Unit 4: Coral Feeding

Khaled bin Sultan Living Oceans Foundation

Coral Reef Ecology Curriculum

Khaled bin Sultan

Living Oceans

Foundation

This unit is part of the *Coral Reef Ecology Curriculum* that was developed by the Education Department of the Khaled bin Sultan Living Oceans Foundation. It has been designed for secondary school students, but can be adapted for other uses. The entire curriculum can be found online at lof.org/CoralReefCurriculum.

Author and Design/Layout: Amy Heemsoth, Director of Education
Editorial assistance provided by: Andrew Bruckner, Ken Marks, Melinda Campbell, Alexandra Dempsey, and Liz Rauer Thompson
Illustrations by: Amy Heemsoth
Cover Photo: ©Michele Westmorland/iLCP

The Khaled bin Sultan Living Oceans Foundation (KSLOF) was incorporated in California as a 501(c)(3), public benefit, Private Operating Foundation in September 2000. The Living Oceans Foundation is dedicated to providing science-based solutions to protect and restore ocean health through research, outreach, and education. The educational goals of the Khaled bin Sultan Living Oceans Foundation and development of the *Coral Reef Ecology Curriculum* are generously supported by Prince Khaled bin Sultan of Saudi Arabia. For more information, visit www.lof.org.

Follow Us on Social Media:
Facebook: facebook.com/livingoceansfoundation
Twitter: @LivingOceansFdn
Instagram: livingoceansfoundation
Pinterest: pinterest.com/livingoceansfdn

Khaled bin Sultan Living Oceans Foundation
7 Old Solomons Island Road, Suite 200
Annapolis, MD, 21401, USA
(443) 221.6844
education@lof.org

SCIENCE WITHOUT BORDERS®

CORAL FEEDING

This lesson is a part of the *Coral Feeding* unit, which explains what corals eat, how they feed, and additional ways that they obtain energy. Below is a summary of what is included in the entire unit.

UNIT CONTENTS

A. Background Information

- Predation
- Symbiosis
- Photosynthesis
- Cellular Respiration

B. Lessons

Watch it! Coral – What Does It Eat?
- A worksheet to accompany the *Coral – What Does It Eat?* video

It's Tentacular!
- An activity to simulate feeding strategies of corals

Symbiosis Charades
- A game of charades adapted to learn different forms of symbiosis

Round and Round
- An art project to show the relationship between coral and zooxanthellae, photosynthesis and cellular respiration

Read it! What's on the Menu?
- A worksheet to accompany the *What's on the Menu: Sunlight, Plankton or Organic Debris?* field blog

Khaled bin Sultan
Living Oceans
Foundation

STANDARDS

- **CCSS**: RST.9-10.1, 2, 3, 4, 5, 6, 7, 8, 10; RST.11-12.1, 2, 3, 4, 6, 8, 9, 10; W.9-10.2, 4; W.11-12.2, 4; SL.9-10.1, 2, 3, 6; SL.11-12.1, 2, 3, 6; HSN.Q.A.1; HSA.CED.A.1
- **NGSS**: ESS 2.A, HS-LS1-5, HS-LS1-7, HS-LS2-5, HS-LS2-6, PS 1.B, PS 3.D
- **OLP**: 4.A.1, 5.A.2, 5.A.6, 5.A.7, 5.B.5, 5.C.23, 5.C.40, 5.C.41, 5.C.42, 5.C.43

ONLINE CONTENTS

- Coral Feeding Quiz
- *Coral: What Does it Eat?* Video Coral polyps are mostly stomach, with a mouth on top. Symbiotic algae, zooxanthellae, live in the coral and provide them with energy. Corals also snatch zooplankton and other food particles right out of the water.

BACKGROUND INFORMATION

A) PREDATION

There are several ways that corals obtain energy. In this unit, we will learn what corals eat, how they feed, and additional ways that they obtain energy.

Corals are **sessile**, meaning they cannot move to get food. Instead, they stick out tentacles to catch prey items like **zooplankton** (animal-like organisms that live in aquatic environments) and other food particles. The prey is dependent on the size of the coral polyp. After catching their prey, corals use their tentacles to place the prey into their mouths.

