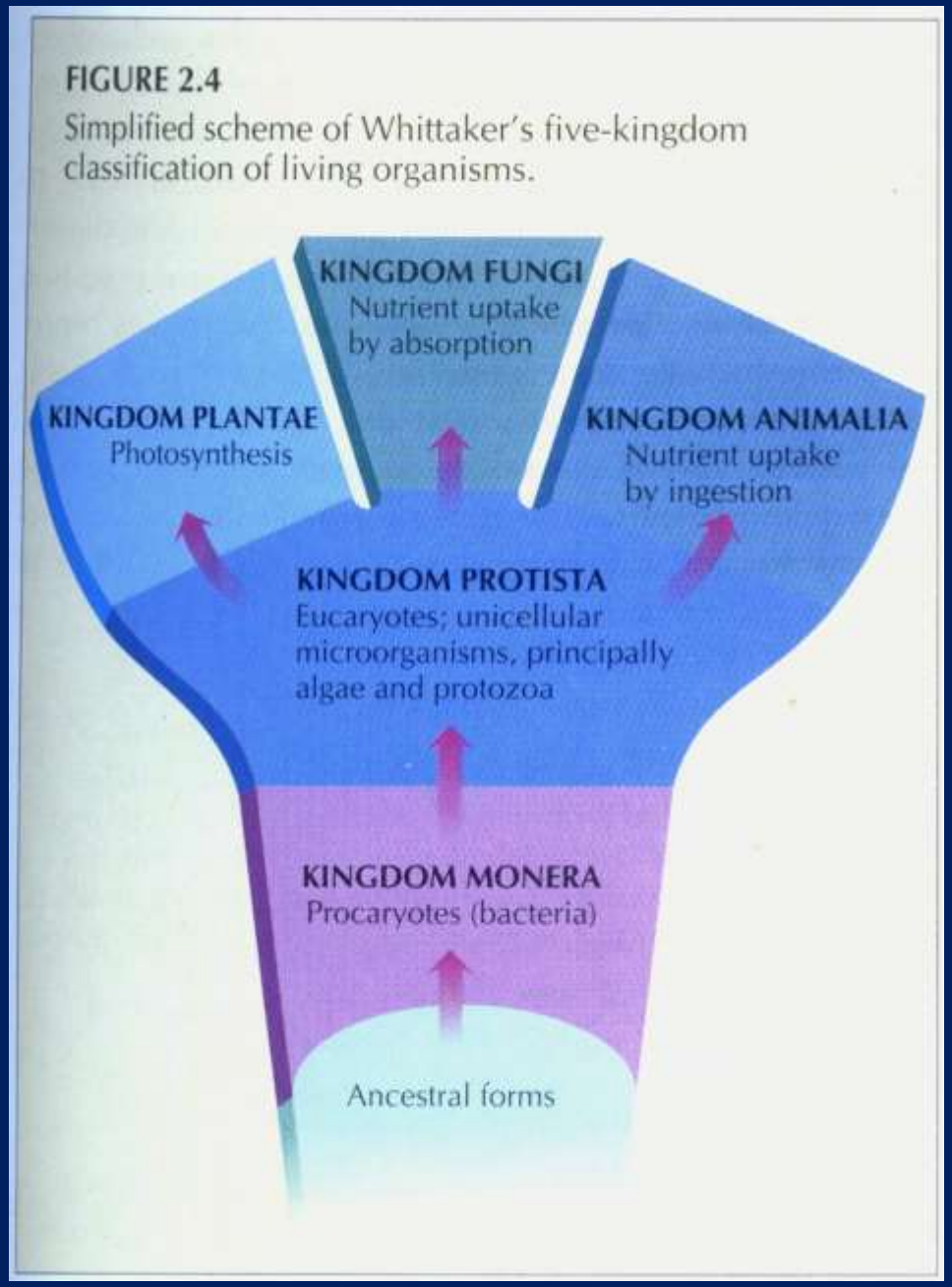
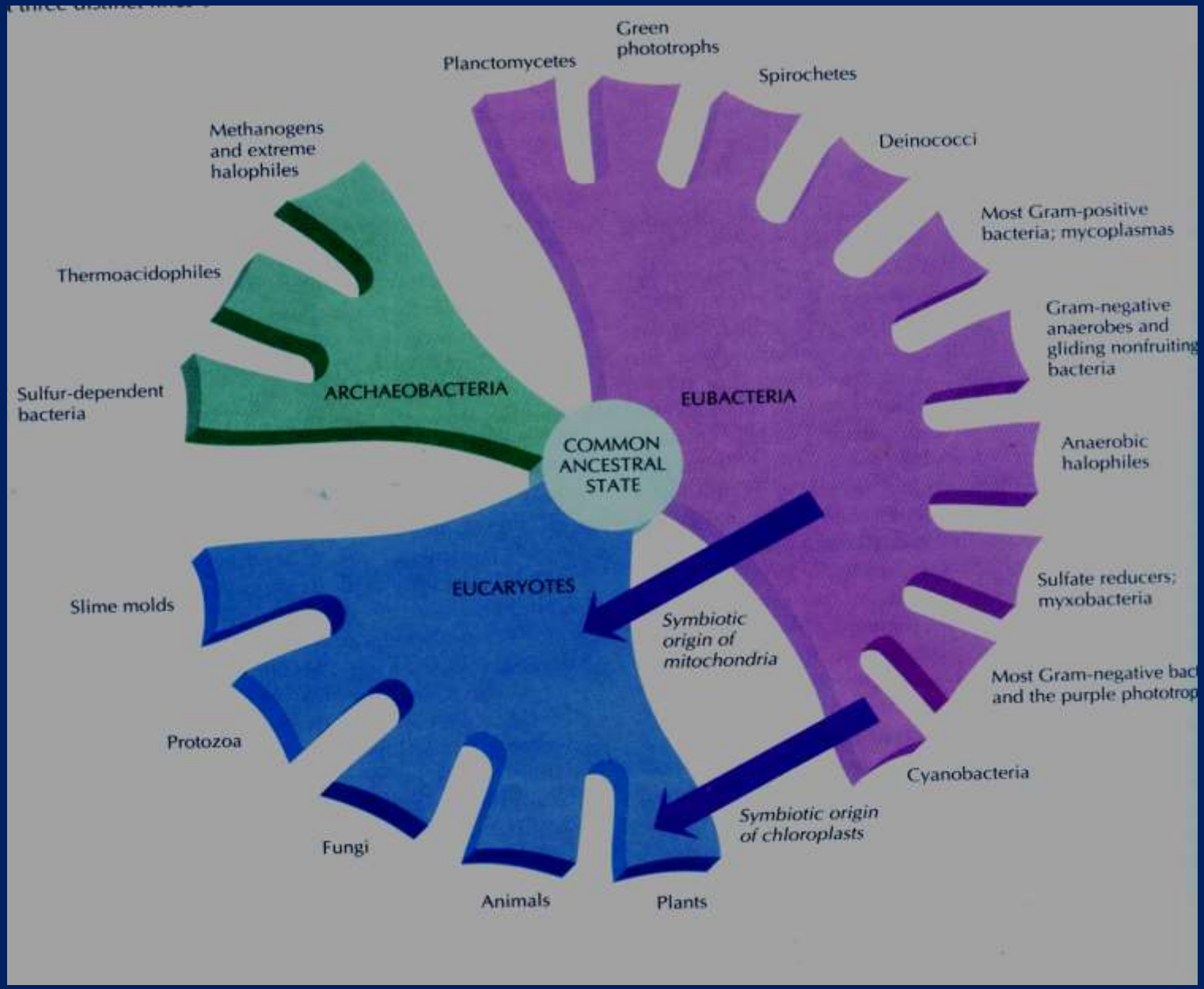
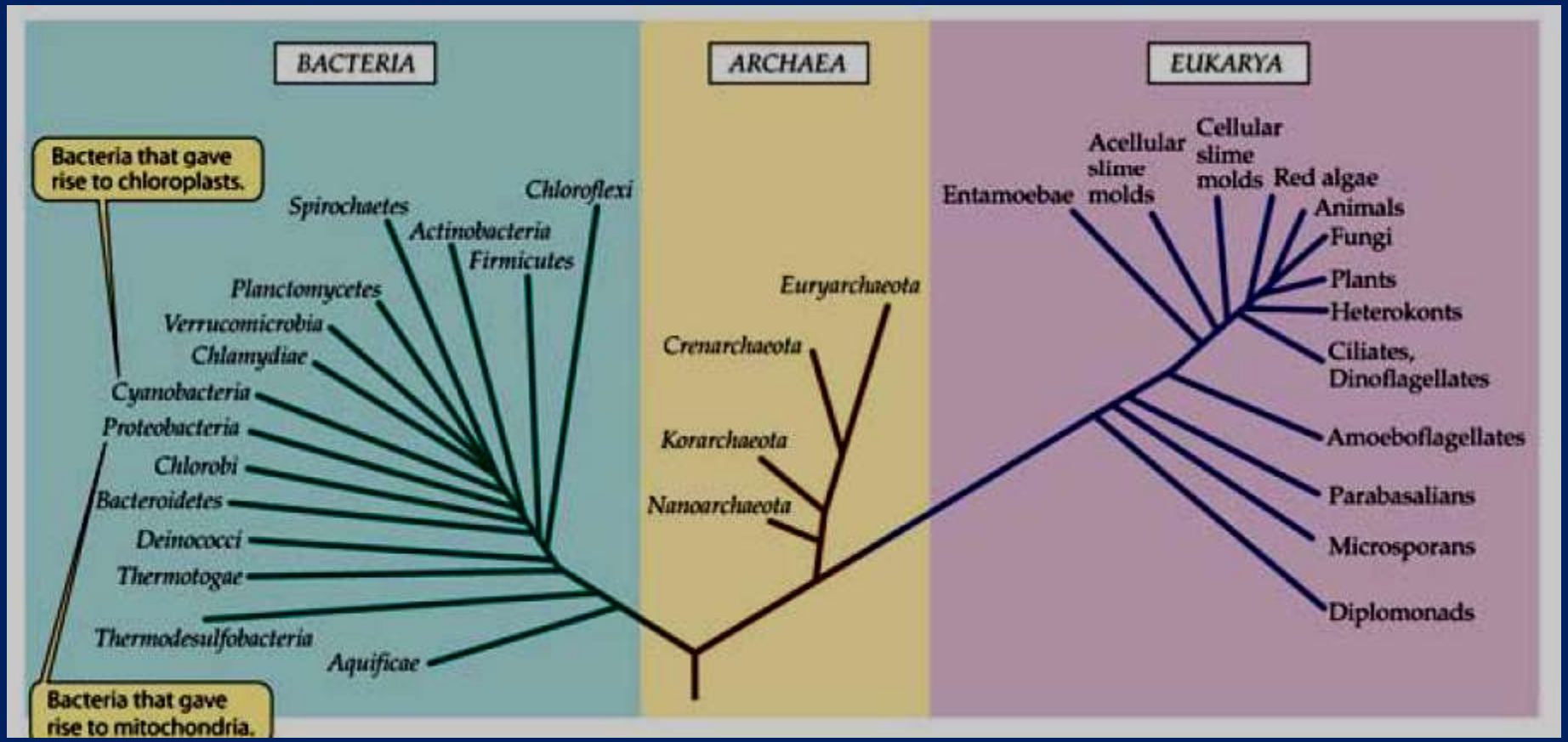


