**Ocean Acidification: Building Blocks of the Sea**

**Summary:**

Human actions on land are connected to changes in the atmosphere, and thus, the ocean. The health and survival of ocean creatures is at risk because of the change in the ocean’s chemical composition due to additional carbon dioxide that is dissolved into sea water from the burning of fossil fuels and land use changes. This change in the ocean’s composition disrupts the ability of organisms with skeletons and shells to grow, due to a change in the availability of a building block crucial to shell and skeleton growth-calcium carbonate. This change can impact the ocean’s food web and the food we eat. We can reduce our carbon footprint in many ways to help maintain the ocean’s composition now and into the future.

**Values:**

Interconnected – Even though humans don’t spend the majority of our time in the oceans, our actions on the land affect the atmosphere (air) and thus, the ocean.

Stewardship – It is our responsibility to take care of the ocean by our actions on land.

Simplifying models – the ocean is composed of building blocks for the organisms that live within it.

Causal chain – burning fossil fuels emits CO2 → the ocean absorbs CO2 → the ocean becomes more acidic → calcium carbonate is not readily available → it is more challenging for calcifying animals to build their shells/skeletons → the food web is disrupted → the food we eat could change.

**Solutions:**

Community Level Solutions – increased public transportation use, alternative/green energy, supporting local community,

Individual/Household Solutions – unplug vampire electronics (phone chargers, computer, laptops); reduces CO2 and saves on the electric bill, reusable water bottles,

**Objectives:**

- students understand and value the importance of how human activities influence the chemistry and thus health of the ocean ecosystem and organisms.
- students understand and value the importance of how changes in the ocean ecosystem affect marine life (specifically calcium carbonate building) and human life.

**Key Messages:**

- Oceans are a vital part in the Earth’s ecosystem and are a home to marine life that
contribute to the health of human life on our planet.

- Human actions are changing the ocean’s chemistry which is altering life below the surface and could potentially change food webs and the food we eat.
- We want to make sure that our ocean marine life remains healthy.
- Together, we can work as stewards of our planet’s oceans and make positive changes in the world we live in.

Materials:

- legos (many of 3 distinct shapes)
  - identify legos of certain shape and color that will represent Calcium (Ca⁺), Carbonate (CO₃⁻), and Bicarbonate (HCO₃⁻) respectively.
    - can label via letters, carbonate can be uniquely shaped (can have same color as Calcium- as they are compatible and bicarbonate and calcium are not), and Carbonate and Bicarbonate can have same shape but different colors.
- chemical equation visuals (available in power point slide-slides 12,13,14)
- visuals of organisms with CaCO₃ shells/skeletons (available in power point slide-slide 15)

Activity Outline:

1. Create two piles of legos or “oceans”
   a. one representing an “acidified” ocean (future atmospheric CO₂ levels) with less carbonate lego and more bicarbonate pieces, set amount of Calcium pieces
2. other a “pre-industrial revolution” ocean (with lower CO₂ levels) with more carbonate pieces and less bicarbonate, with same amount of calcium pieces
3. students or small group of students can decide which shell or skeleton building creature they’d like to become (i.e. clam, oyster, lobster, coral polyp, etc.)
   a. can highlight that these are sessile organisms that deal with what is available can’t travel to a different part of the ocean
4. students or small group of student build a calcium carbonate shell/skeleton by connecting the calcium lego pieces to the carbonate pieces in the pre-industrial ocean and then repeat in the “acidified” oceans
   a. Analogy: this is much like building a home or foundation for a home, a nail is needed to hold together the wooden frame or mortar to hold together bricks, just as carbonate is
needed to create the foundation (skeletons of corals) or home itself (bivalve and mollusc shells)

b. Can have groups compete in the two different oceans, how many happy organisms were you able to build, or can time the different oceans as well.

Follow up Discussion:

1. Compare the two oceans?
   a. How many calcium carbonate pieces were you able to put together to build your shell/skeleton in the different oceans?
   b. Which ocean was it easier to find the building blocks of your shell/skeleton?
   c. In which ocean were you able to put together your building blocks more quickly?
      i. The time lost in searching for carbonate ions instead of bicarbonate
   d. If you were a ________, which ocean would you rather live in or would it be easier to build your shell/skeleton in?
   e. What can we/y as humans do to help ocean creatures be able to to build shells/ and skeleton/homes more easily?

Presentation Write-up:

Slide 1

Chemistry is cool- carbon is cool

Carbon is inside of us our bodies, plants, trees the air, the ocean-it’s everywhere. One thing us and many, if not all living (and many non-living) things have in common.

Slide 2

The carbon cycle:

A large amount of carbon is stored underground in the geologic reservoir. And a portion of carbon travels through the atmosphere, into vegetation (i.e. trees and plants) and also is absorbed by the ocean. Can you point on the natural flow of carbon in this picture versus the carbon that is added to the
cycle from humans (i.e. fossil fuels and cement production & the tractor and fire - land use change, less trees to absorb and store the CO₂)

Slide 3

How humans are changing the carbon balance: sources and sinks

Sources are above the line and add carbon dioxide to the atmosphere. Deforestation releases 1.1. pg of carbon that was stored in trees.

Slide 4

How humans are changing the carbon balance: sources and sinks

Fossil fuels emission contribute 7 x the amount as deforestation, moving a large amount of carbon.

