NAME OF THE COURSE WORK
ENVIRONMENT & AGRICULTURAL MICROBIOLOGY

UNIT-I
ENVIRONMENTAL MICROBIOLOGY

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Historical Perspectives of Microbiology

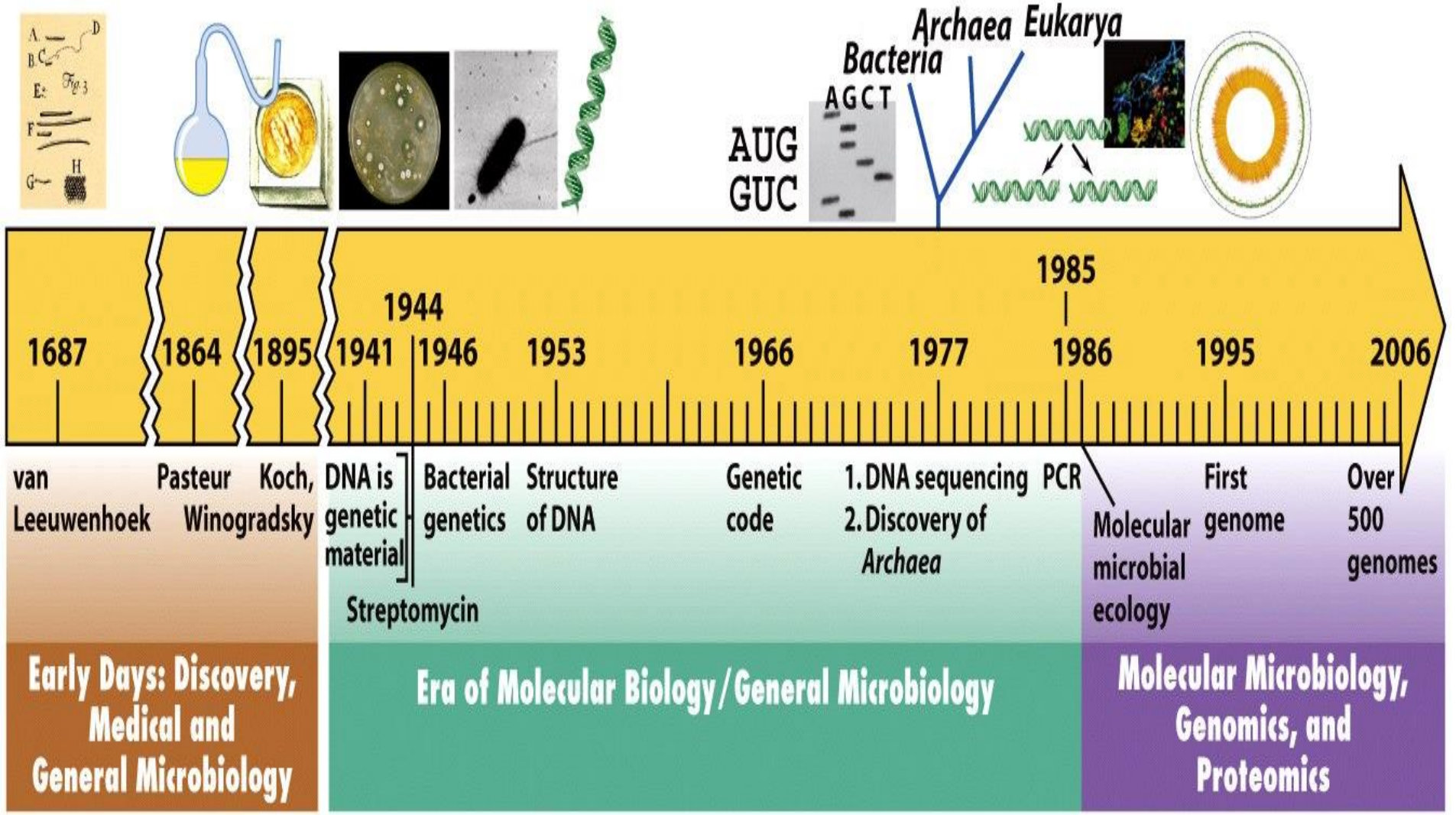


Figure 1-17 Brock Biology of Microorganisms 11/e

Environmental Microbiology – Definition

The study of microbial fate and activity in air, water and soil, and the resulting impact on human health and welfare.

Compare with:
Microbial Ecology – Definition

The science that explores interrelationships between organisms and their living and abiotic environment

Driving force behind Environmental Microbiology:

How can we harness the understanding of environmental microbes to benefit society?

Microorganisms in the Environment

Microorganisms are ubiquitous present in

- Sea water
- Fresh water
- Mesotrophic lakes
- Estuarine water
- Activated sludge
- Sediments and soil

The diverse types of microorganisms include

- Bacteria
- Virus
- Fungi
- Actinomycetes and
- Protozoa

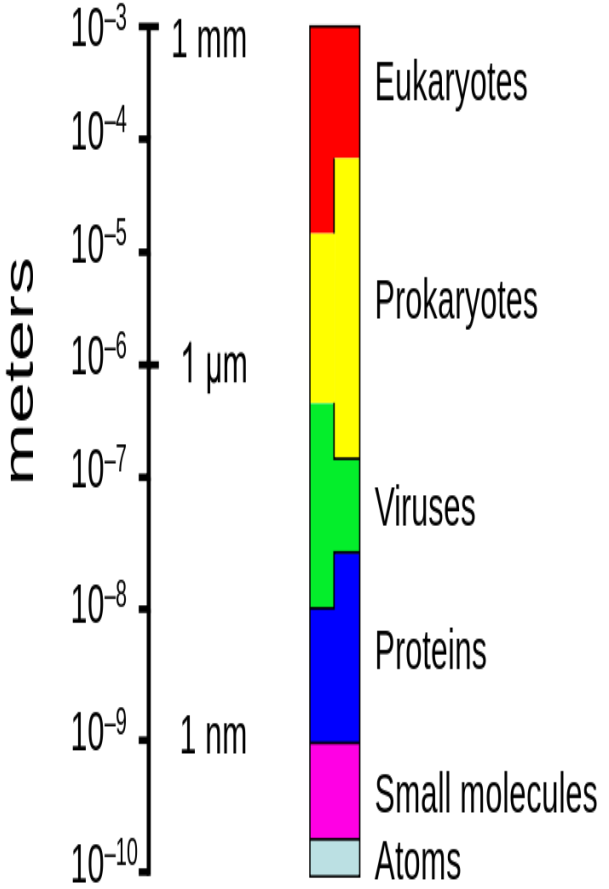
Microorganisms play a role as:

- Primary Producers
- Biodegraders And Consumers

Types of Microorganisms

Microorganisms can be, according to their characteristics, divided into several groups:

- pathogenic (capable of causing disease),
- non-pathogenic, and
- opportunistic (causing disease when they have an opportunity, like in people with low immune system)
- acellular (without cell, like viruses),
- unicellular (bacteria, yeasts and certain parasites), or
- multi-cellular (molds)



Products from Microorganisms

- Various foods and drinks
- Enzymes for varied uses (GM enzymes); biocatalysts
- Engineered proteins (antibodies)
- Vaccines and antibiotics (secondary metabolites)
- Primary metabolites and bulk chemicals (amino acids) and organic acids (acetic acid)
- Pharmaceuticals and novel chiral chemicals
- Recovery of metals in bioleaching
- Biosensors (use of enzymes to specifically detect chemicals in medical field)

Harmful Microorganisms

- Some of the microorganisms cause disease in humans, plants and animals
- Some microorganisms spoil food, clothing and even leather.

Virus

- Viruses have both living and non-living characters.
- Very tiny in size and can pass through bacteria-proof filters.
- They reproduce only in living cells.
- Chemically, they consist of nucleic acid enveloped by protein sheath.

Bacteria

- Generally, bacteria are very small
- Exist as cocci, bacilli, spiral, vibrio (comma) and filamentous forms
- Based on cellwall type, they are classified as G^{+ve} and $G^{-ve.}$
- They divide by means of binary fission.
- A single bacterial cell produce its progeny cell and
- form a colony that is measured by means of Colony Forming Unit (CFU).
- The growth of bacterial cell have four distinct phases:
  - Lag
  - Log
  - Stationary
  - Death

- In environment, they may live as individuals or as communities of same group or mixed group.
- They also form biofilms (aggregation).
- Mixed population of microbes live in close proximity which may be mutually beneficial.
- So, the recalcitrant pollutants are eventually degraded due to combined contributions.
- Under mixed population conditions, there is a possibility of bacteria to make horizontal gene transfer.
- Some bacteria are naturally competent, others exude competence factors.
- Bacteria living in a contaminated environment and develop additional degradative capabilities.

- Still other Bacteria live on the roots of certain plants, converting nitrogen into a usable form.
- Other Bacteria live symbiotically in the guts of animals or elsewhere in their bodies.
- Archebacteria (Methanogens) are anaerobes live in swamp sediments, sewage, and in buried landfills.
- Halophiles (aerobes) are salt-loving Archaebacteria that grow in high saline environment.
- The bacteria which grow best in the range of 0-15°C are known as psychrophiles.
- Barophiles can survive under great pressures.
- They live deep under the surfaces of the earth or water.

Thermophiles

- Archaebacteria are from hot springs and other high temperature environments.
- Thermophiles contain genes for heat-stable enzymes that may be of great value in industry and medicine.
- Taq polymerase, the gene for which was isolated from a collection of Thermus aquaticus in a Yellowstone Park hot spring.

Harmful Effects

- Bacteria are often maligned as the causes of human, plant and animal disease.
- Bacteria can also make our food contaminated and they can cause many serious bacterial diseases.
- Moreover, if they are used in many food products industries,
- Then they can also spoil the food as well, which can cause huge losses.

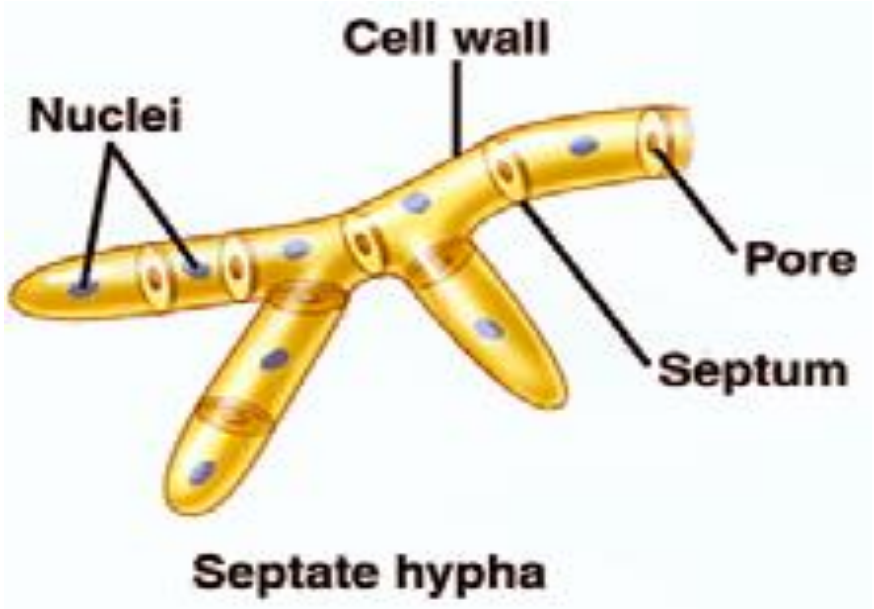
Uses of Bacteria

Beneficial effects of bacteria are wide:

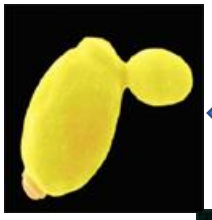
- Agricultural field – biocontrol and biofertilizers
- Environmental field – clean up of environment by bioremediation, recalcitrance, degradation of xenobiotic and toxic compounds
- Industrial field – production of enzymes, vitamins, acids, antibiotics
- Ecology - vital in recycling nutrients, such as the fixation of nitrogen from the atmosphere and putrefaction.

Fungi

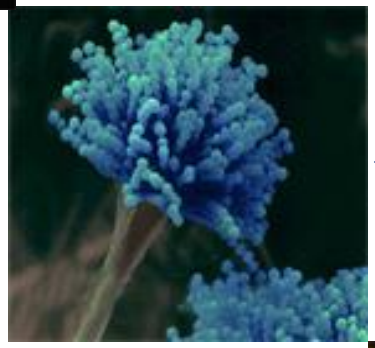
- Fungi is a group of simple plants that have no chlorophyll.
- Fungi are unicellular and multicellular.
- Fungi are made up of filaments called hyphe that are stacked together from end to end.
- Produce spores
- Some kinds of fungi live on land and water environments.
- Fungi live as either parasites, saprophytes and also as symbiotic.