FIGURE 2.4
Simplified scheme of Whittaker's five-kingdom classification of living organisms.

D. Carl Woese (1977) Three Domains of Life

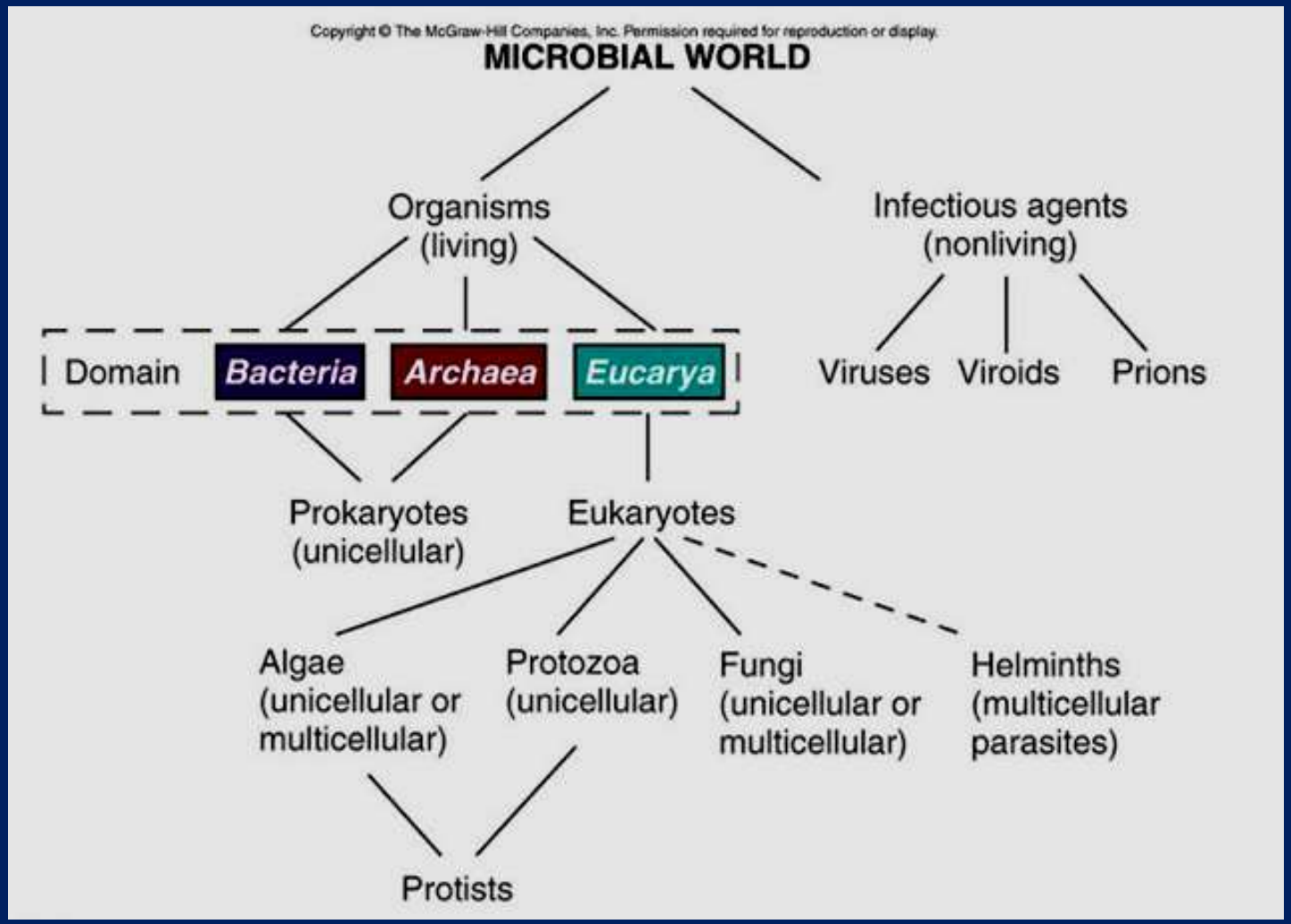



BACTERIA
ARCHAEA
EUKARYA
Bacteria that gave rise to chloroplasts.
Spirochaetes
Chloroflexi
Actinobacteria
Firmicutes
Planctomycetes
Verrucomicrobia
Chlamydiae
Cyanobacteria
Proteobacteria
Chlorobi
Bacteroidetes
Deinococci
Thermotogae
Thermodesulfobacteria
Aquificae
Bacteria that gave rise to mitochondria.
Euryarchaeota
Crenarchaeota
Korarchaeota
Nanoarchaeota
Entamoebae
Acellular slime molds
Cellular slime molds
Red algae
Animals
Fungi
Plants
Heterokonts
Ciliates, Dinoflagellates
Amoeboflagellates
Parabasalians
Microsporans
Diplomonads

II. Characteristics of the Domains of Life

Characteristics of the primary domains **(Table 1.2, 1.3, 1.4)**

Property	Bacteria	Archaea	Eukaryote
Nuclear membrane	NO	NO	YES
Peptidoglycan cell walls	YES	NO	NO
Membrane Lipids: glycerol-hydrocarbon linkage	ESTER O C-O-C~	ETHER C-OC	Should be ester linkage NOT ether
Contain plastids	NO	NO	YES
Mitochondria	NO	NO	YES
Chloroplasts	NO	NO	YES
Transcription			
mRNA processing (capping, polyA tail)	NO	NO	YES
mRNA splicing	NO*	NO*	COMMON
RNA Polymerase	ONE TYPE 4 SUBUNITS	SEVERAL 8-12	3 TYPES 12-14 SUBUNITS
Genes in operons	YES	YES	NO
Transcription Factors Required	NO	YES	YES
Ribosome size	70S	70S	80S
Metabolism: Nitrogen Fixation	+	+	—
Chemolithotrophy	+	+	—
Growth > 80°C	+	+	—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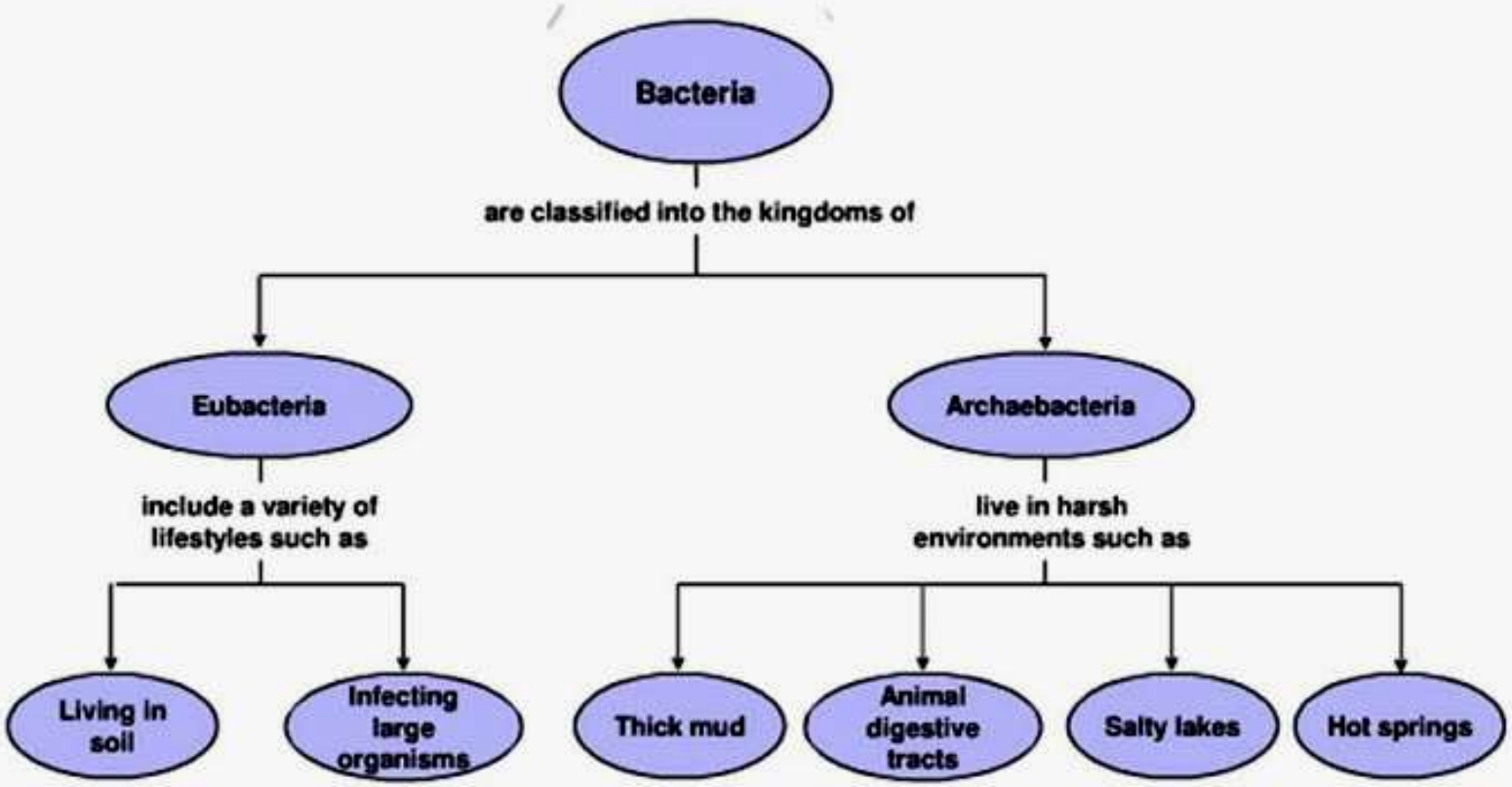
MICROBIAL WORLD
Organisms (living)
Infectious agents (nonliving)
Domain
Bacteria
Archaea
Eucarya
Viruses
Viroids
Prions
Prokaryotes (unicellular)
Eukaryotes
Algae (unicellular or multicellular)
Protozoa (unicellular)
Fungi (unicellular or multicellular)
Helminths (multicellular parasites)
Protists

