Marine Microbiology in the Oligotrophic Ocean
LESSON PLAN
SMILE Workshop August 2019
Giovannoni Lab, Oregon State University

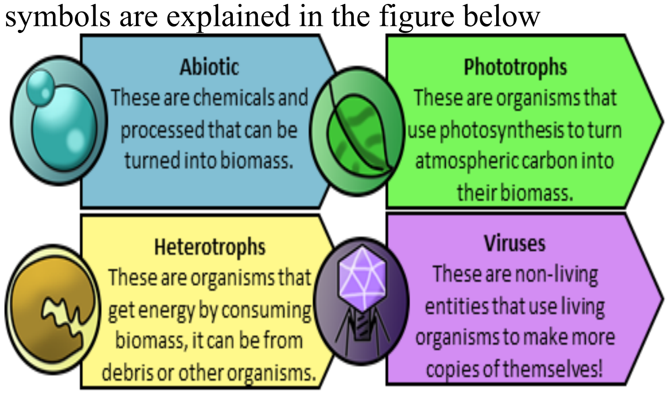
Oligotrophic Simulation developed by Quinn Washburn
Lesson and materials developed by Chris Suffridge, Chih-Ping Lee, Stephen Noell, Quinn Washburn, and Sarah Wolf

Learning Objectives:

- The ocean is the largest biome on Earth and it is full of life.
- Microorganisms are the most abundant and important inhabitants of the ocean.
- Microbes are diverse (size, shape, and function)
- Microbes form ecosystems where their interactions impact global processes including the carbon cycle.
- We can use models to study and conduct experiments on global processes such as the carbon cycle.

Pre-Simulation:

- Teacher gives introductory presentation (provided) introducing marine microbiology.
- Microbial Exploration (flip the classroom):
    - The *Oligotrophic* Simulation contains four classes of cards that represent four different trophic levels in the ocean. Each card in the simulation deck contains a symbol that identifies which class it belongs to. The classes and symbols are explained in the figure below



    - The teacher will break the students into four groups based on the classes of cards. The groups are listed below:
        - Abiotic Factors (nutrients)
        - Phototrophs (phytoplankton)
        - Viruses
        - Heterotrophs (Bacterioplankton, Protists, and Zooplankton)
    - Each group will become experts on their class of cards using the provided “fact sheets”, internet research of each trophic class, and internet research of specific names of organisms/processes found on simulation cards. This simulation is based on actual science! Therefore, all the cards represent

actual organisms/processes in the ocean. The way the cards interact with each other is based off the way these organisms/processes interact in nature.

        - Prior to the lesson starting the teacher should sort one simulation deck by card class. The teacher should provide the simulation cards to each expert-group so that they can use them during their research. NOTE: Before the simulation begins, this deck needs to be completely reshuffled to avoid biased/skewed outcomes.

    - Each group will then teach the rest of the class the information they learned about their assigned microbial group.
- The Carbon Cycle
    - The carbon cycle and the concept of biomass and energy flow will be introduced using familiar macro-ecological systems (e.g., fertilizer=nutrients; grass=phytoplankton; deer=bacteria; cougars=zooplankton).
    - All biomass begins with abiotic factors (sun, carbon dioxide, nutrients), and then flows through the system.
    - Students will then be asked to assemble the four classes of cards (trophic levels) into the proper order, and hypothesize how biomass would flow through the system. Students will then move biomass through their systems to demonstrate the cyclical nature of the flow.

Simulations:

- Introduce models as tools to study marine systems using the provided presentation
    - To test their understanding of a system, scientists often build models of the system. Models show how one part of a system interacts with another. We have built *Oligotrophic* to be a model to simulate the way marine microbial communities function. While this appears to be a board game, there is little actual difference between the way this game functions and the way a large scale global model functions.
- Teacher will explain how the simulation works using the provided presentation, and the provided rules booklet.
    - NOTE: each simulation is a full game, played until one player "wins" by starting their turn with five or less biomass cubes.
- The teacher will break the students into groups. We suggest four groups of five students. SMILE has provided sufficient materials (decks and cubes) for four groups of five students. Each group should contain an expert from each of the five expert groups.
- **Simulation 1:**
    - **Goal**: students become familiar with the gameplay of the simulation. This should be fun!
    - Prior to beginning the simulation, students will be asked to predict which class of cards will accumulate the most biomass. Predictions should be recorded on the provided datasheet. These predictions should be based off what they learned in expert groups, but it's ok if they make uninformed predictions.

- Each group runs the simulation (plays the game).
- At the end of the simulation each group will count up and record the number of biomass pieces on each class of card (regardless of the color of the biomass cube). This data should be recorded on the provided datasheet.
- Some groups will run the simulation (play the game) faster than others. If a group finishes early the teacher should have them shuffle the deck and play again.
- Once all the groups have finished the simulation, the teacher will check in with students.
    - Each group will complete the worksheet activities associated with Simulation 1.
    - Each group will share their ending biomass distribution with the rest of the class.
    - Make sure that the game is flowing smoothly.

