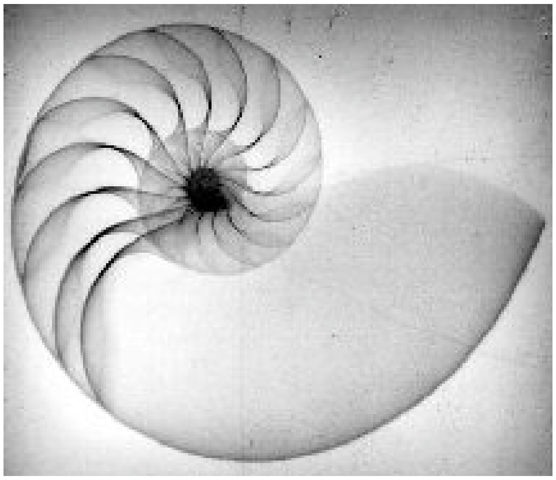
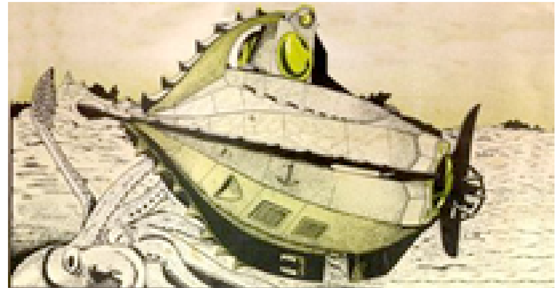
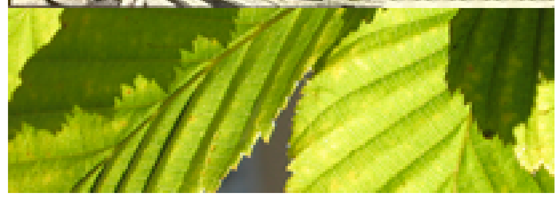




A Life-Support System Under the Sea?

A Case of Recycling Gases

Capitana Nadia Nessuno has constructed a vessel inspired by her uncle Nemo's old submarine and named it *The Chambered Nautilus*. Its actual design is a secret but it is believed to incorporate elements of its two namesakes. During daylight hours she expects its transparent Plexiglas walls to let in enough natural sunlight to power photosynthesis in plants that she will grow onboard. She thinks the plants will remove carbon dioxide from the air inside the submarine. She anticipates that the same arrangement can also produce oxygen to sustain the life of her crew. In the depths of night or the sea her on-board nuclear power generator will provide energy for electric lights for the plants. It all sounds wonderful but: could it work? She is consulting your team for advice.

Pre-Lab Case Analysis

What is this case about? **Underline** terms or phrases above that seem to be important and central to understanding this case. If you are keeping a lab notebook **enter** into it what you know already and what you need to know. You will use these entries in your lab report.

What do I already know about the problem?

What else do I still need to know?

Underline the need-to-know items that you think are most important.

What references would help you explore the issues or answer the questions? Online resources through the CSM Library are available from both on-campus and off-campus locations. Login at http://www.smccd.net/accounts/csmlibrary/ to check them out. If you are off-campus you will need the barcode number from your library card (any library in San Mateo County).

A lot of questions; some may be useful and answerable.

Approximate answers to interesting & vital questions beat exact answers to boring & trivial ones.

Check all you think are useful. **Underline** any that are answerable. **Circle** any that **you** like.

- ☐ Can artificial light work for this purpose?
- ☐ Which would be better: incandescent or fluorescent lights?
- ☐ What color light bulbs would be best? Red, orange, yellow, green, blue, indigo, violet, ultra-violet, infra-red or a combination? White?
- ☐ Would LED (light-emitting diode) lamps work as well?
- ☐ Would the removal of all the carbon dioxide also produce oxygen in the right amount?
- ☐ How much greenery would be required to produce enough oxygen for one person?
- ☐ Would terrestrial plants in soil pots or in hydroponics work better than aquatic plants?
- ☐ Which are better: young tender plants or older, woody ones?
- ☐ How much would the system weigh? How much space would be needed?
- ☐ How deep can she go and still use sunlight as a useful source of energy for photosynthesis?
- ☐ Why would algae that naturally grow at greater depths in the sea be colored differently from those that grow at the surface?

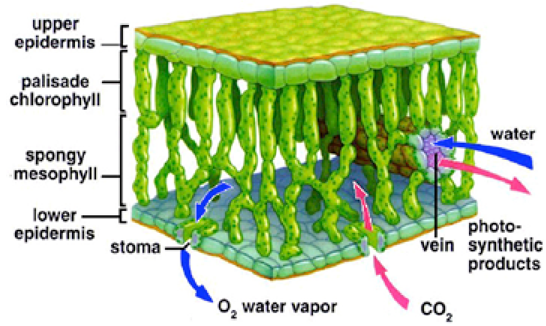
Leaf Description and Comparison

Get two different leaves (from yard or produce aisle) and describe each of them separately, listing both points of similarity and difference. **Bring** fresh examples of each to the next lab meeting.

