Photosynthesis and Light in the Ocean

Adapted from *The Fluid Earth / Living Ocean*

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Algae, like your *Halimeda*, and plants live in very different environments, but they have one big thing in common – they both need sunlight to photosynthesize. Without light, they'd both die. As it turns out, the process of photosynthesis in algae and plants is very similar. This makes sense because land plants evolved from green algae.

Photosynthesis

Algae and most land plants contain some form of the green pigment **chlorophyll**. Chlorophyll is a molecule that enables plants to convert sunlight energy into chemical energy. We call this process **photosynthesis**. Photosynthesis uses the chlorophyll and energy from the sunlight to convert carbon dioxide and water into glucose and oxygen. **Glucose** is a form of sugar, and it builds and fuels living organisms. The energy in glucose can be used to produce the fats, proteins, and starches that plants use to build, repair, and reproduce themselves. The equation below shows the photosynthetic process for producing glucose.

$$6H_2O + 6CO_2 \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

water — carbon dioxide — glucose — oxygen

sunlight

Respiration

Stored chemical energy is released from glucose in a process called **respiration**, which is the reverse of photosynthesis. Some of the glucose produced during photosynthesis is used by the plant for its life processes (such as growing and reproducing); the excess is converted mainly to starch and stored in various plant parts which may be used as food by animals and humans. Animal cells do not contain chlorophyll and cannot photosynthesize. So animals must eat plants or other animals to get the glucose, starch, and other molecules they need to build and fuel their bodies.

The oxygen produced during photosynthesis replenishes the oxygen that was used up by living things during respiration. This cycle of photosynthesis and respiration maintains the balance of carbon dioxide and oxygen on earth.

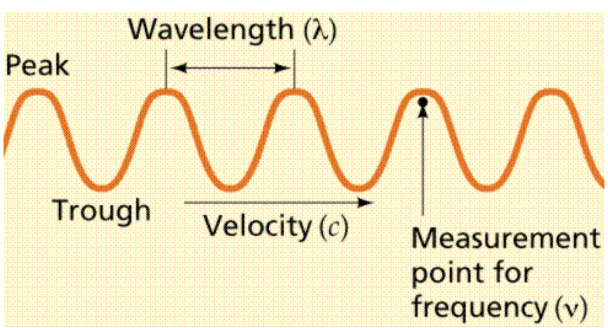
Material developed for the University of Hawaii-Manoa GK-12 program (NSF grant #05385500).
Website: www.hawaii.edu/gk-12/evolution. Duplication for educational purposes only.

Photosynthesis	Respiration
Occurs in the presence of light (and chlorophyll in cells)	Occurs at all times in cells
Requires energy (light) to make sugar (glucose)	Releases energy from sugar
Glucose is formed	Glucose is broken down
Carbon dioxide and water are used	Carbon dioxide and water are produced
Oxygen is produced	Oxygen is used

Solar Energy

The sunlight we see is the same energy that drives the process of photosynthesis, but this part, which we call **light**, makes up only about 40% of the energy received from the sun. The remaining energy takes other forms. About 50% is infrared energy, 9% is ultraviolet energy, and the other 1% is X rays or microwaves. Collectively we call these different forms of solar energy **electromagnetic radiation**.

Sunlight is actually composed of ultra tiny packages of energy called photons. Photons behave like both particles and waves, and so we describe the amount of energy in photons and radiation in terms of their wavelength (the distance between wave peaks). Radiation with short wavelengths has more energy than radiation with long wavelengths. In short waves there are more energy peaks or "kicks" per unit of length.



