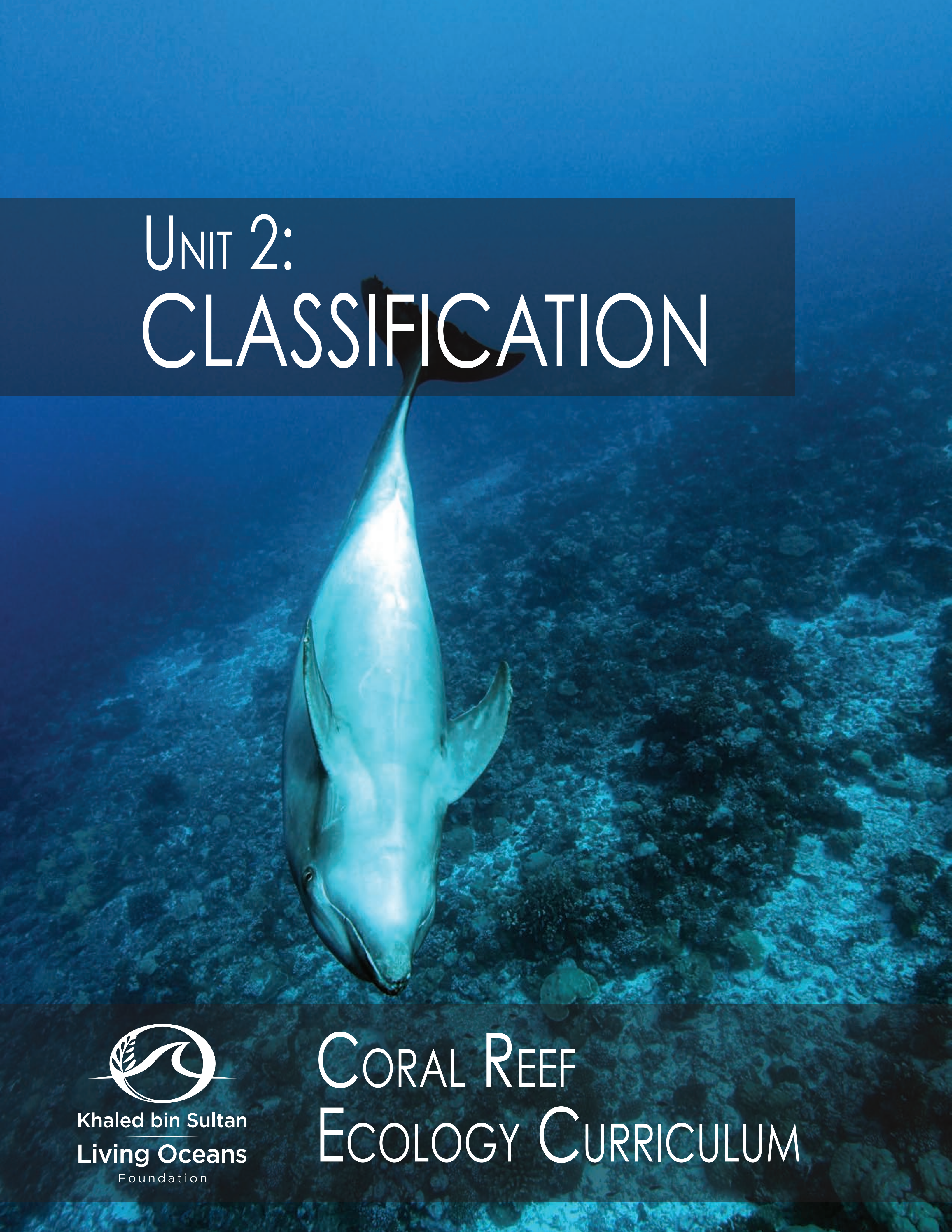

Unit 2:
CLASSIFICATION

Khaled bin Sultan Living Oceans Foundation

Coral Reef Ecology Curriculum

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.](lof.org/CoralReefCurriculum)

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KEYWORDS

- Archaea
- Bacteria (plural)
- Binomial Nomenclature
- Branches (cladogram)
- Calcium Carbonate ($CaCO_3$)
- Carolus Linnaeus
- Clade
- Cladogram
- Classification (biological)
- Cnidaria
- Common Name
- Corallite
- Daughter Lineages (plural)
- Derived Character
- Dichotomous Key
- Eukarya
- Evolutionary Tree
- Hexacorals (plural)
- Internal Node
- Latin Name
- Leaves (cladogram; plural)
- Medusa
- Octocorals (plural)
- Outgroup
- Phylogenetics
- Phylogenetic Tree
- Polyp
- Radially Symmetrical
- Scientific Name
- Sclerites (plural)
- Shared Character
- Speciation
- Systematics
- Taxa (plural)
- Taxonomy
- Terminal Node
- Tips (cladogram; plural)
- Vernacular Name
- Zooxanthellae (plural)

CLASSIFICATION

This unit explains how to organize the millions of organisms on Earth.

STANDARDS

- **CCSS**: RST.9-10.1, 2, 3, 4, 5, 7, 8, 9, 10; RST.11-12.1, 2, 3, 4, 7, 8, 9, 10; W.9-10.2, 4, 7, 8, 9; W.11-12.2, 4, 7, 8, 9; SL.9-10.4, 6; SL.11-12.4, 6
- **NGSS**: HS-LS4-1
- **OLP**: 4.B.1, 4.B.2, 5.C.22

MULTIMEDIA RESOURCES

- *Naming Nature* YouTube video (*https://youtu.be/5h5nSivm1KI*)
- *What Clade R U?* interactive is located at the bottom of the *How to Build a Cladogram* tab (*www.lof.org/education/portal/course/classification/*).

LEARNING OBJECTIVES

- Define taxonomy.
- List and organize the eight divisions of classification from broad to specific.
- Understand who Carolus Linnaeus was and be able to describe his contribution to science.
- Apply the rules of binomial nomenclature.
- Identify how corals are classified.
- Describe the two main subclasses of corals.
- Differentiate between taxonomy and phylogenetics.
- Define phylogenetics and determine the evidence used to determine evolutionary history of organisms.
- Define cladogram and identify what it's used for.
- Identify the parts of a cladogram.
- Learn how to build and read a cladogram.
- Recognize the important role clades of zooxanthellae play in determining coral's survival as climate change takes effect.

CLASSIFICATION

UNIT PROCEDURE

1. Show *Naming Nature* YouTube video.
   a. Complete **Watch It! Naming Nature** student worksheet.

2. Teach *Background Information* section *A) How Do We Classify Organisms?* and *B) Linnaean Naming System*.
   a. Complete **Lesson 1A: Classify This!** and **Lesson 1B: Rules, Rules, Rules** student worksheets.

3. Teach *Background Information* section *C) Coral Classification.*
   a. Complete **Lesson 2: "Taxing" Corals** student worksheet.

4. Teach *Background Information* section *D) Modern Classification.*
   a. Complete **Lesson 3: In Light of New Evidence** student worksheet.
   b. Complete **Lesson 4A: The Key to ID** student worksheet.
   c. Complete **Lesson 4B: And Then There Was One** student worksheet.
   d. Play *What Clade R U?* interactive
   e. Complete **Lesson 5: Cladograms 1** or **Cladograms 2** student worksheet.

5. Teach students how to read and critique blogs.
   a. Complete **Read It! Troubling Taxonomy** student worksheet.
   b. Complete **Read It! Blue, You Say?** student worksheet.

6. Evaluate students using **Unit 2: Classification Quiz** (found online at *www.lof.org/education/portal/quiz/classification-assessment-1/*). NOTE: User must be logged in.

BACKGROUND INFORMATION

A) HOW DO WE CLASSIFY ORGANISMS?

There are millions of organisms on Earth. In this unit, we will learn how to organize them. Scientists classify organisms by putting them into groups that have the same characteristics and a common ancestry. **Classification** is a broad term that means organizing information. The science of classifying organisms is known as taxonomy. **Taxonomy** is a type of classification.

There are eight divisions used to classify all life on Earth (figure 2-1):

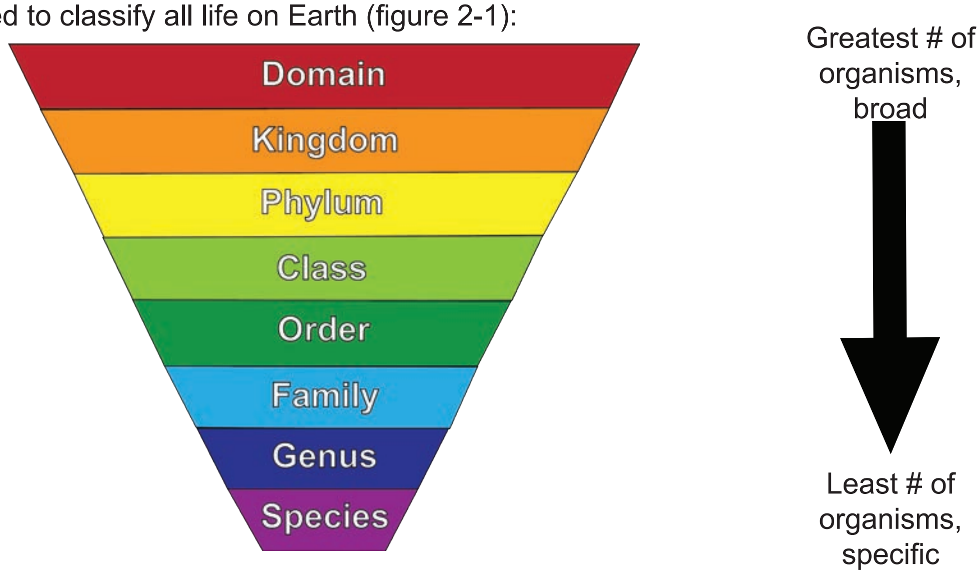


FIGURE 2-1. Diagram of the 8 divisions of classification

To help us remember the order of classification, use the mnemonic device:

Dear	–	**D**omain
King	–	**K**ingdom
Philip	–	**P**hylum
Come	–	**C**lass
Over	–	**O**rder
For	–	**F**amily
Great	–	**G**enus
Spaghetti	–	**S**pecies

Domain is the broadest division, and as we descend down the list, the divisions get more and more specific. In a domain, there are more organisms; however, as we descend down the list, notice that there are fewer and fewer organisms in each classification. This is best illustrated in figure 2-2. Every known organism is classified by these eight divisions.

Let's take a look at the following example of organisms in the Domain Eukarya (figure 2-2). Remember that each organism is grouped by the same characteristics and a common ancestry. As we descend down the list, we eliminate organisms that do not fit into that particular division. For example, Phylum Echinodermata contains only sea cucumbers, sea stars, and a few other organisms not pictured; however it does not contain sharks, sea turtles, and sea slugs. Sea turtles and sharks are in the Phylum Chordata because they have a backbone. Nudibranchs are in the Phylum Mollusca because they have soft bodies. Now, let's look at the Family Ophidiasteridae. Notice that the pink sea star, known as the granular sea star, has short, thick arms. The other sea stars in this family have long semi-tubular arms.

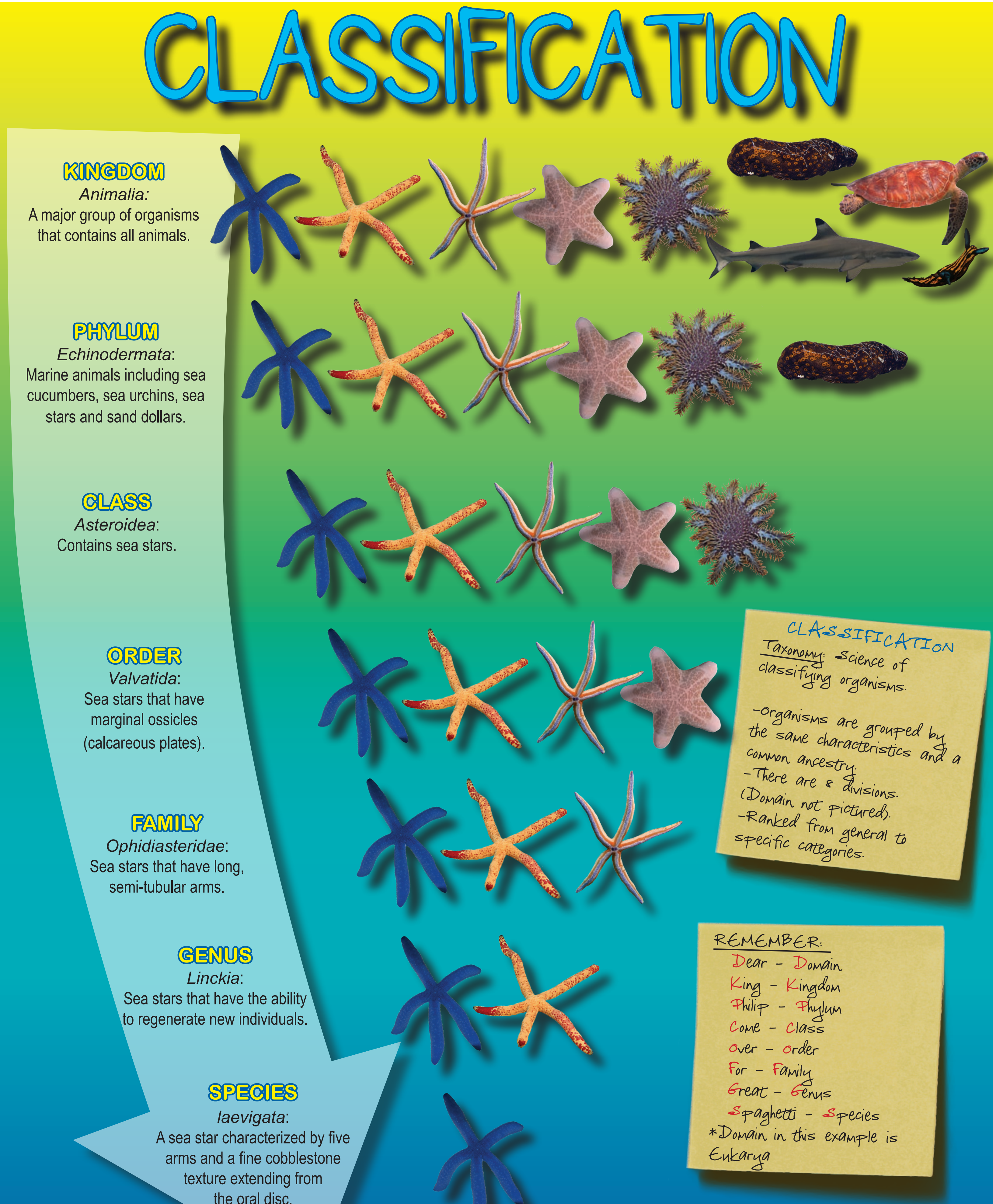

CLASSIFICATION
KINGDOM
Animalia:
A major group of organisms that contains all animals.
PHYLUM
Echinodermata:
Marine animals including sea cucumbers, sea urchins, sea stars and sand dollars.
CLASS
Asteroidea:
Contains sea stars.
ORDER
Valvatida:
Sea stars that have marginal ossicles (calcareous plates).
FAMILY
Ophidiasteridae:
Sea stars that have long, semi-tubular arms.
GENUS
Linckia:
Sea stars that have the ability to regenerate new individuals.
SPECIES
laevigata:
A sea star characterized by five arms and a fine cobblestone texture extending from the oral disc.
CLASSIFICATION
Taxonomy: Science of classifying organisms.
-Organisms are grouped by the same characteristics and a common ancestry.
-There are 8 divisions. (Domain not pictured).
-Ranked from general to specific categories.
REMEMBER:
Dear - Domain
King - Kingdom
Philip - Phylum
Come - Class
Over - Order
For - Family
Great - Genus
Spaghetti - Species
*Domain in this example is Eukarya

FIGURE 2-2

All of the organisms in figure 2-2 are classified in the Domain **Eukarya**, which is made up of organisms that have cells containing complex structures enclosed within membranes like a nucleus. By the time we reach species (specific), only one organism fits the description. The only characteristic that sets the blue sea star, *Linckia laevigata*, apart from other sea stars is the body pattern. That's really specific!

B) LINNAEAN NAMING SYSTEM

The naming system that is used today was first established in the 18th century by a Swedish scientist named **Carolus Linnaeus**. He was the first to develop a hierarchical naming system, which included kingdom, class, order, genus, species, and variety. The original naming system has since changed; however, this was a huge breakthrough for modern science, which is often why Linnaeus is referred to as the *Father of Taxonomy*. Additionally, the naming system is sometimes called *Linnaean taxonomy*.

Linnaean naming system also led to the adoption of modern **binomial nomenclature**, which means *two-name naming system*. It is often referred to as the **Latin name** or **scientific name**. This is the formal naming of organisms that includes the genus and species name. There are specific rules when writing binomial nomenclature. Let's follow the rules using the scientific name, *Amphiprion ocellaris*. You may know this animal to be Nemo, a clownfish, from the movie *Finding Nemo*. The rules are as follows:

1. Genus is written first.	**amphiprion**
2. Species is written second.	amphiprion **ocellaris**
3. Genus is always capitalized.	**A**mphiprion ocellaris
4. Species is never capitalized.	Amphiprion **o**cellaris
5. Genus and species are both italicized (or underlined).	***Amphiprion ocellaris*** or **Amphiprion ocellaris**
6. Genus can stand alone, but species never stands alone. Even when genus is alone, it is italicized.	***Amphiprion*** but not ~~*ocellaris*~~
7. When repeating a scientific name in a document:	
a. The first time the scientific name is written, use the full name, following the binomial nomenclature rules.	The scientific name for the common clownfish is ***Amphiprion ocellaris***.
b. The second time the scientific name is written, abbreviate the genus by using the first letter, capitalize it, and use a period. Then write the species name. The genus abbreviation and species name will be italicized.	The scientific name for the common clownfish is *Amphiprion ocellaris*. ***A. ocellaris*** is the clownfish that Nemo is modeled after in the movie *Finding Nemo*.

Most organisms are also given a simpler name. This name is referred to as the **common name** or **vernacular name**. It is used because of the difficulty to memorize scientific names, and it is often used by members of the general public. We have already seen these examples:

- *Amphiprion ocellaris*, common clownfish
- *Linckia laevigata*, blue sea star

FIGURE 2-3. *Laticauda colubrina*

Sometimes the common name varies depending on geographic locations and cultures. For example, *Laticauda colubrina* (figure 2-3) has three different common names: colubrine sea krait, banded sea krait, and the yellow-lipped sea krait. That's why the scientific name is important – it is one name used universally by scientists. No matter the differences in culture, language, or geographic region, everyone can understand the meaning.

C) CORAL CLASSIFICATION

There are over 1,000 known coral species all of which live in the ocean. Corals are a member of the Domain Eukarya because they have cells that contain complex structures.

FIGURE 2-4. a) *Tubastrea* sp.; b) *Scolymia* sp.; and c) *Porites* sp.

Historically, classifying corals at the kingdom level was misunderstood. Scientists used to believe that corals were plants (Kingdom Plantae); however, today we know that they are animals (Kingdom Animalia).

Corals are part of the Phylum **Cnidaria**. Anemones, hydroids, and jellyfish also belong to this phylum. Cnidarians share several common characteristics. NOTE: We will learn more about most of these characteristics in other units.

1. Two different forms exist: medusa and polyp (figure 2-5).
2. Radially symmetrical (figure 2-8 and 2-9).
3. Diploblastic (two cell layers) with mesoglea (*Unit 3: Coral Anatomy*).
4. Body contains an internal cavity (gastrovascular cavity) and a mouth, but no anus. This is called a blind gut (*Unit 3: Coral Anatomy*).
5. Lack excretory, circulatory, and respiratory systems (*Unit 3: Coral Anatomy*).
6. Reproduction is asexual and/or sexual (*Unit 5: Coral Reproduction*).
7. Have simple netlike nervous system.
8. Have a distinct larval stage, which is planktonic (*Unit 6: Life Cycle*).
9. Live in aquatic environments, mostly marine.
10. Mostly carnivorous, otherwise filter feeders (*Unit 4: Coral Feeding*).
11. May have a minimal skeleton of chiton or calcium carbonate (*Unit 3: Coral Anatomy*).
12. Contain nematocysts, specialized stinging cells (*Unit 4: Coral Feeding*).

Cnidarians have two different body forms – polyp and medusa (figure 2-5). **Polyps** are cylindrical in shape and they have a mouth surrounded by tentacles on top of their body. **Medusae** are shaped like a bell, or they are concave or convex, and possess tentacles, which usually hang from the bottom of their body. Throughout a coral's life cycle, they only possess a polyp body form, though many members of the phylum alternate between the two.

