NAME OF THE COURSE WORK
ENVIRONMENT & AGRICULTURAL MICROBIOLOGY

UNIT-II
AIR & AQUATIC MICROBIOLOGY

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Aerobiology as a term was coined in the 1930's to describe a multi disciplinary research area with the aim of increasing the knowledge of how biological particles in the atmosphere are transported become airborne, deposited and their biological effects.

The biological particles considered in aerobiology covers both microorganisms, for example bacteria, fungi, algae and viruses, as well as spores, pollen, seeds, insects and other biological material.

Mainly deals with microorganisms, their transmission in the atmosphere and their negative effects on humans, animals and plants.

Aerobiology

- The interdisciplinary science that deals with the movement and dispersal of bioaerosols.
- The movement of bioaerosols is generally passive and is greatly influenced by the environment.
- The survival of viable bioaerosols is also dependent on the environmental conditions.

Bioaerosols

- Biological agents carried in the air as large molecules, volatile compounds, single particles, or clusters of particles that are living or were released from a living organism.
- Particles sizes – 0.5 µm to 100 µm.
- Capable of eliciting diseases that may be infectious, allergic, or toxigenic with the conditions being acute or chronic.

Bioaerosols in Our Environment

Outdoor Sources

- Fungal Spores
- Pollen
- Bacteria

Indoor Sources

- Viruses
- Bacteria
- Fungal Spores
- Dust mites
- Cockroaches
- Animal Dander - especially cats

Some Examples of Bioaerosols

Living Source	Examples
❖ Microorganisms (microbes):	
❖ Bacteria	Legionella, Actinomycetes, endotoxins
❖ Fungi	*Histoplasma*, *Alternaria*, *Pencillium*, *Aspergillus*, *Stachybotrys aflatoxins*, aldehydes, alcohols
❖ Protozoa	Naegleria, Acanthamoeba
❖ Viruses	Rhinoviruses (colds), Influenza (flu
❖ Algae	Chlorococus
❖ Green plants	Ambrosia (ragweed) pollen
❖ Arthropods	Dermatophagoides (dust mites) feces
❖ Mammals	horse or cat dander

Some types and diameters of airborne particles

Types	Diameters (μm)
Smoke	0.001–0.1
Condensation nuclei	0.1–20.0
Dusts	0.1–cm
Viruses	0.015–0.45
Bacteria	0.3–10
Fungal Spores	1.0–100
Algae	0.5–cm
Lichen Fragments	1.0–cm
Protozoa	2.0–cm
Bryophyta spores	6.0–30.0
Pteridophyta spores	20.0–60.0
Pollen	10.0–100.0
Vegetal and animal fragments, seeds, insects	> 100

Main Modes of Transmission

Isolation guidelines in Institutions are based on these

AIRBORNE

DROPLET

CONTACT

Direct **Indirect**

Vectorborne, Common source: Water, Food, Equipment, Rx

Droplet Transmission

- A form of contact transmission
- Droplets are propelled a short distance (3 feet)
- Droplets are deposited on hosts such as the mucous membranes of eye, nose or mouth
    - Droplets are generated by coughing, sneezing or talking

Droplet Transmission

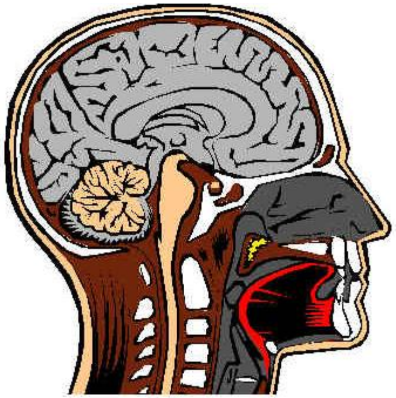
- Droplets transmitted during medical procedures of bronchoscopy or suctioning that put healthcare workers at risk
- Private room ideal
    - Can be placed w/other similar conditions 3’ apart if room availability is an issue
- Healthcare worker must wear mask when caring for a person with droplet isolation precautions
- Example:
    - Influenza

Cough Produces Good Droplet Nuclei

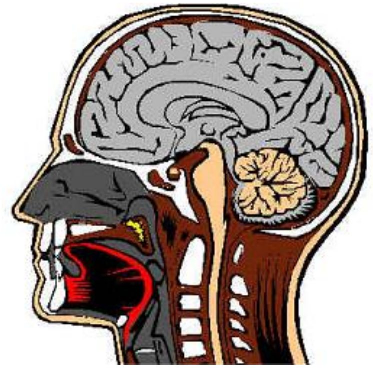
- Cough
  - 1 good cough produces 465 DN
  - after 30 minutes left: 228 DN (49%)

- Speech:
  - count from 1 to 100 1764 DN
  - after 30 minutes left 106 DN (6%)
- Singing

Transmission By Droplet



- **large droplets**
- **from upper respiratory tract**



Short range:
3 to 6 feet

Transmitted By Droplets

- *Hemophilus influenzae*
- Meningococci
- Pneumococcal infections (invasive, resistant)
- BACTERIAL RESPIRATORY Infections
  - \- Diphtheria, Pertussis, pneumonic plague, *Mycoplasma pneumoniae*
  - \- Streptopharyngitis, Pneumonia, scarlet fever
- VIRAL RESPIRATORY Infections
  - \- Adenovirus, Influenza, Mumps, Parvovirus, Rubella
- ANY PAROXYSMAL COUGH (Pertussis)

Aerosol

- Particles of solids or liquids dispersed in a gas (air)
- Coarse mode: ≥ 2 μm, liquid evaporation or mechanical generation

- Intermediate mode: 0.1 - 1 μm coalescence of nuclei
- Nuclei mode: ≤ 0.03 μm, gases, transient ⇨ intermediate

Human Hair 70 μm

Aerosol

- ❖Space aerosol:
  - ❖Insecticide /Household spray
  - ❖30-50 μm
  - ❖1 second ⇨ 120,000,000 particles
- ❖Surface aerosol:
  - ❖Spray paint
  - ❖Larger particles to settle on paint rapidly

Airborne Microbes and Aerosols

- Airborne transmission is possible for essentially all classes of microbes: viruses, bacteria, fungi and protozoans.
- Any respiratory pathogen able to survive aerosolization and air transport is considered a potential cause of airborne disease.
- Aerosols: Airborne particles, either solid or liquid, about 0.5 to 20 microns in diameter, that remain airborne for extended periods of time.
- Droplets: >20 (usually 100+) microns in diameter; settle rapidly or evaporate to form droplet nuclei in the aerosol size range.