Classifying life

Three domains of organisms are now recognized:

- *Bacteria* – numerous and diverse
- *Archaea* – many live in extreme environments
- *Eukarya* – fungi, algae, protozoa, plants, animals


Bacteria
are classified into the kingdoms of
Eubacteria
Archaebacteria
include a variety of lifestyles such as
live in harsh environments such as
Living in soil
Infecting large organisms
Thick mud
Animal digestive tracts
Salty lakes
Hot springs

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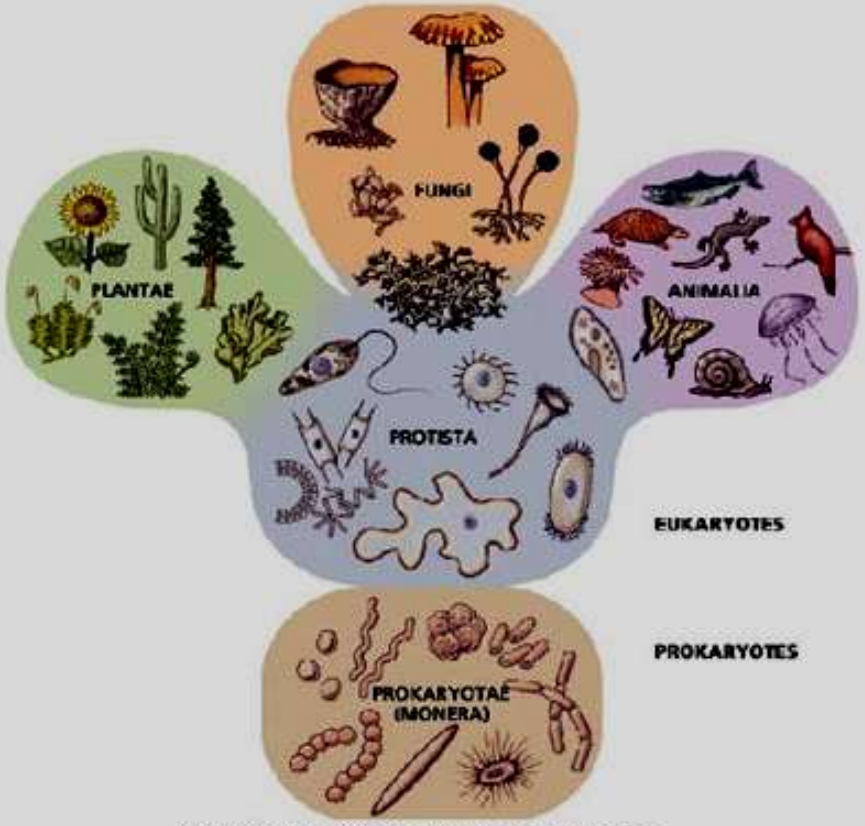
History of Evolution



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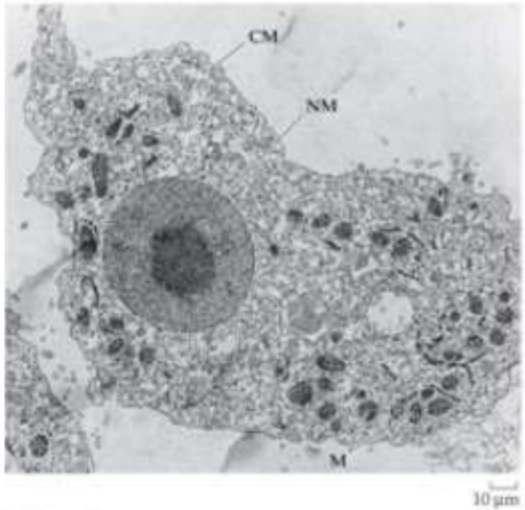
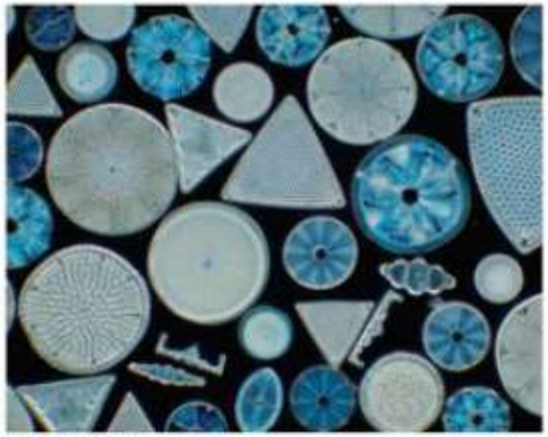
Classifying life: Eukaryotes

- We are eukaryotes
- Some are big some are small.
- Hallmarks of eukaryotes:
  - Nuclei
  - Membrane bound organelles
- Some microbial eukaryotes:
  - Yeast
  - Fungi
  - Protozoa
  - Diatoms



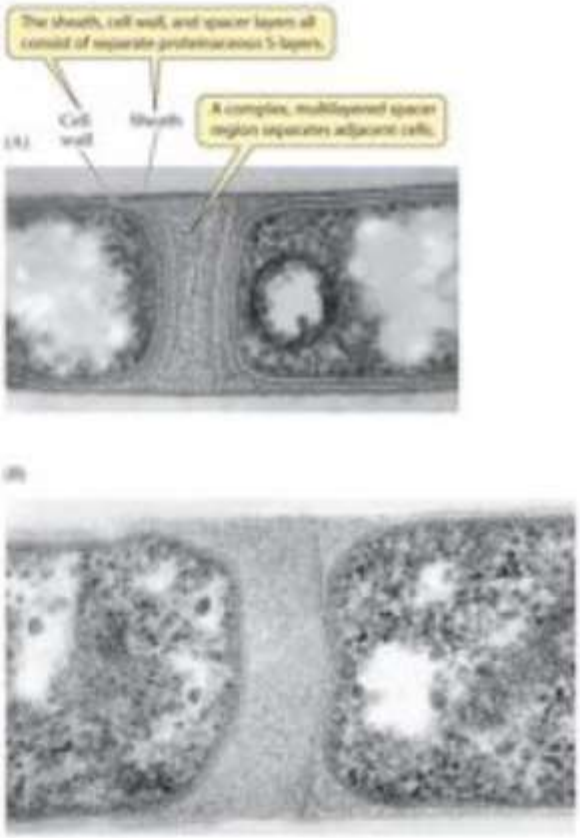
Microbial Life 2e, Figure 1.9



Microbial Life 2e, Figure 23.30

Classifying life: Archaea

- Archaea are microorganisms
- No nuclei
- Different than bacteria
  - To be discussed later.
- Often live in extreme environments
- Mostly non-pathogenic

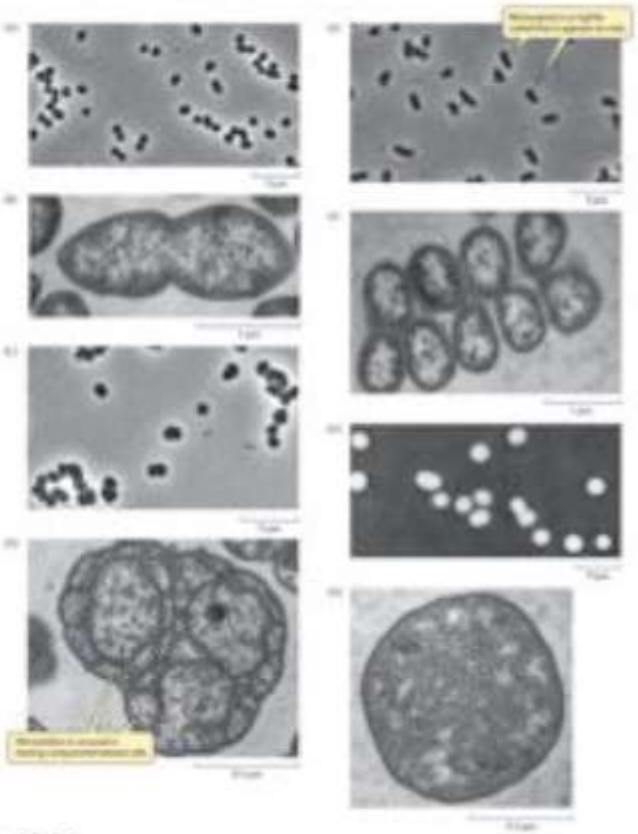


Microbial Life 2e, Figure 18.11

methanoarchaea

Classifying life: Bacteria

- Bacteria are microorganisms
- Most are harmless
- No nucleus
- Pathogenic:
  - *Escherichia coli* (*E. coli*)
  - *Streptococcus* (strep throat)
  - *Yersinia pestis* (plague)
  - *Salmonella* (food poison)
- Non-pathogenic:
  - *Thermus aquaticus* (PCR)
  - *Lactobacillus* (dairy products)
  - *Nitrosomonas* (fish aquariums)



