Ocean Diving and Drifting: Marine Dreamin'

Lesson Type: Career
Target Grade: Elementary/Middle School
Authors: Rosalind Bump
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Introduction

The ocean covers an astounding 71% of earth's surface and can reach depths of up to 36,000 feet (6.8 miles). It's estimated that we've explored a mere 5% of this mysterious biosphere. How have people over the past centuries explored the oceans? What challenges does the fluid world pose? What are the implications of CO2 emissions and subsequent ocean acidification on the health of marine organisms?

In this lesson, mentees will be introduced to marine science by diving into human exploration beneath the waves, and the remarkable life strategies of the abundant, but often overlooked plankton of the sea.

Teaching Goals

- The relationship between density, pressure, buoyancy in the ocean
- Marine biology: the scale, size, and structural diversity
- Threats to ocean life (bioaccumulation, ocean acidification)

Careers and Applications

In this lesson, students will

- Explore these questions with simulations of objects in water, and how they respond to pressure, depth, and salinity.
- Be introduced to careers in marine science, particularly SCUBA as a means of human study of the ocean and its organisms. In the process, they will also learn about some of safety measures a oceanographers must keep in mind due to biological and physical constraints.

Agenda

- **Introduction**
- **Module 0: Hydrometers (10 min)**
- **Module 1: Cartesian Divers (15 min)**
- **Module 2: Plankton Drifters (20 min)**
- **Module 3: Ocean Acidification (5 min)**
- **Conclusion**

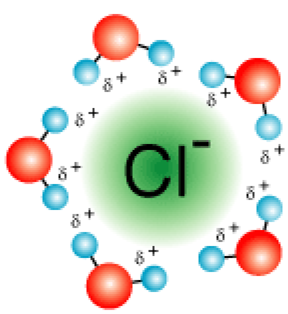
Module #0: Eyedropper Hydrometer

Introduction

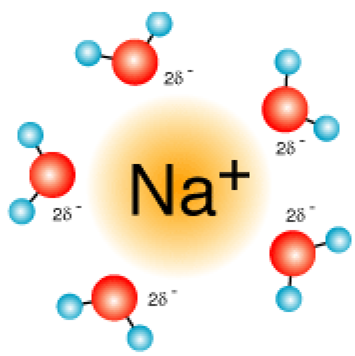
In this module, students will be introduced to the concepts of buoyancy, density, and salinity.

Background for Mentors

- Water has a density of 1 gram per milliliter (1 g/ml).
- Density: $\rho = m / V$ where m = mass of the liquid, V = volume of the liquid
- Introduce **salinity**, and the different properties of saltwater vs. freshwater
  - Density = mass/volume



Slightly positive hydrogen are attracted to chlorine anions

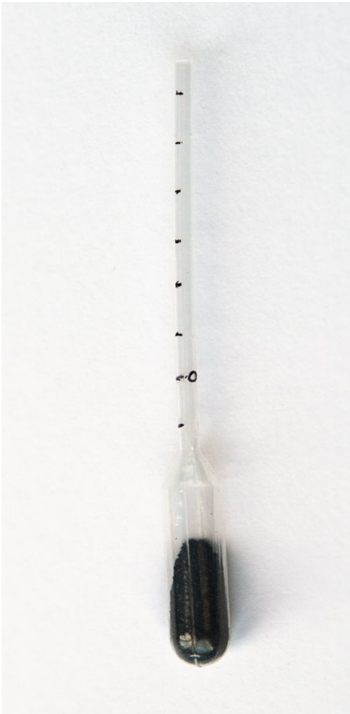


Slightly negative oxygen are attracted to sodium cations

When you add NaCl to water, you are increasing the mass of the solution. The volume does not increase proportionally, because the H20 water molecules are polar, and bind tightly with the Na+ and Cl- ions respectively. Thus, the density of saltwater is greater than freshwater.

Archimedes Principle: the buoyant force on an object is equal to the weight of the fluid displaced by the object.