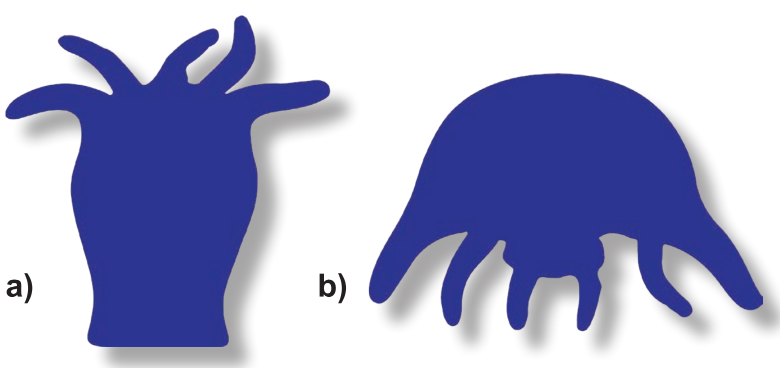


FIGURE 2-5. a) Polyp body form; b) Medusa body form

Can you classify the body form for the four types of cnidarians (figure 2-6): corals, jellyfish, hydroids, and anemones?

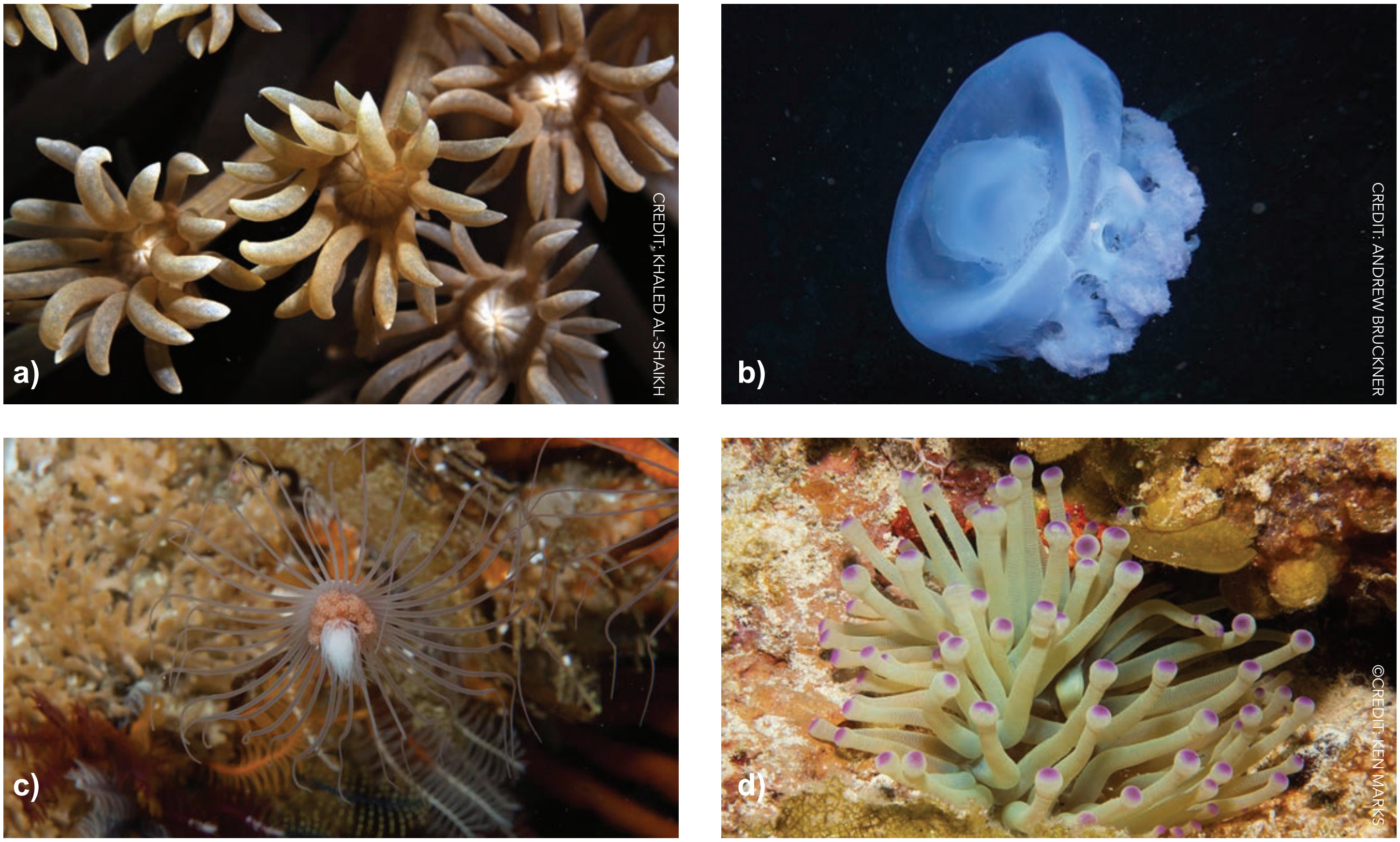


FIGURE 2-6. a) Coral = polyp; b) Jellyfish = medusa; c) Hydroid = polyp; and d) Anemone = polyp

Whether cnidarians have a medusa or a polyp body form, they are both radially symmetrical. To help us understand this definition, let's break down the word. *Radial* refers to lines that meet at a common center. *Symmetrical* means that there are even parts mirrored on each side. For instance, if we evenly fold a piece of paper that is circular or square, no matter which way we fold the paper, it will be symmetrical (figure 2-7).

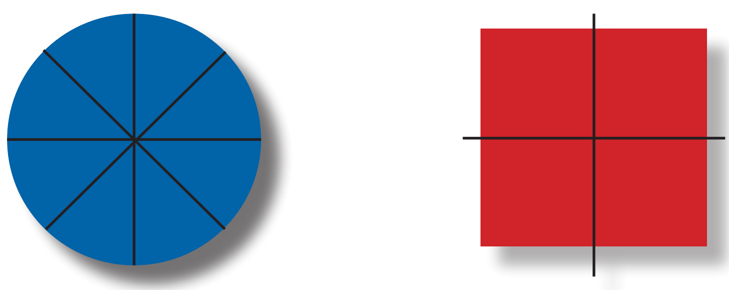


FIGURE 2-7. Some lines of symmetry on a circle and square

Therefore, **radially symmetrical** means that an object can evenly be divided around a central axis. Let's use a pie as an example (figure 2-8). A pie can be evenly divided into pieces. No matter which way we slice the pie through the center, the cut will produce two even sides.

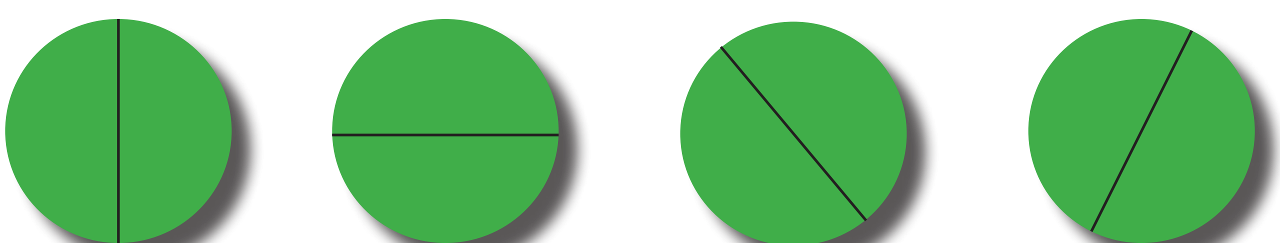


FIGURE 2-8. Radial symmetry

Let's continue using the pie example. There are multiple ways we can slice a pie to get even pieces (figure 2-9). We can make two even slices through the center, creating 4 slices of pie. We can also evenly slice the pie four times through the center, giving us eight pieces. The same is true for cnidarians. Some cnidarians have what is called four-fold symmetry, which means that they can be divided into four even parts or multiples of four (figure 2-9a). Others have six- or eight-fold symmetry (figures 2-9b and c).

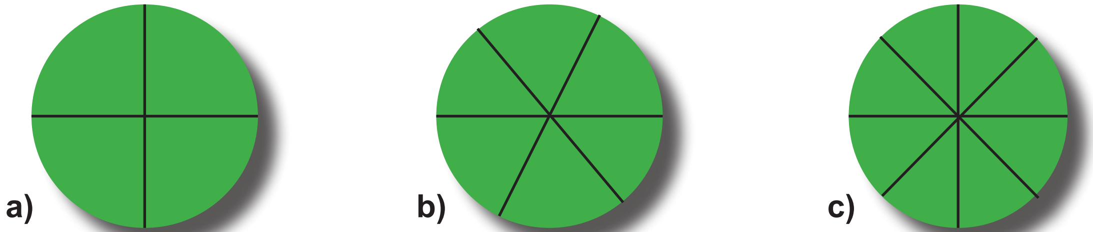


FIGURE 2-9. a) Four-fold symmetry; b) Six-fold symmetry; c) Eight-fold symmetry

There are four classes within the phylum Cnidaria:

- Class Scyphozoa
- Class Cubozoa
- Class Hydrozoa
- Class Anthozoa

The class Scyphozoa include the true jellyfish (figure 2-10), but do not contain corals.

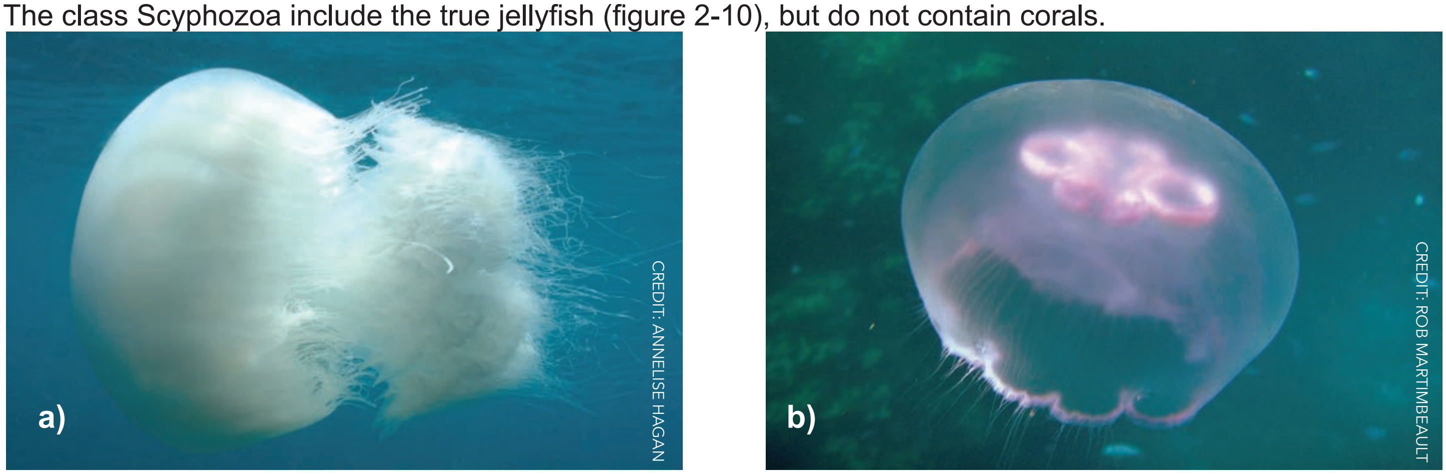


FIGURE 2-10. a) *Rhopilema* sp. jellyfish; b) Moon jellyfish, *Aurelia aurita*

The class Cubozoa are the box jellyfish. They differ from Scyphozoans because they have a cube-like shape. This class also does not include corals.

The class Hydrozoa contains organisms such as hydroids, Portuguese man-of-wars, and some corals including fire corals and lace corals (figure 2-11).

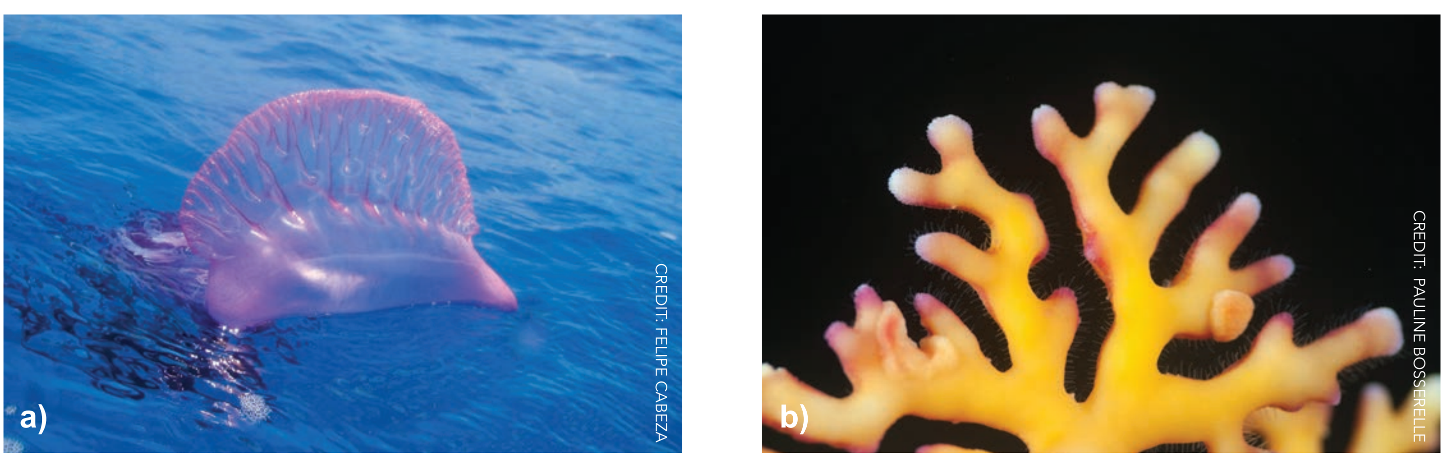


FIGURE 2-11. a) Portuguese man-of-war, *Physalia physalis;* b) *Distichopora* sp. lace coral

Most corals are in the class Anthozoa, which also includes anemones. There are two main subclasses:

- Octocorallia (octocorals)
- Hexacorallia (hexacorals)

Now think back to math class: what does the prefix *octo*- mean? That's right, eight. So **octocorals** means that corals in this class have eight-fold symmetry.

What type of symmetry do you think **hexacorals** have? That's right, these corals have six-fold symmetry because the prefix *hexa*- means six.

Hexacorals and octocorals not only have different symmetry, but they also are very different from one another in structure. Hexacorals are hard or stony corals, meaning they secrete an outer skeleton composed of **calcium carbonate** (**$CaCO_3$**). This is the same mineral that is in limestone (which is often composed of coral skeleton fragments; figure 2-12b).

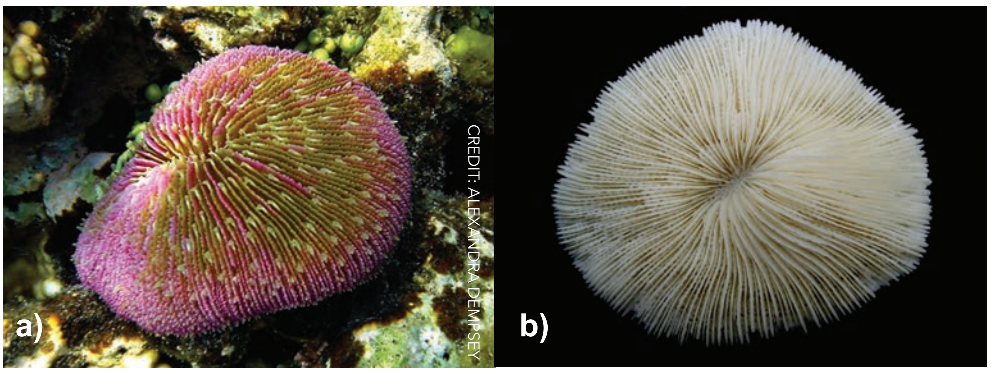


FIGURE 2-12. a) Photo of a living mushroom coral; b) Calcium carbonate skeleton of a mushroom coral

Octocorals are soft corals (figure 2-13) and do not have a limestone structure. Instead, they secrete calcium or aragonite (minerals) sclerites. **Sclerites** are microscopic spicules (shards) that help to support the structure of the corals and anchor them to the substrate. Sclerites can be used to identify different species of soft corals.

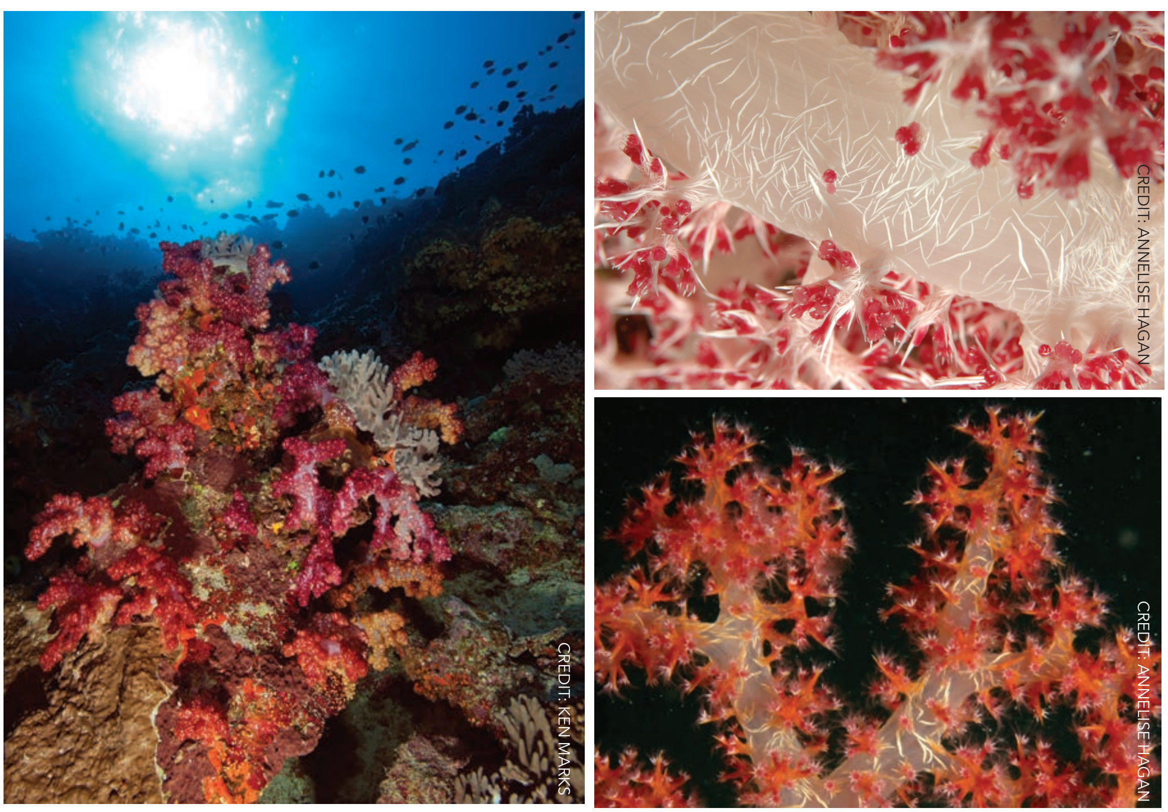


FIGURE 2-13. Various octocorals

From this point on, the taxonomic classification of corals becomes more divided. Remember that there are over 1,000 species of corals worldwide. Please see the list of cnidarian taxonomy classified to suborder below.

SELECT CNIDARIAN TAXONOMY

- Domain – Eukarya
  - Kingdom – Animalia
    - Phylum – Cnidaria (anemones, corals, hydroids, jellyfish)
      - Class – Scyphozoa (true jellyfish)
      - Class – Cubozoa (box jellyfish)
      - Class – Hydrozoa (hydroids, Portuguese man-of-war, lace & fire corals)
        - Order – Stylasterina (lace corals)
        - Order – Milleporina (fire corals)
      - Class – Anthozoa (corals and anemones)
        - Subclass – Octocorallia (soft corals with 8-fold symmetry)
          - Order – Alcyonacea (soft corals)
            - Suborder – Calcaxonia (gorgonians)
            - Suborder – Holaxonia (gorgonians)
            - Suborder – Scleraxonia (gorgonians)
            - Suborder – Alcyoniina (true soft corals)
            - Suborder – Stolonifera (stolon corals)
          - Order – Helioporacea/Coenothecalia (blue corals)
          - Order – Pennatulacea (sea pens and sea pansies)
        - Subclass – Hexacorallia (hard corals with 6-fold symmetry)
          - Order – Scleractinia (stony corals)
          - Order – Actiniaria (sea anemones)
          - Order – Corallimorpharia (disc anemones)
          - Order – Zoanthidea (colonial anemones)
        - Subclass – Ceriantipatharia
          - Order – Antipatharia (black corals)
          - Order – Ceriantharia (tube anemones)

D) MODERN CLASSIFICATION

Historically, biologists grouped, identified, and named organisms solely based on physical evidence, which we learned is called *taxonomy*. With modern technology, taxonomists not only use the physical evidence, but they also use evidence such as DNA. A more modern method of classifying organisms is called **phylogenetics**, the study of an organism's evolutionary history.