Number and Size of Organisms

Number of organisms released

Talking	0-200
Coughing	0-3,500
Sneezing	4,500- 1,000,000

Size of the droplets (function of air velocity)

Sneeze ~3-10 m/s

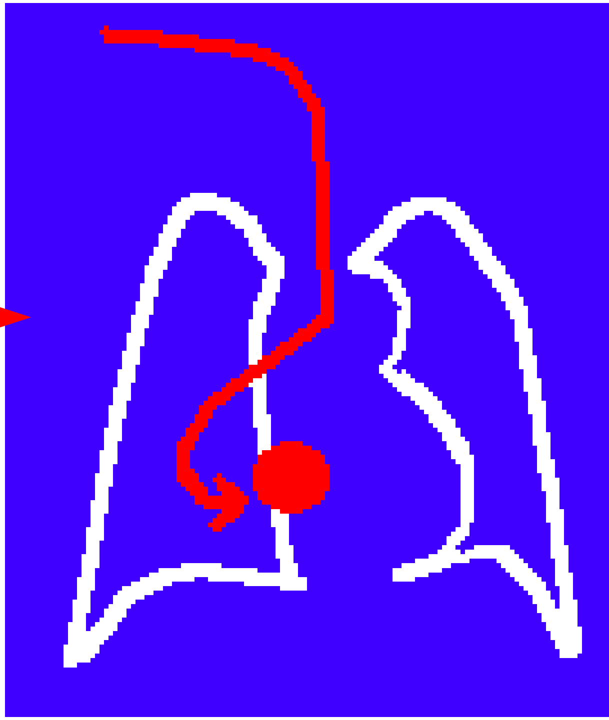
75% are ~10 μm in diameter

< 25% are droplet nuclei (1-5 μm in diameter).

Transmitted Airborne: TB

- ±COUGHING
- ± SINGING
- ± SNEEZING
- ± SPEAKING

droplet nuclei has to reach the alveoli to start an infection



- Large droplets 50 µm fall down
- if inhaled, stick to bronchi,
- then brushed up and swallowed
- Not infectious