Microbial Life 2e, Figure 19.21

Nitrifying bacteria

Distinctive characteristics of the Major Groups of Microorganisms

Protozoa

-single-celled eucaryotic microorganisms
-animal-like since they ingest particulate food
-lack a rigid cell wall
-do not contain chlorophyll
-Some can swim thru water by
a. Beating action of cilia
b. Whip-like action of flagella
-others do not swim but has pseudopods, responsible for the locomotion known as amoeboid movement.
-others formed resting bodies called spores thus They are known as sporozoans
-occur widely in nature, particularly in aquatic environments

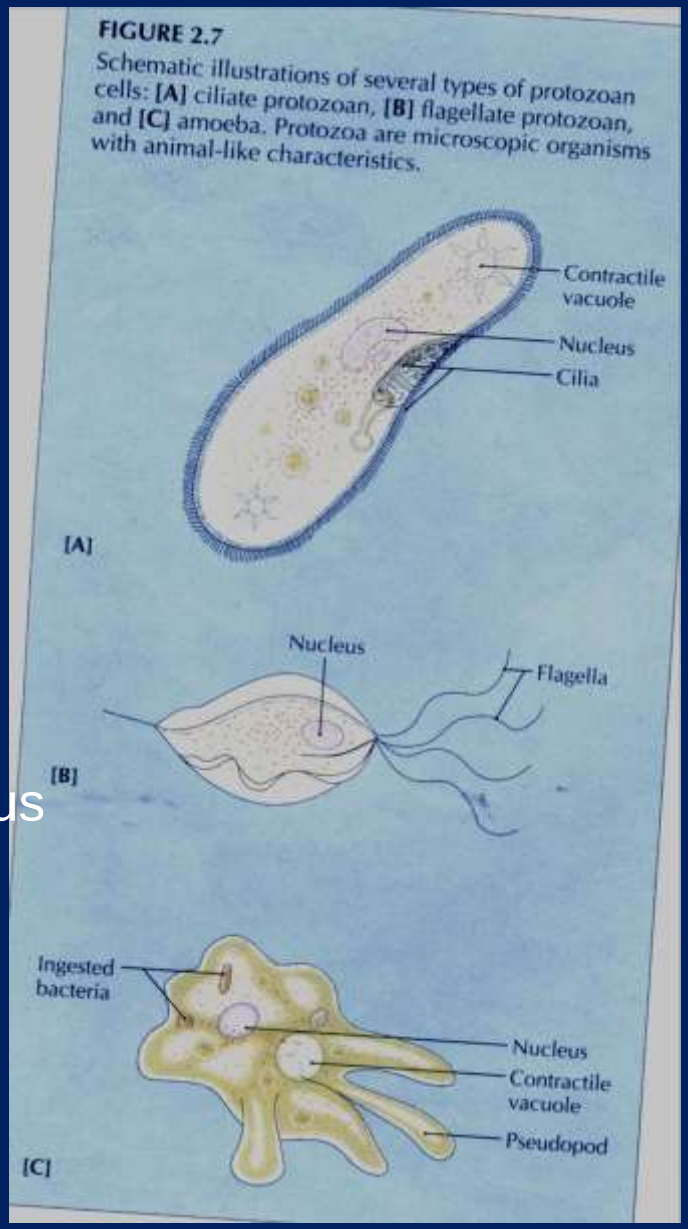


FIGURE 2.7
Schematic illustrations of several types of protozoan cells: [A] ciliate protozoan, [B] flagellate protozoan, and [C] amoeba. Protozoa are microscopic organisms with animal-like characteristics.