Forms of Fungi



Unicellular & Microscopic



Multicellular & Microscopic

Multicellular & Macroscopic

Nutrition of Fungi

- Heterotrophic

  Obtaining their nutrition by absorption

- Saprophytic

  Secrete enzymes to break down dead organic matter in recycling

- Parasitic

  obtaining nutrition from living host

Characteristics of Fungi

- Fungal cells contain membrane-bound nuclei, membrane-bound cytoplasmic organelles such as mitochondria, sterol-containing membranes, and ribosomes of the 80S type
- Cells of most fungi grow as tubular, elongated, and thread-like (filamentous) structures – hyphae, growing at tip.
- Septa—regular cross-walls formed in hyphae.
- Fungal nuclei – 1-3μm dia, 30-40 chromosomes
- Dimorphic fungi can switch between a yeast phase and mold phase in response to environmental conditions.
- 60 fungal species display the phenomenon of bioluminescence

Activities of Fungi in Environment

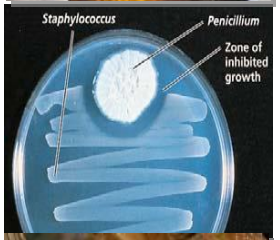
- Fungi are important decomposers of dead animal and plant matter.

Dead Organic Matter → **Simpler Compounds +** CO_2

- Plants also benefit from fungi because some fungi settle around the roots of plants.
- As the fungus decomposes dead matter around the roots of the plant, it leaves behind nutrients that the plant needs.
- Play a critical role in biogeochemical cycles and in many food webs.

Fungi In Industry

- Fungi Produce Many Products Used In The Medical Field Such As Penicillin, Cephalosporin Antibiotics, Cortisone
- Fungi Are Used In Genetic Engineering – Vaccine For Hepatitis B Was Developed Using The Yeast Plasmid As The Vector.
- Yeast Is Used To Make Ethanol.
- Yeast Are Known For Making Breads Rise.

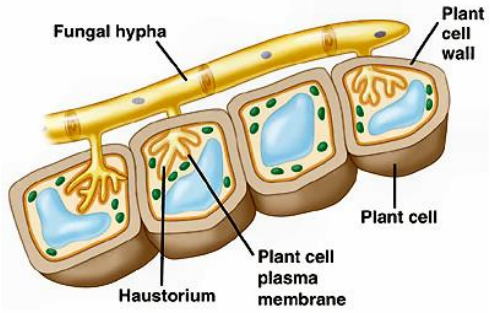


As Experimental Organisms

- Easily cultured, occupy little space, multiply rapidly, short life cycle.
- Study metabolite pathways
- Study growth, development, and differentiation
- Mechanisms of cell division and development
- Microbial assays of vitamins and amino acids
- Genetics - e.g. “one gene one enzyme” in Neurospora won Beadle and Tatum the Nobel prize

Beneficial Activities

- Mushrooms, morels and truffles are widely consumed by humans.
- Fungus in caves break down minerals in rock walls.
- *Trichoderma* is a good fungi, it attacks bad fungus that destroys crops
- Mycorrhizae, fungus-root associations that help plants absorb water and minerals from the soil

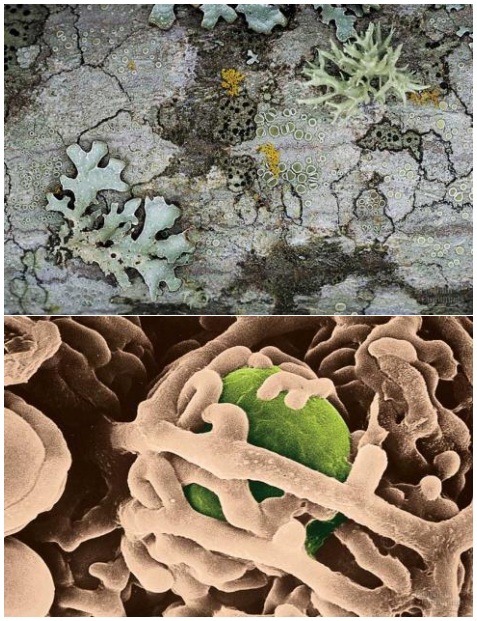


Pest control

- Certain species may be used to eliminate or suppress the growth of harmful plant pathogens, insects, mites, weeds, nematodes and other fungi that cause diseases of important crop plants.
- Entomopathogenic fungi can be used as biopesticides, they actively kill insects

Symbiosis

- Fungi form beneficial partnerships with other organisms such as trees and flowering plants
- Lichen – symbiotic relationship between algae and fungi
  - Algal partner – phycobiont
  - Fungal partner - mycobiont
- Some fungi share their digestive services with animals
- Helping break down plant material in the guts of cows and other grazing mammals
- Many species of ants and termites take advantage of the digestive power of fungi by raising them in "farms"



Lichens Uses

- Lichens break down rocks into soil
- natural dyes
- Thalli act like sponges
- Some species are more sensitive
- Presence of some species indicates air quality
- Most resistant species can also be analysed for pollutants
- Possess antimicrobial, anti-tumor and anti-oxidant activities
- In traditional medicines and cosmetic purposes

Harmful effects

- Many people have allergies triggered by mold.
- Fungal skin infections – skin, nails and hair, Ringworm, athlete’s foot
- Internal organs – Histoplasmosis
- Cause rot and contamination of foods
- Destroy leather, fabrics, plastics, etc.