Table 1. Airborne pathogens and allergens in animal laboratories

Airborne pathogen	Group	Source or species infected	Disease	Mean diameter (m
Avian adenovirus (FAV)	Virus	Birds	Respiratory disease, bronchitis	0.08
Bovine adenovirus	Virus	Bovines	Respiratory disease	0.08
Canine distemper virus (CDV)	Virus	Dogs	Canine distemper	0.14
Coxsackievirus	Virus	Humans, mice, rabbits, hamsters, swine, primates	Colds, acute respiratory disorder	0.03
Echovirus	Virus	Humans, mice, primates	Colds, meningitis	0.03
Equine rhinopneumonitis virus	Virus	Horses	Equine rhinopneumonitis	0.02
Feline picornavirus	Virus	Cats	Feline pneumonitis, upper respiratory disease	0.02
Guineapig adenovirus	Virus	Guinea pigs	Respiratory disease	0.08
Hantaan virus	Virus	Rodents	Hemorrhagic fever, Korean hemorrhagic fever	0.10
Influenza A virus	Virus	Nosocomial; humans, birds, pigs	Flu, secondary pneumonia	0.10
Junin virus	Virus	Rodents	Hemorrhagic fever	0.12
Marburg virus	Virus	Humans, monkeys	Hemorrhagic fever	0.04
Measles virus	Virus	Humans, monkeys	Measles (rubeola)	0.16
Pneumonia virus of mice (PVM)	Virus	Mice	Pneumonia	0.20
Mumps virus	Virus	Humans, primates, rodents	Mumps, viral encephalitis	0.16
Newcastle disease virus (NDV)	Virus	Birds	Newcastle's disease	0.14
Parainfluenza virus	Virus	Humans, monkeys, dogs, rodents	Flu, colds, croup, pneumonia	0.19
Paravaccinia virus	Virus	Cattle, humans	Pseudocowpox	0.24
Poxviruses	Virus	Rabbits, sheep, swine, mice, horses, fowl, goats, cows	Mousepox, sheeppox, rabbitpox, swinepox, monkeypox, horsepox, fowlpox, goatpox, cowpox	0.24
Reovirus	Virus	Humans, birds, mice	colds, fever, pneumonia, rhinorrhea	0.08
Respiratory syncytial virus	Virus	Humans, chimpanzees	Pneumonia, bronchiolitis	0.19
Reston virus	Virus	Monkeys	Reston disease	0.04
Rubella virus	Virus	Humans, monkeys	Rubella (German measles)	0.06
Sendai virus	Virus	Rodents, hamsters	Sendai disease	0.14
Sialodacryoadenitis virus (SDAV)	Virus	Rats	Rat coronaviral disease	0.11
Simian adenovirus	Virus	Primates	Upper respiratory disease, enteritis	0.08
Theiler's virus	Virus	Mice	Encephalomyelitis	0.02
Vaccinia virus	Virus	Agricultural	Pox	0.22
Acinetobacter	Bacteria	Environment, soil, sewage, buildings; rats, swine	Opportunistic infections, sepsis, meningitis	1.22
Actinomyces bovis	Bacteria	Hamsters	Actinomycosis	0.90
Actinomyces israelii	Bacteria	Humans, cattle, rabbits, hamsters	Actinomycosis	0.90
Aerococcus viridans	Bacteria	Rodents, rabbits	Meningitis	1.41
Aeromonas spp.	Bacteria	Environment, soil; rodents	Nonrespiratory opportunistic infections, bacteremia	2.10
Alcaligenes spp.	Bacteria	Soil, water, buildings; humans, swine	Opportunistic infections	0.78
Bacteroides fragilis	Bacteria	Humans, rodents, rabbits	Opportunistic infections	3.16
Bordetella bronchiseptica	Bacteria	Rabbits, cats	Upper respiratory disease, pneumonia	0.32
Brucella	Bacteria	Goats, cattle, swine, dogs	Brucellosis, undulant fever	0.57
Burkholderia cepacia	Bacteria	Environment; rabbits	Opportunistic infections	0.71
Burkholderia mallei	Bacteria	Environment, nosocomial; horses, mules	Glanders, fever, opportunistic infections	0.67
Burkholderia pseudomallei	Bacteria	Environment, nosocomial, soil; rodents	Meliodosis, opportunistic infections	0.49
Chlamydia psittaci	Bacteria	Birds, fowl	Psittacosis/ornithosis, pneumonitis	0.28
Clostridium perfringens	Bacteria	Environment, soil; humans, animals	Sepsis, toxicosis, food poisoning	5.00
Corynebacterium bovis	Bacteria	Mice	Hyperkeratosis	0.70
Corynebacterium kutscheri	Bacteria	Mice	Pseudotuberculosis	0.70
Coxiella burnetii	Bacteria	Cattle, sheep	Q fever	0.28
Diplococcus pneumoniae	Bacteria	Monkeys	Pneumonia	0.71
Enterobacter cloacae	Bacteria	Humans, environment, rabbits	Opportunistic infections	1.41
Francisella tularensis	Bacteria	Animals, hamsters	Tularemia, pneumonia, fever	0.20
Haemophilus spp.	Bacteria	Rodents, guinea pigs, rabbits	Pneumonia, conjunctivitis, meningitis	1.00
Klebsiella orthinolytica	Bacteria	Rodents, rabbits	Pneumonia	0.67
Klebsiella oxytoca	Bacteria	Rodents, rabbits	Pneumonia	0.67
Klebsiella planticola	Bacteria	Rodents, rabbits	Pneumonia	0.67
Klebsiella pneumoniae	Bacteria	Environment, soil, humans, monkeys, mice, swine buildings	Opportunistic infections, pneumonia	0.67
Mycobacterium africanum	Bacteria	Monkeys	TB	0.90
Mycobacterium avium	Bacteria	Environment, water, mice	Cavitary pulmonary disease.	1.12
Mycobacterium bovis	Bacteria	Monkeys	TB-like infections	0.90
Mycobacterium lepraemurium	Bacteria	Rodents	Leprosy	0.90
Mycobacterium microti	Bacteria	Rodents	Tuberculosis	0.90
Mycobacterium tuberculosis	Bacteria	Humans, sewage, monkeys	Tuberculosis, TB	0.64
Mycoplasma pulmonis	Bacteria	Rats, mice	Chronic respiratory disease, murine mycoplasmosis	0.49
Pasteurella lepisceptica	Bacteria	Rabbits	Upper respiratory disease, pneumonia	0.24
Pasteurella multocida	Bacteria	Rabbits, rodents	Chronic respiratory disease, rhinitis, Otitis media, pneumonia	0.24
Pasteurella pneumotropica	Bacteria	Rodents	Rhinitis, sinuitis, otitis media	0.24
Pasteurella spp.	Bacteria	Monkeys	Pneumonia	0.24
Pneumococcus Type II	Bacteria	Rats, guinea pigs	Bacterial pneumonia	0.71
Pseudomonas aeruginosa	Bacteria	Environment, sewage, swine buildings	Pneumonia, toxins	0.49
Pseudomonas diminuta	Bacteria	Rats, guinea pigs	Rhinitis, conjunctivitis	0.49
Staphylococcus aureus	Bacteria	Humans, sewage, rodents	Staphylococcal pneumonia, opportunistic infections	0.87
Staphylococcus cohnii	Bacteria	Rats	Pneumonia, dermatitis	0.87
Staphylococcus haemolyticus	Bacteria	Rats	Pneumonia, dermatitis	0.87
Staphylococcus sciuri	Bacteria	Rats	Pneumonia, dermatitis	0.87
Staphylococcus xylosus	Bacteria	Rats	Pneumonia, dermatitis	0.87
Streptobacillus moniliformis	Bacteria	Rats	Inner ear infection	0.64

Air Sampling Techniques

Principle Collection Methods

- ❖ Gravity
- ❖ Impaction
- ❖ Impingement
- ❖ Filtration

Analytical Methods

- ❖ Microscopy
- ❖ Culture
- ❖ Biochemistry
- ❖ Molecular Biology

Microscopy

- ❖ Identification of total spores (both cultivable and non- cultivable) along with pollen and other particulates
- ❖ Identification to species level usually not possible
- ❖ Identification of morphologically similar spores not possible

Culture

- ❖Only viable bacteria and fungi
- ❖Limited to those taxa able to grow in culture on medium used
- ❖Success based on medium and incubation time and temperature
- ❖Permits speciation when required
- ❖Results expressed as CFU/m^3

Biochemistry

- ❖Detection of specific compounds
- ❖May not be specific for a genus or species
- ❖Assay examples:
  - ❖ Ergosterol
  - ❖ B 1,3-glucan
  - ❖ Endotoxins
  - ❖ Mycotoxins
- ❖Various types of assays such as HPLC