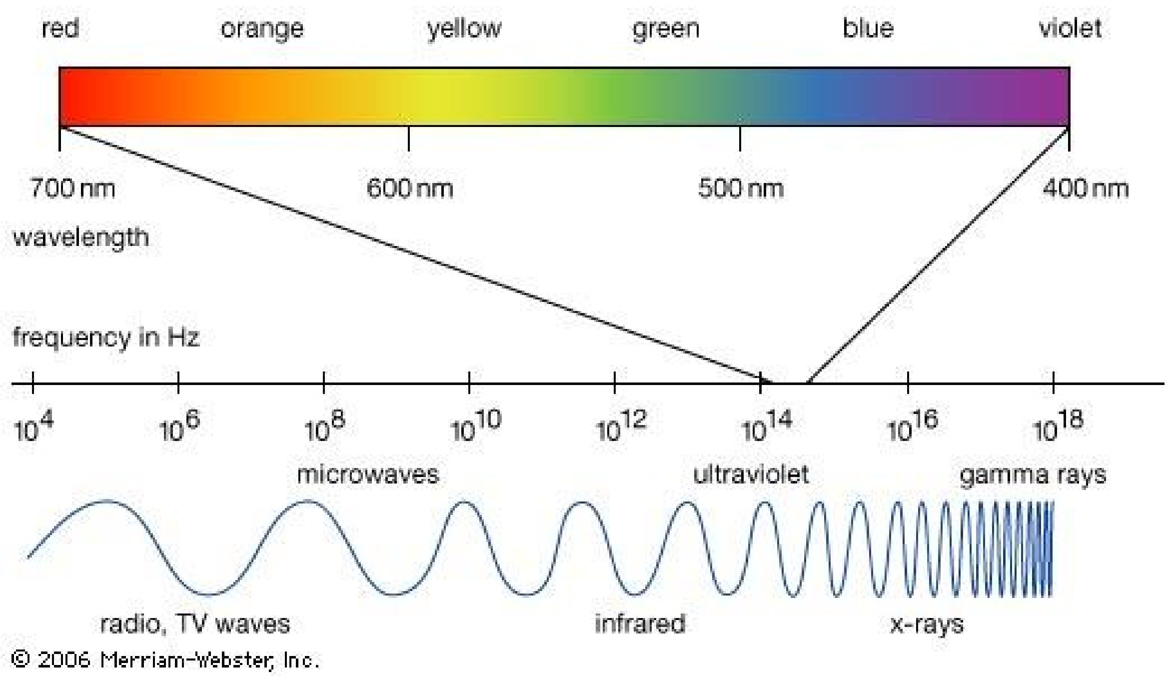
Sunlight is made up of photons. Photons are waves of energy made up of tiny particles. Their energy is measured in wavelengths. Shorter wavelengths have more energy; longer wavelengths have less energy.

The Electromagnetic Spectrum

Visible solar radiation appears as white light, yet when passed through a prism, it breaks up into a rainbow of colors called a **light spectrum**. A spectrum displays light photons of different wavelengths, from the longest (red) to the shortest (violet), with orange, yellow, green, and blue in between.

Electromagnetic radiation extends beyond the light spectrum in both directions. This larger spectrum, which includes light, is called the **electromagnetic spectrum**. At the low-energy end of the electromagnetic spectrum are infrared photons. Though our eyes cannot see it, we feel the warmth from the heat it produces. At the high-energy end of the electromagnetic spectrum are the ultraviolet photons, which can destroy many of the molecules of life. Ultraviolet radiation is used as a sterilizer to kill germs, and we experience its molecular destruction in sunburns. Beyond ultraviolet photons are the very intense X rays, which can pass through our bodies to make photos of our body parts.

Because some of the wavelengths of the electromagnetic spectrum are quite short, they are reported in nanometers (nm). A nanometer is very small, only one billionth (0.000,000,001) of a meter!



Sunlight and Chlorophyll

Sunlight interacts with the chlorophyll pigments in plants and algae. **Pigments** are colored materials that reflect light of certain wavelengths while absorbing or capturing light of other wavelengths. **Chlorophyll**

pigments absorb sunlight, and begin the process of photosynthesis. Plants also contain other pigments besides chlorophyll, including yellow **xanthophylls** and yellow-orange **carotene** (the pigment that gives carrots their color). The classification of macroalgae (seaweed) as red, green, or brown is based largely upon the type of pigments they possess.

To see which wavelengths of light are absorbed by pigments, we can dissolve the pigments from a plant, shine light on them, and measure the wavelengths of light they reflect. The wavelengths that are *not* reflected are absorbed.