Together, taxonomy and phylogeny are used to determine modern classification. Both of these fields are part of an even larger field called systematics. **Systematics** is the study of biological diversity and its origins.

WHAT IS PHYLOGENETICS?

Let's take a closer look at phylogenetics. All organisms come from a shared heritage that dates back 3.8 billion years ago, when life originated. That means that even extinct animals such as dinosaurs are included. We didn't live during the time of dinosaurs, or prior to that time, so in order to understand an organism's evolutionary history, we must first get evidence. This evidence comes from:

- Fossil records (e.g., carbon dating, entire organisms, skeletal remains, molds and casts, impressions)
- Anatomical and morphological evidence (i.e., shape and size of body structures and their functions)
- Embryological evidence (i.e., development of different body parts)
- Molecular evidence (i.e., DNA, protein, and amino acid sequences)

Let's look at an example. Do you remember the part in the movie, *Jurassic Park*, when paleontologist, Dr. Alan Grant claims that "birds may be more closely related to dinosaurs?" Well, he wasn't wrong. Birds evolved from a group of dinosaurs called theropods, which includes velociraptors (figure 2-14).

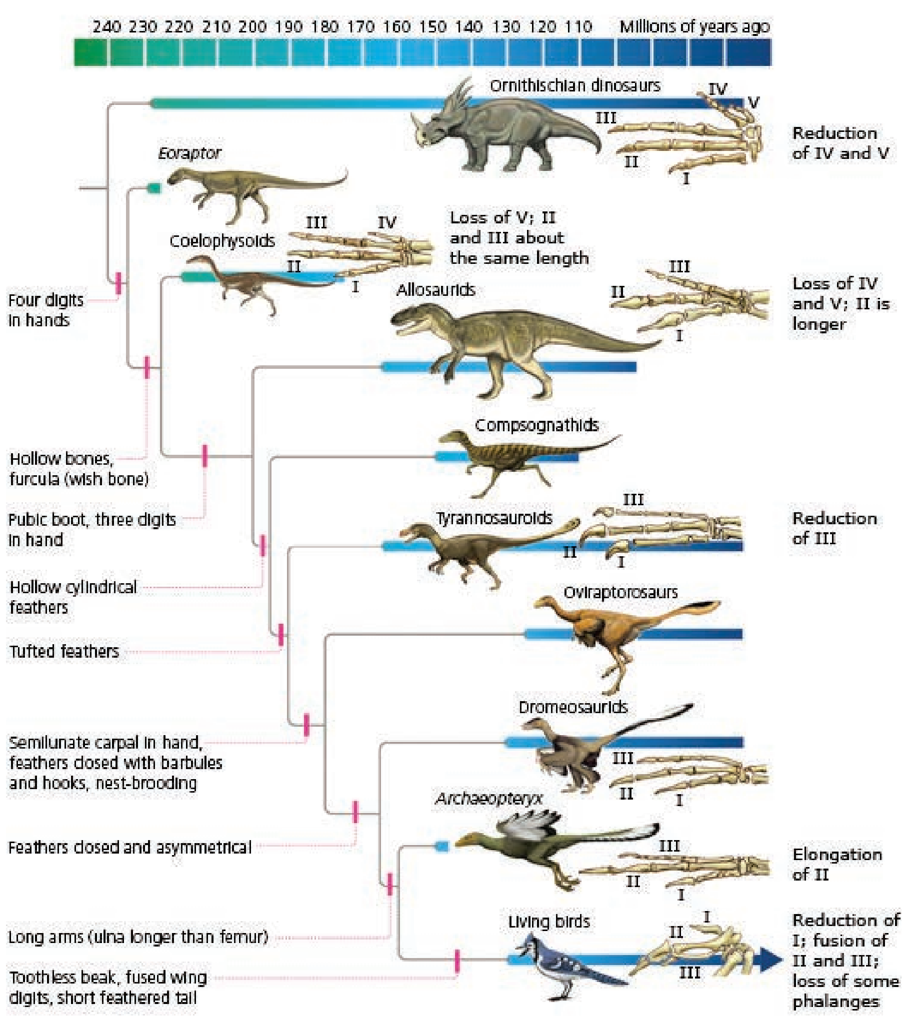


FIGURE 2-14. Shared features between birds and dinosaurs; evidence for the changes in dinosaurs' digits to that of birds'

In the 1860's, the first known bird, *Archaeopteryx*, was discovered. Scientists noticed that the hands, shoulder girdle, pelvis, and feet were not fused and reduced, which is more like dinosaurs than what is seen in today's bird characteristics (figure 2-15). This provided the first piece of fossil evidence linking birds as descendants of dinosaurs. Since then, lots of evidence has been discovered supporting the theory that birds descended from dinosaurs. As more evidence becomes available, scientists can continue to narrow down the evolutionary history of different organisms.

FIGURE 2-15. a) Velociraptor skull; b) Fossil of feather impression found near *Archaeopteryx* fossils; c) Model of *Archaeopteryx* sp.

EVOLUTIONARY TREE

In order to understand evolutionary history, a diagram is used to demonstrate the relationships among organisms. This diagram is called a **cladogram** or sometimes it's referred to as a **phylogenetic/evolutionary tree**. There are some differences between these terms depending on how the cladogram is being used. For example, the cladogram in figure 2-26 does not depict the evolutionary history of these organisms, but shows the characteristics that they have in common.

This 'tree' is much like a family tree. It exhibits current organisms and their relationship to all of their past relatives, including those which are extinct. The phylogenetic tree below represents all organisms on Earth and their relationships to each other. It has been termed the *tree of life* because it encompasses all life on Earth. The tree represents the three domains: Eukarya, **Archaea**, and **Bacteria** (figure 2-16; see *Glossary*).

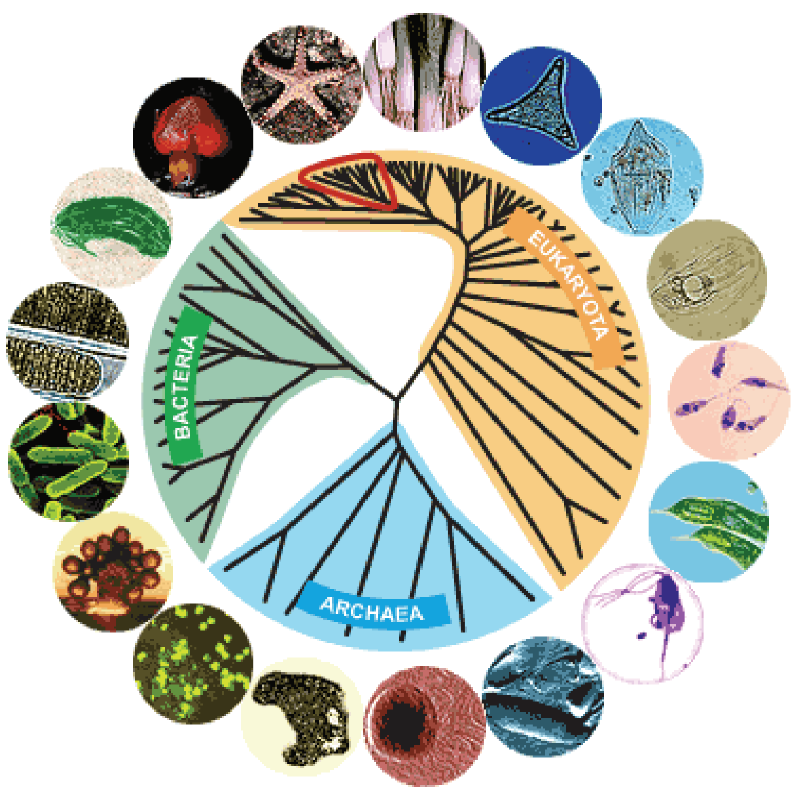


FIGURE 2-16. Phylogenetic tree of life depicting the three domains

UNDERSTANDING CLADOGRAMS

A **clade** (figure 2-17) is a group of organisms that includes ancestors and descendants of that ancestor. There may be many ways to show the relationship between organisms.

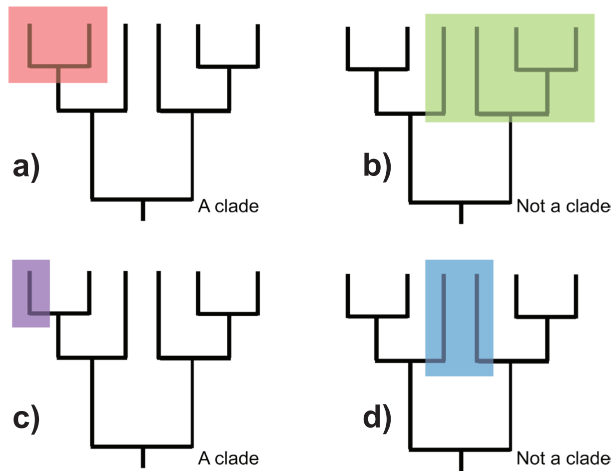


FIGURE 2-17. The colored boxes in cladograms a) and c) represent clades; b) and d) are not clades

There are many ways to draw a cladogram. Figure 2-18 shows two common ways:

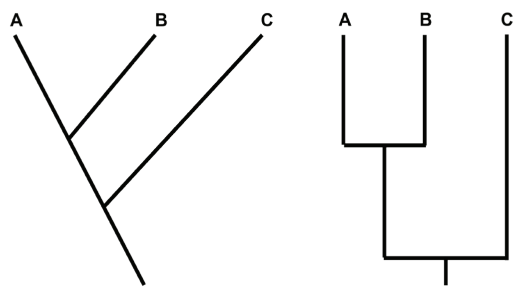


FIGURE 2-18. Two ways to draw a cladogram

Here are some basic words that are important to understanding cladogram terminology (figure 2-19):

1. **Branches**: the evolutionary lineage.
2. **Leaves**, **tips**, or **terminal nodes**: represent the **taxa** (taxonomic groups such as phylum) in the study or the end of the ancestral lineage. This can be a group such as a kingdom or genus or it can be as specific as an individual species.
3. **Outgroup**: lies outside of the group being studied. There is less relatedness to the other groups.

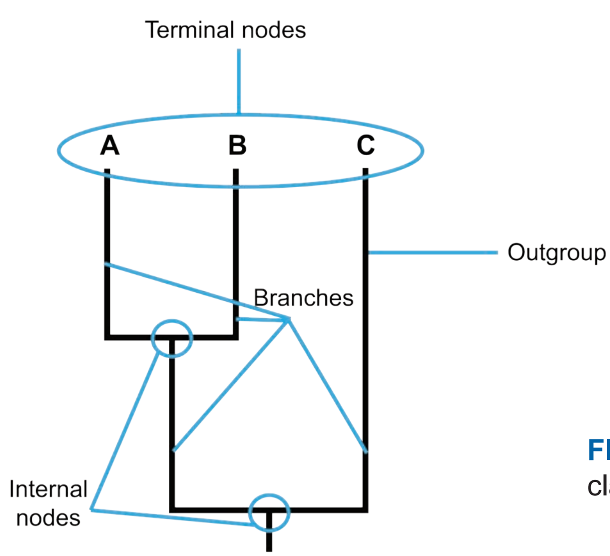


FIGURE 2-19. Basic cladogram terminology

When looking at a cladogram (figure 2-20), you will notice that the branches at the bottom are the ancestors of the branches that are at the top of the cladogram. A cladogram, reads from past ancestors (bottom) to the most recent descendants (top). Note that most cladograms do not specify the timing of these events.

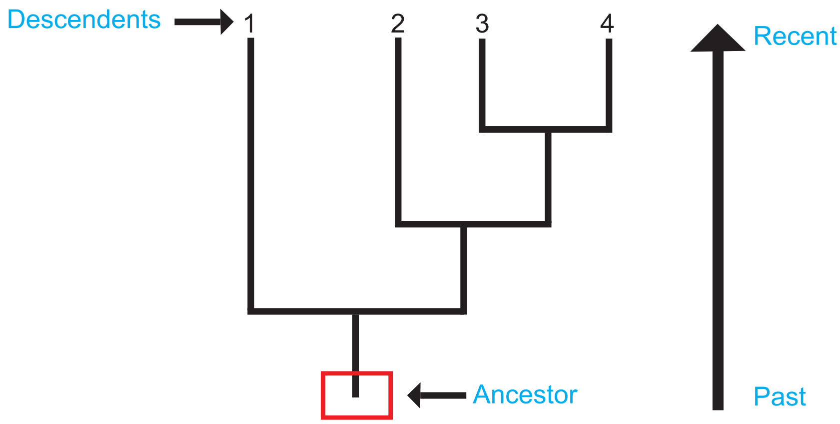


FIGURE 2-20. Cladograms read from past ancestors to their descendants

When a diagram splits into two different organisms or groups this area is known as an **internal node** (figure 2-19). This occurs when a lineage splits, which is known as **speciation** (figure 2-21). On the cladogram, notice that the node is the speciation event and the line below the node is where there is a common ancestral lineage. In this case, the speciation event results in two **daughter lineages,** or taxa that descend from the same ancestor.

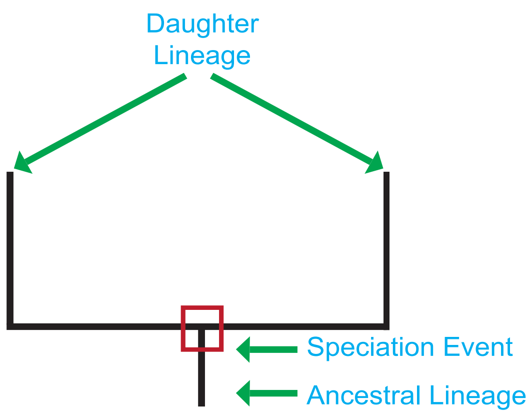


FIGURE 2-21. A speciation event results in two daughter lineages

Cladograms are grouped by their characters. A **shared character** is when two lineages have a trait in common. A **derived character** is a trait that has evolved in a lineage, which trait appears in later organisms, but not earlier ones. In the next section, we will learn how to build a cladogram using shared derived characters.

HOW TO BUILD A CLADOGRAM

Remember that cladograms are constructed by grouping organisms together based off of their shared characters.

Let's construct a cladogram for the following organisms:

Hermit Crab – Starfish – Ctenophore – Jellyfish

Step 1: Make a chart with the derived characters and the taxa (figure 2-22).

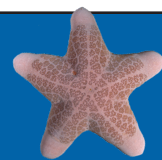
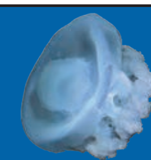
	 HERMIT CRAB	 STARFISH	 CTENOPHORE	 JELLYFISH
Invertebrate				
Diploblastic				
Radial symmetry				
Comb rows				

FIGURE 2-22. Empty cladogram chart

Step 2: Identify the characters of each organism (figure 2-23). Mark an "X" in the box when the organism has the character. In this example, hermit crabs, starfish, ctenophores, and jellyfish are all invertebrates meaning they do not have a backbone. Only ctenophores and jellyfish are diploblastic meaning that they only have two germ (cell) layers. Starfish, ctenophores, and jellyfish have radially symmetric body plans. This means that they can be evenly divided around a central axis. The only animal that has comb rows, used for locomotion, are ctenophores.

	 HERMIT CRAB	 STARFISH	 CTENOPHORE	 JELLYFISH
Invertebrate	X	X	X	X
Diploblastic			X	X
Radial symmetry		X	X	X
Comb rows			X	

FIGURE 2-23. Filled in cladogram chart

Characters that have a greater amount of X's, are ancestral characters that are shared by many or all of the organisms. In this example, *invertebrate* is the ancestral characteristic.

Step 3: Reorganize the cladogram chart (figure 2-24). Order the traits in the chart from most to least number of X's. Order organisms from most to least number of shared characters.

Hermit Crab – Starfish – Jellyfish – Ctenophore

Invertebrate – Radial symmetry – Diploblastic – Comb rows

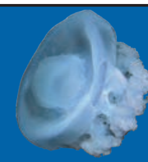
	 HERMIT CRAB	 STARFISH	 JELLYFISH	 CTENOPHORE
Invertebrate	X	X	X	X
Radial symmetry		X	X	X
Diploblastic			X	X
Comb rows				X

FIGURE 2-24. Reorganized cladogram chart

Step 4: Begin to make a cladogram. Using the same order from step 3, write the organisms at the terminal node of each branch from left to right (figure 2-25).

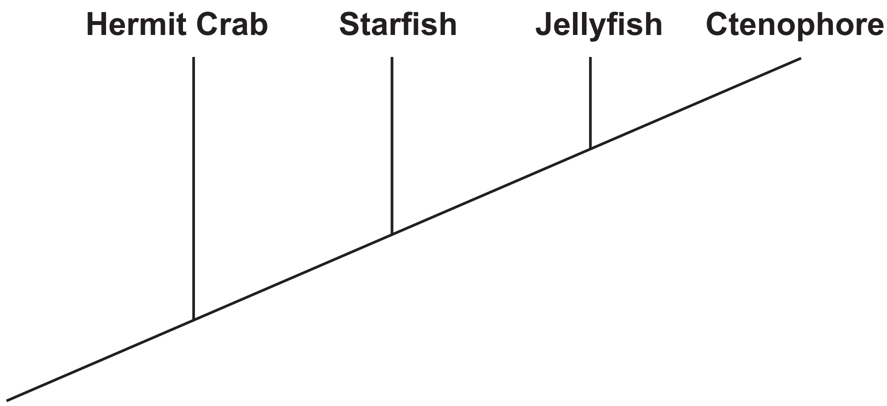


FIGURE 2-25. Beginning of the cladogram with organisms listed from most to least number of shared characters

Step 5: Finish cladogram. On the main line of the cladogram, place the characters in between each branch from left to right (figure 2-26).

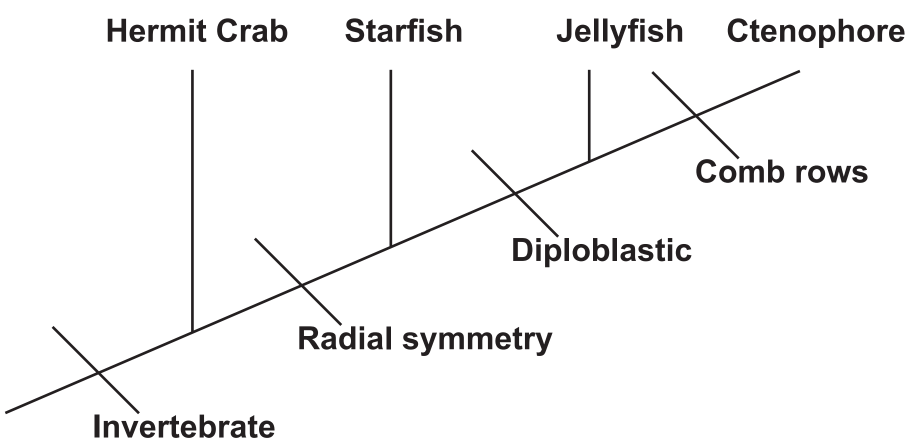


FIGURE 2-26. Completed cladogram

CORAL ZOOXANTHELLAE CLADES

How are clades useful in coral classification? Corals have a single-celled algae called **zooxanthellae** (figure 2-27) that live inside their tissues. These symbiotic algae are crucial to the survival of corals, which provide them with oxygen and other nutrients. We will learn more about this relationship in *Unit 4: Coral Feeding*.