Examples of Protozoa

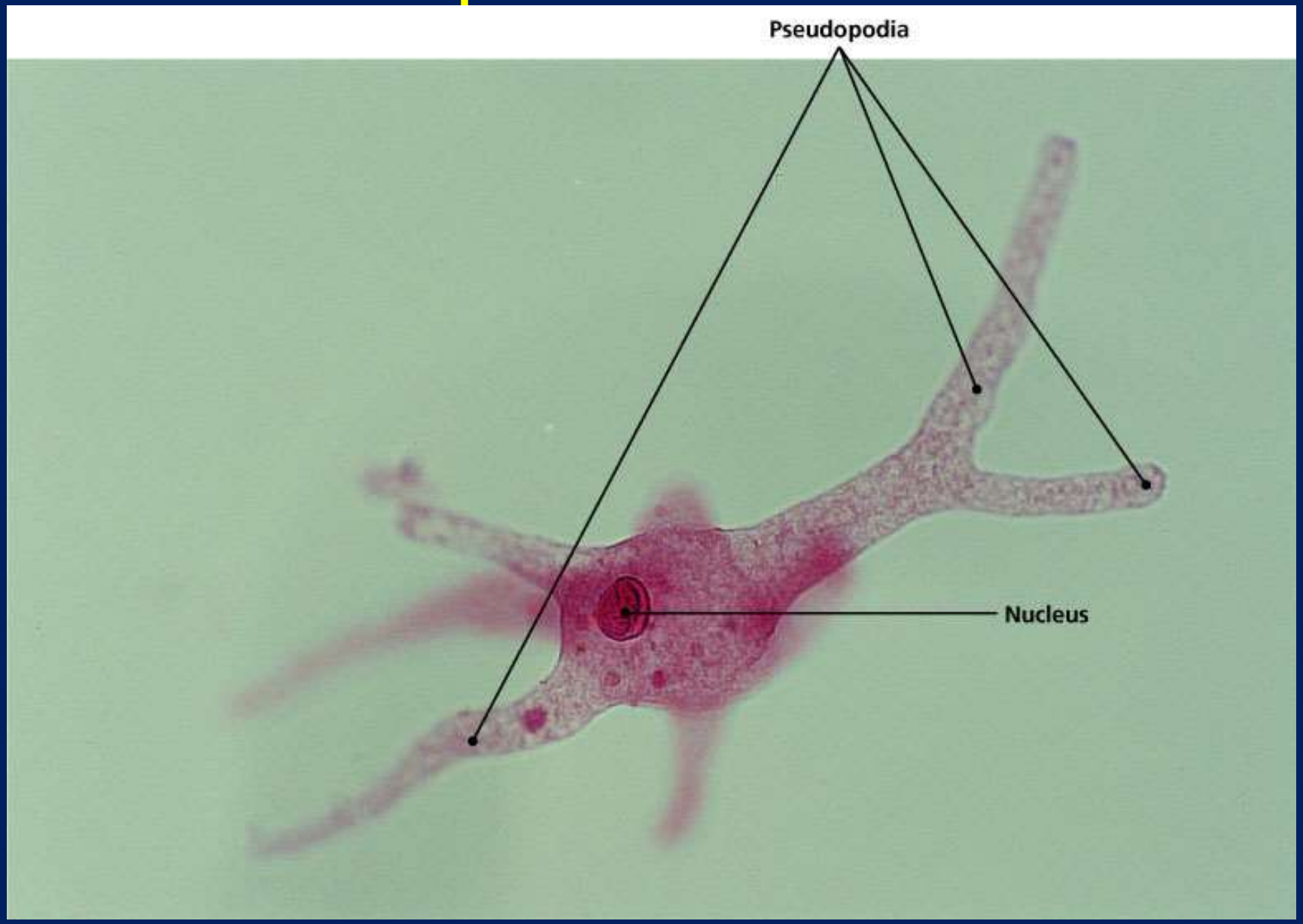


Figure 1.5

Examples of Protozoa

Figure 1.5

Examples of Protozoa

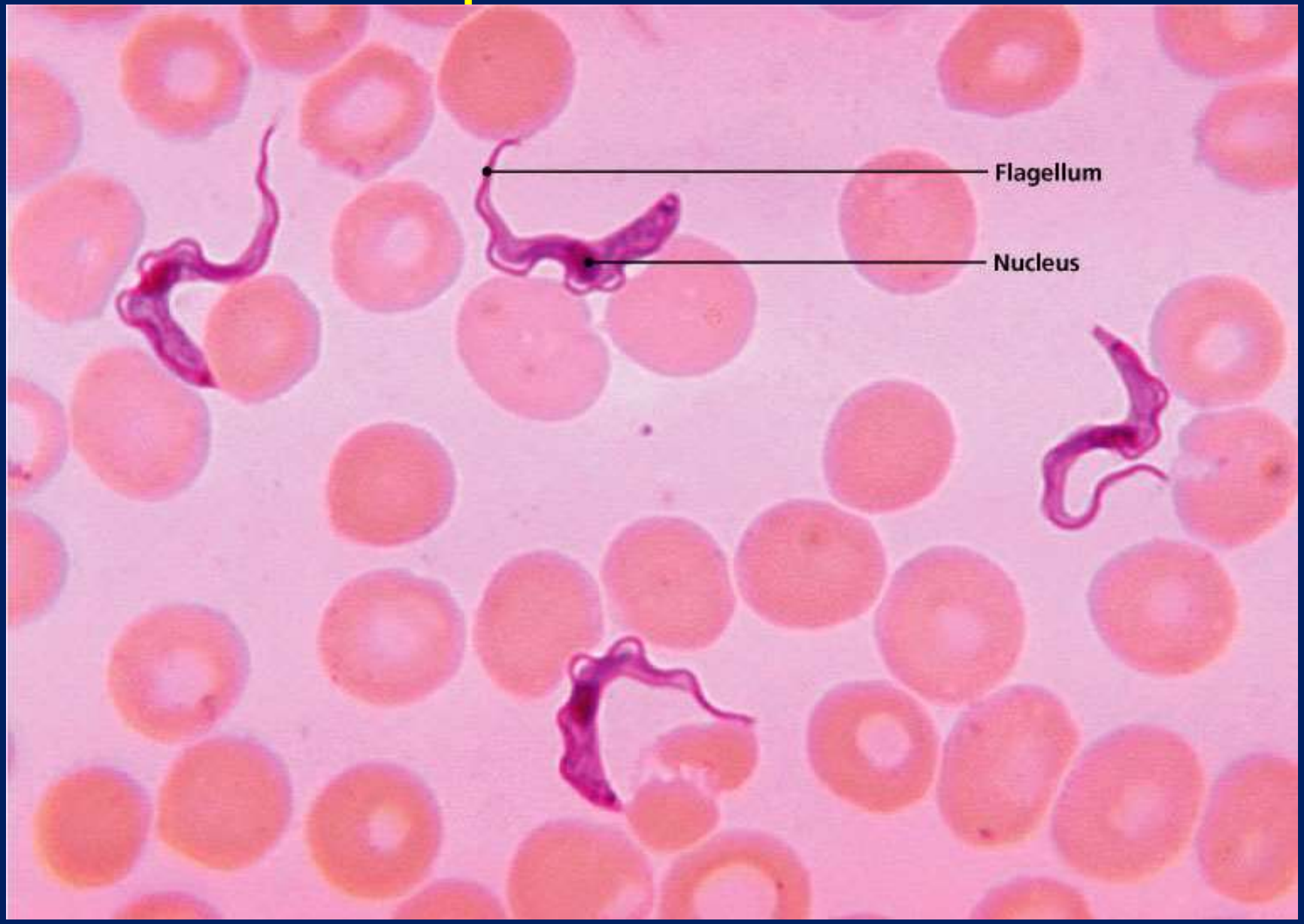
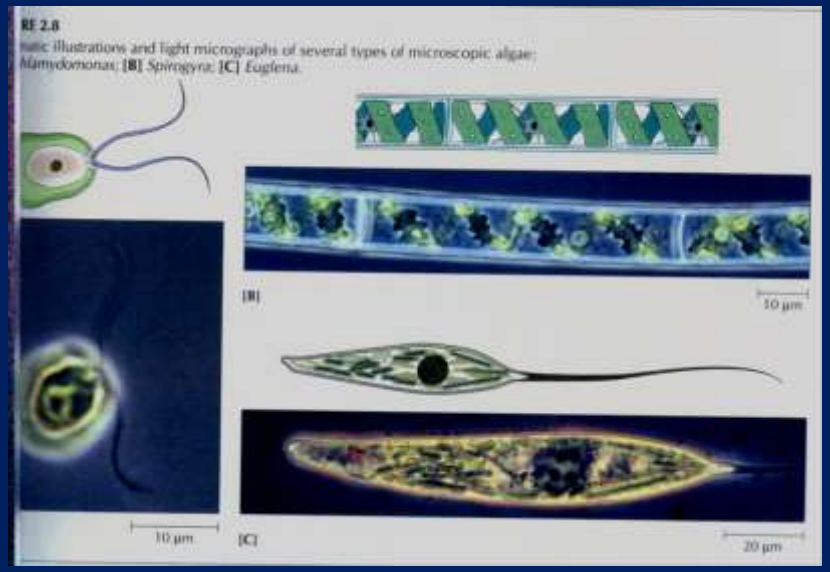


Figure 1.5

Algae

-considered plant-like bec of the green pigment chlorophyll they contain
-carry out photosynthesis
-have rigid cell walls
-multicellular and microscopic in size or up to several meters in length
-grow in many diff environments but most are aquatic and a food source for aquatic animals
-cause problems by clogging water pipes, releasing toxic chemicals into bodies of water or grow in swimming pools
-have impt commercial uses:
. extracts from specific algal species use as thickeners and emulsifiers for foods and ice cream and custards
. As anti-inflammatory drugs for ulcer treatment
. source of agar



Examples of Algae

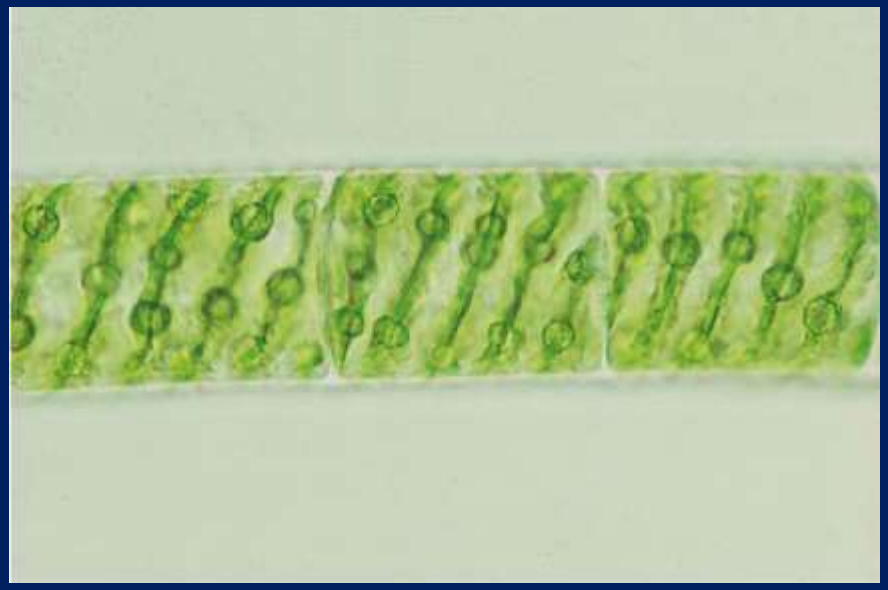


Figure 1.6

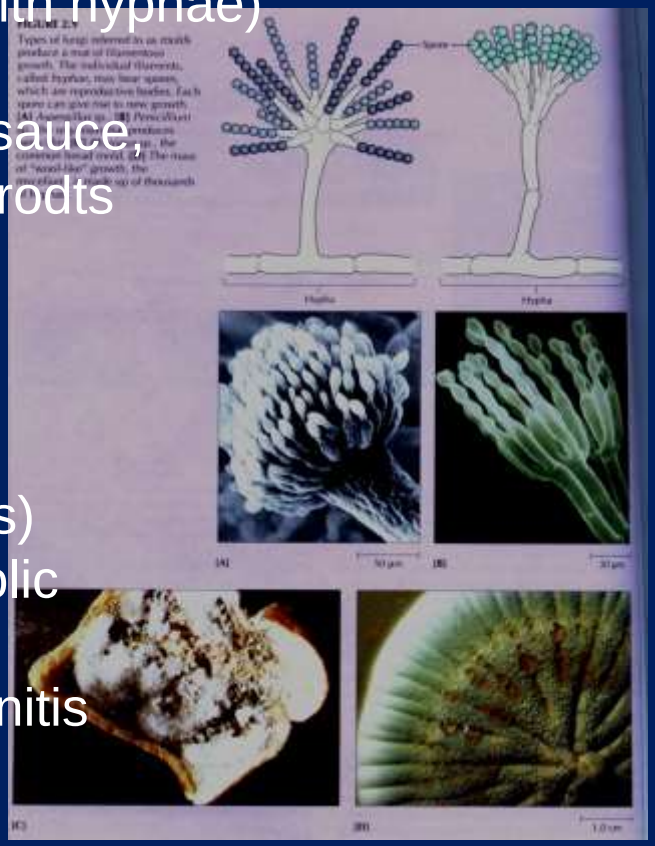
Fungi

-eucaryotic organisms maybe unicellular or multicellular
-have rigid cell wall
-some may be microscopic in size others much larger like the mushrooms and bracket fungi that grows on damp logs or soil
-do not contain chlorophyll
-do not ingest food but absorbed dissolved nutrients from environment
- egs. Molds (multicellular that are filamentous with hyphae)
yeasts (unicellular)
-molds used to produce antibiotic penicillin, soy sauce, Roquefort and Camembert cheeses and many prodts

- also responsible for deterioration of textiles and wood
- cause diseases in humans, animals, plants (athlete's foot and moldy peanuts)

-yeast (spherical, ovoid, ellipsoidal to filamentous)

- widely used in baking industry, prodn of alcoholic beverages
- cause food spoilage and disease such as vaginitis and thrush (oral infection)