Plant Pathogens

- Fungi are our most important plant pathogens, and include rusts, smuts, and many ascomycetes such as the agents of Dutch elm disease and chestnut blight.
- Many fungi attack grain or fruit.
- Witches Broom Fungi attacks cacao trees that produce chocolate
- Tar spot fungus on maple leaves
- Cause Ergots in rye and ergotism in human
- Corn smut on corn

Algae

- Algae are eukaryotes
- Photosynthetic
- Produce accessory pigments
- Can be microscopic or macroscopic
- Reproduce by sexual and asexual
- They are diverse

- Thrive under plenty of sunlight and warm temperatures.
- Algae farms could be located near industrial pollution sources,
- help clean the air by consuming CO2 as they grow.
- can feed off the nutrients in currently discharged wastewater or seawater
- high-quality protein left over from algae harvests can be converted to bio-products, like livestock feed.

red alga

brown alga

green alga

Diversity of Algae

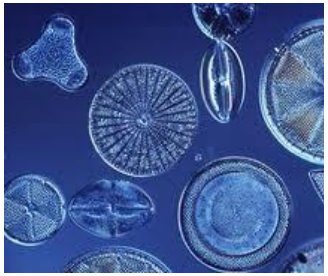
Microalgae

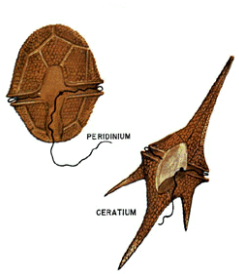
- Blue green algae
- Diatoms
- Dinoflagellates
- others, including raphidophytes

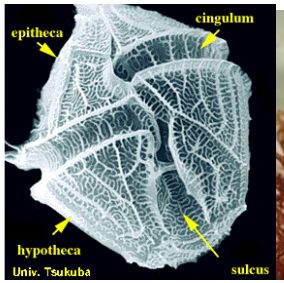
Macroalgae

Known as benthic seaweed

- Green Algae
- Kelps or Brown Algae
- Red Algae

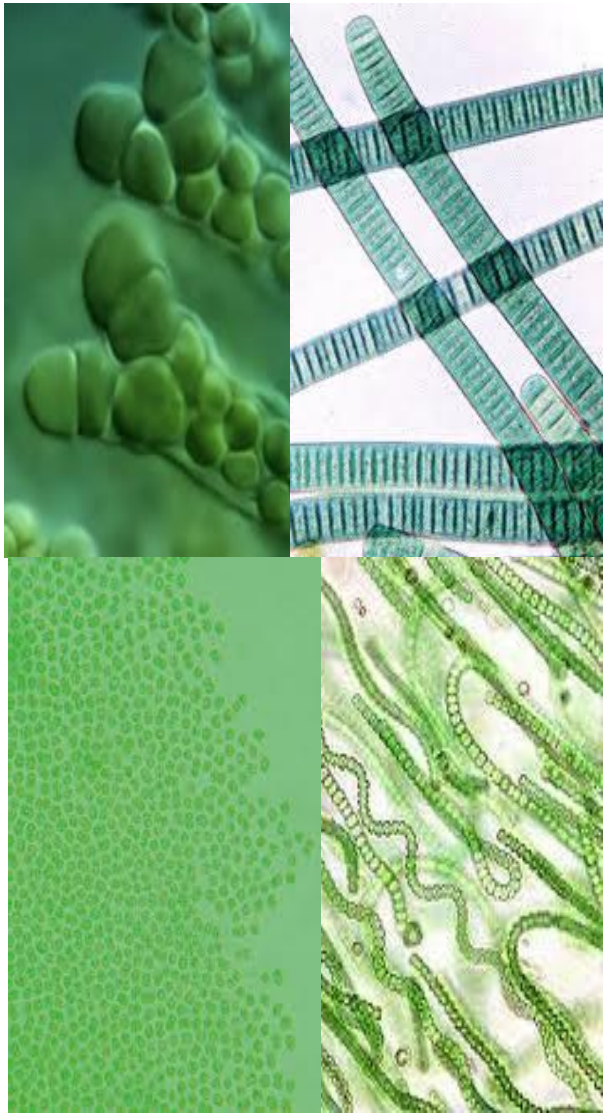






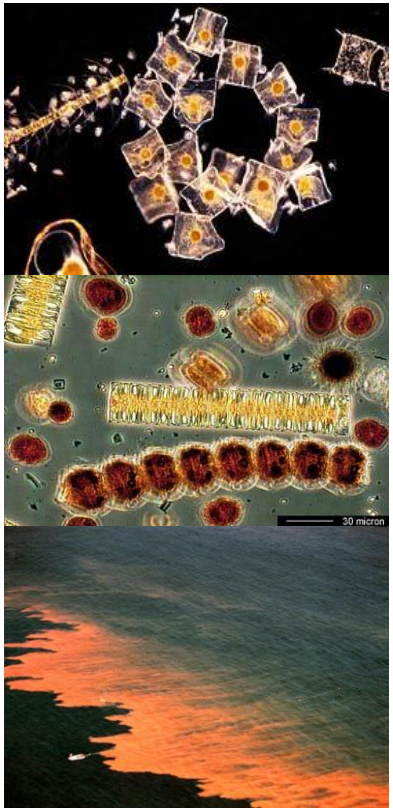
Cyanobacteria

- Blue-green algae, but not always blue-green
- One of the first life forms
- Prokaryotes -simple cells
- Often forms chains
- Organic cell walls –peptidoglycan
- Nitrogen fixers - N2 into organic N – heterocysts
- Some are toxic (microcystins, anatoxins, saxitoxins)
- Can survive in extremely hot environments and even extremely cold environment



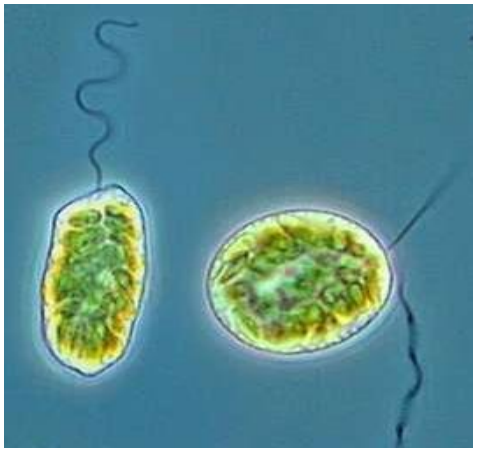
Dinoflagellates

- single cell eukaryotes
- phytoplankton - red tides
- dormant benthic stage
- can be heterotrophic
- active swimmers
- asexual and sexual reproduction
- Bioluminescent
- organic cell walls (cellulose)
- some are toxic (saxitoxins), e.g. Paralytic Shellfish Poisoning (PSP)
- raphidophytes can also cause red tides



Raphidophytes

- Eukaryotic algae
- Unicellular
- Large cells – no cellwall
- Flagellated
- Produce chlorophyll & accessory pigments
- Autotrophic
- Some species are toxic to fish