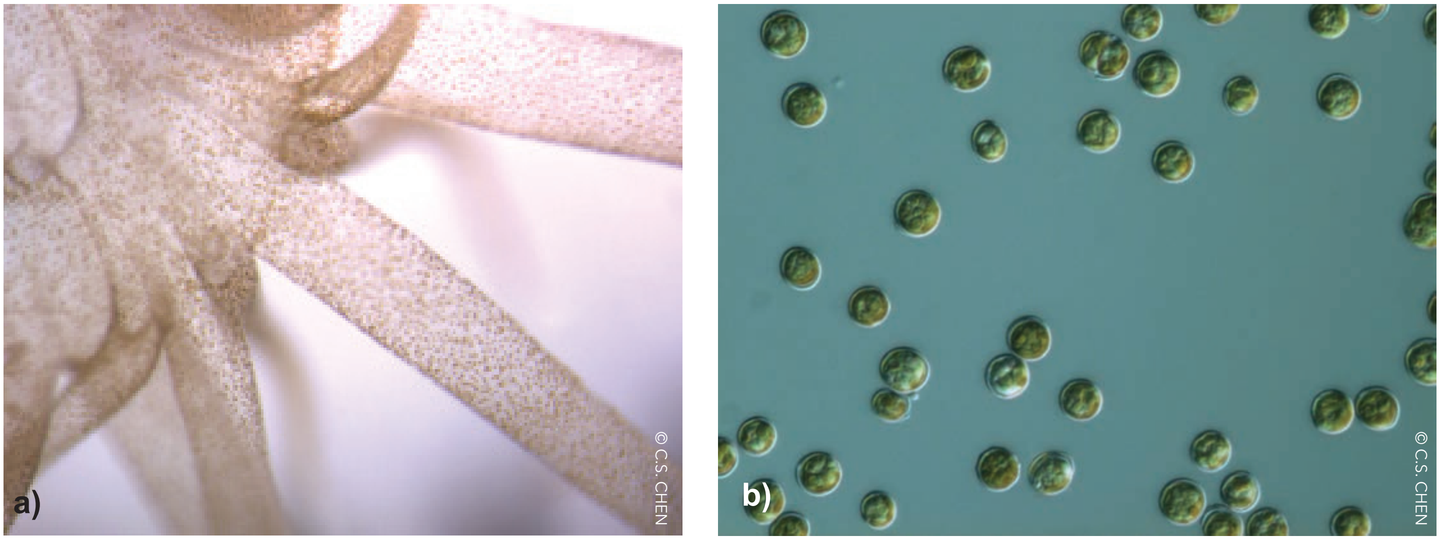


FIGURE 2-27. a) *Symbiodinium* are the yellow-brown algae that give the polyps their color. b) Isolated *Symbiodinium* sp.

These algal cells are actually separate organisms known as dinoflagellates, and they are classified in the genus *Symbiodinium*. There are eight genetic clades of *Symbiodinium*. They are each designated with a letter from A to H. *Symbiodinium* are sensitive to different environmental stressors including high light levels, salinity, and temperature. Various *Symbiodinium* species react differently to these stressors. For instance, clade C has a wide temperature and salinity tolerance (Karako-Lampert *et al.* 2004), whereas, clade B has adapted to lower light and higher latitude environments (Rodriguez-Lanetty *et al*. 2001).

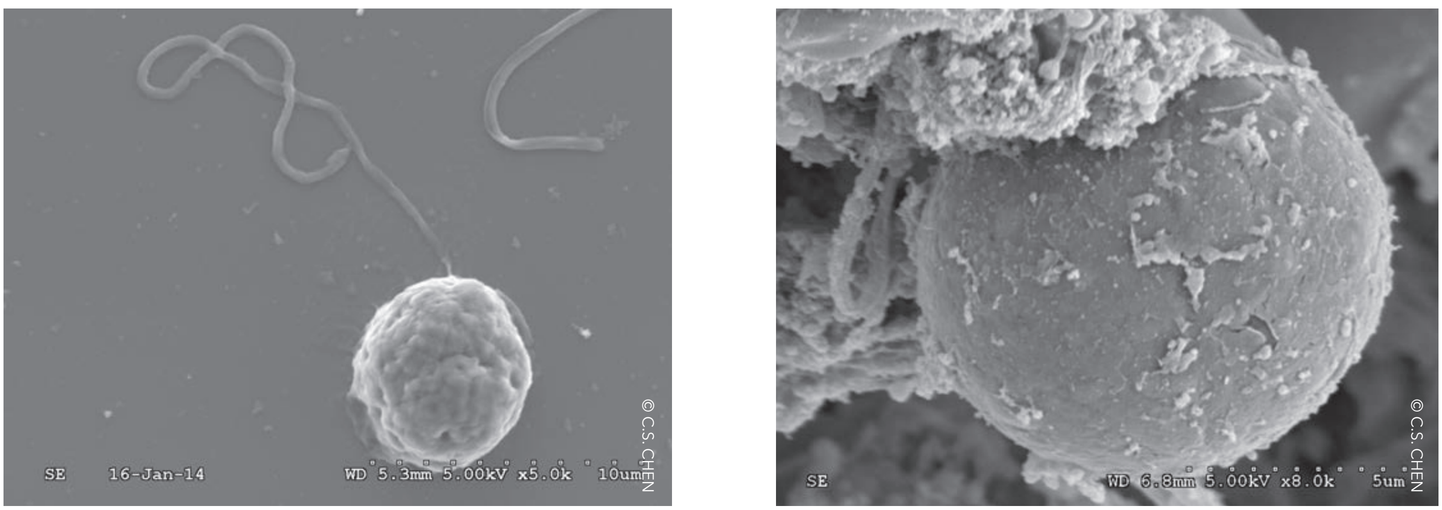


FIGURE 2-28. *Symbiodinium* under an electron micrograph

Why is this important? Scientists study corals and *Symbiodinium* in order to better understand these organisms and how they interact with one another. It's especially important to understand how *Symbiodinium* react to environmental stressors. As the effects of climate change take a toll on the ocean, corals are at risk of facing higher temperatures, greater differences in salinity, and ocean acidification. If there are more tolerant *Symbiodinium*, then corals will have a greater chance of survival.

Take the *What Clade R U?* to find out what clade you're a part of. Go to the bottom of the *How to Build a Cladogram* tab: www.lof.org/education/portal/course/classification/.

ATTRIBUTIONS

Figure 2-6c). By (WT-shared) Seascapeza at wts wikivoyage (This file was imported from Wikivoyage WTS.) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], 5 May 2012 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3ATubular_hydroid_DSF0138.jpg.

Figure 2-12b). I, Jonathan Zander [GFDL (http://www.gnu.org/copyleft/fdl.html), CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/) or CC-BY-SA-2.5 (http://creativecommons.org/licenses/by-sa/2.5)], 31 July 2007 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3AMushroom_Coral_(Fungia)_Top_Macro_91.JPG.

Figure 2-14. By University of California Museum of Paleontology's Understanding Evolution. http://evolution.berkeley.edu.

Figure 2-15.

a) By Thomas Vandenberghe from Leuven, Belgium (*Velociraptor mongoliensis* Uploaded by FunkMonk) [CC-BY-SA-2.0 (http://creativecommons.org/licenses/by-sa/2.0)], 5 August 2008 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3AVelociraptor_Fighting_Dinosaur.jpg.

b) By H. Raab (User:Vesta) (Own work) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], 30 October 2009 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3AArchaeopteryx_(Feather).jpg.

c) Ballista at the English language Wikipedia [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], 30 August 2006 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3AArchaeopteryx_lithographica.JPG.

Figure 2-16. By University of California Museum of Paleontology's Understanding Evolution. http://evolution.berkeley.edu.

Figure 2-17. Adapted from University of California Museum of Paleontology's Understanding Evolution. http://evolution.berkeley.edu.

Figure 2-18. By Alexei Kouprianov (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html), CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], 4 September 2006 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File%3AIdentical_cladograms.svg.

Figure 2-20. Adapted from University of California Museum of Paleontology's Understanding Evolution. http://evolution.berkeley.edu.

Figure 2-21. Adapted from University of California Museum of Paleontology's Understanding Evolution. http://evolution.berkeley.edu.

Figures 2-27 & 2-28. By C.S.Chen National Museum of Marine Biology and Aquarium, Taiwan. http://www.nmmba.gov.tw/en/.

CITATIONS

Karako-Lampert, S., Katco, D. J., Achituv, Y., Dubinsky, Z., & Stambler, N. (2004). Do clades of symbiotic dinoflagellates in scleractinian corals of the Gulf of Eilat (Red Sea) differ from those of other coral reefs? *Journal of Experimental Marine Biology and Ecology* 311: 301-314.

Rodriguez-Lanetty, M., Loh, W., Carter, D., & Hoegh-Guldberg, O. (2001). Latitudinal variability in symbiont specificity within the widespread scleractinian coral *Plesiastrea versipora*. *Marine Biology* 138: 1175-1181.

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WATCH IT! NAMING NATURE

INSTRUCTIONS: Watch *Naming Nature* YouTube video (https://youtu.be/5h5nSivm1KI) and answer the following questions.

1. In your own words, what is modern classification?

____

____

2. What did Carolus Linnaeus contribute to classification?

____

____

3. What are the different categories used to classify all organisms?

a.
b.
c.
d.
e.
f.
g.
h.

4. What is an acronym you can use to remember the order and categories of classification?

a.
b.
c.
d.
e.
f.
g.
h.

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WATCH IT! NAMING NATURE

5. What are the names of the three domains?

   a. ______________________________

   b. ______________________________

   c. ______________________________

6. List the different categories of classification for the bottlenose dolphin.

Category	Dolphin Classification
a.	
b.	
c.	
d.	
e.	
f.	
g.	
h.	

7. What categories of classification make up a scientific name?

   ______________________________ and ______________________________

8. What is the scientific name of the bottlenose dolphin? ______________________________

9. List two reasons why you think that taxonomy is important for scientists.

   ____

   ____

   ____

   ____

   ____

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WATCH IT! NAMING NATURE

VIDEO TRANSCRIPT:

We humans have probably been naming and classifying living things in our environment since we were first able to communicate.

Whether a plant or animal was dangerous or delicious would've been important information for our earliest ancestors.

Modern biological classification got a boost from 18th century botanist Carl Linnaeus.

Linnaeus was the first to group living things according to shared physical characteristics.

Grouping like things together still makes scientists' jobs easier. It helps organize the study of the eight million different species that share our planet.

Modern classification begins with categories.

These categories are like boxes that scientists put related species into.

The categories are ranked from the most general grouping, called domain, to the most specific, called species.

A handy way to remember these categories is with this acronym: <u>D</u>ear <u>K</u>ing <u>P</u>hilip, <u>C</u>ome <u>O</u>ver <u>F</u>or <u>G</u>reat <u>S</u>paghetti.

Every living thing on earth can be classified by these eight categories.

Let's classify this marine favorite. -

There are three domains of living things, and all plants and animals belong in one of them.

The domains of Archaea and Bacteria contain single-celled microorganisms that have no cell nucleus.

The seagoing creature we're classifying belongs to the multi-celled domain Eukarya.

The next category is called kingdom. The kingdoms include plants, animals, fungi, and more.

Obviously, this playful creature has the physical characteristics of an animal, so its kingdom is Animalia.

Next comes phylum, the body type category. There are about 36 phyla. This animal is grouped with other animals that have backbones in a category called Chordata.

It's not cold-blooded like fish and reptiles, and it doesn't lay eggs like birds.

It belongs with animals that are warm-blooded and produce milk. That's the Mammalia or mammal class.

Next comes order. There are dozens of orders, but only one that contains whales and porpoises, which share many characteristics with this animal.

They're all members of the Cetacean order.

Name: ______________________ Date: __________

WATCH IT! NAMING NATURE

Now for its family? It's Delphinidae, or dolphins.

But there are many kinds of dolphins. This one is in the genus called *Tursiops*.

At this point, we've narrowed down this animal's classification from all the living things in the world to a genus that has just three species in it.

The last classification is species. Each species has a unique name. In this case it's *truncatus*.

The scientific name for any creature is a combination of its genus and its species. This one is *Tursiops truncatus*, but you know it as the bottlenose dolphin.

Classification helps scientists tell nature's some eight million species apart.

It helps determine which have healthy populations, and which are at risk.

Giving names to the living things around us probably started as a way to help ourselves to nature's bounty.

Now, scientific classification has become an important tool for helping understand and protect the natural world.

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WATCH IT! NAMING NATURE

INSTRUCTIONS: Watch *Naming Nature* YouTube video (*https://youtu.be/5h5nSivm1KI*) and answer the following questions.

1. In your own words, what is modern classification?

   Classification is the organization of different organisms by putting them into groups that have the same characteristics and a common ancestry.

2. What did Carolus Linnaeus contribute to classification?

   Carolus Linnaeus was the first person to group living things according to shared physical characteristics.

3. What are the different categories used to classify all organisms?

a. **Domain**
b. **Kingdom**
c. **Phylum**
d. **Class**
e. **Order**
f. **Family**
g. **Genus**
h. **Species**

4. What is an acronym you can use to remember the order and categories of classification?

a. **Dear**
b. **King**
c. **Phillip**
d. **Come**
e. **Over**
f. **For**
g. **Great**
h. **Spaghetti**

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WATCH IT! NAMING NATURE

5. What are the names of the three domains?
   a. Archaea
   b. Bacteria
   c. Eukarya

6. List the different categories of classification for the bottlenose dolphin.

Category	Dolphin Classification
a. Domain	Eukarya
b. Kingdom	Animalia
c. Phylum	Chordata
d. Class	Mammalia
e. Order	Cetacea or Cetacean
f. Family	Delphinidae
g. Genus	Tursiops
h. Species	truncatus

7. What categories of classification make up a scientific name?

   Genus and Species

8. What is the scientific name of the bottlenose dolphin? *Tursiops truncatus*

9. List two reasons why you think that taxonomy is important for scientists.

   1. To help scientists learn more about organisms and where they came from in order to understand how to protect them.

   2. To help scientists to have a standardized classification system around the world.

   3. To help scientists understand past relationships between organisms and their ancestors.

Lesson 1 Teacher's Notes

Author

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Learning Objectives

- Demonstrate how to classify organisms.
- Apply the rules of binomial nomenclature.

Keywords

- Binomial Nomenclature
- Classification
- Common Name
- Eukarya
- Scientific Name
- Taxonomy

Materials

- Internet or library
- Computer
- **Watch It! Naming Nature** student worksheet
- **Lesson 1A: Classify This!** student worksheet
- **Lesson 1B: Rules, Rules, Rules** student worksheet

Extension

- Students can give a brief presentation and/or write a paper about the animal that they chose for this assignment.

Standards

- CCSS: RST.9-10.4, 5; RST.11-12.4
- NGSS: HS-LS4-1
- OLP: 4.B.1, 5.C.22

Procedure

1. Watch *Naming Nature* YouTube video (https://youtu.be/5h5nSivm1KI) and answer questions on **Watch It! Naming Nature** student worksheet.
2. Teach *Background Information* section *A) How do we classify organisms?* and *B) Linnaean Naming System*.
3. Hand out **Lesson 1A: Classify This!** student worksheet. Explain the instructions to the students:
   a. Choose an organism (plant or animal).
   b. Write the common name and scientific name of the chosen organism on the lines provided. (Remind them to use the rules of binomial nomenclature.)
   c. Classify the organism by the eight taxonomic divisions.
   d. Write four characteristics that classify it to each division.
   NOTE: Tree of Life (http://tolweb.org/tree/) is a website that is a free resource that students can use to complete this worksheet.
4. Hand out **Lesson 1B: Rules, Rules, Rules** student worksheet. Explain the instructions to the students:
   a. Using Linnaeus' rules of binomial nomenclature write each scientific name in its proper form.
   b. Answer the questions. NOTE: Students may need to research the names.

Name: ______________________________ Date: ______________

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LESSON 1A Classify This!

INSTRUCTIONS:

1. Choose an organism (plant or animal) and write its common name on the line below.
2. Write the scientific name on the line below, following the Linnaean rules of binomial nomenclature.
3. Classify it by its eight taxonomic divisions.
4. For each category, write four characteristics that are used to classify the organism.

Common Name: ____________________________________ Scientific Name: ____________________________________

DIVISIONS	TAXONOMY	CHARACTERISTICS
DOMAIN		
KINGDOM		
PHYLUM		
CLASS		
ORDER		
FAMILY		
GENUS		
SPECIES		

LESSON 1A Classify This!

INSTRUCTIONS: Answers may vary.

1. Choose an organism (plant or animal) and write its common name on the line below.
2. Write the scientific name on the line below, following the Linnaean rules of binomial nomenclature.
3. Classify it by its eight taxonomic divisions.
4. For each category, write four characteristics that are used to classify the organism.

Common Name: **Green sea turtle** Scientific Name: ***Chelonia mydas***

DIVISIONS	TAXONOMY	CHARACTERISTICS
DOMAIN	**Eukarya**	• **Contains cells that have complex structures enclosed within membranes** • **Cell division by mitosis** • **Multicellular**
KINGDOM	**Animalia**	• **Adult animals develop from embryos** • **Multicellular and reproduce sexually** • **Heterotrophic, obtaining their energy by consuming energy-releasing food substances**
PHYLUM	**Chordata**	• **Possess a notochord** • **Three germ layers and a well-developed coelom** • **Bilaterally symmetrical** • **Pharyngeal slits and post-anal tail**
CLASS	**Reptilia**	• **Possess a backbone (vertebrate)** • **Ectothermic or cold-blooded** • **Breathe air with lungs** • **Have scales, leathery shells, lay eggs**
ORDER	**Testudines**	• **Bony or cartilaginous shell** • **Shell is a modified rib cage and part of the vertebral column** • **Do not possess teeth** • **The postfrontal bone is absent**
FAMILY	**Cheloniidae**	• **Marine sea turtles** • **Oval or heart-shaped shells** • **Shells covered with scutes (horny plates)** • **Front legs are stronger than back legs**
GENUS	**Chelonia**	• **Only one species in this genus (see other traits below)**
SPECIES	**mydas**	• **Considered green due to the color of their fat** • **Single pair of prefrontal scales on head** • **Carapace has five central scutes** • **Four pairs of lateral scutes on carapace**

Name: ______________________ Date: ___________

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LESSON 1B Rules, Rules, Rules

PART A:

INSTRUCTIONS: Use the rules of binomial nomenclature to write each scientific name in its formal form.

1. dasyatis Americana ______________________________
2. carcharhinus leucas ______________________________
3. amphiprion perideraion ______________________________
4. carcharhinus melanopterus ______________________________
5. epinephelus tauvina ______________________________

PART B:

INSTRUCTIONS: Answer the following questions (#1-3) using the scientific names above. Then answer #4.

1. Which organisms are the most closely related? Why?

2. How many different genera are represented? ______________________________

3. How many species are represented? ______________________________

4. Why is binomial nomenclature important? List two reasons.

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LESSON 1B Rules, Rules, Rules

PART A:

INSTRUCTIONS: Use the rules of binomial nomenclature to write each scientific name in its formal form.

1. dasyatis Americana — **Dasyatis americana or *Dasyatis americana***
2. carcharhinus leucas — **Carcharhinus leucas or *Carcharhinus leucas***
3. amphiprion perideraion — **Amphiprion perideraion or *Amphiprion perideraion***
4. carcharhinus melanopterus — **Carcharhinus melanopterus or *Carcharhinus melanopterus***
5. epinephelus tauvina — **Epinephelus tauvina or *Epinephelus tauvina***

PART B:

INSTRUCTIONS: Answer the following questions (#1-3) using the scientific names above. Then answer #4.

1. Which organisms are the most closely related? Why?

   Carcharhinus leucas and Carcharhinus melanopterus are the most closely related. They are part of the same genus. No other animals in Part A are that closely related.

2. How many different genera are represented? **Four**

3. How many species are represented? **Five**

4. Why is binomial nomenclature important? List two reasons.
   - **It allows scientists around the world to communicate about the same organism.**
   - **It allows people to see the relationships among organisms.**
   - **It gives species a unique classification.**

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LESSON 2 Teacher's Notes

AUTHORS

- Amy Heemsoth & Alex Dempsey, Khaled bin Sultan Living Oceans Foundation

LEARNING OBJECTIVE

- Create a classification system for corals based on their physical characteristics.

KEYWORDS

- Calcium Carbonate ($CaCO_3$)
- Classification
- Corallite
- Polyp

MATERIALS

- Coral Photographs
- **Watch It! Naming Nature** student worksheet
- **Lesson 2: "Taxing" Corals** student worksheet
- **Appendix A: Coral Pictures**
- **Appendix B: How to Identify Corals**

EXTENSION

- Students can try to figure out the actual genus of corals using identification books. It would be helpful to go through *Unit 3: Coral Anatomy* beforehand, so that students will know the anatomical parts of a coral polyp. **Appendix B: How to Identify Corals** could also be copied and handed out to students.

EVALUATION

- Use grading rubric for activity evaluation.