- The force required to keep your hydrometer buoyant is dependent on the hydrometer's shape, mass, and volume. When it is placed in fluid, it will sink until it displaces enough fluid to balance this force.
- The student's hydrometers will float higher in the saltwater. The salt increase the density of the fluid, thus the volume that the hydrometer needs to displace is less.

Materials

- Plastic pipettes
- Cup of freshwater
- Cup of salt water (~300g salt/L water)
- Markers

Procedure

- Have students work in groups of 3-4.
- Ask students if they have been to the ocean; have they swum in saltwater?
- Explain that a hydrometer is a tool used to measure the density of a liquid ($\rho = m / V$)
- Explain that salt will dissociate into ions (Na^+ Cl^-); and that adding salt will increase the mass, and thus the density, of your cup's liquid.
- Fill pipette with sand. Place first in fresh water. Mark on the pipette where the surface of the water hits. This is the "zero-reference point." Then, take this same hydrometer, and ask the students to predict if the it will sit at the same position in a bottle of salt water. Place in the saltwater and discuss results. See above photos for the difference between fresh and saltwater! Make sure there is enough salt dissolved in your saltwater cup to see a dramatic difference.
- Explain that when conducting science experiments, it is always good to have a baseline control, or a zero-reference point, to observe changes.

References

http://www.exploratorium.edu/snacks/eyedropper-hydrometer

Module 1: Cartesian Divers

Introduction

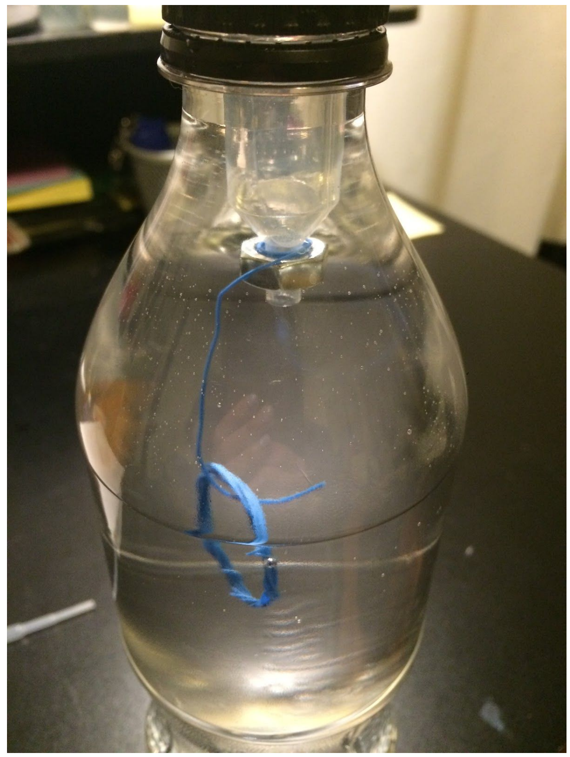
Students will create Cartesian Divers to aid in understanding how SCUBA divers and deep sea submersibles work in real life, by exploring real life applications of neutral buoyancy through SCUBA gear.

Background for Mentors

- A Cartesian diver floats in water at atmospheric pressure, and sinks when the pressure is increased.
- Recall that water has a density of 1 gram per milliliter (1 g/ml). Objects that are less dense than 1 g/ml float in water, while denser objects sink.
- “At atmospheric pressure, the density of the Cartesian diver is approximately 0.8 g/ml, so it floats in water (because 0.8g/ml is less than 1g/ml). However, the Cartesian diver contains air. When you squeeze the bottle containing the diver, the air inside the diver gets compressed (you can see this if you look closely as you squeeze the bottle). This compression causes the diver to become more dense (say, 1.2 g/ml). Since the diver’s density is now greater than 1g/ml, it sinks. Releasing the bottle returns the diver to its original density, so it floats again. ” CMORE
- Explain that divers often wear a weight belt (like the hex nut the Cartesian Diver needed), as well as a BCD (buoyancy control device, which holds air, like the plastic pipette) to control neutral buoyancy at their desired depth. Would be helpful to have a model/image to show to students so they get an idea of what a real scuba diver’s gear looks like! (If mentors can show students an image/video that would be valuable).