When can you observe corals feeding? Most corals feed at night, due to the availability of their food source. Zooplankton have specific movements called **diurnal vertical migration** (figure 4-1). Diurnal refers to a twenty-four hour period. Organisms such as zooplankton move vertically to the surface of the water at sunset. Once the sun begins to rise, the zooplankton move back down to deeper water.

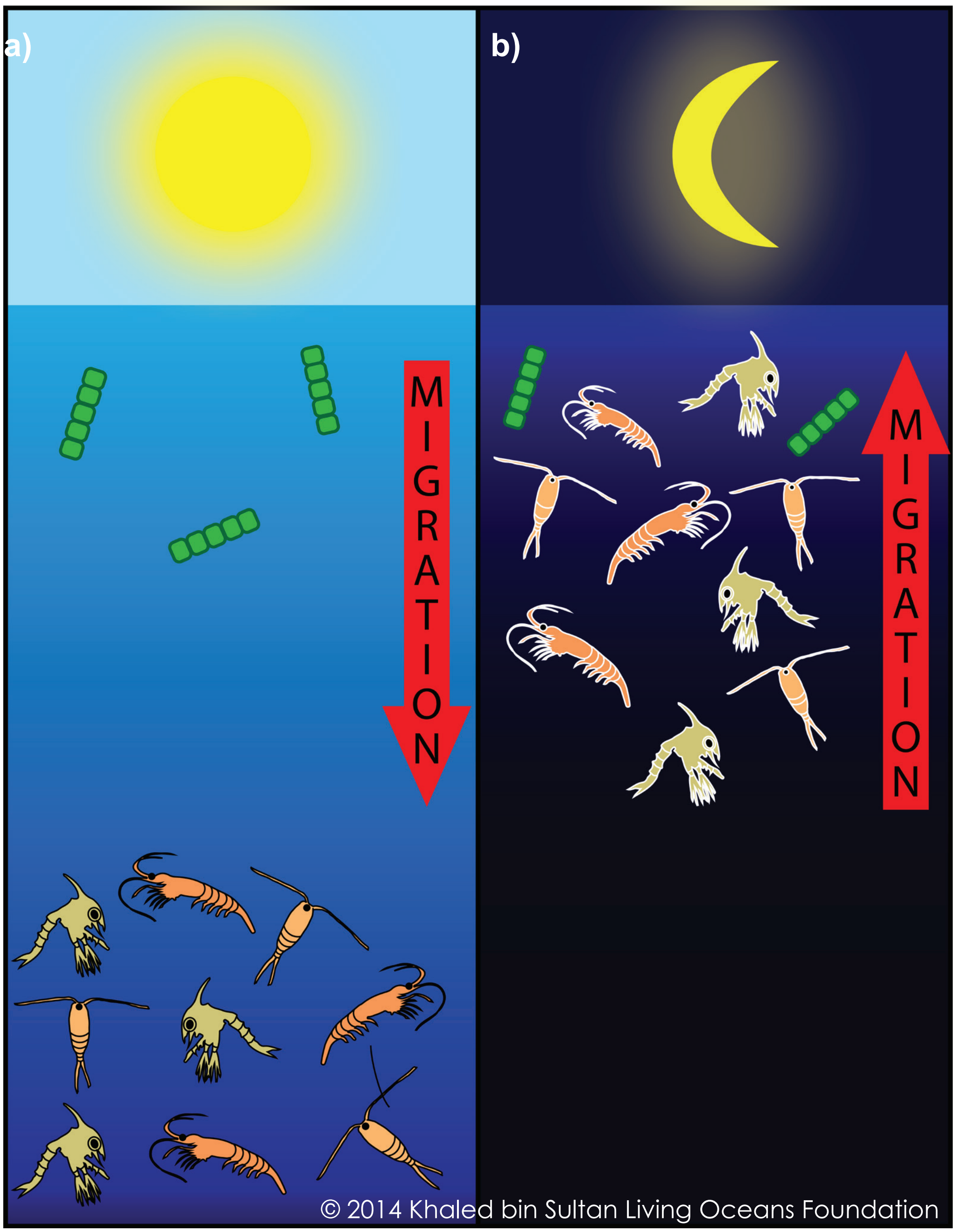

FIGURE 4-1. a) Zooplankton are found in deeper water during the day. b) Zooplankton migrate up near the surface of the water to feed at night.