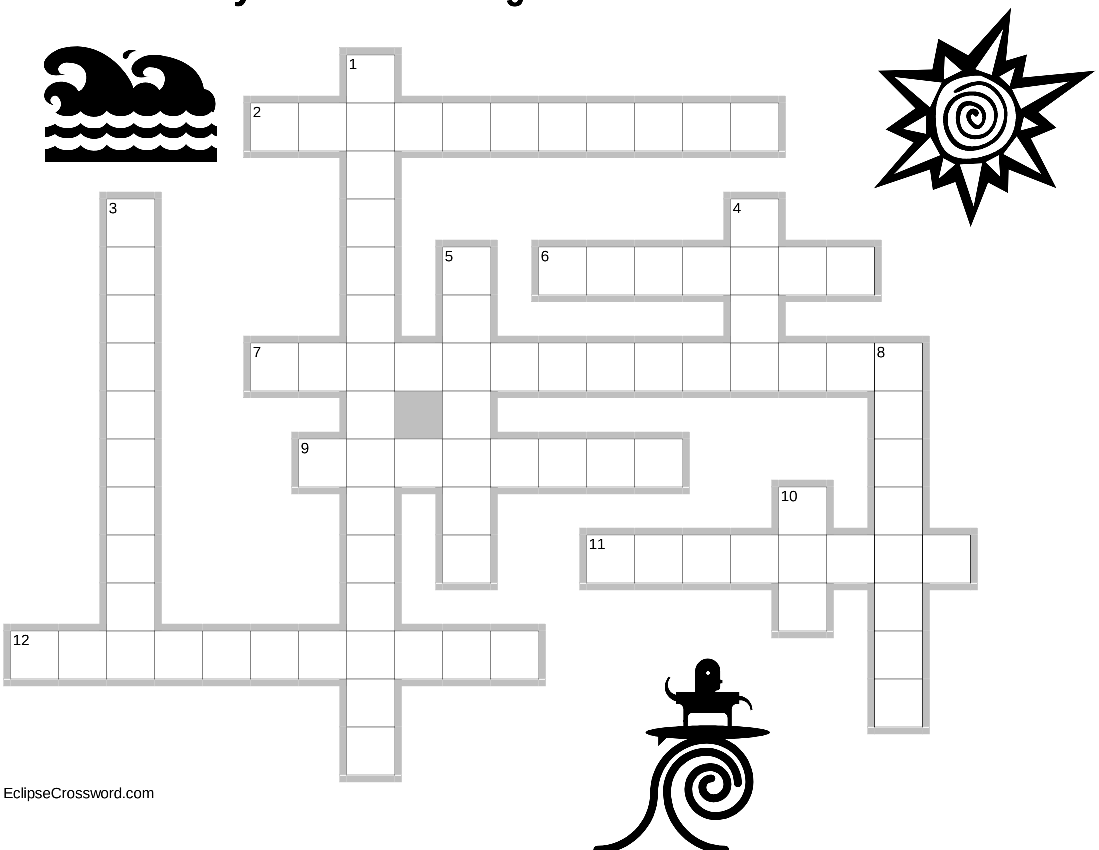
Light in the Ocean

When sunlight strikes the ocean, some of it reflects off the surface, and the rest is absorbed by the water. Within the first 10 meters of the water, water absorbs more than 50% of the visible light energy. The shorter and stronger wavelengths of visible light (blue) penetrate the deepest, while the longer, weaker wavelengths of light (red) are absorbed near the surface. Thus, red light is more strongly absorbed by water than blue-green light. That's why a diver's red wetsuit appears nearly black at 20 m. At 30 m depth, water has absorbed nearly all the visible light colors except blues. For a diver to see other colors besides blue at that depth, they must shine a flashlight directly on the object. Thus, both the **intensity** (amount) and the **color** of visible light various with depth.

Why is the Ocean Blue?