Materials

- 16oz plastic water or soda bottle (students in groups of 3-4)
    - filled with water (pre-fill or have water source at the school)
- Plastic pipette (1 per bottle)
- Hex nuts (1)
- Coated wire

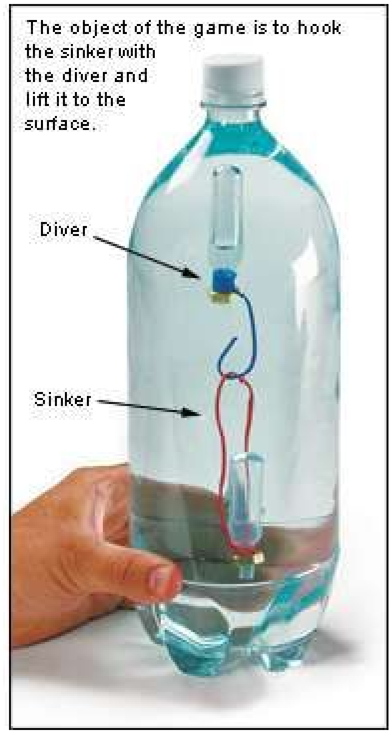


Procedure

- Have students work in groups of 3-4. Give each group one pipette and 1 hex nut. Cut the length of the pipette so that only a bit of plastic remains under the bulb. With the wire, wrap it around the pipette and create a hook at the end, then slide up the hex nut to secure in place. (This may be hard for the kids to secure. Have the kids try to problem-solve before helping them by looping the wire through the hex nut to make it more secure.)
- Add one “diver” to a bottle filled to the brim with water. Then, upon pressing the bottle, the diver should sink. Ask the students what they think is happening, how the diver sinks upon squeezing the bottle. (If it’s really hard for the kids to make the diver sink, let them play around with amount of wire they used for their hook. More wire = more weight, will be easier to make the diver sink).

Challenge Activity

- To make this module more of a competition, can have the Cartesian divers act as “rescue diver” (the diver with the blue hooked wire) that must retrieve a “sinker” (a loop of wire).
- Can present this to the student as rescuing wreckage from a sunken ship, helping on a rescue dive, or helping build essential infrastructure like the Golden Gate Bridge!



Additional Notes for Mentors

- You want to make sure the bottle is filled to the brim with water for this to work properly, so have a water source to top off each of their bottles once the diver is added.
- Water may spill when the students place the diver in the bottle, so either have paper towels on hand, or maybe even take this activity outside.

References

- https://www.youtube.com/watch?v=sNOXFiJ4IDU
- https://www.teachengineering.org/activities/view/uoh_fluidmechanics_lesson01_activity1
- http://thunderbay.noaa.gov/pdfs/cartndiver.pdf
- http://cmore.soest.hawaii.edu/education/teachers/documents/Outreach_Box_Sept2012.pdf
- http://www.exploratorium.edu/snacks/condiment-diver
- http://www.pbs.org/wgbh/americanexperience/features/general-article/goldengate-underwater/

Module #2: Plankton and Neutral Buoyancy

Introduction

What are plankton, and why are they important? How do plankton maintain **neutral buoyancy** in the water column, and how does their shape/structure allows them to do this?