Slide 5

The carbon balance: Where does the carbon go?

There are also carbon sinks, that is a negative in the balance, where CO₂ travels and can be “stored”, shown here below the line.

Slide 6

The carbon balance: Where does the carbon go?

Some amount of carbon is stored in the atmosphere as carbon dioxide (shown in yellow).

Slide 7

The carbon balance: Where does the carbon go?

The ocean then absorbs the CO₂ from the atmosphere (shown in blue).

Slide 8

The carbon balance: Where does the carbon go?

The plants and trees on land absorb and store some of the carbon as well (shown in green).

Slide 9

Importance of the ocean in absorbing carbon.
But getting back to the ocean— it stores about ¼ of all the CO₂ emitted by fossil fuel and deforestation. If we took the carbon that the ocean stored and put it in railroad cars— it would stretch around the earth 7 times!

Slide 10

What is Ocean Acidification

So if carbon naturally is absorbed by the ocean, what are the effects of excess carbon being absorbed by the ocean? Ocean Acidification. Carbon dioxide when mixed with water forms carbonic acid, which quickly dissociates to form hydrogen and bicarbonate. The increase in hydrogen ion coincides with a lower pH (increased acidity). The increase in bicarbonate causes a decrease in the carbonate ion shown here in green.

Slide 11

Ocean acidification: a shift in bicarbonate and carbonate

The increase hydrogen ions causes an increase in bicarbonate by latching on to the free carbonate ions in the water.

Slide 12

Ocean Acidification: carbonate a building block for shells and skeletons

This decrease in carbonate is important for many creatures that live in the ocean. Particularly those with shells and skeletons. Because carbonate is one of the parts of the shell, it mixes with calcium to form calcium carbonate, the material that the shells and skeletons of many marine organisms are made of.

Slide 13

How to get a solid shell from a liquid: a demonstration

When there is a lot of carbonate in a solution, like the ocean it will form a solid with Calcium shown here in the video. Pretty amazing that building blocks are stored in the liquid form of the ocean but can form a solid material like shell and skeletons.

Slide 14

What organisms have shells and skeletons?

Corals, mussels, clams, squid have hard part, the bones of fish, shrimp, lobster...

Slide 15:

What can you do: to help balance the carbon balance
Engineers are creating platforms (in white shown here) to scrub or remove CO₂ from the atmosphere, and also inject the CO₂ back deep into the earth where the geologic reservoir is.

These are still in the works, but you can help right now by...

- Power plants= CO₂ emission=electricity
- save electricity unplug electrical “vampires”-laptop, phone chargers, turn off the lights when you leave the room
- Trees- absorb CO₂→plant a tree
- Buy local, from farmer’s markets
- Use public transportation, ride a bike

Background information

The increase of carbon output is affecting not only our atmosphere, but our oceans as well. Oceans are sometimes referred to as carbon sinks, a helpful buffer against global climate change. In fact, oceans absorb approximately 1/3 of all CO₂ emissions. However, once dissolved in the ocean, CO₂ still makes a significant impact. It binds to water molecules to produce carbonic acid (H₂CO₃), which can then disassociate into H⁺ and HCO₃⁻ (bicarbonate).

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^- \]

So, what does this mean? More H⁺ ions mean a lower pH, or, in other words, a more acidic ocean. PH is measured by the number of H⁺ ions present in a solution and can range from 1-
14, with 1 being the most acidic and 14 being alkaline (basic). Distilled water is neutral, with a pH of 7.0. In pre-industrial times, ocean water had a pH of 8.2. Today, the ocean’s pH is 8.0, and it is projected that if we maintain our current CO2 emissions, pH will drop to 7.7 by the year 2100. If that does not seem overly drastic, consider this: a drop of one pH unit represents a 10-fold increase in acidic H+ ions.

An increase in H+ ions creates two problems. Not only is the ocean’s pH dropping, which can cause the corrosion of the shells and skeletons of many marine animals, such as snails and corals, but the extra H+ ions also tie up carbonate (CO3). When available, carbonate can combine with calcium to form calcium carbonate (CaCO3), an important compound used by many organisms as a building material for their shells and skeletons. Currently, coralline algae, corals, some species of snails, and many important planktonic species are being affected the most drastically by the reduced availability of this important building compound. As corals and coralline algae disappear, so do the many marine animals that rely on them for habitat. While we can talk definitely about the effects of more acidic water and less available calcium carbonate on certain species, we also know that the repercussions of dissolved CO2 in our oceans do not end there. A change in pH can affect respiration and reproduction. It can cause stress to organisms, and affects the nitrogen cycle. Most aquatic species are adapted to a specific range of pH, and the current anthropogenic change is happening more rapidly than any natural flux ever has, including a low pH interval some 55 million years ago, known as the Paleocene-Eocene Thermal Maximum, which caused a major marine die off. The effects of our carbon emissions on the ocean will therefore be amplified by the simple fact that organisms do not have time to evolve with the change.
Background credit:

Ocean’s Recipe for Success

Bay Lab Visitor Program Script

Aquarium of the Bay

www.aquariumofthebay.org

For more information, please contact:

Carrie Chen, Director of Education & Conservation

carrie@bay.org / 415-623-5335