- **Simulation round 2:**
    - **Goal**: increase the frequency that the microbial community is "sampled" to gain more insight into the microbial interactions.
    - Based on their results/observations from Simulation 1, students should predict how the biomass will be distributed in Simulation 2
    - Each group runs the simulation.
        - At the end of each round (each player has played 1 card), stop and use the provided datasheet to record the number and location of all biomass cubes on the board. Students should take notes on the direction the biomass is flowing.
    - After the completion of simulation 2
        - Each group will complete the worksheet activities associated with Simulation 2.
        - Each group will share their ending biomass distribution with the rest of the class.
        - Teacher asks students for observations about how biomass is flowing. What sorts of interactions are the students observing?
- **Simulation round 3**
    - **Goal**: Use the simulation to conduct an experiment. Since the simulation is a model of a natural system, experiments can be conducted using it just as you'd conduct experiments in the natural setting. If the model is built correctly, the results from the model-based experiment will match the nature-based experiment.
        - ***Metaphor***: You have built a model of a racecar (like in the presentation). You have built your model to be as close to the real thing as possible. Your model and the real car function in the same way. Now, you want to determine what impact larger tires will have on the performance of the real racecar, but to test that on the real racecar would be expensive and dangerous. So, since your model performs the same as your real racecar, you could change the tire size on the model, and the way that the model behaves with

        - the larger tires would provide valuable information about how the real racecar would perform with larger tires.
        - ***Real Oceanography Example***: Scientists want to predict how climate change is going to impact the oceans. In order to predict outcomes, scientists need to run experiments. Obviously, scientists can't conduct experiments on the entire ocean, but they can build computer models of the ocean. Just like when building a model car, scientists first break down the ocean into individual components (e.g., wheels, engine, transmission, etc.), and then try to understand how those components interact (e.g., if the engine runs faster, the transmission and wheels will spin faster). Once scientists have determined how all the components interact, they can run their model and see how closely is resembles nature. At this point, just as with the racecar model metaphor, if the scientists can conduct experiments with their model to understand how those changes would impact nature
        - The *Oligotrophic* Simulation is a model of microbial communities in the ocean, and we can use it to run experiments on the ocean while in the classroom!
    - **Experiment**: Each group will exclude one class of card from their simulation deck. The questions being asked in this experiment are: How does the "ecosystem" (simulation) change when one class of organisms is removed? Can a stable "ecosystem" (simulation) exist if one class of organisms is missing?
        - NOTE: One class of cards is missing; therefore the simulation will run differently than it has in previous runs. Some groups' simulations may run longer or shorter than in simulation 1 and 2. This is what is supposed to happen, the "ecosystem" has been interrupted and will therefore behave differently (e.g., if all the dears die, the grass will grow out of control and the cougars will starve)
    - Based on their results/observations from Simulation 1 and 2, and what they know about how biomass moves through trophic levels, students should predict how the biomass will be distributed in their experimental Simulation 3 when one class of cards is removed.
    - Each group runs the simulation.
        - At the end of each round (each player has played 1 card), stop and use the provided datasheet to record the number and location of all biomass cubes on the board. Students should take notes on the direction the biomass is flowing.
    - After the completion of simulation 3
        - Each group will complete the worksheet activities associated with Simulation 3.
        - Each group will share their ending biomass distribution with the rest of the class.
        -

Teacher asks students for observations about how biomass is flowing. What sorts of interactions are the students observing?

Post Simulation
Students should work though the questions and activities in the conclusions section of their worksheet (included below). Once completed, the teacher should lead a discussion based off these questions. If time permits, the students could design and perform additional experiments using the *Oligotrophic* Simulation.

Scientists often make educated predictions that they can test to determine if they are correct or not. Even with lots of background research their predictions are often incorrect. Being able to predict how microorganisms interact and respond to different environmental conditions is something marine microbiologists are keen on understanding, especially due to global climate change.

- State an example of a time your prediction was correct, and what events transpired that made it correct.
- State an example of a time your prediction was incorrect, and what events transpired that made it incorrect.
- Draw a picture or diagram of an interaction that you saw in the simulation and indicate how biomass flowed through the interaction.
- Research one of the organisms from the game online. Draw a picture of it and state three traits of the organism (what they consume, etc).
- What is at least one reason that marine microorganisms are globally important? Do they impact you directly? Do microbial interactions affect their global impact?
- Why is it important for scientists to understand how microorganisms contribute to the cycling of nutrients in the oceans? How can this information be used to inform change beyond the scientific community?