During the day, zooplankton hide in deeper water to avoid predation. At night they migrate towards the surface to feed on **phytoplankton** (microscopic plant-like organisms), which remain in shallow water and do not vertically migrate. It is during this time that corals feed on vertically migrating zooplankton.

In addition to catching prey with their tentacles, most corals also have an outer **mucus** layer that aids in transporting prey to the **gastrovascular cavity** for digestion. In fact, some corals have few to no tentacles and therefore can only feed by drawing the mucus into their gut by tiny **cilia** (hair-like projections) that cover the coral (see *Unit 3: Coral Anatomy*).

Prey items that might be caught by mucus include dissolved nutrients from the water and sediment. In particular, **dissolved organic matter** (**DOM**) forms an important food source for many corals. Marine DOM is a mixture of organic molecules that are found in seawater. Organic molecules contain both carbon and hydrogen atoms. Examples of DOM include amino acids, sugars, and lipids. Additionally, corals take up **inorganic matter,** which are elements or compounds that don't contain either carbon and hydrogen atoms. Corals take up inorganic compounds including calcium, magnesium, potassium, gases such as oxygen and carbon dioxide, and other elements. Inorganic matter is a critical component in the production of the coral's skeleton.

Sediment (sand, fragments of rock, organic matter, and other small particles) can also be an important food source for corals. This sediment is trapped by the mucus, ingested, and digested (Wild *et al.* 2004; Huettel *et al.* 2006). It can contain bacteria, **protozoa** (motile, unicellular eukaryotic organisms), microscopic **invertebrates**, **microalgae** (microscopic algae)**,** and organic matter.

Recall from *Unit 3: Coral Anatomy* that colonial corals have a connective tissue called **coenosarc** (figure 4-2). This tissue allows coral polyps to share this food with each other.