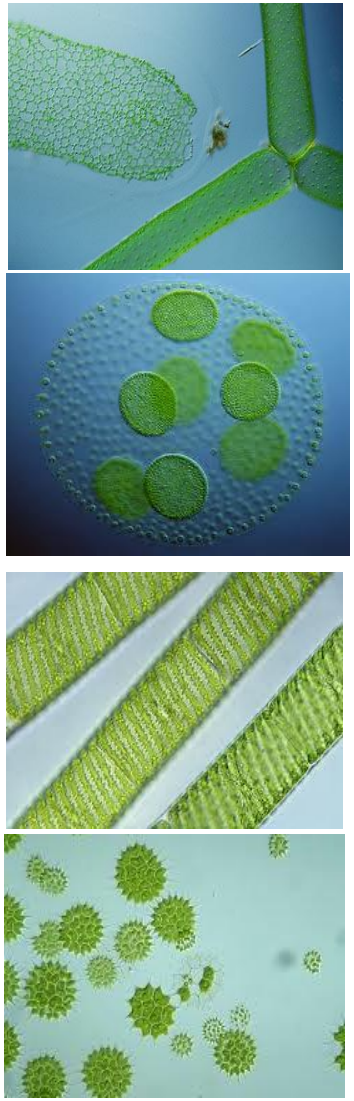


Diatoms

- Unicellular
- Cellwall made up of silica
  - frustules
- Frustules – two symmetrical sides
- phytoplankton and benthic forms
- asexual and sexual reproduction
- Few are toxic

Green Algae

- Unicellular
- colonial flagellates -two flagella per cell
- various colonial-
  - coccoid
  - filamentous forms
  - Macroscopic seaweeds.
- alternating haploid and diploid life stages
- sporophytes and gametophytes are benthic
- spores and gametes swim
- usually nontoxic but can deplete O2
- Bloom formers are often filamentous



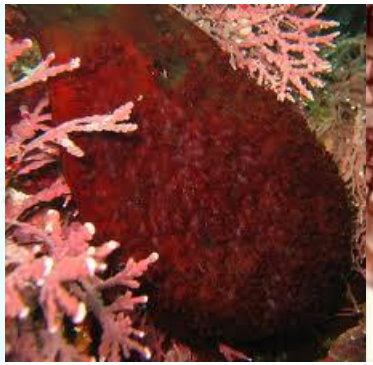
Brown Algae or Kelps

- Marine multicellular algae
- dominance of the xanthophyll pigment fucoxanthin
- Food reserves – polysaccharides, sugar and higher alcohol
- Microscopic to larger size
- largest and fastest growing of seaweeds
- Sexual reproduction
  isogamous, oogamous, or anisogamous
- include a number of edible seaweeds.

Red Algae

- eukaryotic cells without flagella and centrioles
- Multicellular
- Red algae have a double cell wall
  - Outer wall –pectin
  - Inner wall - cellulose
- floridean starch as food reserve,
- phycobiliproteins -accessory pigments
- Sexual reproduction

- Coralline algae -secrete $CaCO_3$ - building coral reefs
- Source of agar-agar
- Several species are used as food
  - High vitamin & protein content


Benefits of Algae

- The base of aquatic food chain – photosynthetic organisms
- Lichens : Algae and fungi symbiosis
- Also serve as shelters: kelps from under water forests and red algae from reefs
- Algae biofuels create a sustainable pathway to energy independence.
- Use photosynthesis to capture sunlight energy to produce oxygen and carbohydrates, creating a natural biomass oil product.
- Grow on non-arable, nutrient-poor land that won’t support conventional agriculture.

Commercial Benefits

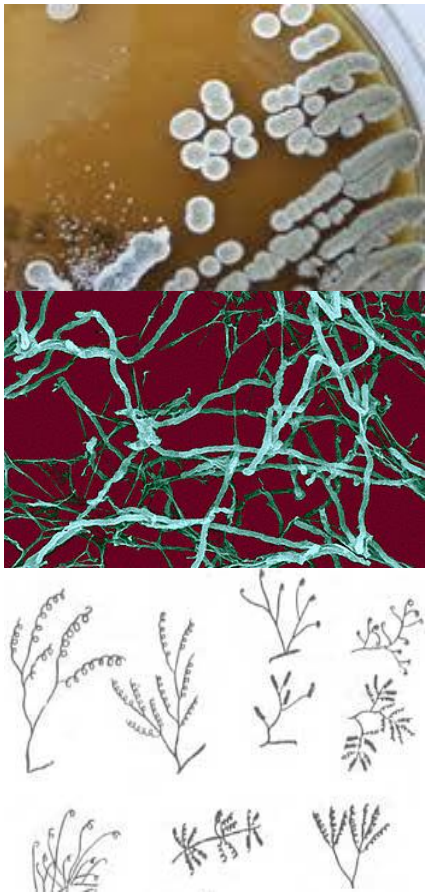
- Carrageenan is used for making ice creams, syrups, jellies and breads.
- Also used for tooth paste, lotions etc.,
- Agar-agar is obtained from red algae
- Algin - food thickening agent
- Red & brown algae as food
- As plant fertilizers
- Diatomaceous earth: used for filtering water, insulating and sound proofing

