Chapter 27

Environmental Microbiology

Microbial Diversity and Habitats

- 27-1 Define extremophile, and identify two “extreme” habitats.
- 27-2 Define symbiosis.
- 27-3 Define mycorrhiza, differentiate endomycorrhizae from ectomycorrhizae, and give an example of each.

Microbes live in a variety of habitats because of their abilities to
- Use a variety of carbon and energy sources
- Grow under different physical conditions
- Extremophiles live in extreme conditions
  - pH
  - Temperature
  - Salinity

Symbiosis

- Two differing organisms living together in a close association that is beneficial to one or both of them
- Examples of symbiosis between animals and microbes:
  - Ruminants (such as sheep and cows) and the bacteria in the rumen
  - Mycorrhizae contribute to plant growth

Mycorrhizae

- Fungi living in close association with plant roots
- Extend surface area of roots

Can you identify two extreme habitats for extremophile organisms? 27-1
What is the definition of symbiosis? 27-2
Is a truffle an example of an endomycorrhiza or an ectomycorrhiza? 27-3

Soil Microbiology and Biogeochemical Cycles

- 27-4 Define biogeochemical cycle.
- 27-5 Outline the carbon cycle, and explain the roles of microorganisms in this cycle.
- 27-6 Outline the nitrogen cycle, and explain the roles of microorganisms in this cycle.
- 27-7 Define ammonification, nitrification, denitrification, and nitrogen fixation.
• 27-8 Outline the sulfur cycle, and explain the roles of microorganisms in this cycle.

11 Soil Microbiology and Biogeochemical Cycles
• 27-9 Describe how the ecological community can exist without light energy.
• 27-10 Compare and contrast the carbon cycle and the phosphorus cycle.
• 27-11 Give two examples of the use of bacteria to remove pollutants.
• 27-12 Define bioremediation.

12 Biogeochemical Cycles
• Recycling (oxidation and reduction) of chemical elements

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• What biogeochemical cycle is much publicized as contributing to global warming? 27-4
• What is the main source of the carbon in the cellulose forming the mass of a forest? 27-5

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16 The Nitrogen Cycle

17 Nitrogen Fixation
• In root nodules
  • Rhizobium
  • Bradyrhizobium
  • Frankia
• In rhizosphere
  • Azotobacter
  • Beijerinckia
  • Clostridium pasteurianum
  • Cyanobacteria: heterocysts
• In lichens
  • Cyanobacteria

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• What is the common name for the group of microbes that oxidize soil nitrogen into a form that is mobile in soil and likely to be used for nutrition by plants? 27-6
• Bacteria of the genus Pseudomonas, in the absence of oxygen, will use fully oxidized nitrogen as an electron acceptor, a process in the nitrogen cycle that is given what name? 27-7

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23 The Sulfur Cycle

24 Life without Sunshine
• Primary producers in the dark
  • Deep-ocean and endolithic communities
  • Chemoautotrophic bacteria

25 Life with Sunshine
• Sunshine provides energy for bacteria that may be used to fix CO2
• Provides carbon for cell growth

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28 The Phosphorous Cycle
• PO43- in rocks and in cells

• Acid from Thiobacillus

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• Certain nonphotosynthetic bacteria accumulated granules of sulfur within the cell; were the bacteria using hydrogen sulfide or sulfates as an energy source? 27-8
• What chemical usually serves as an energy source for organisms that survive in darkness? 27-9
• Why does phosphorus tend to accumulate in the seas? 27-10

30 The Degradation of Synthetic Chemicals
• Natural organic matter is easily degraded by microbes
• Xenobiotics are resistant to degradation

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32 Decomposition by Microbes
• Bioremediation: use of microbes to detoxify or degrade pollutants; enhanced by nitrogen and phosphorus fertilizer
• Bioaugmentation: addition of specific microbes to degrade a pollutant
• Composting: arranging organic waste to promote microbial degradation by thermophiles
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- Why are petroleum products naturally resistant to metabolism by bacteria? 27-11
- What is the definition of the term bioremediation? 27-12

37 **Aquatic Microbiology and Sewage Treatment**

- 27-13 Describe the freshwater and seawater habitats of microorganisms.
- 27-14 Explain how wastewater pollution is a public health problem and an ecological problem.
- 27-15 Discuss the causes and effects of eutrophication.
- 27-16 Explain how water is tested for bacteriological purity.
- 27-17 Describe how pathogens are removed from drinking water.