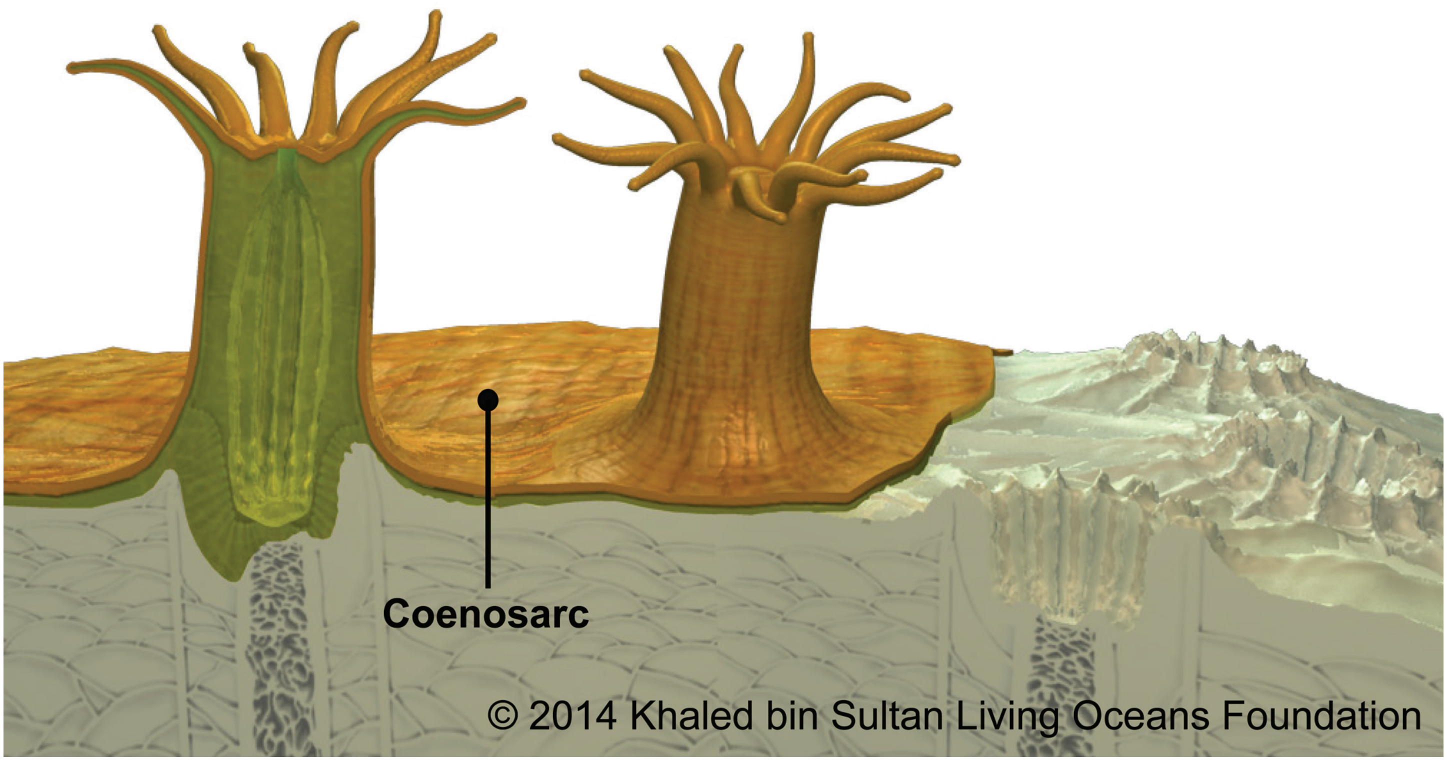

FIGURE 4-2. Coenosarc of coral polyp

Additionally, corals have a predatory mechanism called **nematocysts** that aid in feeding. Recall from *Unit 3: Coral Anatomy* that nematocysts are stinging cells located in the tentacles. Other organisms in the Phyla Cnidaria including some anemones, jellyfish, and hydra, also possess these stinging cells.

There are three types of nematocysts:

1. Glutinant: nematocyst has a sticky surface that is used to stick to prey.
2. Penetrant: nematocyst has a harpoon-like structure that is used to penetrate the **exoskeleton** (hard outer covering) of prey.
3. Volvent: nematocyst has a lasso-like thread that is used to wrap itself around its prey.

The following example describes the firing of a penetrant nematocyst (figure 4-3).

Each nematocyst is encapsulated in the tissue of the **ectodermis**. The **thread** (a rope-like structure) is coiled around the barbs and held in place by pressure from the flap, called the **operculum**. This is similar to a jack-in-the-box; the pressure of the lid holds the jack in the box.

The **cnidocil** is a hair-like projection located externally near the operculum. When stimulated, it acts like a trigger and the operculum opens. Like a harpoon, the barbs shoot out of the capsule, unraveling the coiled thread, and impaling or wrapping around the prey item. The barb contains toxins that also subdue its victim. These stinging cells are mostly harmless to humans, but are lethal to smaller prey items like zooplankton.