STANDARDS

- CCSS: RST.9-10.4, 5, 10; RST.11-12.4, 10; SL.9-10.4, 6; SL.11-12.4, 6
- NGSS: HS-LS4-1
- OLP: 4.B.1, 5.C.22

PROCEDURE

1. Watch *Naming Nature* YouTube video (https://youtu.be/5h5nSivm1KI) and answer questions on **Watch It! Naming Nature** student worksheet.
2. Teach *Background Information* section *C) Coral Classification.*
3. Hand out **Lesson 2: "Taxing" Corals** student worksheet.
4. Read *Additional Background Information* on student worksheet.
5. Use figure in **Appendix B: How to Identify Corals** to show students a diagram of a corallite.
6. Explain to students that in this activity they are going to construct a classification system for the unidentified corals in the photos. This activity can be done individually or in a group.
7. Review grading rubric with students.
8. Give students **Appendix A: Coral Pictures**. Explain that there are three images per coral – a full frame live coral photo, a macro (close-up) live coral photo, and a macro photograph of the coral's skeleton. Tell them that they should use all three photos to classify the coral.
9. Describe the importance of labeling samples when conducting research. Ask students, "What type of information do you think that coral scientists collect?" For instance, when a Coral Ecologist collects samples they record the date, place (GPS coordinates), temperature, time, dive site number, reef type (patch reef, back reef; see *Unit 10: Reef Types and Unit 11: Zonation*), and depth. These are clues that help scientists to determine which species of coral are present. Notice that each brainstorming box on the student worksheet is already labeled with the location and sample number.
10. Explain to students that they should brainstorm the identifying characteristics of each coral.
11. Allow students to figure out ways to classify the corals. If students need other tools such as rulers, wait until they ask for them.
12. Encourage students to label structures on the photos.
13. Students will create a poster that outlines their identification system based on each coral sample's similar characteristics. Use the attached rubric for grading the poster and presentation.
14. Each group or student will present their classification system to the class.

ATTRIBUTIONS

These are the sources for the macro photos of the coral skeletons.

FP 01 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_images/acanthastrea-ishigakiensis/.

FP 02 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_summary/turbinaria-stellulata/.

FP 03 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_summary/galaxea-fascicularis/.

FP 04 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_images/leptoria-phrygia/.

FP 05 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_summary/acropora-hemprichii/.

FP 06 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_images/fungia-fungites/.

FP 07 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_summary/favites-halicora/.

FP 08 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_images/lobophyllia-hemprichii/.

FP 09 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_summary/porites-cylindrica/.

FP 10 Veron J.E.N., Stafford-Smith M.G., Turak E. and DeVantier L.M. (2016). Corals of the World. Accessed 25 Mar 2020. http://www.coralsoftheworld.org/species_factsheets/species_factsheet_images/plerogyra-sinuosa/.

IDENTIFICATION ANSWER KEY:

1. FP01 *Acanthastrea*
2. FP02 *Tubinaria*
3. FP03 *Galaxea*
4. FP04 *Leptoria*
5. FP05 *Acropora*
6. FP06 *Fungia*
7. FP07 *Favites*
8. FP08 *Lobophyllia*
9. FP09 *Porites*
10. FP10 *Plerogyra*

Name: ______________________ Date: ___________

Khaled bin Sultan Living Oceans Foundation

LESSON 2 "TAXING" CORALS

ADDITIONAL BACKGROUND INFORMATION:

With over 1,000 coral species in the ocean, identification and **classification** is not an easy task. That's why scientists use identification keys.

Often when identifying coral, samples have to be collected and transported back to the lab for further identification. The reason is that some corals are identified by the shape of corallite structures. As you will learn in *Unit 3: Coral Anatomy,* a **corallite** is the cup-like skeleton of an individual polyp.

Today, you are a coral ecologist working for the Khaled bin Sultan Living Oceans Foundation. You just returned from scuba diving in French Polynesia where you were conducting coral surveys and identifying corals. You have taken photographs of several corals for further identification and collected samples of each. In the lab, you have removed all of the tissue and now you are left with the corals' skeletons. These corals need to be identified. You will create a classification system based on the living coral photos and the corals' skeletons.

BRAINSTORMING:

UNKNOWN CORAL FP 01:	UNKNOWN CORAL FP 02:

UNKNOWN CORAL FP 03:	UNKNOWN CORAL FP 04:

BRAINSTORMING:

UNKNOWN CORAL FP 05:	UNKNOWN CORAL FP 06:

UNKNOWN CORAL FP 07:	UNKNOWN CORAL FP 08:

UNKNOWN CORAL FP 09:	UNKNOWN CORAL FP 10:

INSTRUCTIONS:

1. Use the *Brainstorming* section to write down the characteristics of each unknown coral.
2. Create a classification system based on the coral's shared characters.
3. See grading rubric for poster and presentation assessment.
4. Make a poster to illustrate your classification system.
5. Present your classification system to the class.
6. Answer the questions below.

1. What characteristics did you use to group your corals? List all of the distinguishing characteristics.

2. Were the characteristics determined by the live or dead coral photos? Explain.

3. Why do scientists classify corals? Give two answers.

4. How do you think scientists classify new species of corals?

5. After listening to your classmate's presentations, would you change your classification system? Why or why not?

GRADING RUBRIC:

Name: ______________________________ Date: ____________________ Score: ________________

Category	4	3	2	1	Score
Organization	Clear title, clearly defined sections, clear flow of topics, and easy to follow	Clear title, sections defined, generally easy to follow, though may require rereading for clarity	Title present, sections unclear or inappropriate, takes effort to follow thoughts and ideas	Title unclear or absent, sections unclear or absent, no flow of ideas, and cluttered, messy	
Attractiveness	The poster is exceptionally attractive in terms of design, layout, and neatness.	The poster is attractive in terms of design, layout and neatness.	The poster is acceptably attractive, though it may be a bit messy.	The poster is distractingly messy or very poorly designed. It is not attractive.	
Grammar/ Spelling	There are no mistakes on the poster.	There are 1-3 mistakes on the poster.	There are 4-6 mistakes on the poster.	There are more than 6 mistakes on the poster.	
Knowledge Gained	Student can accurately answer all questions related to facts in the poster and processes used to create the poster.	Student can accurately answer about 75% of questions related to facts in the poster and processes used to create the poster.	Student can accurately answer about 50% of questions related to facts in the poster and processes used to create the poster.	Student appears to have insufficient knowledge about the facts or processes used in the poster.	
TOTAL				**Out of 16:**	

You will be awarded one point for accurately labeling each distinguishing characteristic. ______/50

TOTAL SCORE ______**/66**

Khaled bin Sultan Living Oceans Foundation

LESSON 2 "TAXING" CORALS

ADDITIONAL BACKGROUND INFORMATION:

With over 1,000 coral species in the ocean, identification and **classification** is not an easy task. That's why scientists use identification keys.

Often when identifying coral, samples have to be collected and transported back to the lab for further identification. The reason is that some corals are identified by the shape of corallite structures. As you will learn in *Unit 3: Coral Anatomy,* a **corallite** is the cup-like skeleton of an individual polyp.

Today, you are a coral ecologist working for the Khaled bin Sultan Living Oceans Foundation. You just returned from scuba diving in French Polynesia where you were conducting coral surveys and identifying corals. You have taken photographs of several corals for further identification and collected samples of each. In the lab, you have removed all of the tissue and now you are left with the corals' skeletons. These corals need to be identified. You will create a classification system based on the living coral photos and the corals' skeletons.

BRAINSTORMING: Answers may vary.

UNKNOWN CORAL FP 01:

1. Colonial/Solitary: Colonial
2. Growth Form: Massive
3. Identifiers:
   - Coral: hemispherical shape
   - Corallites: up to 25 mm in diameter
   - Septa: uniform, with large teeth

UNKNOWN CORAL FP 02:

1. Colonial/Solitary: Colonial
2. Growth Form: Foliose
3. Identifiers:
   - Corallites: conical, thick-walled averaging 2.5 mm in diameter
   - Septa: short and neat

UNKNOWN CORAL FP 03:

1. Colonial/Solitary: Colonial
2. Growth Form: Encrusting
3. Identifiers:
   - Coral: small colonies are cushion-shaped or low domes or irregular
   - Corallites: cylindrical, thin walled; mixed sizes (usually less than 10 mm in diameter)
   - Septa: numerous septa reaching corallite center; exsert

UNKNOWN CORAL FP 04:

1. Colonial/Solitary: Colonial
2. Growth Form: Submassive
3. Identifiers:
   - Coral: meandering valleys
   - Corallites: sinuous and uniform valleys
   - Septa: uniformly spaced and of equal size

BRAINSTORMING:

UNKNOWN CORAL FP 05:

1. Colonial/Solitary: Colonial
2. Growth Form: Branching
3. Identifiers:
    - Coral: irregular branches
    - Corallites: irregularly spaced; dome shaped axial corallites; large, conical radial corallites
    - Septa: smooth
    - Costae: smooth

UNKNOWN CORAL FP 06:

1. Colonial/Solitary: Solitary
2. Growth Form: Free-living
3. Identifiers:
    - Coral: often circular in shape
    - Corallite: circular polyps with central mouth
    - Septa: triangular, pointed septal teeth; tall, smooth, conical costal spines

UNKNOWN CORAL FP 07:

1. Colonial/Solitary: Colonial
2. Growth Form: Massive
3. Identifiers:
    - Coral: rounded or hillocky
    - Corallites: thick walls, can become subplocoid; share common walls

UNKNOWN CORAL FP 08:

1. Colonial/Solitary: Colonial
2. Growth Form: Phaceloid
3. Identifiers:
    - Coral: flat to hemispherical
    - Corallites: large valleys
    - Septa: taper in thickness from the wall to columnella; tall, sharp teeth

UNKNOWN CORAL FP 09:

1. Colonial/Solitary: Colonial
2. Growth Form: Branching
3. Identifiers:
    - Coral: can be bifurcated
    - Corallites: shallow, giving branches a smooth surface
    - Septa: fill the corallite

UNKNOWN CORAL FP 10:

1. Colonial/Solitary: Colonial
2. Growth Form: Phaceloid
3. Identifiers:
    - Corallites: flabella-meandroid with valleys; vescicles the size of grapes
    - Septa: large, solid, smooth-edged
    - Costae: poorly developed

INSTRUCTIONS:

1. Use the *Brainstorming* section to write down the characteristics of each unknown coral.
2. Create a classification system based on the coral's shared characters.
3. See grading rubric for poster and presentation assessment.
4. Make a poster to illustrate your classification system.
5. Present your classification system to the class.
6. Answer the questions below.

1. What characteristics did you use to group your corals? List all of the distinguishing characteristics.
   - **Color**
   - **Corallite shape, size, spacing**
   - **Presence or absence of tentacles**
   - **Presence or absence of connective tissue**
   - **Coral shape and size**
   - **Number, shape, size of septa/costae**
   - **Number of polyps**

2. Were the characteristics determined by the live or dead coral photos? Explain.
   The characteristics that we used to classify corals came from both dead and live corals.
   - **From live corals I used color, shape and size of coral, approximate number of polyps, presence or absence of tentacles, presence and absence of connective tissue**
   - **From dead corals it was easier to tell the shape, size, number, and spacing of the corallite; number, shape, and size of septa and costae**

3. Why do scientists classify corals? Give two answers.
   - **To establish a standardized classification system so that scientists around the world can effectively communicate with each other about various organisms.**
   - **There are millions of organisms on Earth and creating a classification system allows scientists to be able to more easily study, sort, and group them.**

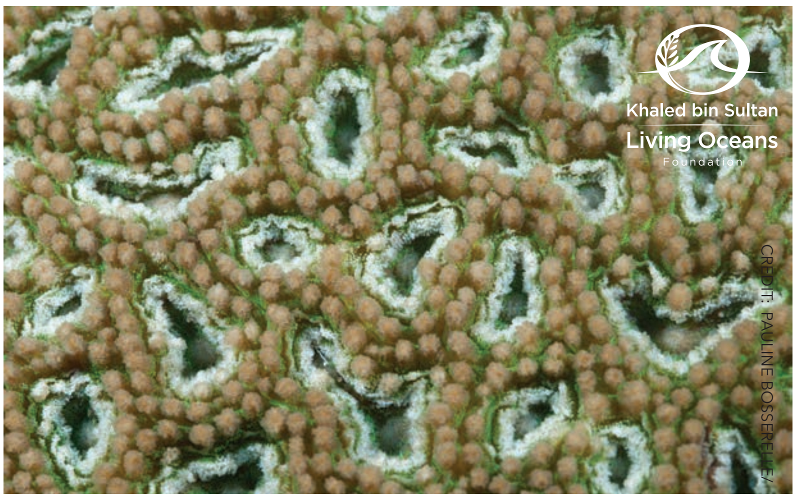
4. How do you think scientists classify new species of corals?
   Scientists classify new species by comparing similar characteristics of other species. They may observe their physical characteristics as well as their behavior. Additionally, scientists may look at the organism's evolutionary history and/or genetics.

5. After listening to your classmate's presentations, would you change your classification system? Why or why not?
   Answers may vary.