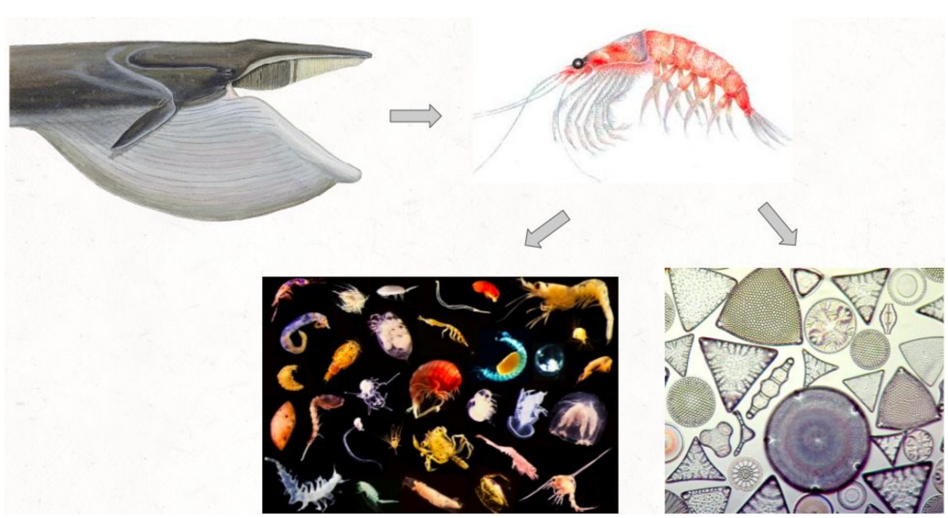
Students will become familiar incredible range of **scale** and size in the ocean, and begin to formulate ideas on how such various structural features allow different marine organisms to be suited to their environments.

Background for Mentors

Segue from module 1:
- How do SCUBA divers maintain neutral buoyancy, and why do they need to?
- Divers plan "safety stops" when they are reascending. At ~15 meters, they wait for 3-5 minutes, to prevent decompression sickness. (Also known as "the bends", a severe condition that occurs when the the pressure on your lungs decreases too quickly, causing an offloading of the gasses in your lungs to form "micro bubbles" of nitrogen in the bloodstream). To maintain neutral buoyancy during this waiting period, they can control amount of air in their gear (to ascend or descend slightly) as well as the amount of weight in their weight belt.

Some of the most important organisms in the ocean live their lives being **neutrally buoyant***.*
These tiny, but essential organisms, are known as **plankton.**

- Phytoplankton are plant-like organisms, capable of photosynthesis.
- Zooplankton (think "zoo" = animals) are animal plankton species that get their nutrients by eating other microscopic organisms. Ex. rotifers
- Plankton "float," suspended in the water column, rather than using a real form of propulsion. They can be capable of some movement, with beating cilia, but cannot propel themselves very far. That being said, plankton partake in "the world's largest migration" ! They drifting up at night, via their microscopic cilia, and sinking gradually down before dawn.
- These tiny creatures are eaten by huge creatures!



Materials

- Live rotifers (~ 1-2 oz per site)
- Magnifying glasses (4-5 per site)
- Pipe cleaners
- Clear plastic bottle with top cut off, filled with water

Procedure

Start this module by posing questions:

What is the biggest animal in the world? Blue whales

- Length of 3 school buses, hearts the size of small cars!

What do these huge whales eat?

- Very small animals! Use their fine baleen as a filter (ie in Finding Nemo)
- Introduce plankton (phyto and zoo)

These very small little animals, zooplankton, are **neutrally buoyant**, just like Scuba divers must be. They can use cilia to drift up at night, but they sink back down before sunrise. Why? (To avoid predation during the day, but feed on algae and phytoplankton that sit at the surface b/c they need sunlight to live).

Observing zooplankton: Rotifers under a magnifying glass

- Students will have the chance (in small groups) to observe live rotifers, a common zooplankton
- After observing, record students' observations about the animals on the board.
  - *What **adaptations** allow the plankton to be well-suited to a neutrally-buoyant life?*
  - (i.e. small mass, little waving arms, a "tail" to balance, etc)

Building their plankton

- Using their Cartesian Divers as a base, each group of students will build a model zooplankton that must maintain neutral buoyancy (hover in water).
- Encourage students to include the structures they observed in their design (i.e. cilia-like features with pipe cleaners!)
- Allow students to experiment with materials, and ask them to create novel biological structures what would make them well-suited to life in the open ocean (let them be creative!)
- Then, have them test to see if their plankton

can sit hovering in the water column.