Molecular Biology

- ❖Detection of specific genetic elements
- ❖Highly specific and sensitive
- ❖Currently restricted to a few organisms

Aquatic Habitats

Aquatic Environments

- ❖ Cover 70% of the earth's surface
- ❖ Important zone of primary production
- ❖ Provides potable water
- ❖ Provides water for agriculture and industry
- ❖ Provides unique and extreme habitats
- ❖ Includes: Freshwater (rivers, lakes, streams, aquifers Marine (oceans, estuaries)

Aquatic Environments

<u>Freshwater</u>

- ❖ Lentic (standing) vs. lotic (running)
- ❖ Springs
- ❖ Lakes oligotrophic - deep, low biomass eutrophic - shallow, high biomass
- ❖ Groundwater

<u>Marine</u>

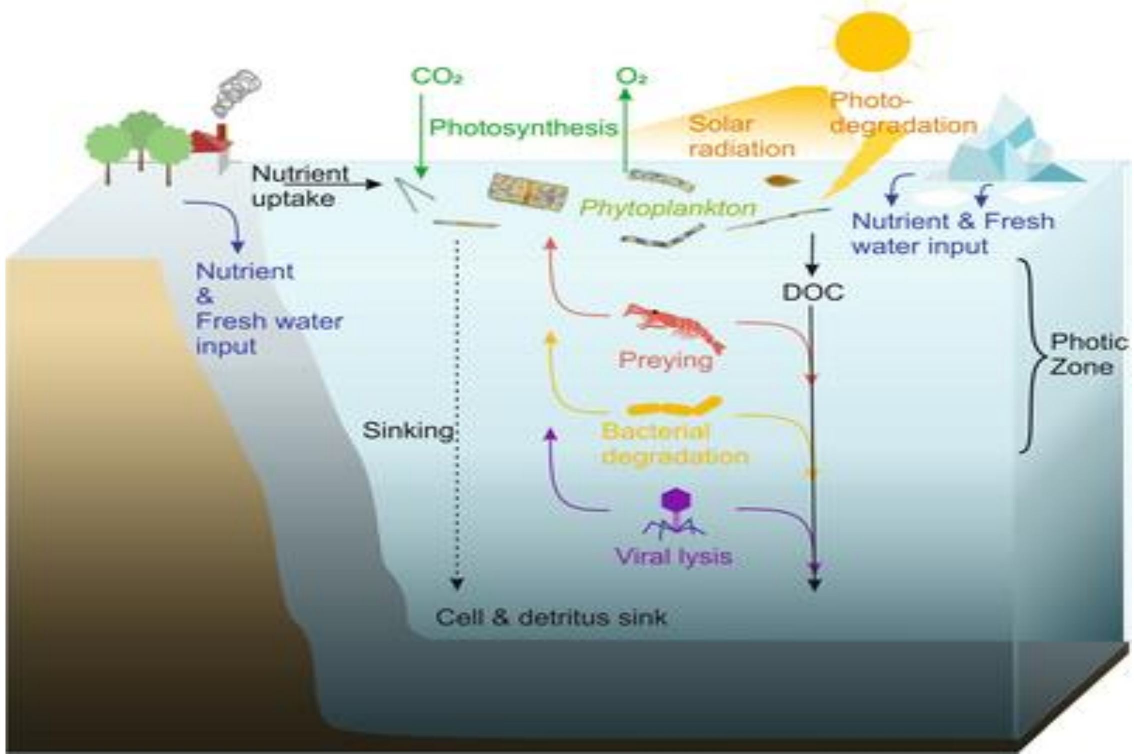
- ❖ Estuaries
- ❖ Oceans

All Microbes Live in an Aqueous Environment

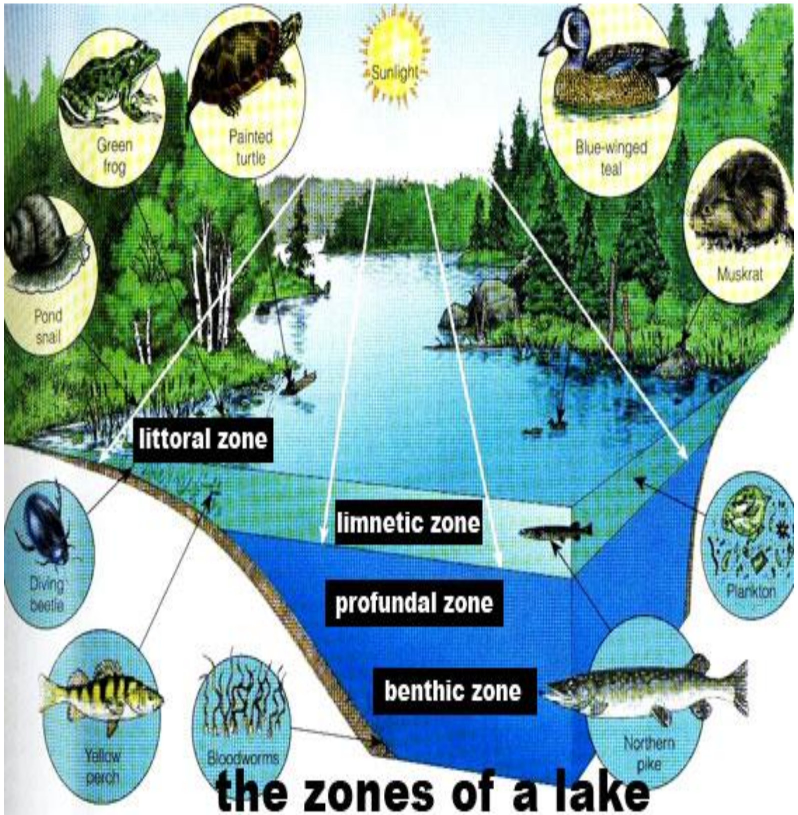
- ❖Ecology of aquatic environments is complex
- ❖Most aquatic environments are teaming with life
- ❖Microbes have evolved to live in:
  - ❖Saturated salt solutions
  - ❖Below freezing to >110°C
  - ❖Waters full of toxic substance , i.e. copper, cyanide, lead, silver, gasoline, oil, benzene, and many others

1. Planktonic - Microbes Suspended In The Water Column

- ❖ Phytoplankton are photosynthetic microbes (primarily cyanobacteria and algae).
- ❖ Responsible for most of the primary production in aquatic environments.
- ❖ Major food supply in aquatic environments.
- ❖ Support a complex food web.



