Biogeochemistry: Carbon Cycle

Lesson Goal: Introduce the global carbon cycle and the role of microbes in carbon processing

Pre Class Readings: *Chapters 4 & 5 of Kirchman D. 2012 Processes in Microbial Ecology*

Objectives: The purpose of this lesson is to introduce students to the carbon cycle. The first part of the lesson will deal with the classical phototrophic/heterotrophic carbon cycle. First, we will explore the carbon cycle as a class. We will work together to design our own model of how carbon is processed in the environment. The starting and end points will be CO_2, and students will be asked to think about this in terms of macro-organisms (plants, animals, etc.). Once we create our class model and compare it to a pre-drawn model, the students will be asked to work in small groups to add more complexity to the cycle. They will be asked to use their knowledge of microbes and the various processes that microbes catalyze in order to put microbes 'on the map'. Once students have worked together in groups to assign microbial components to their maps we will come together and present our ideas as a class. The second part of the lesson we will use to explore major areas of carbon cycle (more lecture style). Topics covered will be: photosynthesis, degradation by bacteria and fungi. This class section will be an overview of these processes. The following class will address the details, mechanics, and biogeochemistry of carbon processing as well as the diversity of organism that are involved. In addition, the next class section will be used to cover area of carbon cycling that are less discussed in other classes: Anaerobic Photosynthesis, Methanogenesis, and Methanotrophy.

General Lesson Outline

Introduction – Recap the previous lecture (1 -2 minutes)

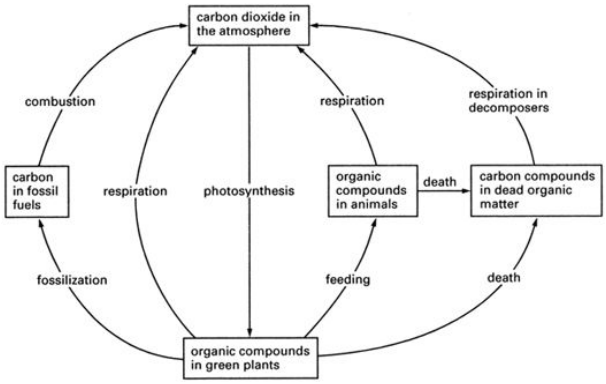
General Statements of microbes and ecosystem processes

This should tie into the previous lesson and finish any open thoughts

What is the carbon cycle? (General Overview, Class Discussion, 5 min)

Classroom engagement to draw out cycle on board, used partially as a 'pre-test' assessment and partially as a transfer technique to build upon previous knowledge. Students encouraged to add plants and animals.

Provided Example:



Where are the microbes? (Student Discussion, Small Groups, 5 min)

Students will be asked to use the class carbon cycle model as a starting point. From here they should work together to identify where microbes fit into the carbon process. How many links to microbes can we make?

Types of microbes they should consider are: decomposers, phototrophs, plant and animal associated organisms. Students should think about both terrestrial and aquatic organisms and include Bacteria, Archea, Fungi, Protists, and Viruses.

Classroom Discussion (Interactive Discussion, Think-Pair-Share, 10 min)

Now that student groups have an idea of the microbial mediated carbon cycle, they will be asked to share with the class. Representatives from groups will draw their groups carbon cycle on the board.

After all groups have presented their model we will come together to create a class agreed upon model of the carbon cycle and identify as many linkages to bacteria as we can.

Microbes and Photosynthesis (Classroom Lecture, Clicker Questions, 12-15 min)

A Brief intro into photosynthesis (should be recall from physiology lessons in section 1)
What types of organisms are involved? Bacteria, Protists, …
Where are these organisms located? Oceans/Lakes, Soils, Surfaces
A look into Procholorococcus and Synecococcus
    The source of ~50% of net primary productivity

Microbial Consumers and Decomposers (Classroom Lecture, Clicker Questions, 12-15 min)

What do microbes eat? How about other microbes (the protists, viruses)
Microbial Degradation and the Microbial Loop Concept (Decomposition)
Bacterial vs Fungal Decomposition, Bacterial:Fungal Ratios and Resource Quality

Microbial Physiology: DNA Replication

Lesson Goal: Introduce to the general principals of DNA and microbial DNA replication

Pre Class Readings: Chapter 7; sections I, II, & III in Brock Biology of Microorganisms

Objectives: The purpose of this lesson is to introduce students to an important process in the growth and development of microbial cells – DNA replication. This lesson is part of a larger section on basic growth physiology of bacteria (students will have just learned about cell division); however, this is a bit of a redesign from classic ways of teaching DNA replication. Instead of first starting by introducing DNA in the context of biomolecules, I am starting with the process – replication. First, I will introduce students to the complex challenged faced by cell when they need to replicate their chromosome. They will know from previous classes that DNA is the information storage unit of the cell and required for cellular function. However, they now have a problem: the cell is going to divide and each daughter needs all of the essential materials. This means that each daughter cell needs a single copy of DNA – thus the DNA must be replicated. However, bacteria (most bacteria) have a single circular chromosome. How does the cell replicate this chromosome? The lesson will start with this problem work with the students to solve it. I will also introduce one caveat: from previous studies we know that DNA replication is semiconservative (introduce the Stahl experimental results). The first key will be to get students to recognize that the DNA double helix must be separated in order for semiconservative replication to begin (by DNA helicase). I will introduce some other enzymes that help in this process, but not go into too much detail. Then the next step will be to make a new copy of the DNA by DNA polymerase, which happens to work similar to the RNA polymerase we have previously talked about. However, this means that the opening in the chromosome can only go one way (5' to 3'). But cells want to do this fast and efficient – so what is the option? (this introduces bidirectional replication). This introduces leading and lagging strand synthesis and (Okazaki Fragments). We will go into details about each of these topics.