Additional Concepts for advanced/middle school students:

Bioaccumulation & endocrine disrupters

- Some of the chemicals in our everyday household items or used in large manufacturing plants can disrupt hormone pathways in biological systems, even in very miniscule amounts.
- "All drains lead to the ocean." Our liquid waste ends up in the ocean. At the bottom of the food chain, the tiny plankton can be exposed to trace amounts of these chemicals. A blue whale eats ~ 40 million krill a day. Imagine a krill eats 100 plankton a day.
    - If every one of the 100 plankton is exposed to the chemical, how many fold greater of the chemical will be in a whale's body after a day of eating krill?
    - If you were an environmental scientist, how would you approach solving this issue?

References

- http://teachoceanscience.net/teaching_resources/education_modules/plankton_-_aquatic_drifters/teach/
- https://www.insidescience.org/news/new-explanation-earths-biggest-migration
- http://animals.mom.me/difference-between-plankton-krill-7856.html
- http://www.whalefacts.org/what-do-blue-whales-eat/

Module 3: Ocean Acidification

Introduction

This is a short module where students will be able to pass around shells that have been degraded by an acid, and compare them (their strength or fragility), with untreated shells. It will be a simple, tactile chance for students to think about the effects of ocean acidification.

Background for Mentors

- The ocean is acidifying, as global atmospheric CO2 increases.
    - Fig. 1: A wonderfully tracked data set from Mauna Loa in Hawaii
    - Fig. 2: A pteropod's shell when subjected to the predicted oceanic pH by 2100
    - Fig. 3: General reaction for how dissolved CO2 disrupts marine organisms that make calcium carbonate shells