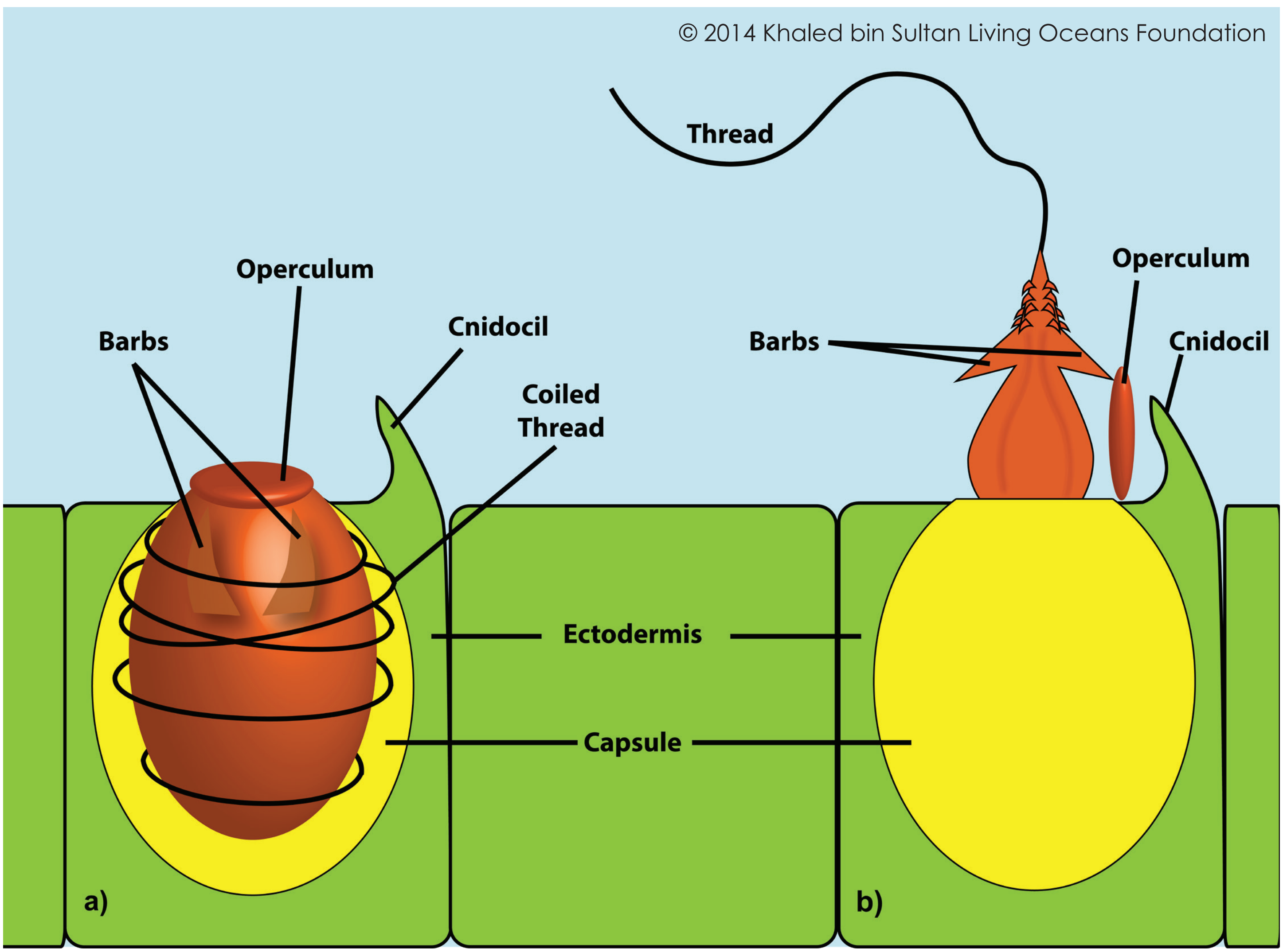

FIGURE 4-3. Penetrant nematocyst; a) Nematocyst still in capsule; b) Nematocyst after it has fired

B) SYMBIOSIS

The final way that corals obtain food is through a symbiotic relationship with a type of algae, which are known as zooxanthellae. Let's break the word apart:

zoo	***xan***	***thella***
zoo	xanthos	thalla (Greek)
of animals	yellow	indicates smallness

Zooxanthellae are yellow-brown, single-celled algae that live in the **endoderm** of the coral polyp (figure 4-4). The zooxanthellae can give the corals their color. Without them, the polyps would be clear, just like jellyfish. However, there are some corals that have tissues with orange, yellow, green, blue, red and purple pigments. The pigment colors can vary depending on the reflection of the light.

FIGURE 4-4. Coral polyp with blown up microscopic photo of zooxanthellae

Before we dive into this relationship, let's take a closer look at symbiosis.

Symbiosis is a close ecological relationship between the individuals of two (or more) different species. Here are the definitions for different symbiotic relationships:

- **Mutualism**: when both organisms benefit (figure 4-5).
- **Parasitism**: when one organism benefits and the other is harmed.
- **Commensalism**: when one organism benefits and the other is neither benefiting nor being harmed.
- **Obligate symbiosis**: when organisms require the relationship to survive.
- **Facultative symbiosis**: when organisms can survive without the relationship, but it increases the chances of survival.
- **Endosymbiont**: living inside another organism.
- **Ectosymbiont**: living on the body of another organism.

There are many different symbiotic relationships that occur in the coral reef ecosystem.

FIGURE 4-5. a) Anemones and clownfish have a mutualistic relationship. The clownfish gets protection from the anemone and a home and the clownfish wards off predators and drops pieces of food for the anemone. b) Cleaner shrimp and eels have a mutualistic relationship. The eel benefits by getting rid of parasites, while the cleaner shrimp makes a meal out of these parasites. c) Guard crabs and *Pocillopora* corals have a mutualistic relationship. Guard crabs are thought to defend the coral against predators such as snails that prey on the coral (Stier *et al.* 2010). The coral, in turn, provides food and shelter for the crab.