Examples of Fungi

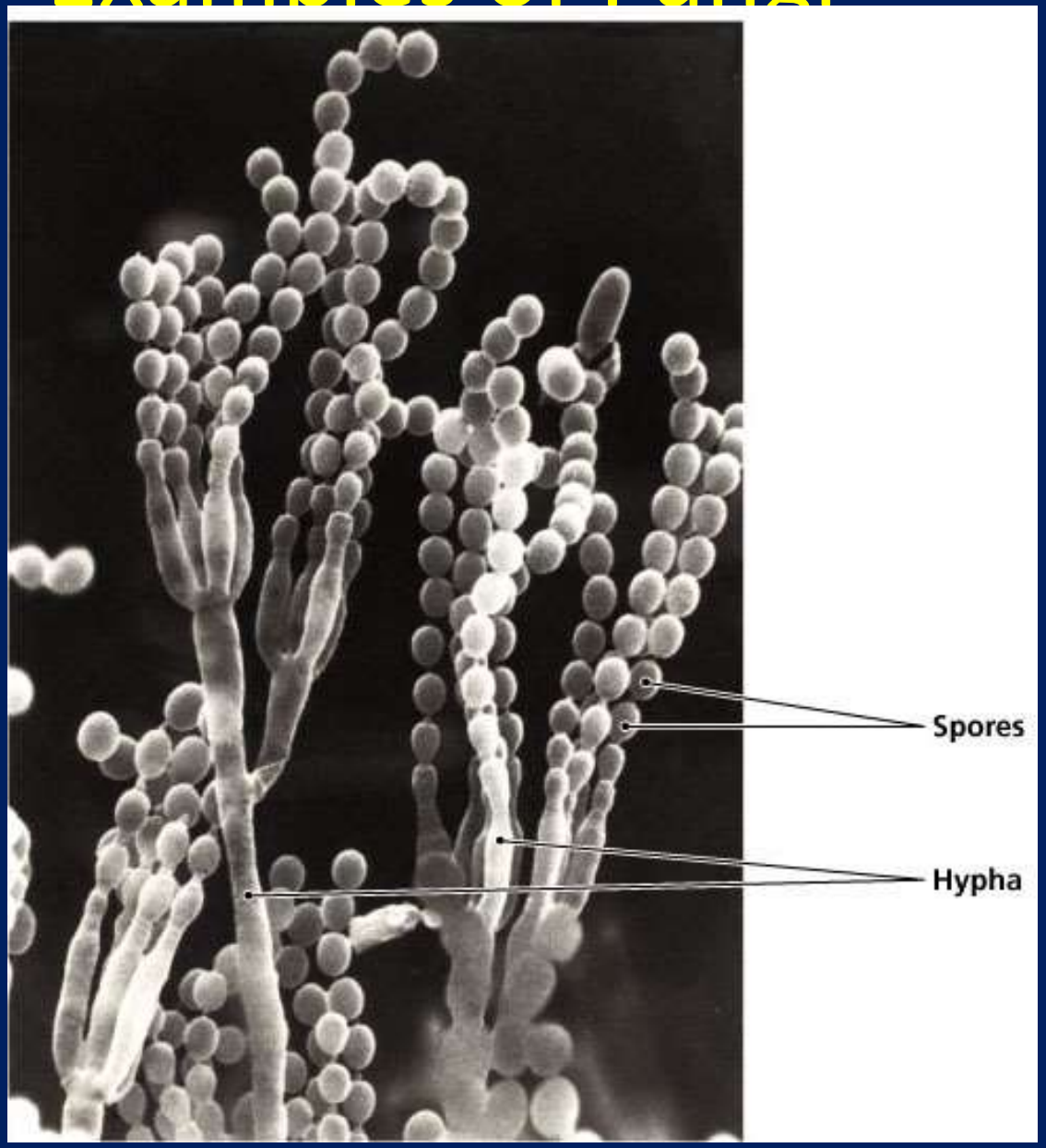


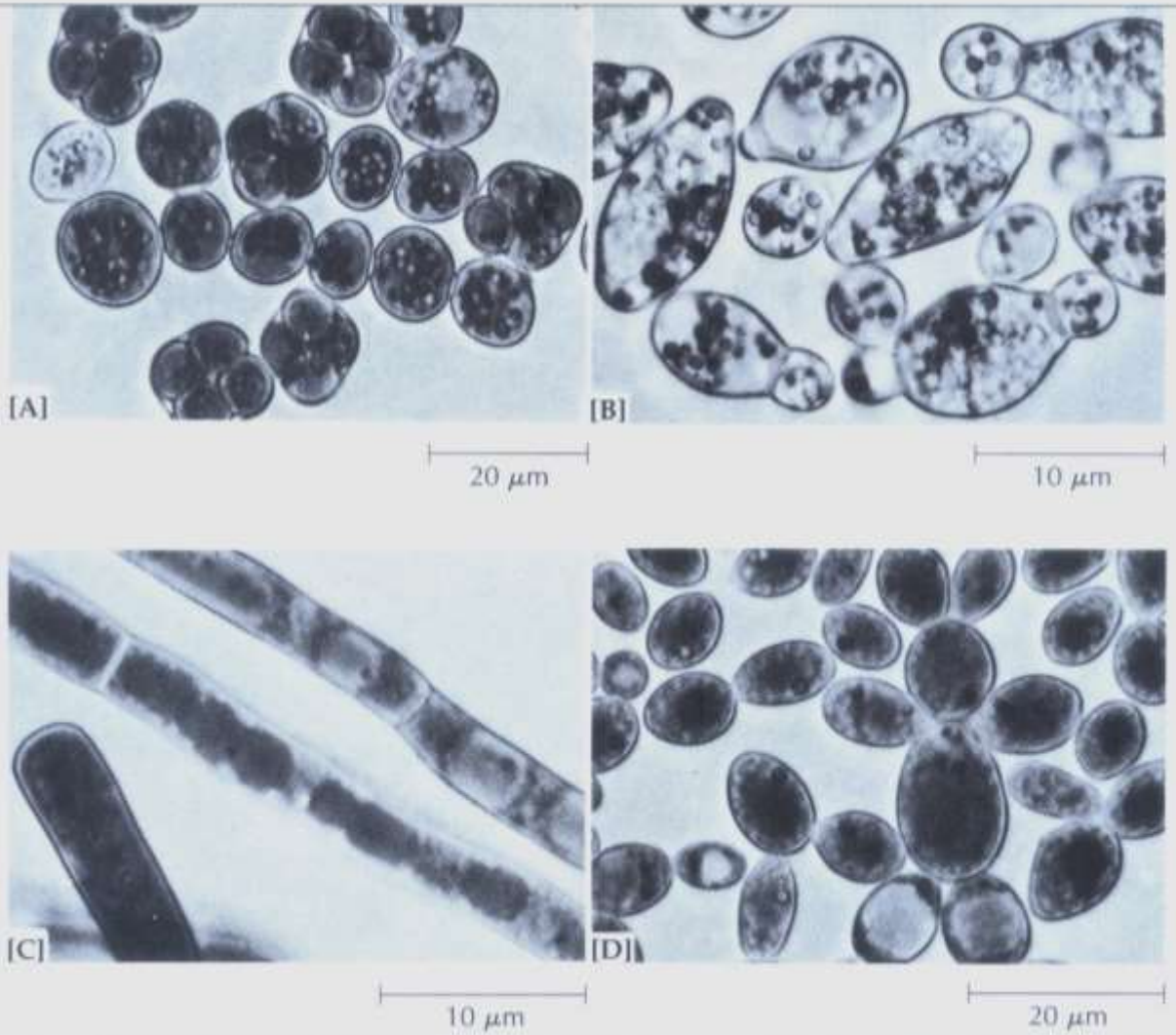
Figure 1.4

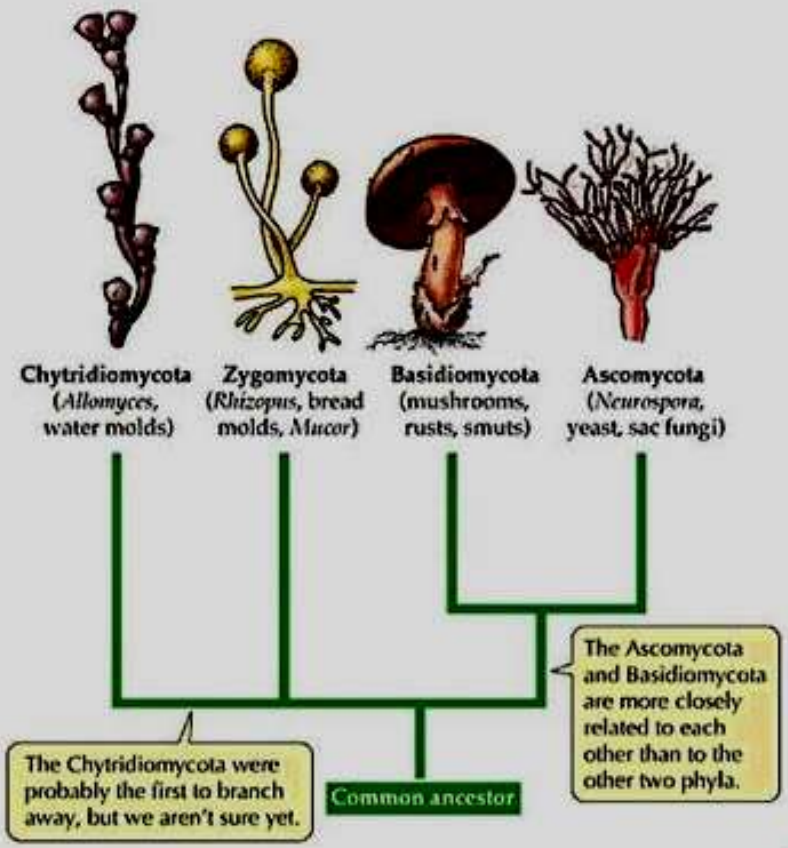
Examples of Fungi

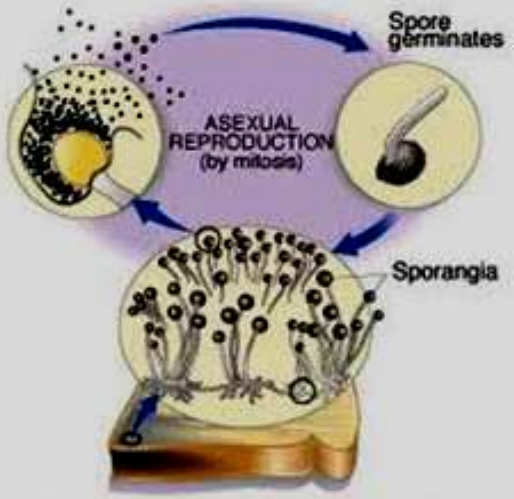
Figure 1.4

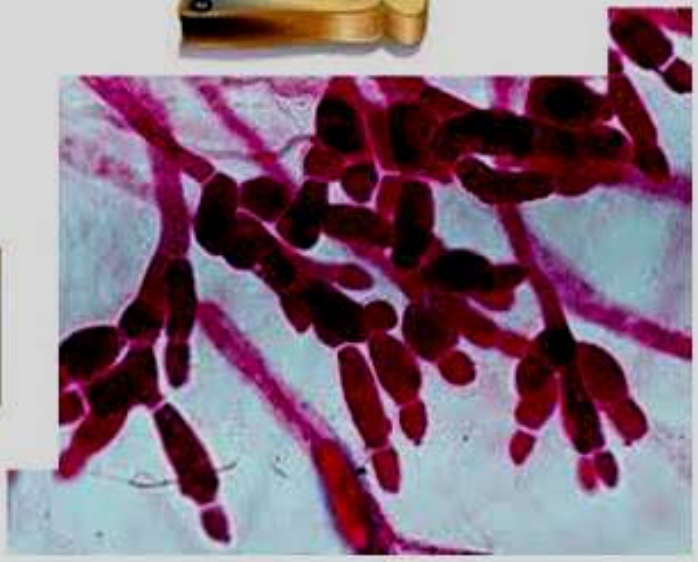
FIGURE 2.10

The morphology of yeasts varies widely.
[A] *Saccharomyces cerevisiae* with cells appearing as vegetative forms, budding cells, and spores.
[B] *Saccharomyces ludwigii*.
[C] *Geotrichum candidum*.
[D] *Pichia membranaefaciens*.