General Lesson Outline

Introduction – Recap the previous lecture (1 -2 minutes)
- General Statements of Microbial Cell Division (short movie clip)
- This should tie into the previous lesson and finish any open thoughts

The Bacterial Chromosome (Lecture, Multimedia Presentations, 5 min)
- What is the structure of the bacterial chromosome? Circular
- How much information is contained? (Analogy comparison with various books)
- What does this look like?

Replication: Step-by-Step (Student Discussion, Interactive Lecture, Problem Solving, 15 min)
- As a class we will decide how a cell can best replicate its genome.

Students have handouts with relevant terms (no definitions) that they are to use during the discussion.
We will work together to 'design' a set of instructions for cells to use to replicate their DNA.

Leading Vs. Lagging Strand (Lecture, Emphasis for Comprehension, Video, 10 min)
This is a key concept for students to learn. Thus, we are going to spend extra time on the subject
Why are there two different strands?
What are Okasaki Fragments?

DNA Molecule Chemistry (Lecture, Clickers, 10 min)
This part of the lecture will be an in-depth look at the molecules that form DNA.
Purine and pyrimidine structure
Hydrogen bonding
DNA Double Helix, Major vs Minor Grove.

Historical Experiments (Lecture, Clickers, 10 min)
Watson and Crick – DNA Structure
Stahl Experiments – Semi Conservative DNA Replication

Managing Microbial Services: Human and Environmental

Lesson Goal: Introduce to the idea of microbial services through class discussion

Pre Class Readings: Fierer 2012; Peralta (In Press); Others

Objectives: The purpose of this lesson is to introduce students to the positive interactions we have with microbes and the services they provide to humans and the environment. Overall, the goal is to overcome common misconceptions about bacteria being negative factors for human wellbeing. The first part of the lecture will deal with human microbe interactions. Where are microbes on our body? Do they all cause disease? What are the benefits? What are probiotics? We will address these questions in order to improve our understanding of the human-microbe interaction. I will briefly mention disease, but hopefully students will leave thinking about microbes as more than just disease-agents. The second half of the lecture will involve microbial services in the environment. What are the benefits of microbes in food production? In ecosystem restoration? We will discuss what microbes do in the environment and how we may be able to manage them to promote a healthier ecosystem. Throughout this lecture, students should be using concepts from the previous lectures to think about microbes as complex systems and interactions instead of just mysterious organisms.

General Lesson Outline

Introduction – Recap the previous lecture (1 -2 minutes)

So far in the semester we have considered microbes in the context of populations and communities and we are now starting to understand some of the ecosystem implications of microbes.

As we consider microbes in various ecosystems, we should mention that many if not most ecosystems have become human dominated. As such, we should consider the connections between humans and microbes.

Microbes and human health (Assessment Activity, 5 min)

Students will have handouts depicting various human microbe interactions. For example: microbes in the gut; microbes on the skin; microbes in the reproductive tract.

Students will be asked to score these interactions as: (A) Mostly Positive, (B) Positive and Negative, (C) Mostly Negative. In addition, students will be asked to justify their response.

Microbes and Humans: A General Overview (Lecture, Interactive Lecture, 12-15 min)

This will be a lecture on the known status of human-microbe interactions. The information will be structured as presented in the Fierer 2012 Annual Reviews Paper. Students will have been expected to read this prior, but the lecture will explore the topics with more detail.

As a class we will try to identify the positive and negative interactions presented in this paper. We will diagram this on the smart board.

Once we have gone through the paper students will be asked to repeat their assessment and explain any changes they made.

Microbes and Humans: An Exploration (Discussion, Thought based clickers, 10 min)

Throughout we will ask a few questions/explore a few areas:

How common are microbes on the human body? (out number 10:1) "Am I a collection of microbes or a human?"

What are they doing? (Rhetorical Question, but give time for student replies before you continue and elaborate on these topics)

Role in preventing infection (Think about this in terms of competition for space)

Benefits to digestion: Case study – E. coli produce vitamin K in the gut

Scent – Does Corynebacteria produce human pheromones (Kohl et al. 2001. Neuroendocrinology). Also introduce some of Kevin Theis work with hyenas (Theis et al. 2012 Nature). This paper will also tie into next topic

Behavior? Listen to Radio Lab (http://www.radiolab.org/story/197112-guts/)

Disease – the goal here is not to have a long lecture on med micro but to say: "yes they do cause disease, but is this the most common thing?"

Only 1,500 species of bacteria cause disease out of the estimated 120,000 – 150,000 on earth

Microbial Services and the Environment (Lecture with Discussion, Clickers, 12-15 min)

What are ecosystem services?

What do we mean by Microbial Services?: Recall from previous lectures

Classroom Provided Examples of 'Services'

Nitrogen Fixation For Ag, Denitification in Wetlands, Bioremediation

How do these services benefit human wellbeing?

Managing Microbial Services (Discussion, 5 min)

How can we best live with microbes?

This is an open discussion with the class about ways humans can interact with microbes in the environment. What practices can we do that promote healthy bacteria in agriculture? How can we maintain diverse aquatic assemblages that promote denitrification in rivers?