25/09/2012 - FP 01

Full Frame Photo – Live coral

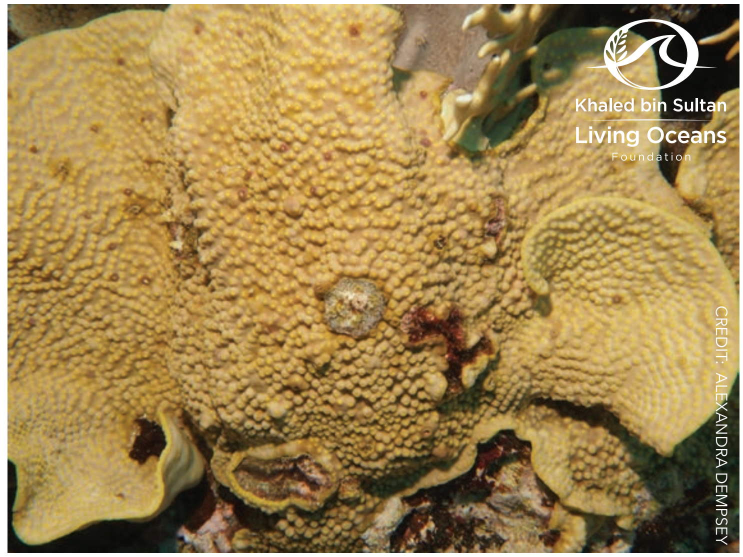
Macro Photo – Live coral



Macro Photo – Coral skeleton

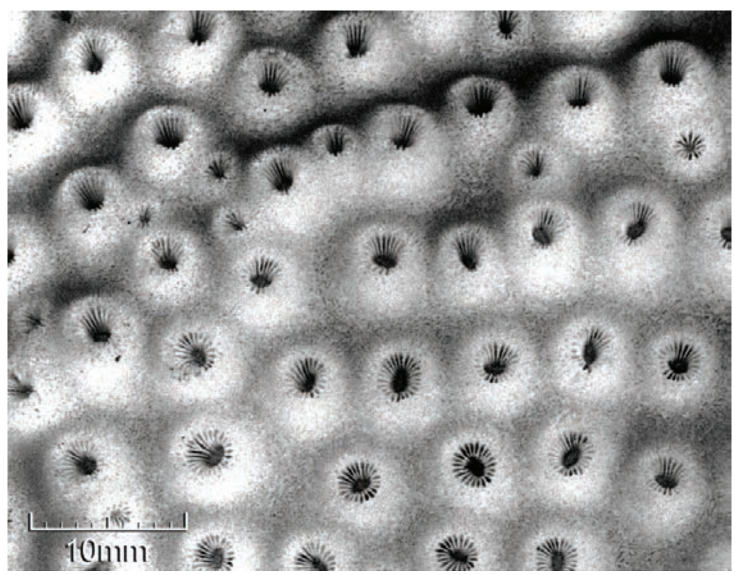
25/09/2012 - FP 02

Full Frame Photo – Live coral



Macro Photo – Live coral

Macro Photo – Coral skeleton

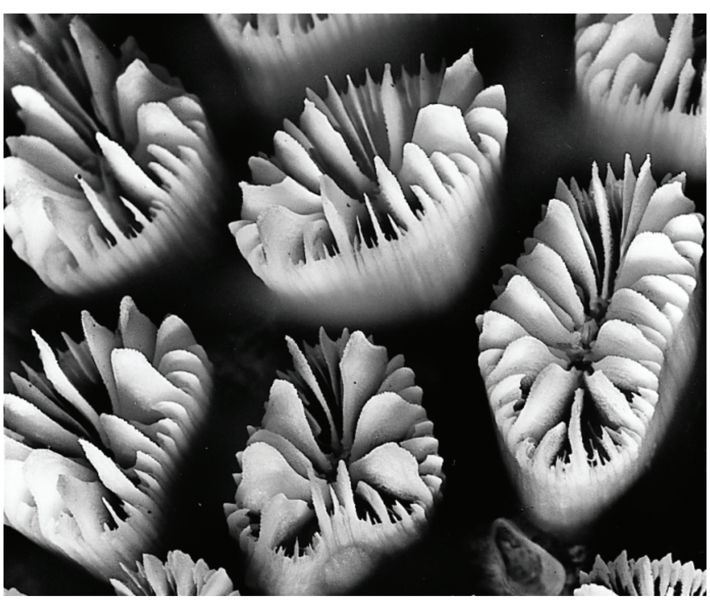


30/09/2012 - FP 03

Full Frame Photo – Live coral

Macro Photo – Live coral

Macro Photo – Coral skeleton

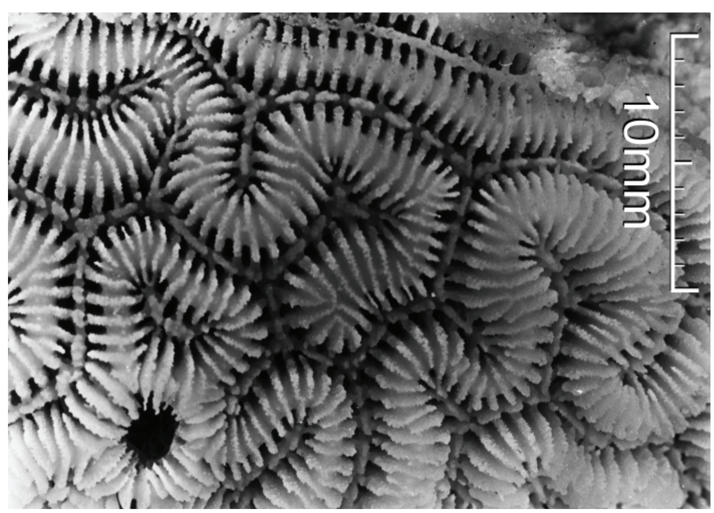


09/10/2012 - FP 04

Full Frame Photo – Live coral

Macro Photo – Live coral

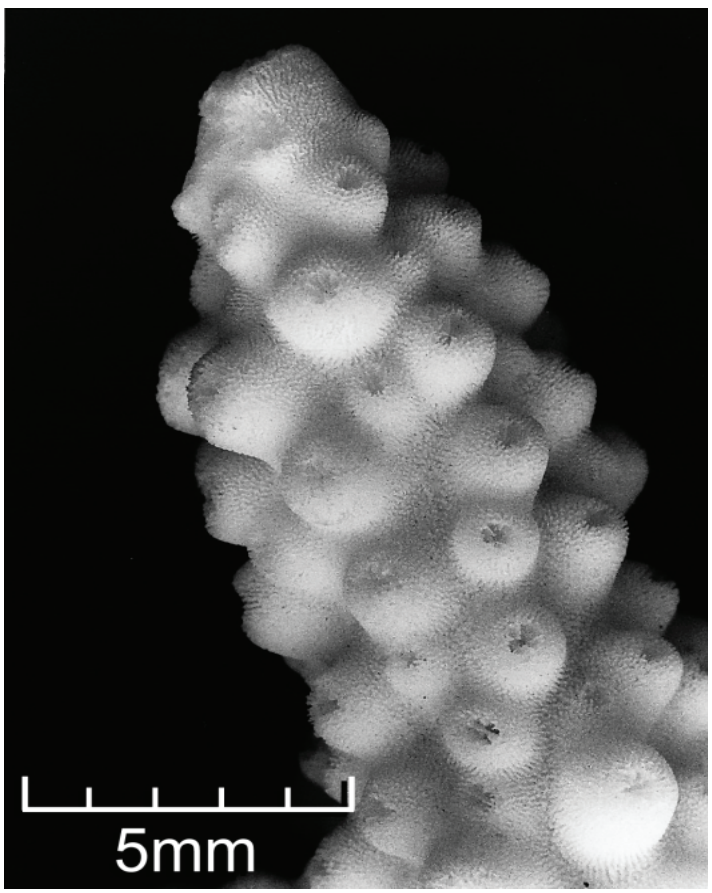
Macro Photo – Coral skeleton



10/10/2012 - FP 05

Full Frame Photo – Live coral

Macro Photo – Coral skeleton



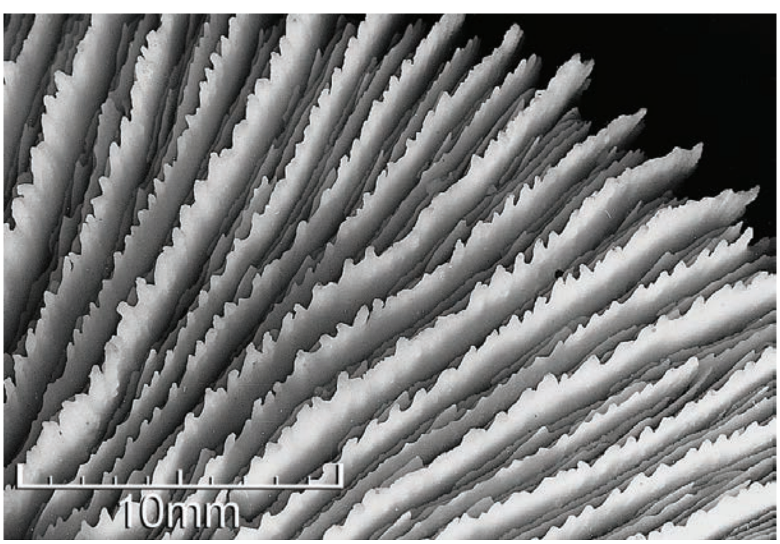
Macro Photo – Live coral

15/10/2012 - FP 06

Full Frame Photo – Live coral

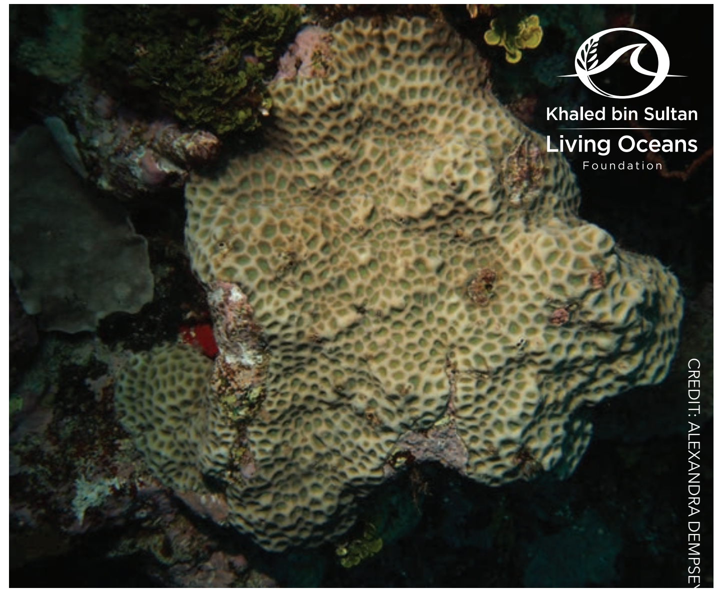
Macro Photo – Live coral

Macro Photo – Coral skeleton



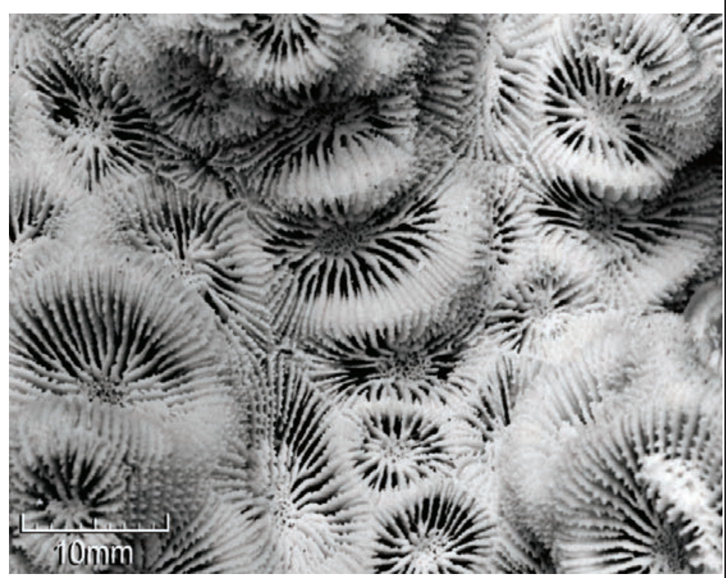
17/10/2012 - FP 07

Full Frame Photo – Live coral



Macro Photo – Live coral

Macro Photo – Coral skeleton

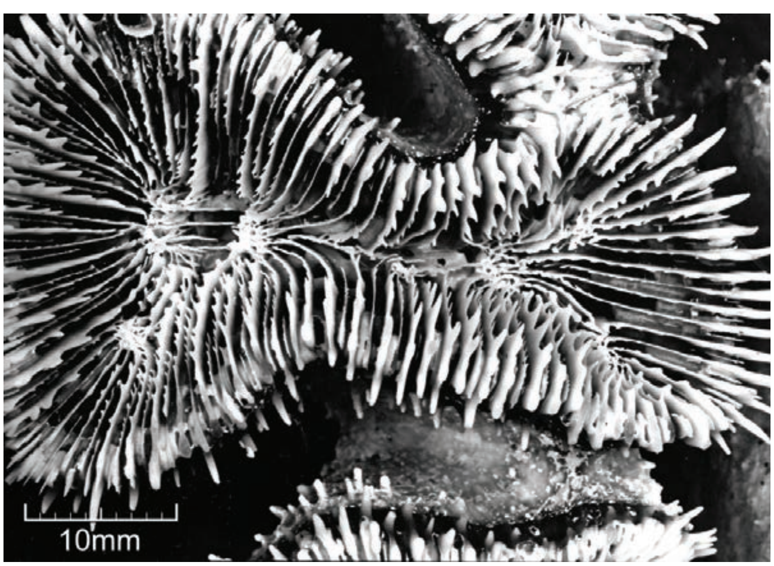


18/10/2012 - FP 08

Full Frame Photo – Live coral

Macro Photo – Live coral

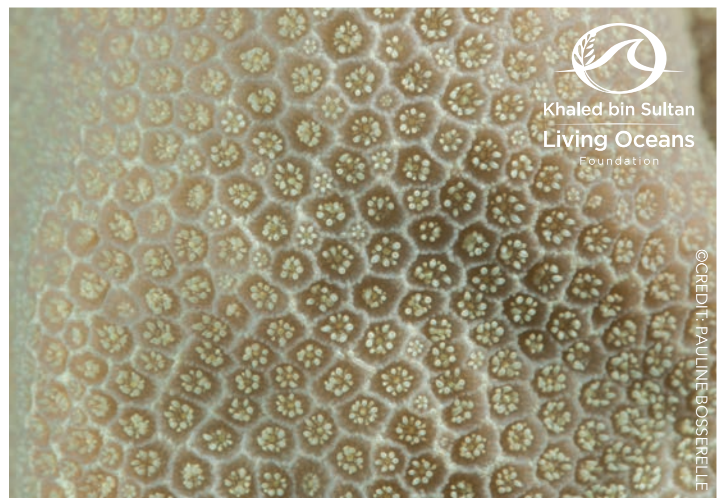
Macro Photo – Coral skeleton



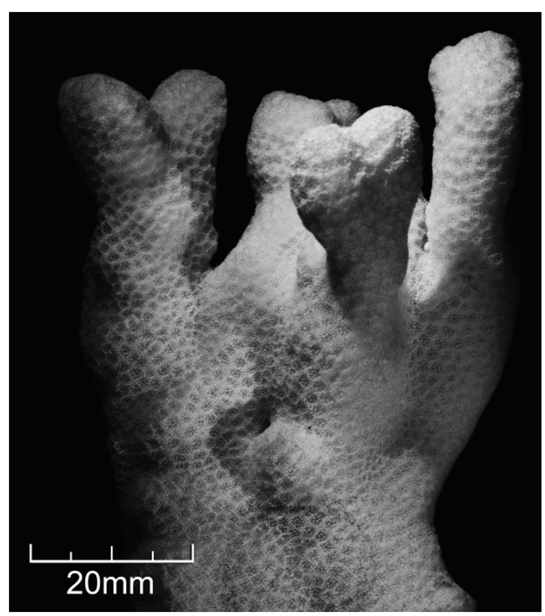
18/10/2012 - FP 09

Full Frame Photo – Live coral

Macro Photo – Live coral

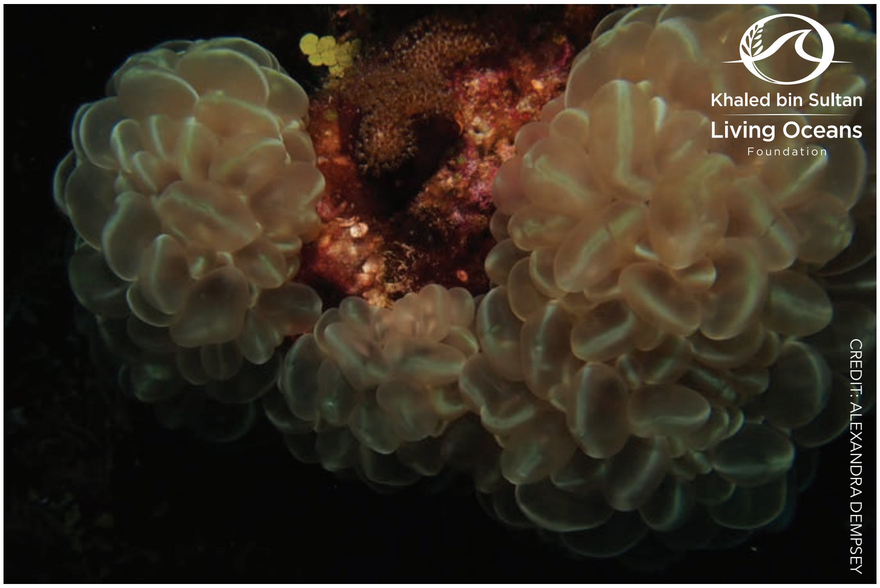


Macro Photo – Coral skeleton



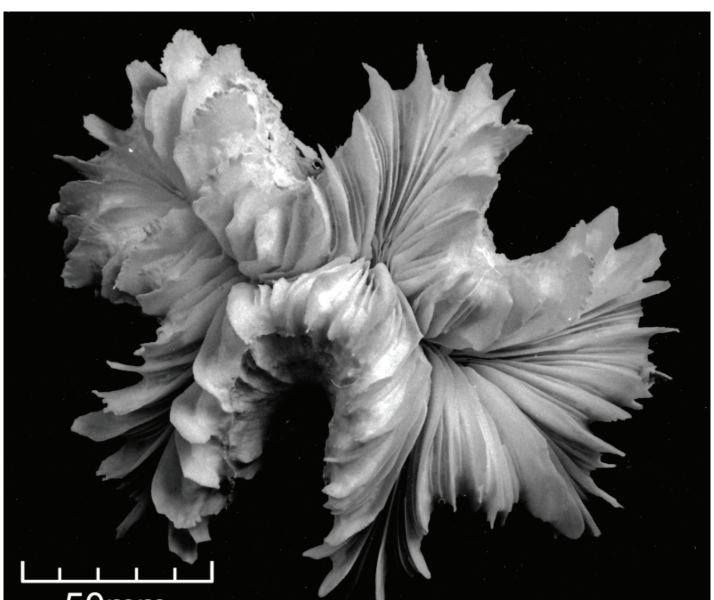
22/10/2012 - FP 10

Full Frame Photo – Live coral



Macro Photo – Live coral

Macro Photo – Coral skeleton



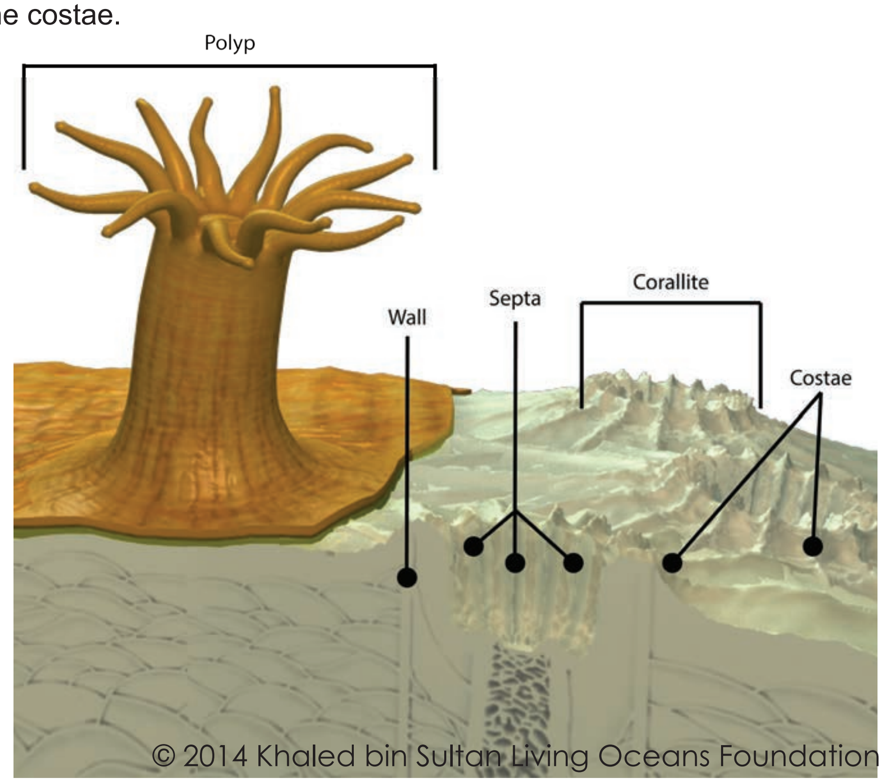
HOW TO IDENTIFY CORAL

Identifying corals is a tedious task. There are several methods that allow scientists to identify corals. Here is an overview of the methods that coral ecologists use:

1. Corals can be *solitary* or *colonial*. An individual is called a coral *polyp*. A solitary coral is an individual polyp, while colonial corals have more than one polyp. Depending on the size, a single colonial coral can have hundreds or even thousands of polyps. All but one of the corals in this activity are colonial corals. See the answer key for more details.

2. Corals possess certain shapes called *growth forms*. These growth forms help scientists to identify corals. Growth forms include branching, columnar, encrusting, foliose, free-living, massive, phaceloid, and plating. The growth forms for each coral are listed in the answer key. For more information, see *Unit 9: Coral Growth*.

3. Stony corals can be identified by their *corallite*. Before you understand how to identify corals, you must first learn some coral terminology. Please refer to the graphic below.
   - Corallite: cup-like skeleton that is made of calcium carbonate ($CaCO_3$).
   - Septa: vertical blades that are inside the corallite. When septa cross the wall outside the corallite, they become costae.
   - Costae: vertical blades on the outside of the corallite. When costae cross the wall to the inside of the corallite, they become septa.
   - Wall: the raised part of the skeletal structure. Separates corallites from each other. It also separates the septa from the costae.



The shape, size, and pattern of the corallite can help to identify corals. Scientists do not identify corals by their color. Here are some examples below:

- The septa, costae, and walls all have different spacing, size, and structures that help scientists to identify corals. For example, septa can have *septal teeth* (projections on the septa). These teeth can be used to help identify coral species. For example, *Ctenactis* spp. have large, spiky septal teeth, whereas *Trachyphyllia* spp**.** have small teeth.
- The walls can also help to identify corals. Here are some examples below:

Separate Walls	Common Walls	Indistinct
		
Each corallite has its own wall.	Corallites share a wall.	Corallite walls are not present or they are indistinct

There is an extra step when identifying branching corals. These corals have two types of corallites:

- *Axial corallite*: a single corallite that is located at the tip of a branch. NOTE: not all branching corals have axial corallites.
- *Radial corallite*: corallites that are typically smaller than the axial corallite that occur on the sides of branching corals.

This is just the tip of the iceberg. There are many other structures that help scientists to identify corals. For more information, check out the resources below.

RESOURCES

- Kelley, R. (2009). The Australian Coral Reef Society Finder, Indo-Pacific. Published by BYOGUIDES, Townsville, Australia.
- Veron, J.E.N. (2000). *Corals of the World. Volumes 1-3.* Townsville: Australian Institute of Marine Science.

Lesson 3 Teacher's Notes

Author
- Amy Heemsoth, Khaled bin Sultan Living Oceans Foundation

Learning Objectives
- Students will be able to search through scientific journals, summarize information, and express this information into words determining why an organism has been reclassified.
- The student will be able to cite specific textual evidence to support the reclassification.

Keywords
- Classification
- Scientific Name
- Taxonomy

Materials
- Computer
- Internet
- **Watch It! Naming Nature** student worksheet
- **Lesson 3: In Light of New Evidence** student worksheet

Integrating Subjects
- English Language Arts, Reading Comprehension, Writing

Prior Knowledge
- Students will need to understand how to search, read, and cite scientific journals.

Extension
- Teachers can include a speech component where the student has to give a short presentation about their findings.

Evaluation
- Use grading rubric to evaluate this activity.

References

- Kondo, B., Baker, J., & Omland, K. (2004). Recent speciation between the Baltimore oriole and the black-backed oriole. *The Condor* 106: 674-680.
- Rohwer, S. & Manning J. (1990). Differences in timing and number of molts for Baltimore and bullock's orioles: implications to hybrid fitness and theories of delayed plumage and maturation. *The Condor* 92: 125-140.

Standards
- **CCSS**: RST.9-10.4, 5, 9, 10; RST.11-12.4, 7, 8, 9; W.9-10.2, 4, 7, 8, 9; W.11-12.2, 4, 7, 8, 9
- **NGSS**: HS-LS4-1
- **OLP**: 4.B.1, 4.B.2

Procedure
1. Watch *Naming Nature* YouTube video (*https://youtu.be/5h5nSivm1KI*) and answer questions on **Watch It! Naming Nature** student worksheet.
2. Teach *Unit 2: Classification - Background Information.*
3. Hand out **Lesson 3: In Light of New Evidence** student worksheet.
4. Go over *Additional Background Information* on student worksheet. Review the reasons why organisms may be reclassified.
5. Go over the instructions on the student worksheet and make sure that students understand the essay requirements and the grading rubric.

Name: ______________________ Date: __________

LESSON 3 In Light of New Evidence

ADDITIONAL BACKGROUND INFORMATION:

When you think of the Baltimore oriole, you usually think of the baseball team; however, in this case, we are talking about the bird. The Baltimore oriole, *Icterus galbula*, received its name due to the black and orange plumage of its feathers that resembled the colors of the crest of Lord Baltimore (1605-1675), the English noble credited with founding the state of Maryland. This bird was not always classified as a Baltimore oriole. In 1973, about 200 years later, ornithologists renamed the bird after discovering that it was crossbreeding with another species from the Great Plains called Bullock's oriole, *Icterus bullockii*. The American Ornithologist's Union (AOU) reclassified the Bullock's and Baltimore oriole into one species called the northern oriole. It wasn't until 1996 that the AOU again decided to separate the two species. Genetic research showed that even though the Baltimore orioles were migrating further west, they were rarely interbreeding with the Bullock's orioles. The Baltimore oriole's name remains today.

But how is it that scientists can change the taxonomic names of these birds? Like science, taxonomy evolves too. There are many reasons why organisms are reclassified, including relationships between organisms changing, animals evolving, better technology, misclassifications, and advancements in science. For instance, advancements in genetics has allowed for the reclassification of many organisms including the Baltimore oriole.

Now, it's your turn to investigate.

INSTRUCTIONS:

1. Research a species that has been reclassified.
2. Investigate scientific journals for scientific evidence. There are many free journals on Google Scholar®.
3. Before writing your essay brainstorm ideas.
4. Review essay format:
   a. No more than 250 words
   b. Written in MLA style or preferred style
   c. Title
   d. Citations list
5. Write your essay. Include these items:
   a. Discuss original classification. Make sure to include the organism's original scientific name.
   b. Explain why the organism was reclassified. Scientists do not rename organisms without evidence, so make sure to back up your claim with scientific evidence and include citations. Make sure to include the organism's new scientific name.
   c. See grading rubric for more details.

