**Study Plan: Episode 8—Microbial Ecology**

* **Read the UNIT OVERVIEW presented in this Study Guide.**
* **View the video “Microbial Ecology.”**
* **Read UNIT OBJECTIVES and KEY CONCEPTS sections of this study guide.**
* **View the video a second time, this time taking notes. Pay particular attention to topics identified by the UNIT OBJECTIVES or KEY CONCEPTS as significant.**
* **Read Chapter 16 in the text (pgs. 325 – 344) and take notes on the points that are not mentioned in this study plan.**
* **Return to the Unit Objectives and Key Concepts listed in this Study Guide. Do you feel you have achieved each objective? Review sections of the text or video pertinent to material you don’t feel you have mastered.**
* **Test your mastery of the material by answering the Review Questions at the end of this Study Guide.**
* **Check your answers against the answer key; review material relating to any questions you missed.**
* **Explore further! Retrieve from the library database articles listed in Suggested Further Reading that sound interesting.**

**Unit Overview**

The fragile balance of an ecosystem’s available mineral nutrients and physical surroundings is sustained by the collective metabolism of the organisms it supports. An ecosystem is the system of interactions between living organisms and the physical environment, while microbial ecology is the study of these relationships with respect to microbes. Microbial metabolism plays a fundamental role in transforming the state of organic and mineral nutrients, thus regulating the flow of matter through systems. It is interesting how things work together so well. Microorganisms, such as algae, produce volatile sulfur as part of their metabolism. The sulfur ends up in the atmosphere where it collects attracts water to form clouds. The greater the amount of water the whiter the cloud becomes and, in turn, the cloud reflects the sun’s rays back into space.

Biosphere 2 taught us the importance of microbes in the maintenance of a balanced ecosystem. Remember that the Earth is referred to as Biosphere 1.

When an excess of nutrients flows into a system, such as the discharge of organic wastes into rivers and streams, the system becomes unbalanced. This process is called eutrophication. Microbial populations expand and microbial respiration depletes available oxygen; fish and other animals die. This is because aerobically-respiring microorganisms preferentially use oxygen in cellular respiration, converting sugar (C6H12O6) to water. The chemical formula for cell respiration is: C6H12O6 + 6O2 = Energy + 6CO2 + 6H2O.

In balanced terrestrial and aquatic systems, plants use the sun’s energy and CO2 to form organic structural and storage compounds such as cellulose. Microbes alone can decompose many of the complex polymers formed by plants. Certain nutrients, such as cellulose in plants, are unavailable to animals until after their transformation by microbes. Additionally, microbes transform atmospheric nitrogen and integrate it into the carbon harvested from nitrogen-poor plant material to form their own cellular components. These activities make organic carbon and nitrogen available to other life forms in the system. Microbial metabolism is used to restore unbalanced systems, such as dumpsites and wastewater. The careful introduction of a limiting factor, such as oxygen, supports rapid microbial degradation of accumulated wastes.

**Unit Objectives**

* Define ecosystem
* List the cycles of matter that are mediated by microorganisms.
* Explain the role microbes and the sulfur cycle play in the earth's temperature.
* Provide examples that demonstrate the importance of microbes in the cycles of matter.
* Explain how knowledge about the microbial role in cycles of matter is being applied to waste disposal systems.
* Explain how human activities such as fixing nitrogen (the Haber process) and burning fossil fuels have created unbalanced ecosystems.

**Key Terms**

* *Beggiatoa*
* Biofilm
* Biological Oxygen Demand (BOD)
* Bioremediation
* Carbon cycle
* Coliform bacteria
* Cyanobacteria
* Decomposer
* Ecosystem
* Flocculation
* Habitat
* Nitrogen cycle
* Nitrogen fixation
* Phosphorous cycle
* Primary treatment
* Oxidation lagoon
* Secondary treatment
* Sulfur cycle
* *Thiobacillus*