Some organisms may fit into one or more categories of symbiosis. There are three forms of symbiosis that exist between corals and zooxanthellae. First, corals form a *mutualistic relationship* with zooxanthellae; both organisms benefit. Second, zooxanthellae are also considered *endosymbionts* because they live inside the tissues of the coral polyps. Finally, they have an *obligate symbiotic* relationship; corals require this relationship with zooxanthellae to survive.

Can you think of some ways that the corals and zooxanthellae may benefit each other?

Coral	Zooxanthellae
• Receive oxygen	• Receive carbon dioxide
• Nitrogen and phosphorus recycling	• Nitrogen and phosphorus recycling
• Receive food	• Receive protection
• Waste removal	• Waste removal
• Aid in calcification	

Remember that corals prefer low nutrient water, meaning there is less phosphorus and nitrogen present. Corals are able to pass the waste products of phosphorus and nitrogen to the zooxanthellae and vice versa. Each recycles these nutrients in different ways.

Zooxanthellae are important in helping the corals produce the calcium carbonate that they need to create their skeletons. We will learn about this process in *Unit 9: Coral Growth*.

Additionally, algae receive a safe place to live. During sexual reproduction, there are two ways that corals can incorporate the zooxanthellae in their tissues. The first way is by **closed-system transmission**. This occurs when the coral transfers zooxanthellae directly to their offspring. The second way is through **open-system transmission** where the polyps must retrieve zooxanthellae from the surrounding ocean waters (Dubinsky 2011).

Corals do not make their own food. Instead, they receive the byproducts of photosynthesis from the zooxanthellae. In fact, up to 95% of these byproducts (Falkowski *et al.* 1984) are transferred from the algae to the coral. These byproducts include oxygen and food in the form of glycerol, sugars, organic acids, amino acids, lipids, and polyunsaturated fatty acids (Dubinsky 2011). In return the zooxanthellae receive the byproducts of cellular respiration (carbon dioxide). These two processes will be described below.

1) PHOTOSYNTHESIS

Photosynthesis is the primary source of energy for nearly every food chain on Earth (see *Unit 17: Food Web Dynamics* for more about food chains). In breaking this word apart, we get:

photo	***synthesis***
with light	to make

When we put this word back together, it means *to make with light*. **Photosynthesis** is the process that plants or other organisms use to convert light energy into chemical energy.

Photosynthesis is represented by a **chemical reaction**, meaning that molecules are being rearranged to produce something new. Below is the reaction equation for photosynthesis:

$$CO_2 + H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + O_2$$

carbon dioxide + water + sunlight → glucose + oxygen

The ingredients in a reaction are called **reactants** and they are found on the left side of the arrow (figure 4-6). Reactants undergo a change during the reaction. The reactants of photosynthesis are carbon dioxide (CO_2) and water (H_2O). The arrow means *reacts to produce* or *yields*. It separates the reactants from the products. The molecules that are formed during a reaction are called **products** and they are found to the right of the arrow (figure 4-6). The products of photosynthesis are glucose ($C_6H_{12}O_6$) and oxygen (O_2). When we read the chemical reaction above, it reads "carbon dioxide, water, and energy combine to yield glucose and oxygen."

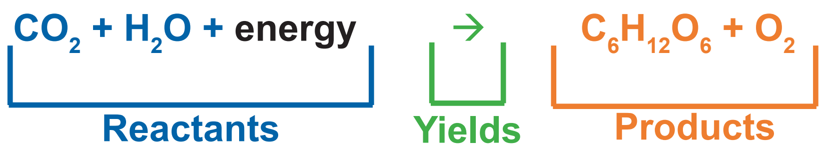

FIGURE 4-6. Parts of a chemical reaction

What about energy? Energy is not matter; therefore, it is not considered a reactant. Energy is included with the reactants here to show that it is necessary for the reaction to take place. Sunlight is the energy required for photosynthesis to occur.

What do plants require so they can survive? That's right! They need carbon dioxide, water, and sunlight. Did you notice that all of these are reactants in the photosynthesis equation?