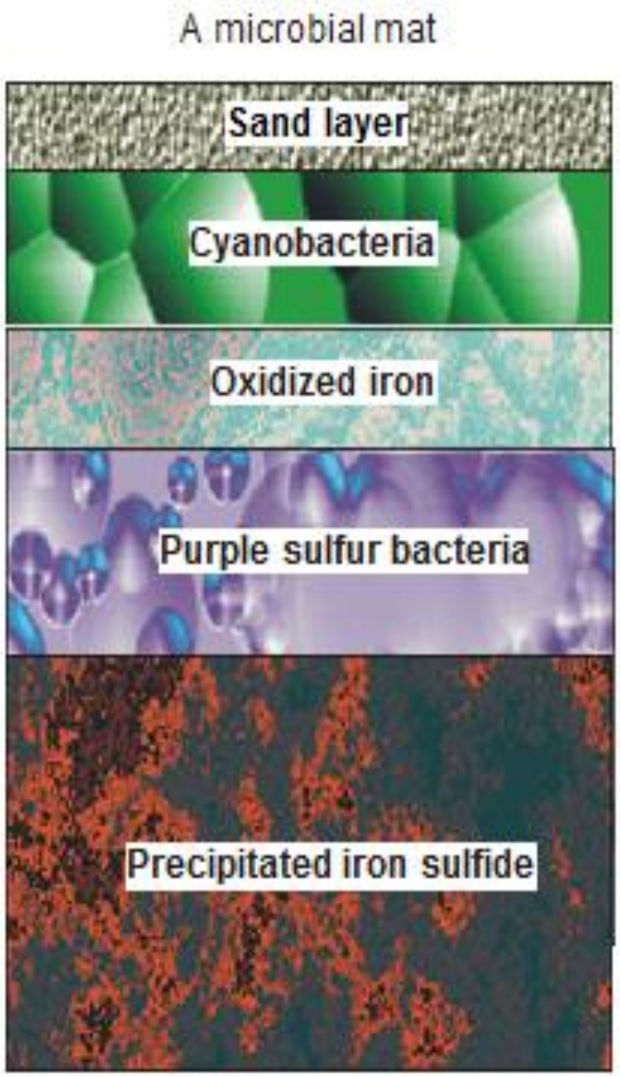
2. Benthic Habitat



- The benthos is a transition zone between the water column and the mineral subsurface.
- This interface is a diffuse and non-compacted mix of organic matter that has settled from the surface/mineral particles/water.
- Microbial numbers are up to 5 orders of magnitude higher than in the planktonic environment.
- Since activity is high, oxygen is utilized quickly and as a result, biogeochemical gradients develop that control the types of microbes and microbial activities found in this region.

3. Mats

- Microbial mats are also an interface in the aquatic environment in which many microbial groups are laterally compressed into a thin mat.
- The width of the mat ranges from several mm to cm
- Mats are vertically stratified with an aerobic zone on the top which is separated from the bottom anaerobic zone by a layer of oxidized iron.



Mats form in extreme environments.

- Stromatolites are fossilized mats that are 3.5 billion years old and are among the first indications of life on earth.
- Stromatolites were thought to be extinct but were discovered 40 years ago in Shark Bay, Australia in a hypersaline area. The hypersalinity prevents marine animals from thriving and grazing on the mat material.

Habitats

1. Planktonic – microbes suspended in the water column
2. Benthic
3. Mats
4. Biofilms

Grazing food chain:

Primary producers → zooplankton → filter feeders/fish

In coastal zones it take 1.5 to 3.5 steps to produce fish because plants are responsible for some primary production

In the open ocean it takes approximately 5 steps to produce exploitable fish.

Freshwater Microbiota

- ❖**Littoral zone**: Along shore
  - ❖Producers: Plants
- ❖**Limnetic zone**: Surface of open water along shore
  - ❖Producers: Algae and cyanobacteria
- ❖**Profundal zone**: Deeper water, under limnetic zone
  - ❖Producrs: Anaerobic purple and green photosynthetic bacteria
- ❖**Benthic zone**: Bottom sediment

Freshwater Microbiota

Benthic zone: Bottom sediment, often no light and little O_2

- *Desulfovibrio*
- Methanogens
- *Clostridrium*

Bacteria Found In Surface Water

Bacteria	**Disease/ infection**	**Symptoms**
Aeromonas	Enteritis	Very thin, blood- and mucus-containing diarrhea
Campylobacter jejuni	Campilobacteriose	Flue, diarrhea, head- and stomachaches, fever, cramps and nausea
Escherichia coli	Urinary tract infections, neonatal meningitis, intestinal disease	Watery diarrhea, headaches, fever, homiletic uremia, kidney damage
Plesiomonas shigelloides	Plesiomonas-infection	Nausea, stomachaches and watery diarrhea, sometimes fevers, headaches and vomiting
Typhus	Typhoid fever	Fevers
Salmonella	Salmonellosis	Sickness, intestinal cramps, vomiting, diarrhea and sometimes light fevers
Streptococcus	(Gastro) intestinal disease	Stomach aches, diarrhea and fevers, sometimes vomiting
Vibrio El Tor *(freshwater)*	(Light form of) Cholera	Heavy diarrhea