GRADING RUBRIC:

CATEGORY	4	3	2	1	SCORE
Introduction	Exceptional introduction that grabs interest of reader and states topic.	Proficient introduction that is interesting and states topic.	Basic introduction that states topic but lacks interest.	Weak or no introduction of topic. Paper's purpose is unclear.	
Quality of Information/ Evidence	Paper is exceptionally researched, extremely detailed, and historically accurate.	Information relates to the main topic. Paper is well-researched in detail and from a variety of sources.	Information relates to the main topic, few details and/ or examples are given. Shows a limited variety of sources.	Information has little or nothing to do with the topic.	
Organization	Exceptionally clear, logical, mature, and thorough development with excellent transitions between and within paragraphs.	Clear and logical order with good transitions between and within paragraphs.	Somewhat clear and logical development with basic transitions between and within paragraphs.	Lacks development of ideas with weak or no transitions between and within paragraphs.	
Conclusion	Excellent summary of topic with concluding ideas that impact reader. Introduces no new information.	Good summary of topic with clear concluding ideas. Introduces no new information.	Basic summary of topic with some final concluding ideas. Introduces no new information.	Lack of summary of topic.	
Style/Voice	Style and voice are not only appropriate to the given audience and purpose, but also show originality and creativity. Word choice is specific, purposeful, dynamic and varied. Sentences are clear, active (subject-verb-object), and to the point.	Style and voice appropriate to the given audience and purpose. Word choice is specific and purposeful, and somewhat varied throughout. Sentences are mostly clear, active, and to the point.	Style and voice somewhat appropriate to given audience and purpose. Word choice is often unspecific, generic, redundant, and clichéd. Sentences are somewhat unclear; excessive use of passive voice.	Word choice is excessively redundant, clichéd, and unspecific. Sentences are very unclear.	

GRADING RUBRIC CONTINUED:

CATEGORY	4	3	2	1	SCORE
Citation Format	Conforms to MLA rules for formatting and citation of sources are perfect.	Conforms to MLA rules for formatting and citation of sources with minor errors.	Frequent errors in MLA format.	Lack of MLA format/ numerous errors.	
Works Cited/ Bibliography	Entries entirely correct as to MLA format.	Entries mostly correct as to MLA format.	Frequent errors in MLA format.	Lack of MLA format/ numerous errors.	
TOTAL				**Out of 28:**	

Lesson 4A Teacher's Notes

Author

- Amy Heemsoth, Khaled bin Sultan Living Oceans Foundation

Learning Objectives

- Use a dichotomous key to classify organisms.
- Classify organisms based on their physical characteristics.

Keywords

- Classification
- Dichotomous Key
- Taxonomy

Materials

- **Appendix A: Sea Star Photos**
- **Appendix B: Sea Star Dichotomous Key**
- **Watch It! Naming Nature** student worksheet
- **Lesson 4A: The Key to ID** student worksheet

Resource

- Humann, P. & DeLoach, N. (2010). *Reef Creature Identification: Tropical Pacific*. New World Publications.

Standards

- CCSS: RST.9-10.4, 5; RST.11-12.4
- NGSS: HS-LS4-1
- OLP: 4.B.1, 5.C.22

Procedure

1. Watch *Naming Nature* YouTube video (*https://youtu.be/5h5nSivm1KI*) and answer questions on **Watch It! Naming Nature** student worksheet.
2. Teach *Unit 2: Classification - Background Information*.
3. Before beginning the activity, you may want to print dichotomous keys and sea star photos (found in **Appendix A** and **B**) and laminate them, so that they can be used again. The sea star photos will need to be printed in color in order to correctly identify them.
4. Hand out **Lesson 4A: The Key to ID** student worksheet.
5. Teach *Additional Background Information* on **Lesson 4A: The Key to ID** student worksheet.
6. OPTIONAL: Provide an example on how to use a dichotomous key. There are two additional photos included in this lesson plan. Use these photos as an example.
7. Ask students to use the dichotomous key to classify the sea stars in the photos.
8. Instruct students to answer questions on their worksheet using the sea star dichotomous key.

Name: ______________________ Date: __________

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LESSON 4A THE KEY TO ID

ADDITIONAL BACKGROUND INFORMATION:

What is a dichotomous key? A **dichotomous key** is a tool used to help identify unknown organisms based on a key. The key has a series of choices that leads the user to correctly identify organism(s). Dichotomous means to *cut into two*. Each series of statements consists of two choices. These statements describe different characteristics that the unknown organism may have. The person using the key must decide which statement best describes the unknown organism. Once the user chooses the statement, then they follow the directions, which will lead them to the next set of two statements. Again, the user chooses the best statement and again follows the directions leading them to another set of two statements. This process will continue until the user is left with the name that identifies the organism.

Why do scientists use dichotomous keys? Dichotomous keys help scientists to classify organisms into different taxonomic levels (kingdom, phylum, family, etc.) based off of their similar characteristics. You will now learn how to use a dichotomous key.

INSTRUCTIONS:

Scientists just got back from surveying a coral reef. They need help identifying these sea stars. Use the *Sea Star Dichotomous Key* to identify these unknown species. Write your answers in the table below. The number in the table corresponds to the number on the sea star photos.

Photo #	Sea Star Common and Scientific Name
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

INSTRUCTIONS: Answer the following questions.

1. Which sea stars are the most closely related?

2. Do you think that there are any other ways to create this dichotomous key? Provide one example.

3. Were there any species that were more difficult to identify than others? Explain.

4. Are there any disadvantages to using a dichotomous key?

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Lesson 4A The Key To ID

ADDITIONAL BACKGROUND INFORMATION:

What is a dichotomous key? A **dichotomous key** is a tool used to help identify unknown organisms based on a key. The key has a series of choices that leads the user to correctly identify organism(s). Dichotomous means to *cut into two*. Each series of statements consists of two choices. These statements describe different characteristics that the unknown organism may have. The person using the key must decide which statement best describes the unknown organism. Once the user chooses the statement, then they follow the directions, which will lead them to the next set of two statements. Again, the user chooses the best statement and again follows the directions leading them to another set of two statements. This process will continue until the user is left with the name that identifies the organism.

Why do scientists use dichotomous keys? Dichotomous keys help scientists to classify organisms into different taxonomic levels (kingdom, phylum, family, etc.) based off of their similar characteristics. You will now learn how to use a dichotomous key.

INSTRUCTIONS:

Scientists just got back from surveying a coral reef. They need help identifying these sea stars. Use the *Sea Star Dichotomous Key* to identify these unknown species. Write your answers in the table below. The number in the table corresponds to the number on the sea star photos.

Photo #	Sea Star Common and Scientific Name
1	**Granular sea star (*Choriaster granulatus*)**
2	**Indian sea star (*Fromia indica*)**
3	**Cushion star (*Culcita novaeguineae*)**
4	**Blue sea star (*Linckia laevigata*) – white**
5	**Watson's sea star (*Gomophia watsoni*)**
6	**Panamic sea star (*Pentaceraster cumingi*)**
7	**Crown-of-thorns sea star (*Acanthaster planci*)**
8	**Galapagos blue sea star (*Phataria unifascialis*)**
9	**Blue sea star (*Linckia laevigata*) – blue**
10	**Luzon sea star (*Echinaster luzonicus*)**
11	**Warty sea star (*Echinaster callosus*)**
12	**Cuming's sea star (*Neoferdina cumingi*)**

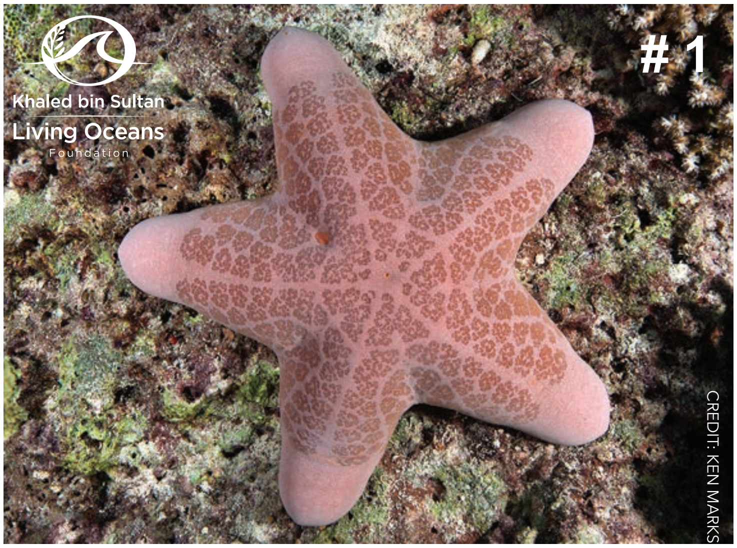
INSTRUCTIONS: Answer the following questions.

1. Which sea stars are the most closely related?
   The two blue sea stars (*Linckia laevigata*) are the most closely related. In fact, they are the same species. This might be a good time to explain to students that color is not always the best method for identifying organisms. These two sea stars are the same species, but they are able to have different color variations such as blue and white. NOTE: Students might suggest that the warty sea star (*Echinaster callosus*) and luzon sea star (*Echinaster luzonicus*) are the most closely related to each other. They are both in the same genus, *Echinaster*.

2. Do you think that there are any other ways to create this dichotomous key? Provide one example.
   Answers may vary. Yes, there are other ways to construct dichotomous keys. For example, some students may have started with the number of arms for the first set of steps. This would have completely changed the structures and steps of the dichotomous key.

3. Were there any species that were more difficult to identify than others? Explain.
   Answers may vary. Yes, the panamic sea star was difficult to identify because it was not clear if the bumps were spines or not. It was also difficult to tell if Cuming's sea star had bumps or not.

4. Are there any disadvantages to using a dichotomous key?
   Yes, there are disadvantages of using a dichotomous key. Dichotomous keys only take into account the physical characteristics of organisms. Some organisms are not easily identified by their physical characteristics and further identification is required. Second, dichotomous keys are created using a specific set of organisms. If there is a new species discovered, then the dichotomous key would have to be reconstructed to add in the new species. This can be a lot of work. Third, the scientific terminology used in dichotomous keys may not be easy to understand. Fourth, the person creating the dichotomous key may not include. a physical characteristic that is important in identifying the species. Instead, the creator uses a contrasting pair of traits that is not important to the identification of that specific organism. For example, if a scientist were to identify Watson's sea star, they would not use the blue tubercles to identify it. The color of the tubercles is actually not important. Instead, scientists would use characteristics such as tapering cylindrical arms, white undercolor with red to brown banding, and smaller tubercles than other genus members, etc.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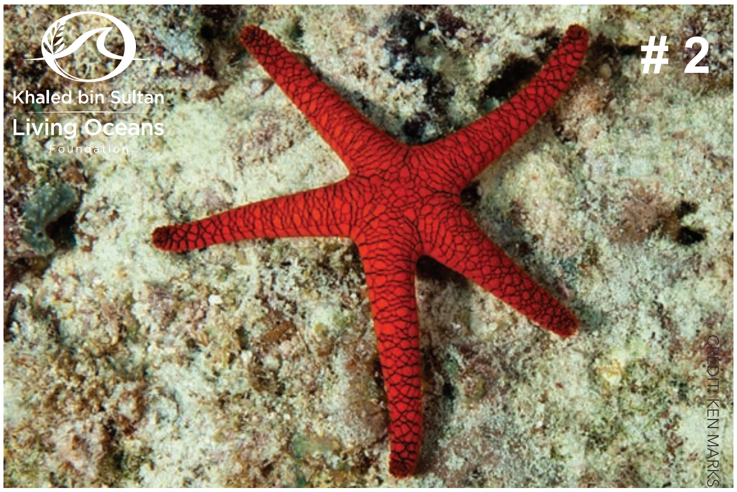
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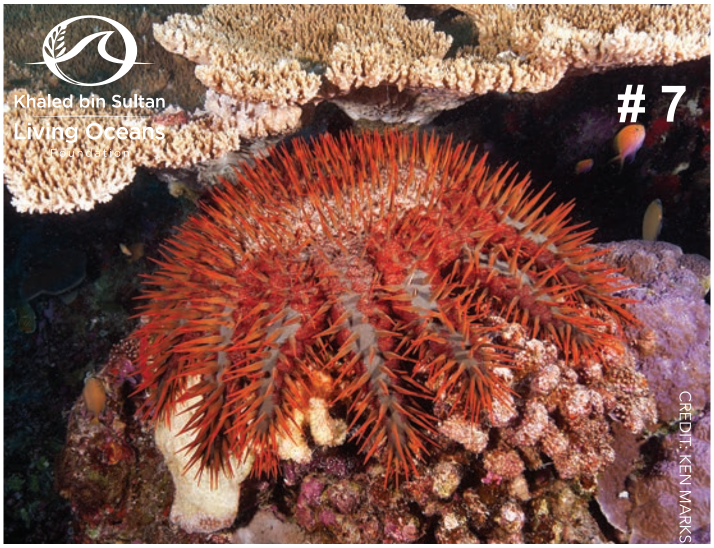
CREDIT: JOSH FEINGOLD



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CREDIT: BRIAN BECK

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CREDIT: KEN MARKS

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9
CREDIT: KEN MARKS

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#12
CREDIT: KEN MARKS

SEA STAR DICHOTOMOUS KEY:

1a	Sea star is smooth or flat.	Go to step 2.
1b	Sea star is bumpy or spiny.	Go to step 7.
2a	Sea star has five arms.	Go to step 3.
2b	Sea star has more than five arms.	Lazon sea star (*Echinaster luzonicus*)
3a	Sea star has thin arms.	Go to step 4.
3b	Sea star has thick, short arms.	Granular sea star (*Choriaster granulatus*)
4a	Sea star has lines.	Go to step 5.
4b	Sea star does not have lines.	Go to step 6.
5a	Sea star has long blue lines down arms.	Galapagos blue sea star (*Phataria unifascialis*)
5b	Sea star has black lines in circle-like pattern.	Indian sea star (*Fromia indica*)
6a	Sea star is blue with cobblestone texture.	Blue sea star (*Linckia laevigata*) – blue
6b	Sea star is white.	Blue sea star (*Linckia laevigata*) – white
7a	Sea star has spines.	Go to step 8.
7b	Sea star does not have spines.	Go to step 9.
8a	Sea star has five arms.	Panamic sea star (*Pentaceraster cumingi*)
8b	Sea star has more than five arms.	Crown-of-thorns sea star (*Acanthaster planci*)
9a	Sea star is inflated.	Cushion star (*Culcita novaeguineae*)
9b	Sea star is not inflated.	Go to step 10.
10a	Sea star has large and pointed tubercles.	Warty sea star (*Echinaster callosus*)
10b	Sea star has small tubercles.	Go to step 11.
11a	Sea star has small blue tubercles over entire body.	Watson's sea star (*Gomophia watsoni*)
11b	Sea star does not have blue tubercles over entire body.	Cuming's sea star (*Neoferdina cumingi*)

Lesson 4B Teacher's Notes

Author

- Amy Heemsoth, Khaled bin Sultan Living Oceans Foundation

Learning Objectives

- Classify organisms based on their physical characteristics.
- Design and construct a dichotomous key using coral photographs.
- Use a dichotomous key to classify organisms.

Keywords

- Classification
- Dichotomous Key
- Taxonomy

Materials

- Coral photographs from **Lesson 2: "Taxing" Corals**
- **Watch It! Naming Nature** student worksheet
- **Lesson 4B: Then There Was One** student worksheet

Extension

- Using the information from this activity, create a field guide and/or cladogram.

Standards

- CCSS: RST.9-10.3, 4, 5, 7; RST.11-12.3, 4
- NGSS: HS-LS4-1
- OLP: 4.B.1, 5.C.22

Procedure

1. Watch *Naming Nature* YouTube video (*https://youtu.be/5h5nSivm1KI*) and answer questions on **Watch It! Naming Nature** student worksheet.
2. Teach *Unit 2: Classification - Background Information*.
3. Handout **Lesson 4B: And Then There Was One** student worksheet.
4. Provide students with an example of how to create a dichotomous key using the steps listed on the student worksheet. Use everyday objects that you might have in your classroom or home.
5. Ask students to create a dichotomous key using the coral photographs from **Lesson 2: "Taxing" Corals**. OPTIONAL: The teacher may choose to give the students the answer key from **Lesson 2: "Taxing" Corals** so that students can use the scientific names of the corals to create the key.
6. Ask students to exchange dichotomous keys. Explain that they need to use another student's dichotomous key to identify the corals. Remind students to record their results on their worksheets.
7. Instruct students to answer the questions on their worksheets.

Name: ____________________ Date: __________

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LESSON 4B And Then There was One

INSTRUCTIONS: You will now construct your own dichotomous key.

1. Create a dichotomous key for the corals in the photographs provided by your teacher. Follow the instructions below titled *How to create a dichotomous key?*
2. Swap your dichotomous key with two other students. Use their dichotomous key to identify each of the corals. Space is provided for your answers called *Student 1 and 2 Dichotomous Key*. Make sure to include the name of each student (on the line provided) whose keys that you are using.
3. Answer the questions on your worksheet.

TIPS WHEN CREATING A DICHOTOMOUS KEY:

- Do not use characteristics that change with the seasons or are influenced by environmental factors.
- When using measurements make sure to use descriptive terms such as *3 inches* or *4 yards* and not terms that are vague such as *large* or *small* and *tall* or *short*.
- Make sure that at least one organism has the characteristic before choosing to use it in the key. Do not start off with a negative statement such as *does not have* or *is not*.

HOW TO CREATE A DICHOTOMOUS KEY:

1. Observe the photos of corals. Think about how you can group each coral together. Only use observable traits. Brainstorm your ideas in the box provided called *Brainstorm Characteristics*.
2. Create a *yes or no flow chart* as demonstrated by your teacher in class. A box is provided for your answers called *Yes or No Flow Chart*.
   a. In order to create the *yes or no flow chart,* Choose two characteristics that are very broad. Divide the corals into each category. Let's refer to this as *division 1*. NOTE: You want to be able to divide the corals into almost two even groups. Make sure to look at all of the characteristics before creating the *yes or no flow chart*.
   b. Choose a new category to divide corals from division 1. Divide the corals into each category. This process will continue until you are left with the name that identifies the organism. If you do not have the scientific name use the title (e.g. FP 03, FP 10, etc.).
3. Use the *yes or no flow chart* to create your dichotomous key. You may want to use a piece of scrap paper. Then transfer your answers to the worksheet. Place your final key in the area titled *Dichotomous Key*.
   NOTE: To determine how many steps are needed in the dichotomous key, count the number of organisms that you identify. Then subtract 1. In this activity, we are identifying 10 corals. Ten minus one is nine. You will create a sequence of 9 steps. Again, there will be two choices for each step (a and b).
4. When creating the dichotomous key, make sure to write out all of the steps to the first question (1a) until you reach the identification of your first coral.
5. Then go back to the first place where the division stopped after step 1a. In many cases, this will probably be step 2b.
6. Continue to create step 1a before starting to key out step 1b.
7. Once you have created the key for 1a, repeat the same steps for 1b corals.

BRAINSTORM CHARACTERISTICS:

YES OR NO FLOW CHART:

DICHOTOMOUS KEY:

1a		
1b		
2a		
2b		
3a		
3b		
4a		
4b		
5a		
5b		
6a		
6b		
7a		
7b		
8a		
8b		
9a		
9b		

STUDENT 1 DICHOTOMOUS KEY
STUDENT'S NAME: ______________________________________

Photo #	Coral ID or Species Name
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

STUDENT 2 DICHOTOMOUS KEY
STUDENT'S NAME: ______________________________________

Photo #	Coral ID or Species Name
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

INSTRUCTIONS: Answer the following questions.