Leaf A only	Both leaves	Leaf B only

Lab Activity

Examine this picture of a slice through a leaf. Notice that it has some empty spaces normally filled with air as well as a vein carry liquids into and out of the leaf. The amount of space is somewhat exaggerated compared to most leaves, but all will have capacity for oxygen, carbon dioxide, water vapor, and other gases. What else can you see that was not visible to the naked eye in your own leaves?



http://www.life.uiuc.edu/plantbio/102/lectures/LEAFSEC.JPG

Consult with members of your team and **compare** the leaves you described and brought to class. **Tell** why you chose the ones you did. **Speculate** on what the similarities in the leaves suggest about the design function of leaves.

Although the differences among the leaves might be trivial and insignificant, **assume** for this discussion that they are critical and vital. **List** what you think those differences might be about.

Case Discussion

Which questions did you and the other members of your group focus on?

What other questions have occurred to any of you in considering this case? Circle the questions above or below that would you like to pursue if you could?

Demonstration

The instructor will demonstrate the use of a device called a Vernier LabPro, a computer interface that takes signals from sensitive probes and converts them into numerical measurements that computer software (LoggerPro) can store and translate into understandable data. Each probe is like a specific sense receptor that is sensitive either to temperature, or pH (acidity), or the presence of oxygen or carbon dioxide, *etc.* With the LabPro it is even possible to measure several of these things at the same time.

What would you measure to answer the questions and solve the problems you identified in the case of the undersea life support system? We just might have a probe to measure directly exactly what you want. Some things can be measured indirectly. What would you like to measure?

Pigment Extraction

What gives the leaves their color? Different pigments or combinations of them? One way to separate the components of a mixture is paper chromatography, a technique that uses differences in the size and charges of molecules. (Big ones with sticky pluses and minuses move more slowly.)

a. A volunteer will use a mortar and pestle to prepare a spinach extract in acetone. Each group will perform a procedure to separate the various pigments contained in the spinach cells.

b. **Obtain** a piece of chromatography paper from your instructor, and then **draw** two lines in pencil on the paper. One line should be 1 cm from the bottom and the other 1 cm from the top. Notches may already be cut where the bottom line goes. In addition, **pour** a small quantity of solvent into a large test tube (the level of solvent cannot be higher than 0.5 cm from the bottom of the tube).

c. **Use** a capillary pipette to put a droplet of the spinach extract on the bottom line that you drew. Ideally your dab of spinach should not get bigger than this capital 'O.' When it is dry, **add** another drop, letting it dry also; **repeat** until you have loaded a high concentration of pigment onto the spot. **Place** the strip of paper with spinach extract into the tube and close the tube with a rubber stopper. The pigment spot should not directly contact the solvent

d. **Check** the paper strip in the test tube regularly and remove it once the solvent line touches the top pencil line. **Be careful** not to let the pigments run off your chromatography paper.

e. **Examine** the strip immediately and look for evidence of different pigments. **Compute** Rf values to each pigment that you see. Rf value is the distance from the origin (pigment spot) to the leading edge of the traveling pigment divided by the distance that the solvent traveled.

f. **Consult** the chart of Rf values to determine which pigments were in the spinach. Rf values vary a bit with the solvents used. Yours won't match exactly. Check (✔) relative darkness.

Molecule	*Rf value*	*Your Rf values*	*Density (dk/lt)*			
beta carotene	0.98					
pheophytin	0.81					
chlorophyll *a*	0.59					
chlorophyll *b*	0.42					
xanthophyll 1	0.28					
xanthophyll 2	0.15					

Application of Knowledge

Tell how the results of the pigment extraction and separation can be used to account for any of the similarities and differences in the leaves you described earlier.

Suggest how it might be applied to the Case of Recycling Gases

Experimental overview (See following pages for details.)

1. Select enough greenery to measure changes but enough to block light to its interior parts.
2. Weight an empty gas chamber.
3. Place the sprig of greenery in a gas chamber so that it is open and all its parts lighted.
4. Weigh the gas chamber with the sprig and calculate the mass of the vegetation.
5. Connect the appropriate probes to the chamber and the LabPro and the LabPro to a Mac.
6. Launch the LoggerPro software and run it with the vegetation in relative darkness.
7. Illuminate the chamber with natural light (if a sunny day) or a fluorescent ring if available, otherwise an incandescent lamp with a vessel of water in the light path to absorb heat.
8. Analyze the data. Estimate the rate of photosynthesis. In the detailed instructions that follow you will be guided to select a portion of a graph and click a button to automatically "perform a linear regression." If you are new to the idea of "Linear Fit," think of it as a mathematical way to simplify one collection of points (or a curve) into a straight line for easier comparison with another. The steeper the line (the slope), the faster the rate. (Think: downhill racing.)
9. Compare the rate of oxygen production and carbon dioxide consumption, or vice versa.

Reflections (after you've run the experiment on pp. 6–8)

Reread the case scenario on page 1.

Again **ask** yourself (or your group) the original question about whether photosynthesis by plants on board the submarine can sustain the life of the crew?

Tell how you would now answer this question to Capitana Nadia Nessuno?

Cite any evidence you have to support your answer?

Cite one question that still remains unanswered to your satisfaction.