What are the plants and other photosynthetic organisms making with light? They make **glucose**, a sugar that organisms use as a source of energy. They also make oxygen, which is then released into the atmosphere and used by other organisms, such as humans.

2) CELLULAR RESPIRATION

Organisms use the sun's energy that is stored in glucose to charge their molecular batteries. This battery is called **ATP**, short for adenosine triphosphate. ATP consists of adenosine (the sugar ribose attached to the base adenine) and three phosphate groups. Energy is stored in the bond between the last two phosphate groups (figure 4-7). When an organism needs to use energy, like when a human is playing baseball or a plant is growing tall, this bond is broken and a phosphate is released. The new molecule is called **ADP**, short for adenosine diphosphate (di-, instead of tri-, since there are only two attached phosphates now). When a new source of glucose comes along, a phosphate is put back onto ADP, reforming ATP. Now, the battery is charged again, ready to go.

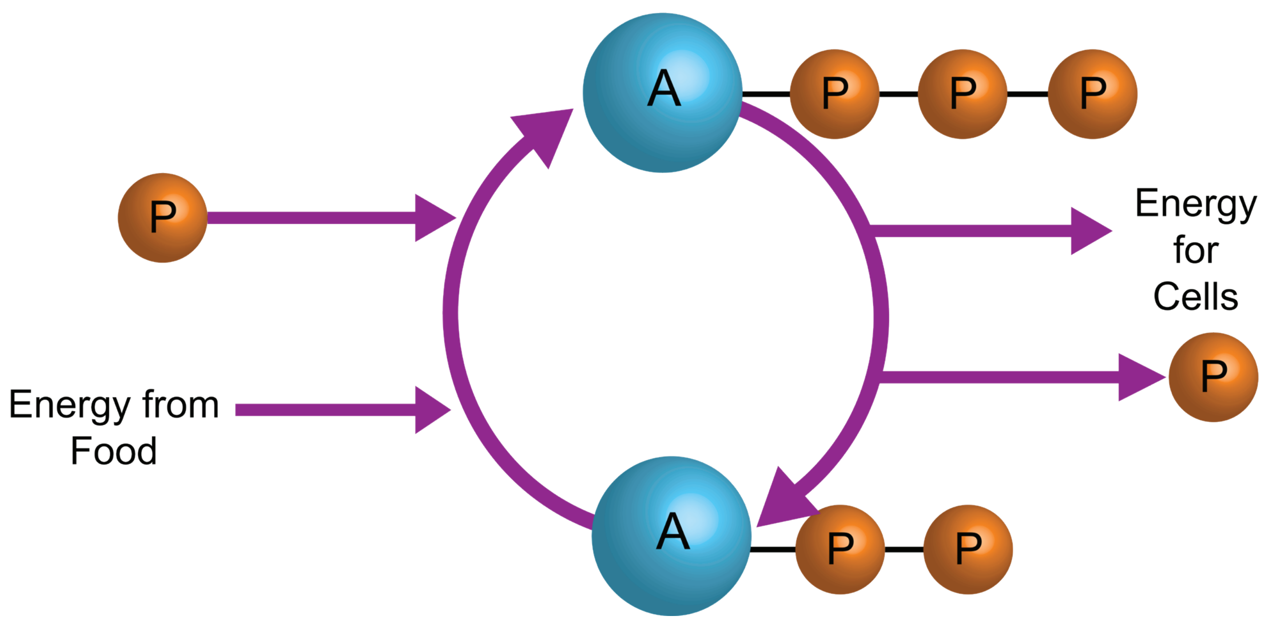

FIGURE 4-7. ATP is constantly converted into ADP in all organisms. Energy is released when the high energy bond is broken.

Where does the energy that adds a phosphate to the ADP molecule come from? It comes from cellular respiration. **Cellular respiration** is the process of breaking down glucose to release the energy that is stored. Here is what the reaction equation looks like:

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{energy}$$

glucose + oxygen → carbon dioxide + water + ATP

All living organisms perform cellular respiration. Plants use some of the glucose they have produced to undergo this process. Organisms that cannot perform photosynthesis have to eat other organisms in order to obtain glucose. When glucose is broken down, it releases energy, which is then used to re-bond phosphate to the ADP molecule (recharging it, making ATP). Glucose is not the only reactant. Oxygen is usually present for this reaction to take place. To release energy during cellular respiration, glucose ($C_6H_{12}O_6$) and oxygen (O_2) are broken apart, rearranged, and formed into carbon dioxide (CO_2) and water (H_2O).