**Key Concepts**

**THE CYCLES OF MATTER**

* The major biological elements occur in several different chemical forms that are inter-convertible. Microbes play an instrumental role in making nutrients available for the rest of the food chain.
* In the nitrogen cycle, nitrogen gas (N2) is converted to ammonia (NH3) – this process is called nitrogen fixation. Nitrification converts ammonia to nitrate (NO3), whereas, denitrification converts nitrate to nitrogen gas. Each step in the process is mediated by a different group of bacteria.
* Nitrogen-rich run-off from fertilized soils into rivers and streams increases microbial growth and consequently respiration, decreasing the oxygen available to fish and other life forms in the system.
* In the carbon cycle, CO2 in the atmosphere is converted to, or fixed in, organic molecules by autotrophs such as the cyanobacteria; CO2 is returned to the atmosphere through cell respiration (by decomposers), diffusion, and combustion.
* Today, the carbon cycle is out of balance; carbon that was fixed in organic form over the course of many years has rapidly returned to the atmosphere as CO2 through the burning of fossil fuels.
* The phosphorus cycle has no significant gaseous intermediate; inorganic phosphate is converted to organic phosphate and back.
* FYI: The bacterium, *Acinetobacter calcaoceticum,* can be used to remove phosphate from sewage. This bug produces a calcium-phosphorus compound that is insoluble in water and can then be removed from the wastewater.
* Sulfur is found in most living things because it is a component of some amino acids, where it serves to form disulfide bonds between amino acids and thus, contribute to the tertiary structure of proteins. In the sulfur cycle, sulfate (SO4) is changed to hydrogen sulfide (H2S) by sulfate-reducing bacteria and back again to sulfate by oxidizing bacteria and certain phototrophs.
* Ocean phototrophs return the sulfur to the atmosphere by converting the sulfur into "a gas". In the atmosphere, sulfur and oxygen combine to create sulfur particles that serve as "nucleation sites" for cloud formation. In turn cloud-cover affects the amount of the sun's rays that reach the earth, thereby possibly influencing climate.

**TREATMENT OF WASTE**

* If too much waste gets into our streams and rivers the microorganisms start breaking the waste down rapidly and in the process they deplete the oxygen. This results in the fish suffocating and you get a bunch of smelly fish carcasses floating around.
* The goal of sewage treatment plants is to reduce the biological oxygen demand (BOD) of the incoming water. The BOD is measure of the amount of oxygen used by microbes in the water and is in indication of the amount of organic matter. The greater the organic matter, the greater the BOD will be.
* Sewage plants add oxygen to sewage at a faster rate than it is removed by microbial respiration. This enables microbes to rapidly degrade waste matter in water. Without the use of added oxygen the waste would be degraded very slowly.
* Sewage plants additionally use anaerobic digesters, in which methanogens convert the byproducts of aerobic respiration to methane. Methane is a useful fuel.
* The digested sludge (remains of the dead microbes!) is filtered from the water and used as fertilizer; treated water is safe to return to natural water systems, assuming that no industrial wastes have contaminated the water with heavy metals or organic compounds that aren’t easily broken down by microorganisms.
  + In most cities sewage sludge contains heavy metals and other toxic substances, and therefore should not be applied to agricultural land that produces food for humans or other animals.
* Landfill waste sites can be remediated by applying the same principles used in the aerobic digestion of wastewater. Waste normally degrades very slowly because there is sufficient compaction that excludes water and oxygen. When landfills are oxygenated the process speeds up.

**ESCAPE FROM THE CARBON CYCLE**

* All naturally-occurring organic compounds can be broken down by some microorganism.
* Humans have created products that are extremely resistant to microbial attack (recalcitrant organic compounds), including most plastics and chlorine-containing pesticides.
* Solutions include the use of biodegradable products and microorganisms genetically engineered to degrade recalcitrant compounds.