Chytridiomycota
(Allomyces, water molds)
Zygomycota
(Rhizopus, bread molds, Mucor)
Basidiomycota
(mushrooms, rusts, smuts)
Ascomycota
(Neurospora, yeast, sac fungi)
The Chytridiomycota were probably the first to branch away, but we aren't sure yet.
Common ancestor
The Ascomycota and Basidiomycota are more closely related to each other than to the other two phyla.


Spore germinates
ASEXUAL REPRODUCTION (by mitosis)
Sporangia



Eubacteria

-have variety of shapes: spheres, rods and spirals
-0.5-5.0 um width
-unicellular appear in pairs, chains, tetrads or clusters
-those with flagella swim rapidly thru liquids
-importance both in nature and in industry: recycling of wastes and production of antibiotics
-cause infection and disease like tetanus, cholera and tuberculosis

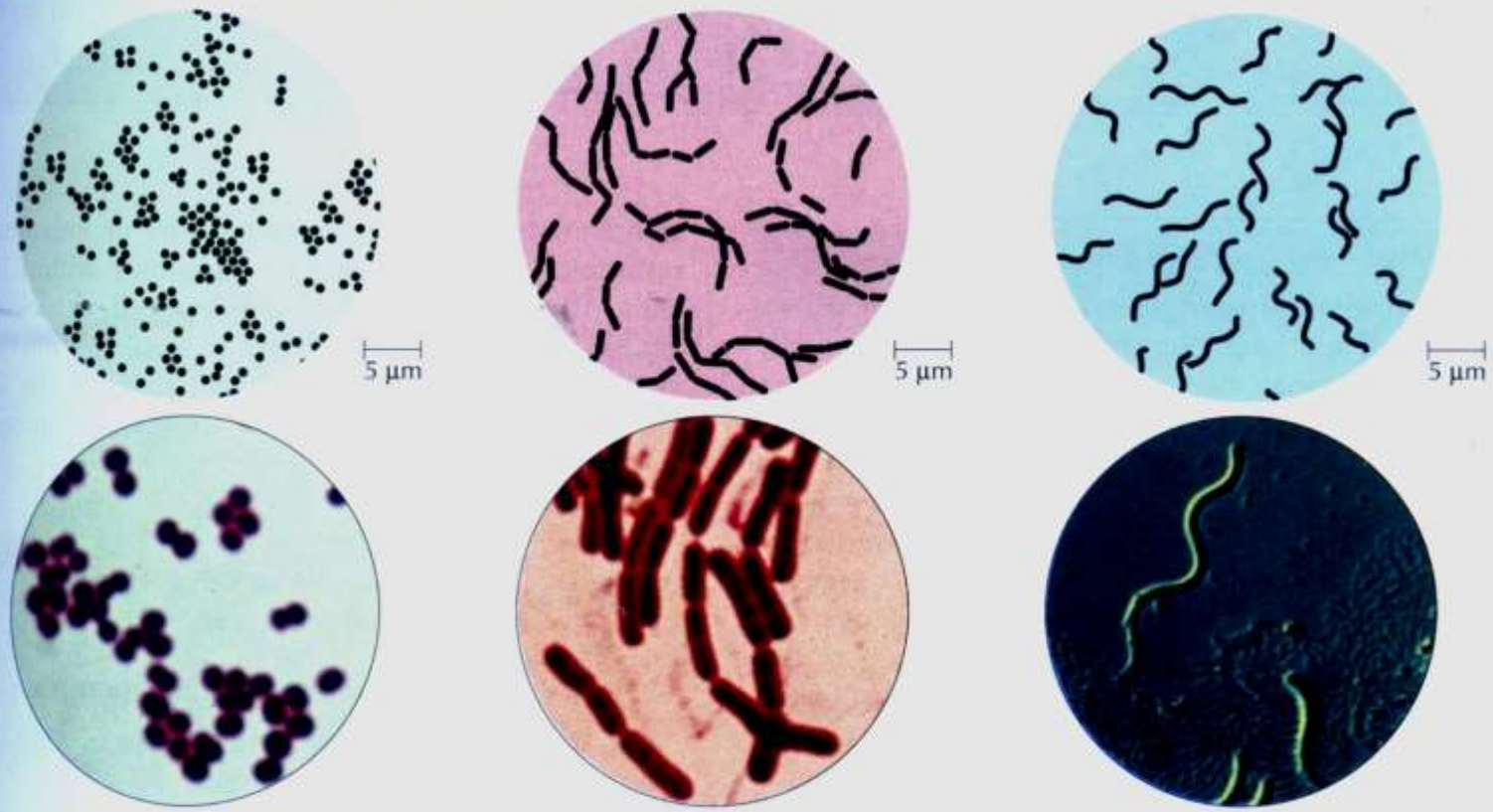
Archaebacteria

-differ with eubacteria in their chemical composition and activities and environment s in which they thrive

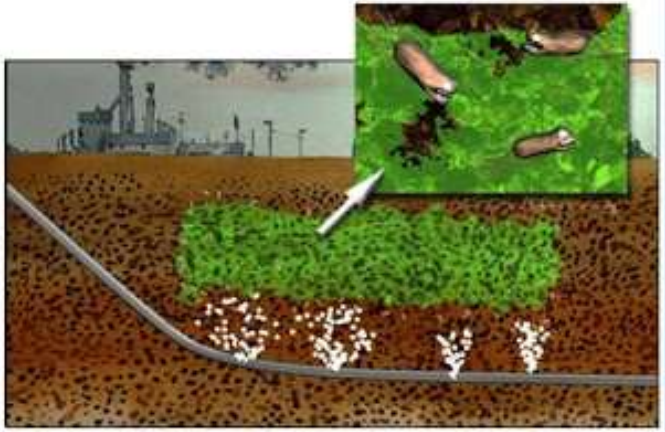
- high levels of salt or acid or high temperature
- produce methane gas

FIGURE 2.11

Bacteria. Bacterial cells are generally one of the following shapes: **[A]** spherical (cocci); **[B]** rodlike (rods or bacilli); **[C]** helical (spirilla). There are, however, many modifications of these three shapes, and bacteria of all shapes vary in sizes.



Microbiologists have found microbes living just about everywhere: in the soil, water and air; in animals, plants, rocks and even us!

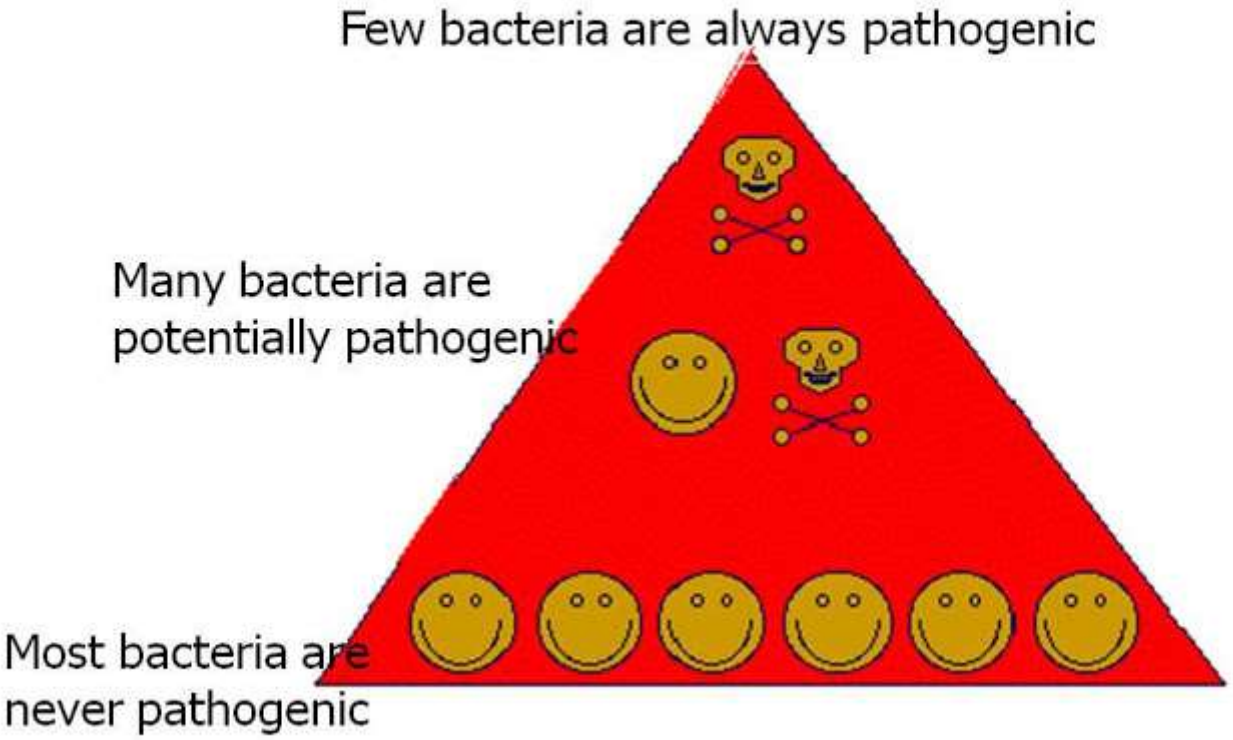


BACTERIA RULE!