If someone were to ask you, "What is the color of the ocean?", chances are that you would answer "blue". For most of the world's oceans, your answer would be correct. Pure water is perfectly clear, of course. But if there is a lot of deep ocean water, then it appears as a very dark navy blue. The ocean is blue for two reasons: the absorption of light in the water and reflection of the sky. The red, orange, yellow, and green wavelengths of light are absorbed so that the remaining light we see in the water is composed of the shorter wavelengths - blues and violets. If you have a clear, blue sky, then the blue sky will also reflect off the top of the water like a mirror, making the ocean water appear more blue.

Photosynthesis and Light in the Ocean Crossword Puzzle



Across

2. A green pigment
6. A form of sugar produced by photosynthesis
7. The process for converting sunlight energy into chemical energy
9. This yellow-orange pigment gives carrots their color
11. Colored materials that absorb or reflect wavelengths of light
12. The opposite of photosynthesis

Down

1. The different forms of solar energy are called ____ radiation
3. Wavelengths in the electromagnetic spectrum are measured in ____
4. Shorter wavelengths have ____ energy than longer wavelengths
5. Tiny packages of light energy formed of particles and waves
8. Visible solar radiation breaks up into a rainbow of colors called a light ____
10. The longest wavelength of visible light is this color

CSI:*Halimeda*

Hui Malama Learning Center
Heather Spalding, UH GK-12 Program

Your *Halimeda* does not look good, and it's up to you to figure out why. Using the information you've learned about light, photosynthesis, pigments, and nutrient cycling, try and solve the mystery! Heather Spalding, your CSI captain, has made **abiotic** (non-living) measurements in the same *Halimeda* meadow where your plants were collected. This will help you to compare the normal range of values in the field with the conditions in your aquaria. Are the conditions the same? Does something need to be changed? Only you can find out!

ACTIVITY

Measure the light, nutrients, salinity, and temperature in the *Halimeda* aquaria, and compare with the normal range found in an actual *Halimeda* meadow in the ocean. Determine if any of these abiotic factors are causing a decline in *Halimeda* health.

MATERIALS

- LiCOR LI1400 computer and spherical light sensor (looks like a light bulb)
- Aquarium nutrient testing kit
- Hydrometer
- Thermometer
- *Halimeda* in aquaria

PROCEDURE

1. Observe the *Halimeda* in the tank. What looks wrong with it? Record your observations below.

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2. What do you think is wrong with the *Halimeda*? Make a hypothesis about what you think is causing the *Halimeda* to decline in health.

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~Now it's time to test your hypothesis! Maybe one of the measurements below will help us to understand why the *Halimeda* isn't looking too good.~

3. Measure the amount of light in both aquaria at the level of the *Halimeda*. Record the results in the chart below.

4. Using the nutrient testing kit, measure each of the nutrients and the pH in both of the aquaria. Record the results in the chart below.

5. Measure the salinity in ppt (parts per thousand) with the hydrometer. Record the results in the chart below.

6. Measure the temperature in the aquaria with the thermometer. Record the results in the chart below.

CHART 1: *Halimeda* Crime Scene Data

Measurement	**Your Data**	**Normal Range**
Light (um)		400-600 um
Nitrite		0
Nitrate		5-10
Ammonia		5-10
pH		8
Salinity		33-35 ppt
Temperature		75˚ Fahrenheit, or ~24 Celsius

QUESTIONS

1. Are all of your measurements in the aquaria within the normal range found in the field? Circle **NO** or **YES**. If not, then which ones are outside the normal range?

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2. Was your hypothesis correct? Circle **NO** or **YES.**

3. What do you think could be done to the aquaria to make the *Halimeda* more healthy?

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The graph below is a measurement of light in a *Halimeda* meadow with increasing depth. As it gets deeper, more light is absorbed and the water gets darker. This means that less light is available for photosynthesis by the *Halimeda*. Eventually, it gets so dark that the *Halimeda* cannot photosynthesize or grow. This depth is called the **lower depth limit**.

4. What is the light level at the depth your *Halimeda* was collected?

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5. Are the light levels in your aquaria similar to the light levels where your *Halimeda* was collected? Circle **NO** or **YES.**

6. At what depth do you think photosynthesis is not possible for the *Halimeda*? Why?

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