How do plants create glucose? That's correct! They make glucose by photosynthesizing. Take a look at the equations below. Notice that the reactants for photosynthesis (in blue) are the same as the products for cellular respiration (in blue). Cellular respiration produces the molecules needed to perform photosynthesis. Next, look at the orange part of each equation. The products of photosynthesis are the reactants needed for cellular respiration to take place. Therefore, photosynthesis and cellular respiration have a cyclical relationship.

Cellular Respiration	$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{energy}$
Photosynthesis	$CO_2 + H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + O_2$

Now does it make more sense that corals have such a close symbiotic relationship with zooxanthellae? Corals produce carbon dioxide during cellular respiration. They pass this gas to zooxanthellae, which use it to photosynthesize. One of the products that zooxanthellae create during photosynthesis is oxygen. Corals use the oxygen created during photosynthesis for cellular respiration.

Corals are animals and they cannot produce glucose on their own, zooxanthellae can. Through the process of photosynthesis, zooxanthellae create glucose and share some of it with the coral. This is why most corals live in the **euphotic zone,** so they have access to sunlight.

It's easy to see that this unique symbiotic relationship between coral and zooxanthellae strengthens life-sustaining processes.

ATTRIBUTIONS

Figure 4-1. Copepod Adapted from Kils at the English language Wikipedia [GFDL (www.gnu.org/copyleft/fdl.html), CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/) or GFDL (www.gnu.org)], 21 October 2004 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3ACopepod.jpg.

Figure 4-1. Zoea Adapted from Obsidian Soul (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], 3 September 12 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3AOregonia_gracilis_Zoea_II.png.

Figure 4-1. Shrimp Adapted from Andrew c at the English language Wikipedia [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/) or GFDL (www.gnu.org)], 7 October 2006 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3AShrimp.svg.

Figure 4-4. Zooxanthellae Adapted from Allisonmlewis (Own work) [CC BY-SA 4.0 (http://creativecommons.org/licenses/by-sa/4.0)], 21 February 2015 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3ASymbiodinium.png.

Figure 4-7. Adapted from Hobbs, B. (25 May 2011). Renewable energy: you're soaking it up (ATP graphic). Retrieved from http://www.abc.net.au/science/articles/2011/05/25/3226741.htm.

CITATIONS

Falkowski, P. G., Dubinsky, Z., Muscantine, L., & Porter, J. W. (1984). Light and the bioenergetics of a symbiotic coral. *Bioscience* 34: 705-709.

Dubinsky, Z. & Falkowski, P. (2011). Light as a source of information and energy in zooxanthellate corals. In: Dubinsky Z. & Stambler N. (eds.) *Coral reefs: an ecosystem in transition*, Springer, Dordrecht.

Huettel, M., Wild, C., & Gonelli, S. (2006). Mucus trap in coral reefs: formation and temporal evolution of particle aggregates caused by coral mucus. *Marine Ecology Progress Series* 307: 69-84.

Stier, A. C., McKeon, C. S., Osenberg, C. W., & Shima, J. S. (2010). Guard crabs alleviate deleterious effects of vermetid snails on a branching coral. *Coral Reefs* 29: 1019-1022.

Wild, C., Huettel, M., Klueter, A., Kremb, S. G., Rasheed, M. Y. D., & Jorgensen, B. B. (2004). Coral mucus as an energy carrier and particle trap in the reef ecosystem. *Nature* 428: 66-70.

Coral Reef Ecology Curriculum

The Coral Reef Ecology Curriculum is a comprehensive educational resource designed to educate people about life on coral reefs. Developed by educators and scientists at the Khaled bin Sultan Living Oceans Foundation, this curriculum strives to increase ocean literacy by creating awareness about coral reefs, the threats they face, and how people can help to preserve these diverse ecosystems.

Khaled bin Sultan
Living Oceans
Foundation

The Khaled bin Sultan Living Oceans Foundation is a US-based nonprofit environmental science organization. The Foundation was established to protect and restore the world's oceans through scientific research, outreach, and education.