Many of us know bacteria only as "germs"

... or invisible creatures that can invade our bodies and make us sick

Not all bacteria cause disease



Types of Bacteria

Heroes

Some microbes are newsworthy because they help fight diseases, control pollution, or perform some other useful function.

Microbe heroes

crop pest killer

helps us digest food

makes antibiotics

helps crops take up nutrients

cleans waste

makes bread rise

Dangerous

Others are notorious for causing diseases, creating hazardous substances, or posing some threat to other living things.

Ancient

Many microorganisms have captured the public's interest recently because of discoveries related to their great age.

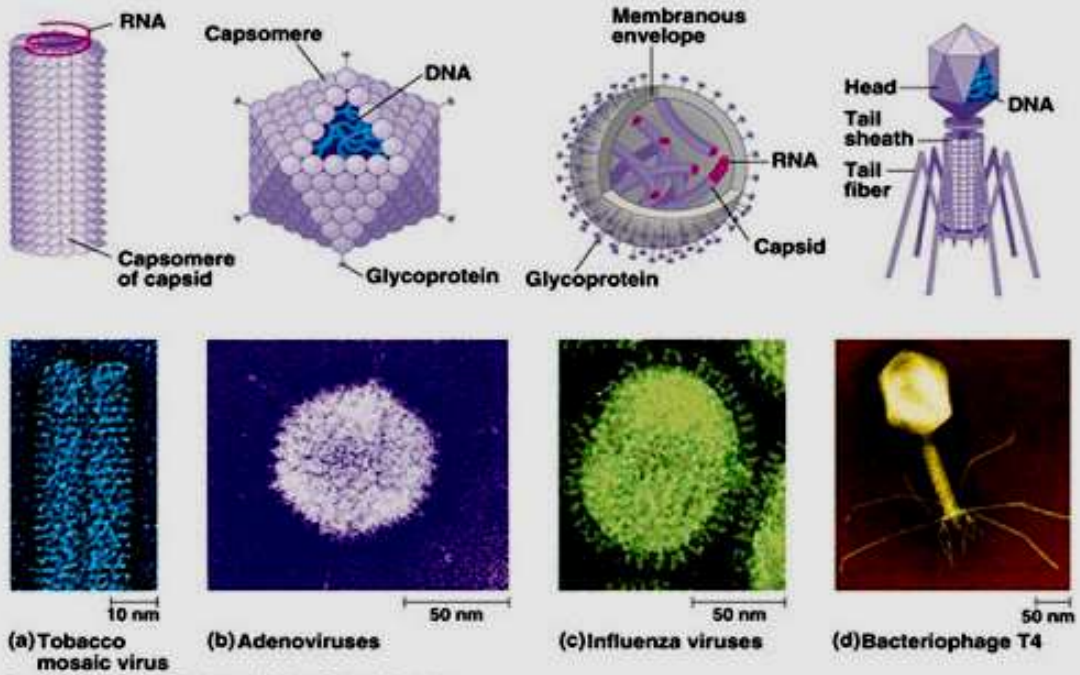
Strange

Some microbes grab attention because of their immense size, bizarre diet, or other unusual characteristics

Viruses

- borderline between living and non-living things
-they are not cells
-much smaller (20 to 300 nm in diameter)
-much simpler in structure than bacteria
-contain only one type of nucleic acids either RNA or DNA which is surrounded by a protein envelope or coat
-multiply within living organism
-exist in several shapes

Virology



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VIRION- an entire virus particle, consisting of an outer protein shell called a capsid and an inner core of nucleic acid (either ribonucleic or deoxyribonucleic acid—RNA or DNA).

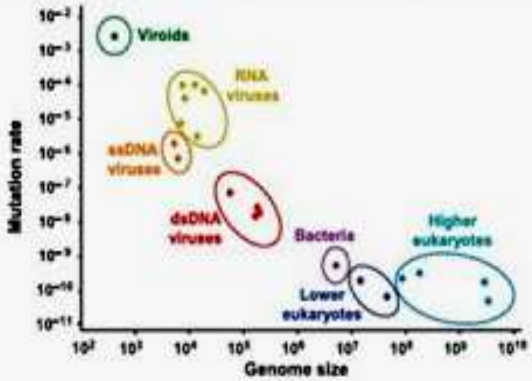
Viroids -are plant pathogens that consist of a short stretch of highly complementary, circular, single-stranded RNA without the protein coat that is typical for viruses.

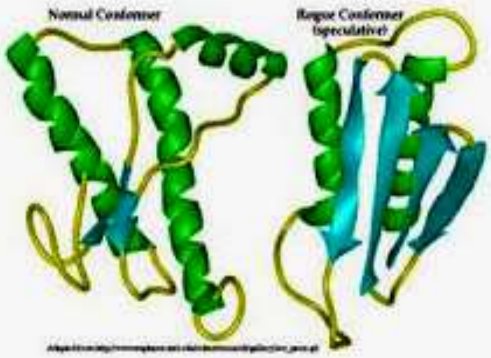
PRION - is an infectious agent that is composed primarily of protein.

-caused the ”mad-cow disease” or bovine spongiform encephalopathy (BSE) in cattle

-caused Creutzfeldt-Jakob disease (CJD) in humans.

Viroids and prions





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Other Organisms of Importance to Microbiologists

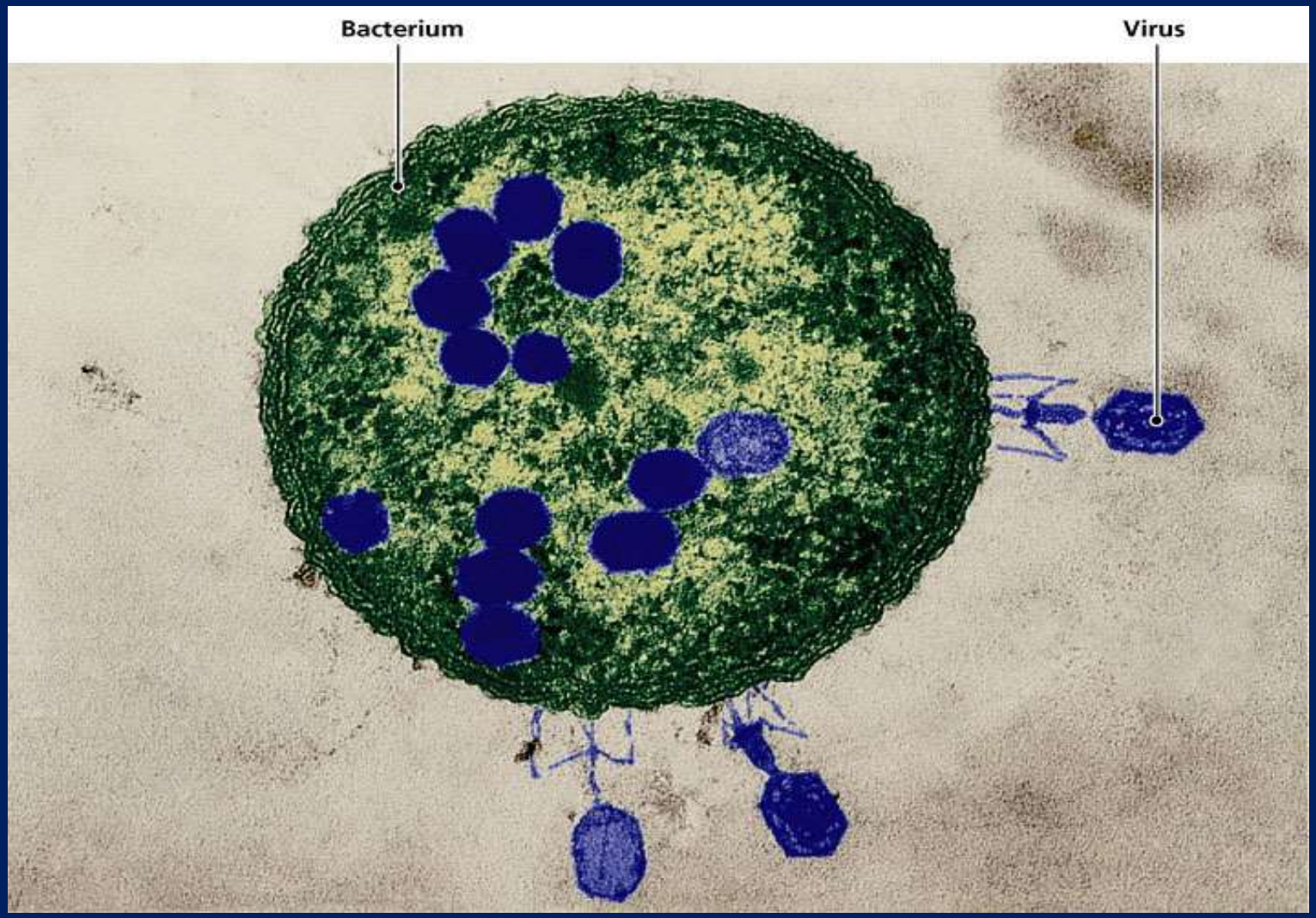

Figure 1.9

Thank you for listening!