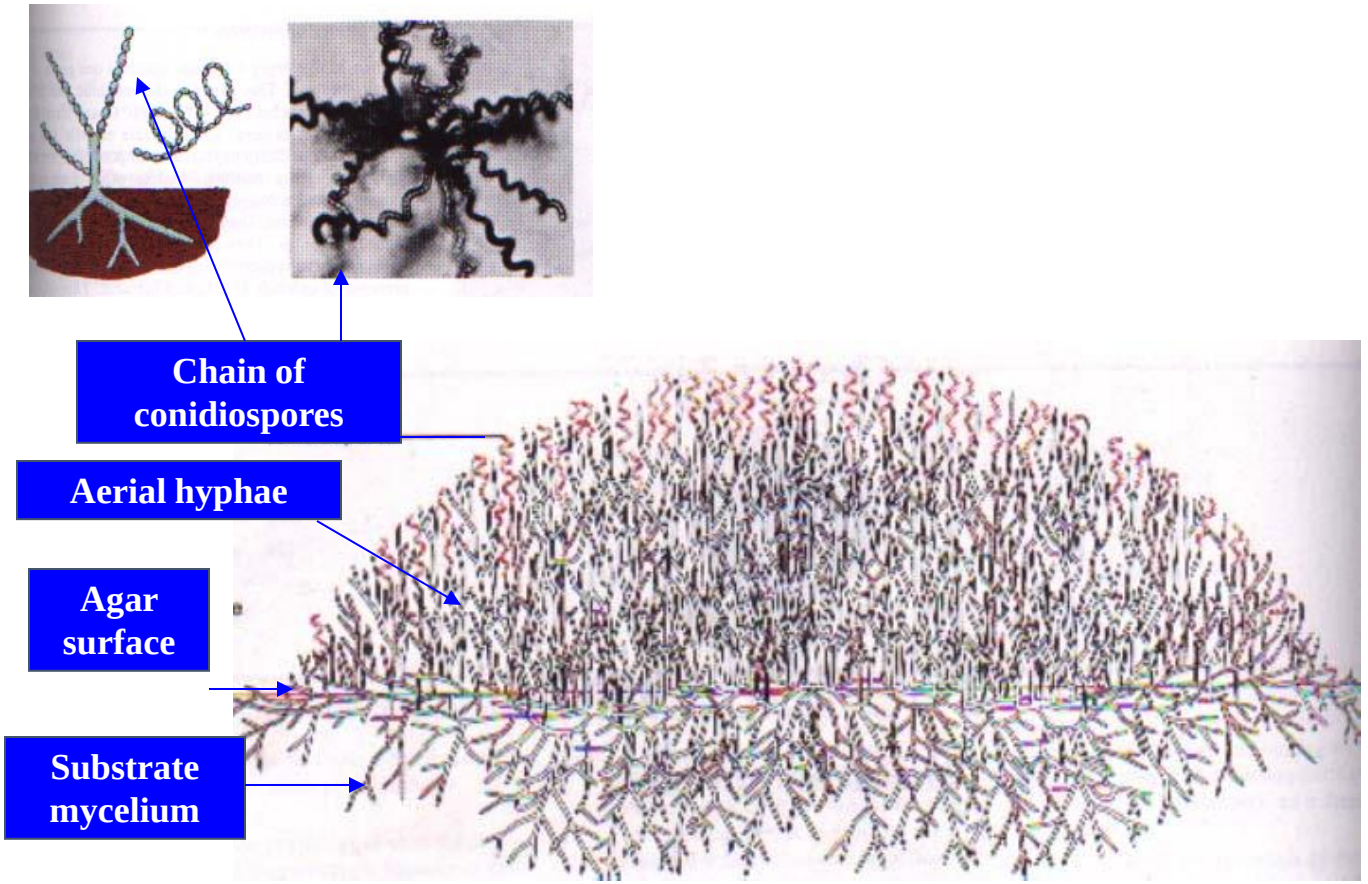

Harmful Effects

- Clogging of water ways, streams, filters that makes water taste in bad
- Can be toxic to animals
- ‘Red tides’ caused by dinoflagellates

Actinomycetes

- Transitional forms between bacteria & fungi
- Resemble bacteria:
  - Thin
  - Muramic acid cell wall
  - Prokaryotic nuclei
  - Susceptible to antibacterials
- Resemble fungi
  - Mycelial network of branching filaments
- Higher bacteria with
  - superficial resemblance to fungi
- Related to mycobacteria & corynebacteria
- Gram +ve, NM, NS, NC
- Filaments break up → bacillary & coccoid





The cross section of an actinomycete colony showing the substrate mycelium and aerial mycelium with chains of conidiospores

Benefits Antibiotics

- Over 500 distinct antibiotic substances have been shown to be produced by streptomycete.
- Most antibiotics are efficient against different bacteria.
- More than 50 antibiotics have been used in human and veterinary medicine, agriculture and industry
- The important role they play in soil ecology.
- They produce a number of enzymes that help degrade organic plant material, lignin and chitin.
- As such, their presence is important in the formation of compost.
- Frankia – Nitrogen fixer

Harmful Diseases

- Cause diseases in human
  - Actinomycosis,
  - Nocardiosis and
  - Streptomycosis

Protozoa

- These are microscopic, animalcule but few are visible to the unaided eyes.
- Spherical, amoeboid, ovoid, spindle & cup shaped.
- Body is a unicellular.
- Protoplasm, differentiated into ectoplasm, endoplasm.
- thick cell wall that allows for survival in harsh environments
- Free living forms

Benefits of Protozoa

- Some of the protozoans are photosynthetic
- Can produce eighty times as much food as the most efficient protein producing crops.
- Numerous holozoic protozoa feed upon bacteria live in wastes
- Play an important role in the sanitary betterment and keeping water safe for drinking.
- Protozoa are both herbivores and consumers in the decomposer link of the food chain.
- Helps in activated sludge process
- Recycle nutrients through their excretions
- Form symbiotic association with other organisms

Harmful Effects of Protozoa

- They commonly infect human intestines, can infect other tissues such as the heart, lungs, liver, and kidneys.
- Flukes are very difficult to get rid of once infected.
- Examples of human diseases caused by protozoa:
  - Malaria
  - Amoebiasis
  - Giardiasis
  - Toxoplasmosis
  - Cryptosporidiosis
  - Trichomoniasis
  - Leishmaniasis
  - Sleeping Sickness
  - Dysentery

Nematodes

- The nematodes are quite species diverse (about 10,000 species)
- Multicellular animals
- Many parasitic forms have a significant impact on humans.
- Most nematodes are under 5cm and many are microscopic.
- Some parasitic forms can be over a meter in length.
- Free-living nematodes live in the sea, in fresh water and in the soil.
- They occur worldwide in all environments
- most live in the interstitial spaces of sediments and soils.

Nematodes – Many Different Groups and Habits

- Beneficial in agriculture
  - Decomposers
  - Predators
  - Insect parasites
- Pests in agriculture
  - Animal parasites (often host-specific)
  - Plant parasites
- Others (freshwater, marine, etc.)

Plant Parasitic Nematodes – Habits and Habitat

- **Ectoparasites -** many kinds inhabit soil around plant roots, feed on roots
- **Endoparasites -** some kinds enter roots (bulbs, and other below-ground plant parts) and feed internally
- **Semi-endoparasites -** partially enter into roots
- **Foliar nematodes -** a few kinds enter above-ground plant tissue (leaves, seeds, stems)

Symptoms – Many are Typical of Plants with Root Damage

- Yield loss
- Stunting
- Yellowing
- Water deficiency and wilting
- Nutrient deficiency
- Some direct damage (knots on roots, misshapen potatoes, peanuts, etc.)

Beneficial Nematodes

- Many of the parasitic species cause important diseases of plants, animals, and humans.
- Nematodes has the potential of creating wholesale destruction of crops,
- Especially those grown in regions of wide weather fluctuation.
- Epidemics may destroy crops completely.