**OTHER COMMENTS**

* In Arizona Biosphere 2 was constructed in preparation for the colonization of other planets and our moon. Scientists were attempting to recreate the Earth in this “biosphere.” Biosphere was to have been completely self-contained. However, oxygen levels began to drop and some of the living components started to die after several months. Eventually, oxygen had to be pumped into Biosphere 2 so that the eight scientists would not die. There were other problems that eventually led to the declaration that the experiment was a failure. The failure was due to microorganisms. The population of microbes expanded when an imbalance was created by the use of fertilizers. The aerobic microorganisms quickly took advantage of the situation and started to deplete the oxygen. Essentially, the oxygen cycle was disrupted.
* Marsh grasses have a large amount of carbon, but little else. When it dies microbes start breaking down the carbon, but at the same time they fix nitrogen that enriches the area with needed nitrogen.
* Complex ecosystems of microbes exist within living systems themselves. An example of this is the rumen of cattle. The cow ingests grass, which brings cellulose into the cow’s rumen. The microbes breakdown the cellulose and the byproducts of the process provides nutrients for the cow.

**Review Questions**

**Fill In**

1. The process of\_\_\_\_\_ \_\_\_\_\_converts nitrogen from the atmosphere into a usable form.
2. Carbon is present in the atmosphere mainly as\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ are organisms that generally fix carbon dioxide from the atmosphere, oceans, or other aquatic ecosystems by photosynthesis.
4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is the principal metabolic process that returns carbon dioxide to the atmosphere.

**Multiple Choice**

1. An ecosystem is

a) composed of all life in a environmental niche

b) composed of the physical environment

c) composed of the physical environment and all the organisms in that environment

d) composed of the physical environment and all the microbes in that environment

2. Which is the major reason that caused the Biosphere 2 to fail?

a) The scientists did not know which microbes to include and guessed wrong.

b) The microbes that were inadvertently included were overfed with "fertilizer"

c) The scientists did not plant the right kind of trees.

d) They broke the seal to pump in oxygen .

3. Carbon dioxide is returned to the atmosphere by

a) photosynthesis.

b) carbon fixation.

c) fermentation.

d) respiration.

4. Which of the following would upset the balance of the ecosystem?

a) rapid increase in available oxygen

b) increased run-off of nitrogen fertilizer

c) lack of nitrogen-fixing bacteria in the coastal estuaries

d) lack of photosynthetic microbes

e) All of the above

**True or False**

1. By providing microbes the moisture and oxygen that they need to flourish, researchers have found ways to speed up the degradation of solid waste.

2. Microbes recycle organic and mineral nutrients as they acquire their nutrients.

3. Without bacteria in their gut (rumen) cows would not survive.

4. Burning of fossil fuels has no known effect on the carbon cycle.

5. Microbes are at the bottom of the food chain.

**Discussion Questions**

1. What ecological problems are created when materials are not biodegradable?

2. Chlorinated carbon compounds have been used in agriculture for about 50 years and are known to persist in soils. For many years, no microorganisms were known to degrade these recalcitrant compounds. In recent years, microorganisms that degrade them have been isolated from nature. Explain this.

**Answers**

**Fill In**

1. nitrogen fixation

3. carbon dioxide

4. Autotrophs

5. Respiration

**Multiple Choice**

1. C 2. B 3. D 4. E

**True - False**

1. T 2.T 3. T 4. F 5. T

**Discussion**

1. Compounds that are not biodegradable do not cycle through the ecosystem and their elements become unavailable. Compounds that do not breakdown can persist in living tissue and are often toxic.

2. Through random mutation, some microorganisms gained the ability to use these compounds for their metabolism. The ability to use a compound other organisms can’t, increased their fitness and over time, their frequency in the population increased. Before the synthesis and use of such compounds, an organism with such a mutation would not enjoy a selective advantage; its frequency in the population would remain very low. Such a mutation might have a cost attached, such as an inhibited growth rate when metabolizing natural compounds, and it would be selected out of the population.

**Suggested Readings**

Anderson , A. and Dawes, E.A. 1990. Occurrence, metabolism, metabolic role and industrial uses of bacterial polyhydroxyalkanoates. *Microbiological Reviews* 54:450-72.

Atlas, R.M , and Bartha, R. 1987. *Microbial ecology: Fundamentals and applications.* Menlo Park, Calif.: Benjamin/Cummings.

Racke, K.D., and Coats, J.R., eds. 1990. *Enhanced biodegradation of pesticides in the environment.* Washington , D.C. : American Chemical