38 **Aquatic Microbiology and Sewage Treatment**

- 27-19 List some of the biochemical activities that take place in an anaerobic sludge digester.
- 27-20 Define biochemical oxygen demand (BOD), activated sludge system, trickling filter, septic tank, and oxidation pond.

39 **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
  - Producers: anaerobic purple and green photosynthetic bacteria
- Benthic zone: bottom sediment

40 **Freshwater Microbiota**

- Benthic zone: bottom sediment, often no light and little O2
  - Desulfovibrio
  - Methanogens
  - Clostridium

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42 **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

43 Bioluminescent Bacteria
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• Purple and green sulfur bacteria are photosynthetic organisms, but they are generally found deep in freshwater rather than at the surface. Why?

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47 Microbial Water Pollution
• Microbes are filtered from water that percolates into groundwater
• Some pathogens are transmitted to humans in drinking and recreational water

48 Chemical Water Pollution
• Resistant chemicals may be concentrated in the aquatic food chain
• Mercury is metabolized by certain bacteria into a soluble compound, which is concentrated in animals

49 Eutrophication
• Overabundance of nutrients in lakes and streams
• Due to
  • Addition of organic matter
  • Or inorganic matter
    • Phosphates
    • Nitrogen
• Cause algal blooms

50 Biochemical Oxygen Demand (BOD)
• Bacterial decomposition of organic matter uses up O2 in water

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53 Water Purity Tests
• Indicator organisms  
  • Used to detect fecal contamination  
  • Coliforms  
  • Enterococcus  
• MPN: most probable number

54 Coliforms
  • Aerobic or facultatively anaerobic, gram-negative, non-endospore-forming rods that ferment lactose to acid plus gas within 48 hours, at 35°C

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58 The ONPG and MUG Coliform Test
  • ONPG causes E. coli to make β-galactosidase

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• Which disease is more likely to be transmitted by polluted water, cholera or influenza? 27-14
• Name a microorganism that will grow in water even if there is no source of organic matter for energy or a nitrogen source—but does require small inputs of phosphorus. 27-15
• Coliforms are the most common bacterial indicator of health-threatening water pollution in the United States. Why is it usually necessary to specify the term fecal coliform? 27-16

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64 Wastewater Treatment: Oxidation Ponds
  • For small communities  
    • Pond 1: settle solids, pump water to pond 2  
    • Pond 2: bacterial decomposition of dissolved organic matter in water

65 Municipal Sewage Treatment
  • Primary treatment  
    • Removal of solids  
    • Disinfection
- **Secondary treatment**
  - Removal of much of the BOD
  - Disinfection
  - Water can be used for irrigation
- **Tertiary treatment**
  - Removal of remaining BOD, N, and P
  - Disinfection
  - Water is drinkable

**Anaerobic Sludge Digestion**
- \( CO_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2 \text{H}_2\text{O} \)
- \( \text{CH}_3\text{COOH} \rightarrow \text{CH}_4 + \text{CO}_2 \)

**Tertiary Sewage Treatment**
- Secondary effluent contains
  - Residual BOD
  - 50% of the original nitrogen
  - 70% of the original phosphorus
- Tertiary treatment removes these by
  - Filtration through sand and activated charcoal
  - Chemical precipitation

**Questions**
- How do flocculants such as alum remove colloidal impurities, including microorganisms, from water? 27-17
- Which type of sewage treatment is designed to remove almost all phosphorus from sewage? 27-18
- What metabolic group of anaerobic bacteria is especially encouraged by operation of a sludge digestion system? 27-19
- What is the relationship between BOD and the welfare of fish? 27-20