Nematode Diseases

- They are used as biological insecticides and pest control
- very effective against termites, German cockroaches, flies, ant, and fleas.
- Larvae, caterpillars, grubs, and maggots, are most susceptible
- Other benefits are pollination
- Play vital role in nutrient cycling
- Enhance the soil health
- They are now being commercialized

Microorganisms And Their Adaptations

- Most of the microorganisms in the world, survive in extreme environments.
- Is a way in which certain micro organisms biologically adapt to the environment
- For survival, they have special adaptive mechanisms to those exceptional environments
- Acidophiles
  - prefers highly low pH (acidic) for their survival.
- Cytoplasmic membrane is the important factor responsible for obligate acidophillic.
- When pH is raised to neutral, cytoplasmic dissolves and cell dies.
- High concnetration of H^+ ions are necessary for their survival.

Adaptation In Bacteria

- Their surrounding layers and the genetic information for these and other structures associated with a bacterium are capable of alteration.
- Some alterations are reversible, disappearing when the particular pressure is lifted.
- Other alterations are maintained
- can even be passed on to succeeding generations of bacteria.
- Resistance is an example of the adaptation of the bacteria to the antibacterial agent.
- Bacteria adapt to other environmental conditions as well.
- These include adaptations to changes in temperature, pH, concentrations of ions such as sodium, and the nature of the surrounding support.
- Ex: *Vibrio parahaemolyticus* to growth in a watery environment versus a more viscous environment.
- In the more viscous setting, the bacteria adapt by forming what are called swarmer cells.
- These cells adopt a different means of movement, which is more efficient for moving over a more solid surface.
- This adaptation is under tight genetic control, involving the expression of multiple genes.

- Bacteria react to a sudden change in their environment by expressing or repressing the expression of a whole lost of genes.
- This response changes the properties of both the interior of the organism and its surface chemistry.
- Adaptation is the phenomenon of chemotaxis
- whereby a bacterium can sense the chemical composition of the environment and either moves toward an attractive compound, or shifts direction and moves away from a compound sensed as being detrimental.

Possible Mechanisms of Adaptation

- Increase in population size of those organisms that tolerate unusual environment by induction of appropriate genes.
- Cells can adapt through mutations may acquire genetic information from either related or
- Phylogenetically distinct populations in the community by horizontal gene transfer (HGT)
- HGT is mediated by transferable plasmids, (conjugative) transposons, integrons, genomic islands or phage

Alkalophiles

- Alkalophiles contain unusual diether lipids bonded with glycerol phosphate.
- These lipids in the cell membrane maintains the intracellular pH near neutral
- Protects the cell under alkaline environments

Halophiles

- Contain K^+ ions higher inside the cells than Na^+ ions outside the cell – cell integrity is maintained.
- Cellwall of halobacteria is made up of ether-linked lipids, which maintains the cell integrity

Psychrophiles

- Active transport occurs at low temperature
- Cytoplasmic membrane are made to withstand low temperature
- Membrane contains poly unsaturated fattyacids in their lipids
- These PUFA maintains the cell integrity

Thermophiles & Hyperthermophiles

- Have heat stable enzymes and proteins
  - regulate molecular mechanisms at high temperature
- Different aminoacid composition in proteins to resist denaturation by heat
- Contains hydrocarbons of different length, 5-6 compound phytans linked with glycerophosphate in their membrane
- Special lipids like haponoids are present in thermophiles
- Makes membrane more rigid to high temperature

Barophiles

- The amount of unsaturated fatty acids is more in the membrane
- So, the loss of membrane fluidity due to pressure is restricted
- Protein composition of the cell wall outer membrane called OmpH protein – porin proteins
- Porins are structural proteins meant for the diffusion of organic molecules through the outer membrane and into the periplasm.
- OompH is pressure-dependent and required for growth at high pressure.
- Adaptive mechanism are highly helpful for survival and existence of microorganisms
- Thus, they can able to resist or degrade highly toxic xenobiotic compounds, pesticides and insecticides
- Further, detoxification is also possible
- Finally, it cleans up the environment .
- Depends on the type of microorganism and mechanism, the beneficial or harmful effects takes place.

At The Most Basic Level, Humans Depend Upon The Earth:

- Atmosphere…air to breathe
- Hydrosphere …water to drink
- Lithosphere …food to eat
- Biosphere … get to everything

Physical, Chemical and Biological Factors In Different Environment

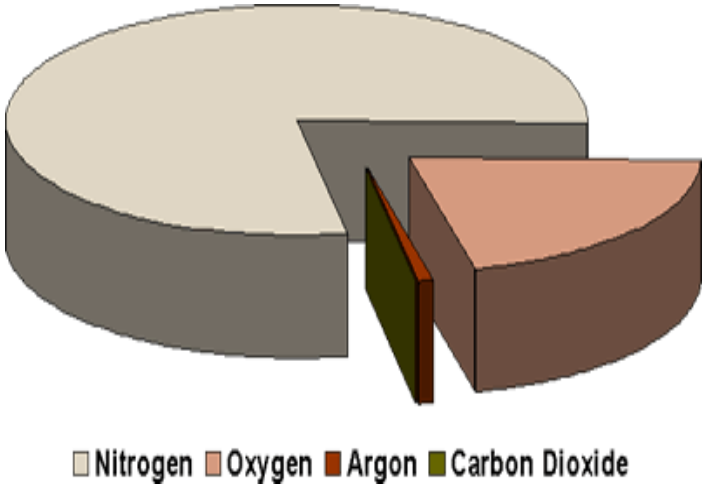
- The atmosphere is a life-giving blanket of air that surrounds our Earth.
- The greenhouse gases trap infrared radiation (heat) emitted from Earth's surface and atmosphere, causing the atmosphere to warm.
- Physical processes affect trends in temperature, humidity, clouds, and aerosols and help us assess the impact of a changing atmosphere on the global climate.
- Air is mainly composed of nitrogen, oxygen, and argon, which together constitute the major gases of the atmosphere.
- Important factors which determine the weather of the earth include:
  - Temperature
  - Pressure and
  - Density

Atmosphere

- The gases are all produced (or consumed) as a result of microbial processes in the soil,
- But the size of the fluxes between the soil and the atmosphere depends heavily on soil physical factors.
- Soil temperature and water content directly affect production and consumption of greenhouse gases, through their effects on microorganism and root activity.
- Gas movement in the atmosphere affects soil aeration indirectly controls the capacity of the soil to produce or consume CO_2, N_2O and CH_4.
- Soil water content is other factor -Soil dries there comes a point at which microbial activity is inhibited, and respiration decreases.
- Methane is formed in soils by the microbial breakdown of organic compounds in strictly anaerobic conditions