Seawater Microbiota

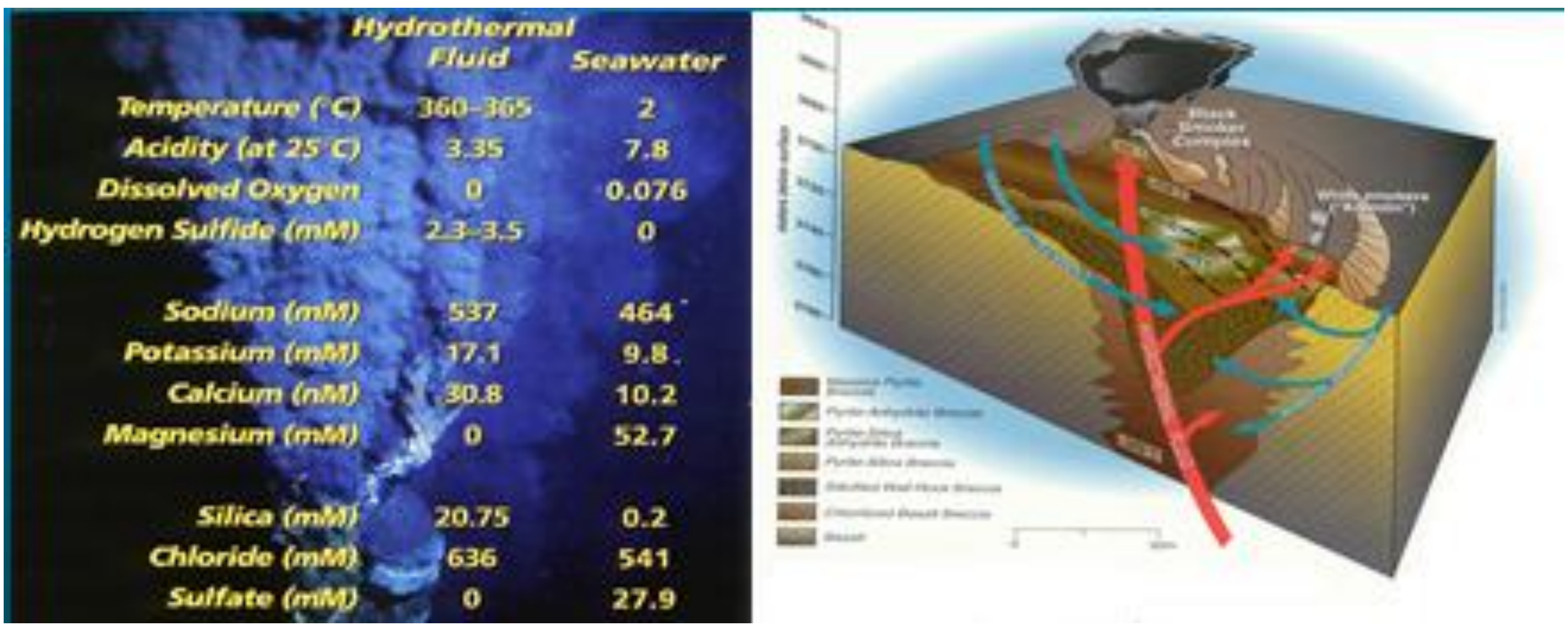
- **Phytoplankton** in top 100 m
  - Photosynthetic cyanobacteria fix carbon
    - *Prochlorococcus*
    - *Synechococcus*
  - And fix nitrogen
    - *Trichodesmium*
- Decomposed by
  - *Pelagibacter ubique*
- Archaea dominate below 100 m
  - *Crenarchaeota*
- **Bioluminescent** bacteria are present

Hydrothermal Vents

- ❖ A hydrothermal vent is a fissure in a planet's surface from which geothermally heated water issues.
- ❖ Hydrothermal vents are commonly found near volcanically active places, areas where tectonic plates are moving apart, ocean basins, and hotspots.
- ❖ Hydrothermal vents exist because the earth is both geologically active and has large amounts of water on its surface and within its crust.
- ❖ Common land types include hot springs, fumaroles and geysers.
- ❖ Under the sea, hydrothermal vents may form features called black smokers. Relative to the majority of the deep sea, the areas around submarine hydrothermal vents are biologically more productive, often hosting complex communities fueled by the chemicals dissolved in the vent fluids.
- ❖ Vent chemistry provides the energy and raw materials with which microorganisms grow.
- ❖ These microorganisms particularly - Chemosynthetic archaea form the base of the food chain, supporting diverse organisms, including giant tube worms, clams, limpets and shrimp.

Hydrothermal Vents

- ❖ Vents are associated with mid-ocean ridges, spreading centers.
- ❖ Cold waters percolate into crust and are geothermally heated before being vented at very high temperatures. Vent waters are not only hot, but low in oxygen and rich in metals and hydrogen sulfide.



	Hydrothermal Fluid	Seawater
Temperature (°C)	360–365	2
Acidity (at 25°C)	3.35	7.8
Dissolved Oxygen	0	0.076
Hydrogen Sulfide (mM)	2.3–3.5	0
Sodium (mM)	537	464
Potassium (mM)	17.1	9.8
Calcium (nM)	30.8	10.2
Magnesium (mM)	0	52.7
Silica (mM)	20.75	0.2
Chloride (mM)	636	541
Sulfate (mM)	0	27.9

Chemosynthesis

- Basis of life around deep sea hydrothermal vents is chemosynthesis rather than photosynthesis.

  Chemical energy rather than solar energy supports the ecosystem.

  Bacteria rather than plants are the primary producers.

  Aerobic chemoautolithotrophy

  $CO_2 + H_2S + O_2 + H_2O \rightarrow [CH_2O] + H_2SO_4$
- Organisms must have adaptations to prevent sulfide from poisoning oxygen binding site.