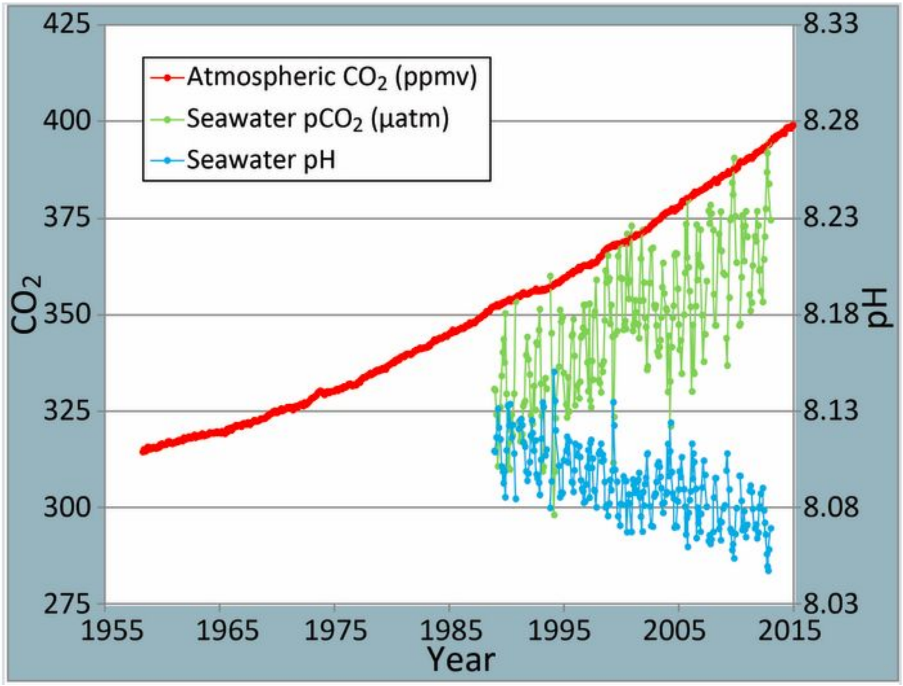


Fig. 1

Fig. 2

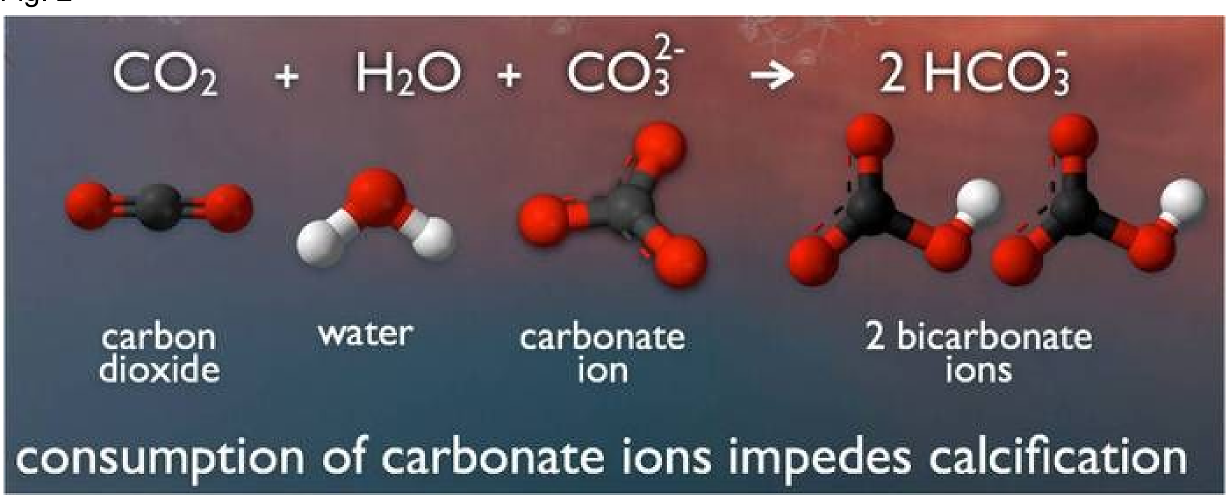


Fig. 3

Materials

- Shells pre-soaked in vinegar
- Shells (untreated)

Procedure

- Have students first pass around non-treated shells and make observations.
- Ask them if they have heard of carbon dioxide. (What are CO2 emissions, and where do they come from? Why are their levels rising?)
- Then, have them touch and evaluate the treated shells. Make hypotheses about why more brittle shells might be a concern for animals in the ocean (Will it affect them or not? Why do they have shells in the first place? What affect could this have on the ecosystem/the other animals in the ocean?) Elementary students will likely be familiar with food chains, so can try to direct the conversation via this framework.

References:

- http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F
- http://www.exploratorium.edu/snacks/shell-shifts
- http://web.uri.edu/smile/files/Shells-in-Acid-LAB1.pdf
- https://www.st.nmfs.noaa.gov/Assets/Nemo/documents/lessons/Lesson_3/Lesson_3-Teacher's_Guide.pdf
- http://www.cosee.net/best_activities/activity/Plankton_Races.pdf

Summary Materials Table

Material	Amount per Group	Expected $$	Vendor (or online link)
2 L empty soda bottle, with top cut off	1 / site		Recycling?
16 oz plastic water or soda bottles	1 / group		Recycling?
Plastic pipettes	1 / group	$ 4.77/100 pipettes (enough for 4-5 per site)	https://www.amazon.com/gp/product/B00N3Y0BFE/ref=pd_sbs_328_1?ie=UTF8

Hex nuts	1 / group	$ 6.28 / 100 hex nuts	https://www.amazon.com/Hillman-Group-150003-20-Inch-100-Pack/dp/B000BPEPNW/
Coated copper wire	One piece of ~ 6 inches/group	$ 6	https://www.amazon.com/gp/product/B008AGUAII/
Salt			
Sand	~ 1 tbsp/site		
Pipe cleaners /straws/popsicle sticks/ extra random materials	A few assorted items/group		Bechtel? https://www.amazon.com/Creativity-Street-Cleaners-100-Piece-Assorted/dp/B0016P48GA/
Live rotifers		~ $ 15	https://www.amazon.com/gp/product/B00I112H88/
Magnifying glasses		~ $ 15	https://www.amazon.com/gp/product/B003U6SL8E/
Sea shells			
Vinegar		$ 2	