Composition of Air

Gas	Proportion by Volume
nitrogen, N	78.03
oxygen, O	20.99
carbon dioxide, CO	0.03
hydrogen, H	0.01
argon, Ar	0.94



- There are many different types of gasses in the atmosphere
- They include nitrogen, oxygen, argon, carbon dioxide and other noble gasses
- The gas that is most abundant is nitrogen

Hydrosphere

- The hydrosphere includes all the water that is on Earth.
- Sources of water include freshwater (e.g. rivers, lakes), saltwater (e.g. oceans), groundwater (e.g. boreholes) and water vapour.
- Ice (e.g. glaciers) is also part of the hydrosphere.
- The hydrosphere interacts with other global systems, including the atmosphere, lithosphere and biosphere.
- The hydrosphere has a number of important functions.
- Water is a part of all living cells, it provides a habitat for many living organisms,
- It helps to regulate climate and it is used by humans for domestic, industrial and other use.
- The polar nature of water means that ionic compounds dissociate easily in aqueous solution into their component ions.
-

Lithosphere

- The **lithosphere** is the rigid outermost shell of a rocky planet.
- Surface of the planet that forms the continents and the ocean floor.
- Below the lithosphere (which makes up the tectonic plates) is the asthenosphere
- There are two types of lithosphere:
  - Oceanic lithosphere
    - associated with oceanic crust and exists in the ocean basins.
    - Oceanic lithosphere is typically about 50–100 km thick
  - Continental lithosphere
    - associated with continental crust.
    - Continental lithosphere has a range in thickness from about 40 km to perhaps 200 km, of which about 40 km is crust.

Biosphere

- The biosphere is the biologically inhabited portion of the Earth in which ecosystems operate
- Studies of the biosphere are linked with geology, ecology, soils, atmospheric processes and climate, oceans
- Humans influence the biosphere through a range of deliberate and inadvertent practices
- Biomes are major global scale zones with characteristic life forms of plants and animals

Functions and Processes within the Biosphere: Controlling Factors

- **Temperature regime**
  - Actual temperature and seasonal pattern is critical for life
  - Growing season creates a base-line of food for others
  - Adaptability to temperature ranges
- **Moisture availability**
  - Local rainfall regime – esp. length of dry season
  - Potential evapotranspiration and accessibility to river/groundwater
- **Zonal factors**
  - Regional macroclimate (equatorial, monsoonal etc) correlate to biomes
  - Creates favourable/unfavourable conditions for life
- **Azonal factors**
  - Disrupt otherwise climatically-controlled pattern
  - Geomorphology affects drainage and aspect.
  - Geology

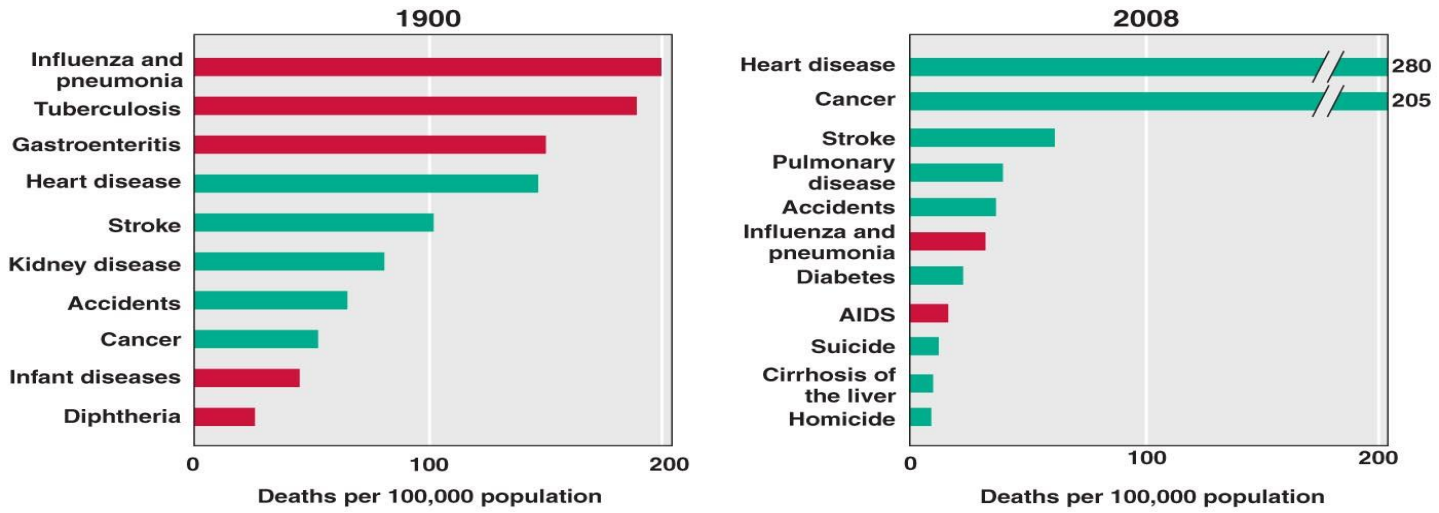
Significance of Microbial Ecology

1. Origin of life
2. Microbial ubiquity and diversity
3. Biogeochemical cycle and biosphere formation
4. Bioremediation and biotechnology

The Impact of Microorganisms on Humans

- Microorganisms can be both beneficial and harmful to humans
- Emphasis typically on harmful microorganisms (infectious disease agents, or pathogens)
- But many more microorganisms in nature are beneficial than are harmful microorganisms as disease
- Control of infectious disease during last century

Death Rates and the Leading Causes of Death in the U.S.



- **Microorganisms and Agriculture**
  - Many aspects of agriculture depend on microbial activities
    - Nitrogen-fixing bacteria
    - Cellulose-degrading microbes in the rumen
    - Regeneration of nutrients in soil and water

- **Microorganisms and Food**
  - Negative impacts
    - Food spoilage by microorganisms requires specialized preservation of many foods
  - Positive impacts
    - Microbial transformations (typically fermentations) yield
      - Dairy products (e.g., cheeses, yogurt, buttermilk)
      - Other food products (e.g., sauerkraut, pickles, leavened breads, beer)

- **Microorganisms, Energy, and the Environment**
  - The role of microbes in *biofuels* production
    - e.g., methane, ethanol, hydrogen
  - The role of microbes in cleaning up pollutants (*bioremediation*)