Hydrothermal Vent Communities

❖ 25 years of exploration have revealed:

A new phylum

At least 20 new families

Over 90 new genera

Over 300 new species

Over 250 new strains of free-living bacteria

Biomass

◆ Up to 30 kg/m2

◆ 1000 x greater than typical biomass observed on deep-sea floor

Tube Worm: *Riftia pachyptila*

◆ Unusual animal No mouth

No anus

No digestive tract

Dependent upon bacteria living in its gut or troposome

→ Gills extracts hydrogen sulfide, carbon dioxide & oxygen

from seawater; blood delivers these to troposome

In return, bacteria provide nourishment for *Riftia*

Saltpans

- Saltpans are sites where it contains different ions, including metals
- Saltpans and salt lakes have been reported to harbor high number of taxonomically diverse halophilic microorganism - Bacteria, which differ in salt requirement and metabolic capabilities.
- Halophilic bacteria evolve, suppressing the less halophilic and halotolerant forms.
- Microbial life can be found over the whole range of salt concentrations from freshwater and marine biotopes to hypersaline environments with NaCl concentrations up to saturation.
- Halophilic and halotolerant microorganisms are found in all three domains of life: Archaea, Bacteria, and Eucarya. Colonization of hypersaline environments such as salt lakes and salted food products by these microorganisms is often highly successful, and salt-loving and/or salt-tolerant microorganisms may reach high population densities in such ecosystems

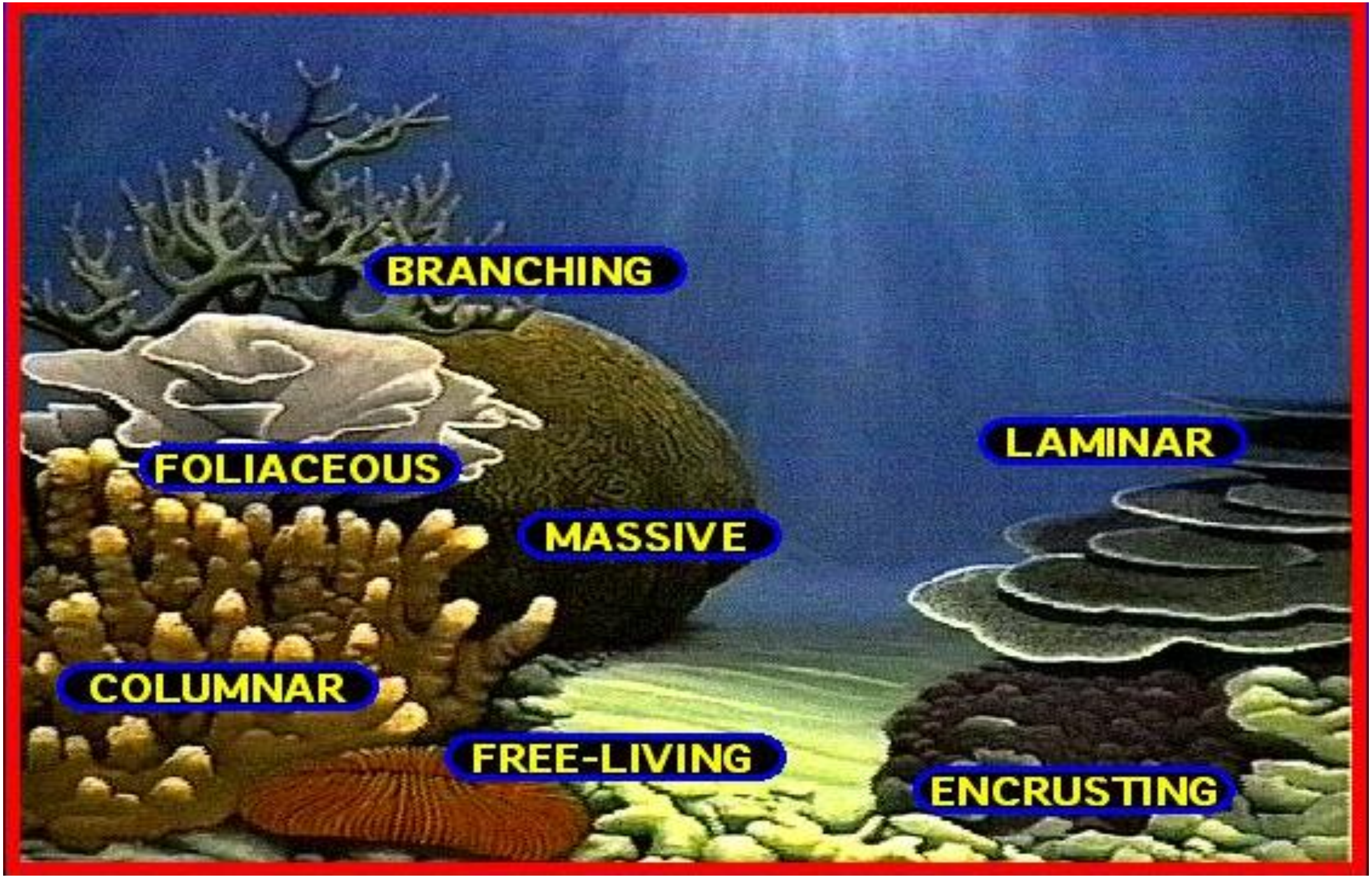
Coral Reefs

- One of the most biological diverse and productive ecosystem
  - Found in warm, clear and shallow tropical oceans
  - On $CaCO_3$ substrate deposited by reef building corals (50% of all Ca deposit in the sea) and other calcified organisms.
  - Provide shelters and food to fish

Why Is Diversity So High In Coral Reefs And Rain Forest?

- ❖High level of mutualism and symbiosis
- ❖High productivity and high rates of nutrient cycling
- ❖Finely divided niches
- ❖Control by herbivores and competitions?

Types Of Reef Building Corals
Colony Growth Forms

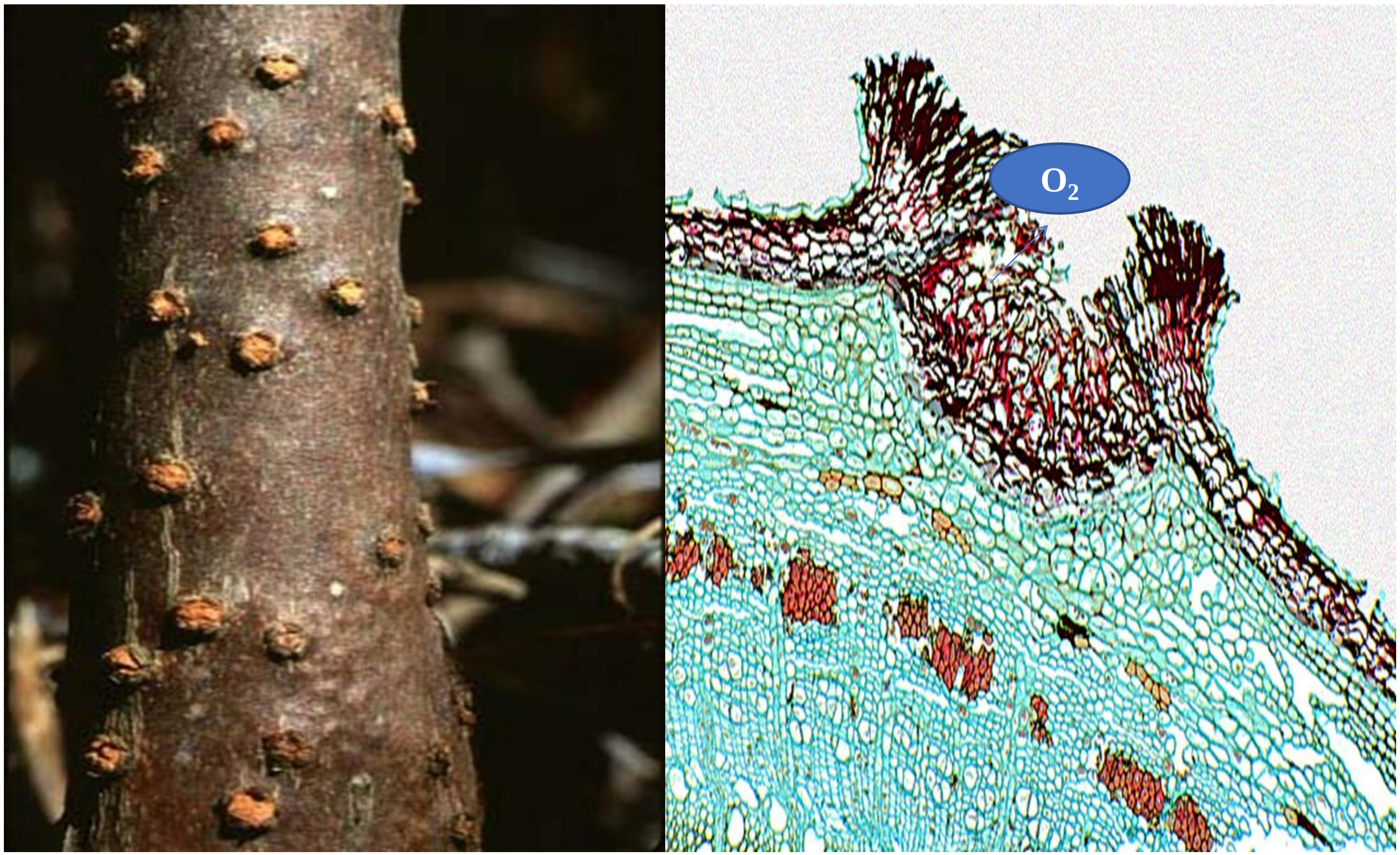


Mangrove

Mangrove forests are important natural ecosystems, located in tropical and subtropical countries

Red Mangrove *(Rhizophora mangle)*

Mangrove Lenticels
(Breathing Pores)



Physiological Adaptation of Mangroves

- ❖Salt management:
  - ❖exclude (*Rhisophora*)
  - ❖excrete (from salt glands in leaves, *Avicinnia*, *Laguncularia*)
  - ❖tolerate (accumulate in vacuoles – not in FL)
- ❖Thick cuticles on leaves to tolerate desiccation
- ❖High tannin to prevent herbivory
- ❖Pneumatophores and lenticels to send oxygen to roots

Plants of the Mangrove Community

- *Rhizophora mangle* – red mangrove
  - prop roots; extrudes salt
- *Avicennia germinans* – black mangrove
  - pneumatophores; extends to coastal Louisiana where it, unusually, coexists w/ *Spartina*
- *Laguncularia racemosa* – white mangrove
- These have viviparous propagules
- Much higher diversity in the Indo-Pacific

Animals of the Mangrove Community

- ❖Prop roots of red mangroves provide substrate for benthic organisms (algae, sponges, hydroids, tunicates, bryozoans)
- ❖Mangrove swamps provide critical protected nursery areas for fishes, crustaceans, and shellfish.
- ❖Dense mangrove branches serve as rookeries for many coastal species of birds
- ❖Organisms reared in mangrove swamps become food for fish (snook, snapper, tarpon, jack, sheepshead, red drum) oysters, and shrimp.

Microorganisms of the Mangrove Community

N2 fixing bacteria

Phosphate solubilizing bacteria

Sulfate reducing bacteria

Methanogenic bacteria

Amoxygenic bacteria

Manglicolous fungi

Actinomycetes