1. Did other students come up with the same dichotomous keys? Provide an example of any step that was the same.

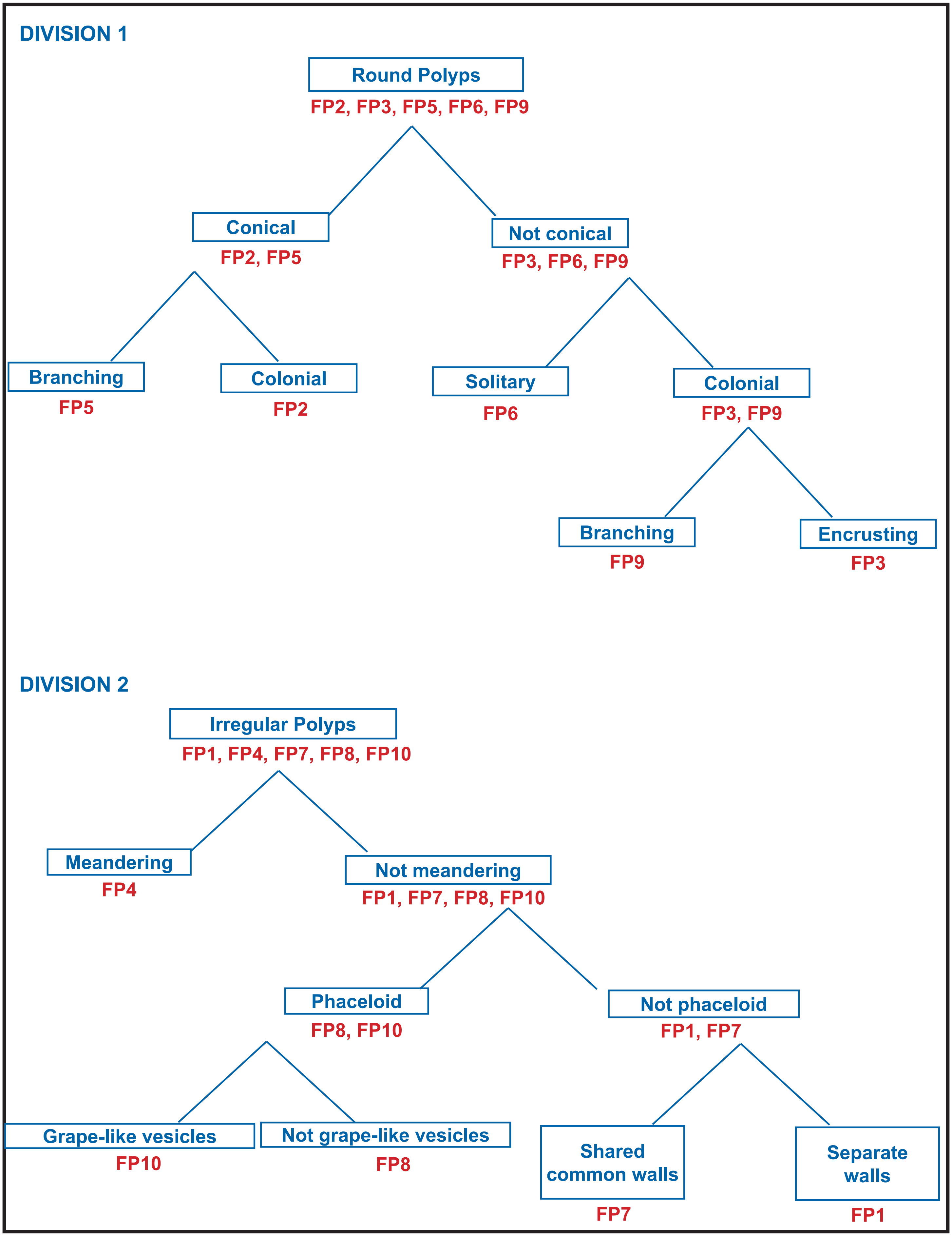
2. Did other students come up with different dichotomous keys? Provide an example of any step that was different.

3. After completing this activity, do you think that there are multiple ways to construct dichotomous keys? Is your key better than other students' keys that differed?

4. Why is it important for field scientists to correctly classify organisms?

5. Dichotomous keys are based on physical characteristics of an organism. Do you think that classification systems that use genetics to classify organisms are more accurate than using a dichotomous key? Explain your answer.

YES OR NO FLOW CHART:



DICHOTOMOUS KEY: Answers may vary.

1a	The individual polyp is round.	Go to Step 2.
1b	The individual polyp has an irregular shape.	Go to Step 6.
2a	The polyp has a conical shape.	Go to step 3.
2b	The polyp is not conical in shape.	Go to step 4.
3a	The coral is branching.	FP 05
3b	The coral is foliose.	FP 02
4a	The coral is solitary.	FP 06
4b	The coral is colonial.	Go to step 5.
5a	The coral is branching.	FP 09
5b	The coral is encrusting.	FP 03
6a	Coral has meandering valleys.	FP 04
6b	Coral does not have meandering valleys.	Go to step 7.
7a	The coral is phaceloid.	Go to step 8.
7b	The coral is not phaceloid.	Go to step 9.
8a	The coral has grape-like vesicles.	FP 10
8b	The coral does not have grape-like vesicles.	FP 08
9a	The polyps have shared common walls.	FP 07
9b	The polyps have separate walls.	FP 01

INSTRUCTIONS: Answer the following questions. **Answers may vary.**

1. Did other students come up with the same dichotomous keys? Provide an example of any step that was the same.
   John and I both divided corals as being solitary and colonial.

2. Did other students come up with different dichotomous keys? Provide an example of any step that was different.
   John did not have a step that classified corals as having meandering valleys.

3. After completing this activity, do you think that there are multiple ways to construct dichotomous keys? Is your key better than other students' keys that differed?
   Yes, there are different ways to construct a dichotomous key. I learned that there is not one way to construct a key that is right or wrong. Other students had different ways of thinking than I did, which is why they came up with a different dichotomous key. However, even though our keys were different, we were still able to identify the corals correctly. Sometimes there were steps on other students' dichotomous keys that were more difficult to identify then mine because the other student had more knowledge about corals then I did. This is another reason why students can have such differences in their keys.

4. Why is it important for field scientists to correctly classify organisms?
   There are many reasons why it's important for field scientist to correctly classify organisms. For instance, scientists studying ecosystems need to know what organisms are present so that they can get an idea of the processes that are controlling that ecosystem, the amount of biomass present, and food web dynamics. For instance, in large numbers, the crown-of-thorns sea star can be very destructive to a coral reef because they eat corals. If a scientist were to misidentify the animal, then they may not realize that this is the organism causing mass destruction on the coral reef. This means that the scientist would possibly not be able to identify the problem or they could blame the problem on a different organism or a natural process. If this happened then it's possible that scientists could remove the wrong animal from the ecosystem and the sea stars would continue to damage the corals. This is, of course, a general example; however, you can understand the importance of correctly identifying organisms.

5. Dichotomous keys are based on physical characteristics of an organism. Do you think that classification systems that use genetics to classify organisms are more accurate than using a dichotomous key? Explain your answer.
   We learned that modern classification is not only based on the organisms' physical characteristics, but also their evolutionary history. This includes their genetic makeup. Yes, I believe that including an organism's genetic makeup is more accurate than only using a dichotomous key. Some organisms are misclassified when only using their physical characteristics to determine their classification. For example, the black marlin was classified as *Makaira indica* and later reclassified as *Isiompax indica*. By figuring out the genetics of this animal, scientists figured out that the black marlin is actually more closely related to the striped or white marlin, than to the blue marlin, which is why it was reclassified.

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Lesson 5 Teacher's Notes

Author

- Amy Heemsoth, Khaled bin Sultan Living Oceans Foundation

Learning Objective

- Construct a cladogram.

Keywords

- Clade
- Cladogram
- Classification

Materials

- Internet and/or library
- **Watch It! Naming Nature** student worksheet
- **Lesson 5: Cladograms 1** or **Cladograms 2** student worksheet

Standards

- CCSS: RST.9-10.4, 5, 7; RST.11-12.4
- NGSS: HS-LS4-1
- OLP: 4.B.1, 4.B.2, 5.C.22

Procedure

1. Watch *Naming Nature* YouTube video (https://youtu.be/5h5nSivm1KI) and answer questions on **Watch It! Naming Nature** student worksheet.
2. Teach *Unit 2: Classification - Background Information*.
3. There are two worksheet options:
   a. **Lesson 5: Cladograms 1** student worksheet. This worksheet is more challenging. Students must come up with their own set of shared characters.
   b. **Lesson 5: Cladograms 2** student worksheet. Students are already provided with shared characters.
4. Students will need access to the internet and/or library.
5. See *Background Information*: *Understanding Cladograms* for a procedure on how to make cladograms.

Name: ______________________ Date: ____________

LESSON 5 CLADOGRAMS 1

INSTRUCTIONS:

1. Figure out the shared characters of the organisms in the chart.
2. Mark an 'X' in the boxes when the organism shares that characteristic.

Characters	Butterflyfish	Coral	Flatworm	Nudibranch	Sea Star	Sea Turtle	Shark	Sponge

3. Draw a cladogram based on the results from the chart. Make sure to include the organism's name and the shared characters.

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LESSON 5 CLADOGRAMS 2

INSTRUCTIONS:

1. Mark an ‘X’ in the boxes when the organism shares that characteristic.

Characters	Butterflyfish	Coral	Flatworm	Nudibranch	Sea Star	Sea Turtle	Shark	Sponge
Cartilaginous Skeleton								
Deuterostome Development								
Multicellular								
Symmetrical								
Triploblastic								
True Coelom								
Use Gills to Breathe								
Vertebrate								

2. Draw a cladogram based on the results from the chart. Make sure to include the organism’s name and the shared characters.

INSTRUCTIONS: Answer the following questions based on the cladogram that you drew.

1. How many traits do sea turtles and sharks have in common? ______________________

2. What organism evolved before nudibranchs? ______________________

3. What organism evolved after sea stars? ______________________

4. In which organism did a true coelom begin to develop? ______________________

5. Which characteristic evolved first? ______________________

6. Which organism(s) have a deuterostome? ______________________

7. Which organism(s) have a true coelom and gills? ______________________

8. Are corals more closely related to sponges or flatworms? Explain:

   ____

   ____

9. Are there characteristics that all of these organisms share? If so, which one(s)?

   ____

   ____

10. Which organisms are most distantly related? ______________________

11. You discovered a new organism that has these characteristics: multi-cellular, symmetrical, triploblastic, but does not have a true coelom or deuterostome. Where would you place the organism in your cladogram?

    ____

    ____

12. Describe three pieces of information that you can obtain from a cladogram.

    ____

    ____

    ____

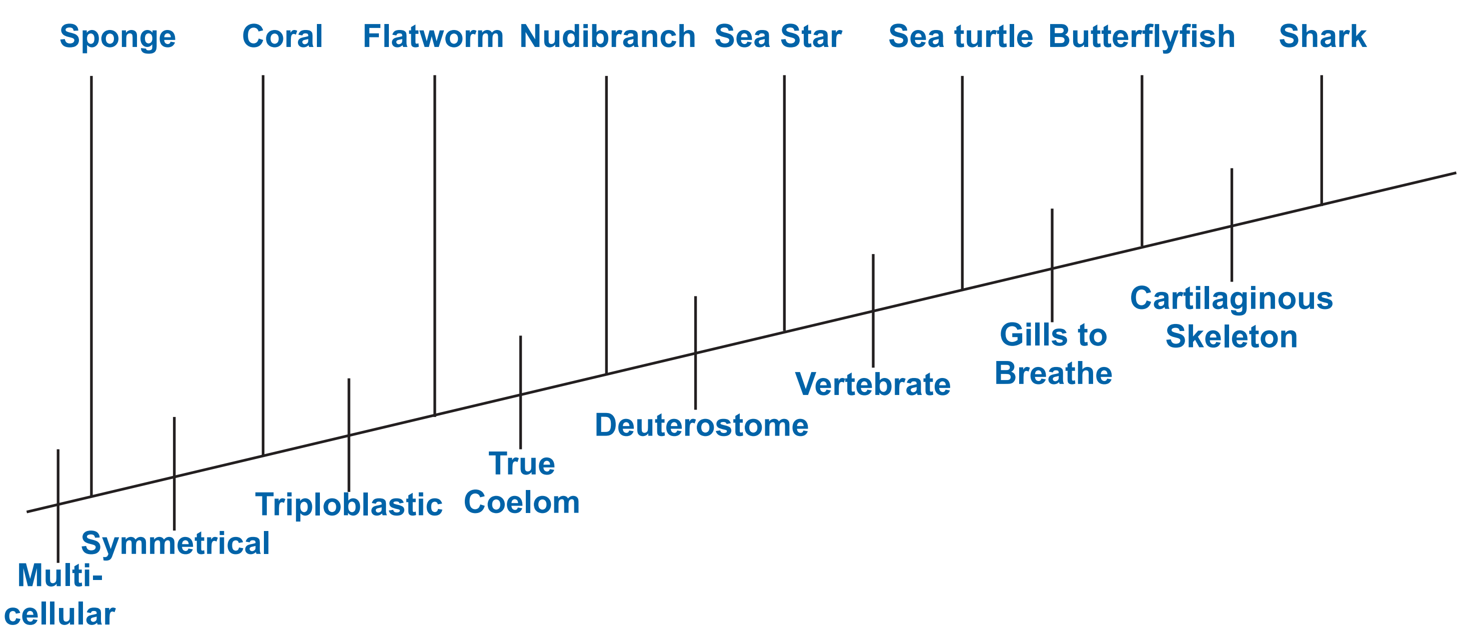
Lesson 5 Cladograms 1 & 2

INSTRUCTIONS:

1. Mark an ‘X’ in the boxes when the organism shares that characteristic.

Characters	Butterflyfish	Coral	Flatworm	Nudibranch	Sea Star	Sea Turtle	Shark	Sponge
Cartilaginous Skeleton							X	
Deuterostome Development	X				X	X	X	
Multicellular	X	X	X	X	X	X	X	X
Symmetrical	X	X	X	X	X	X	X	
Triploblastic	X		X	X	X	X	X	
True Coelom	X			X	X	X	X	
Use Gills to Breathe	X						X	
Vertebrate	X					X	X	

2. Draw a cladogram based on the results from the chart. Make sure to include the organism’s name and the shared characters.



INSTRUCTIONS: Answer the following questions based on the cladogram that you drew.

1. How many traits do sea turtles and sharks have in common? **6**

2. What organism evolved before nudibranchs? **Flatworm**

3. What organism evolved after sea stars? **Sea turtle**

4. In which organism did a true coelom begin to develop? **Nudibranch**

5. Which characteristic evolved first? **Multicellular**

6. Which organism(s) have a deuterostome? **Sea star, sea turtle, butterflyfish, shark**

7. Which organism(s) have a true coelom and gills? **Butterflyfish, shark**

8. Are corals more closely related to sponges or flatworms? Explain:

   Flatworms because corals and flatworms have two characteristics in common. Sponges and corals only have one characteristic in common

9. Are there characteristics that all of these organisms share? If so, which one(s)?

   Yes, all of the organisms are multicellular.

10. Which organisms are most distantly related? **Sponges and sharks**

11. You discovered a new organism that has these characteristics: multi-cellular, symmetrical, triploblastic, but does not have a true coelom or deuterostome. Where would you place the organism in your cladogram?

    This organism would branch from the flatworm because it has the same characteristics as the flatworm

12. Describe three pieces of information that you can obtain from a cladogram.
    - **Shared characteristics**
    - **Probable relationships**
    - **Probable sequence of origins**
    - **Number of shared characteristics between organisms**
    - **Closest evolutionary relationship; furthest evolutionary relationship**

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READ IT! Teacher's Notes

AUTHOR

- Melinda Campbell, Khaled bin Sultan Living Oceans Foundation

LEARNING OBJECTIVES

- Read, interpret, and comprehend a blog.
- Determine how to responsibly use the internet for collecting and responding to information.

MATERIALS

- Internet access
- *Troubling Taxonomy* blog (http://www.lof.org/troubling-coral-taxonomy/)
- **Read It! Troubling Taxonomy** student worksheet

INTEGRATING SUBJECTS

- English Language Arts

PRIOR KNOWLEDGE

- Students will have prior knowledge about bias and how to critique the validity of websites.

STANDARDS

- CCSS: RST.9-10.1, 2, 4, 5, 8, 10; RST.11-12.1, 2, 4, 10
- NGSS Practices: 6, 7, 8

PROCEDURE

1. Have students read *Troubling Taxonomy* blog (http://www.lof.org/troubling-coral-taxonomy/).
2. While reading, instruct students to take notes, connecting the information to their prior knowledge. They can note things that they agree and disagree with. A space, called *Notes*, is provided for this on the **Read It! Troubling Taxonomy** student worksheet.
3. Ask students to analyze the blog to determine the elements (like tone or visual design) and content that they like and dislike. Remind students to explain why they like or dislike each element they mention. There is also a space provided for these answers on the student worksheet.
4. Have students answer the questions on their worksheet. When they are looking for definitions, they should use the context from the blog, our glossary, or other online resources. You may want to set rules distinguishing other websites or resources that they are allowed to access.
5. If you set up an online community for your class, have the students post their comment(s) from the last question and allow them to respond to each other. If you do not have an online community, have the students share their comment(s) with each other, either orally or by passing their written responses around the classroom.

Name: ______________________________ Date: ______________

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READ IT! Troubling Taxonomy

INSTRUCTIONS:

1. Read *Troubling Taxonomy*, a blog from our Palau mission (*http://www.lof.org/troubling-coral-taxonomy/*).
2. While reading the blog, take notes and connect it to your prior learning. Note things that you agree or disagree with. There is a space, below, for this.
3. Next, document what you like and dislike about this blog in the space below. Be sure to pay attention to things like style and tone, along with the content and visual design. Be sure to *explain* what it is that you do or do not like about each element.
4. Answer the questions.

NOTES

LIKES	DISLIKES

1. What is the central idea of this blog?

2. How did scientists previously classify coral? Why has this been changed? Cite specific textual evidence to support this.

3. How does your answer to #2, above, impact the work of the scientist who wrote the blog?

4. Did the author fully support his claim? Explain why you think this.

5. *Corallite*, *intra/extratentacular budding*, and *septa* are specific vocabulary for the topic of this blog. Define them below.

6. Write a sentence of your own creation that connects the three words from #5, above.

7. Is this blog a reliable source for scientific information? Why or why not?

8. Do you notice any bias in this writing? If so, what?

9. Describe three things that you learned while reading this blog entry (they do not have to relate to the central idea).

10. Construct a comment to post in response to this blog. Remember that a good comment makes connections, asks a question, or gives an opinion in a respectful manner. You might want to quote the part of the blog that you are specifically referring to. Don't be afraid to disagree with another writer, but be sure to explain yourself and remain polite.

1. What is the central idea of this blog?

   Corals are difficult to identify because there are hundreds of corals. Their classification has changed from advances in genetics, and individuals of the same species can have different growth forms.

2. How did scientists previously classify coral? Why has this been changed? Cite specific textual evidence to support this.

   Corals used to be classified by their morphology, but scientists have proved through genetic studies that many of these were inaccurate, so the classification has been rearranged. Students should have specific quotes to back up this claim, which may vary, but might include the following:

   - **"…coral nomenclature is in a state of flux…"**
   - **"Traditionally, species were described and named based on morphology…"**
   - **"With new genetic tools, we've learned that many of the corals placed in certain families are actually more closely related to other families."**
   - **"…growth form is not necessarily a feature that can be used to distinguish a species…"**

3. How does your answer to #2, above, impact the work of the scientist who wrote the blog?

   The scientists have to be sure to accurately document the organisms during a dive and spend a lot of time at the end of the day examining evidence, so they can identify the corals they surveyed.

4. Did the author fully support his claim? Explain why you think this.

   Answers may vary. Be sure they explain their reasoning.

5. *Corallite*, *intra/extratentacular budding*, and *septa* are specific vocabulary for the topic of this blog. Define them below.

   - **Corallite: cup-like skeleton of an individual polyp.**
   - **Intra/extratentacular budding: types of asexual reproduction where a parent polyp pinches off to form a new individual. Intratentacular is where a bud forms from the parent polyp's oral disk, producing same-sized polyps within the ring of tentacles. Extratentacular is where a bud forms outside the parent polyp's ring of tentacles, producing a smaller polyp.**
   - **Septa: radial skeletal elements projecting inwards from the corallite wall that support the inner folds called the mesenteries.**

6. Write a sentence of your own creation that connects the three words from #5, above.

   During *intratentacular budding*, a new coral polyp is produced in the same *corallite*, with the same *septa*, as the original polyp.

7. Is this blog a reliable source for scientific information? Why or why not?

   Yes. This is a first-hand account of what the author has seen. It is from a reputable organization that is based on scientific research. It also links you to the author's credentials.

8. Do you notice any bias in this writing? If so, what?

   Answers may vary, but should mention that this scientist is writing about a difficult part of his job.

9. Describe three things that you learned while reading this blog entry (they do not have to relate to the central idea).

   Answers may vary.

10. Construct a comment to post in response to this blog. Remember that a good comment makes connections, asks a question, or gives an opinion in a respectful manner. You might want to quote the part of the blog that you are specifically referring to. Don't be afraid to disagree with another writer, but be sure to explain yourself and remain polite.

    Answers may vary.

Khaled bin Sultan Living Oceans Foundation

READ IT! Teacher's Notes

Author

- Melinda Campbell, Khaled bin Sultan Living Oceans Foundation

Learning Objectives

- Read, interpret, and comprehend a blog.
- Determine how to responsibly use the internet for collecting and responding to information.

Materials

- Internet access
- *Blue, You Say?* blog (http://www.lof.org/blue-coral/)
- **Read It! Blue, You Say?** student worksheet

Integrating Subjects

- English Language Arts

Prior Knowledge

- Students will have prior knowledge about bias and how to critique the validity of websites.

Standards

- **CCSS**: RST.9-10.1, 2, 4, 5, 8, 9, 10; RST.11-12.1, 2, 4, 8, 10
- **NGSS Practices**: 6, 7, 8

Procedure

1. Have students read *Blue, You Say?* blog (http://www.lof.org/blue-coral/).
2. While reading, instruct students to take notes, connecting the information to their prior knowledge. They can note things that they agree and disagree with. A space, called *Notes*, is provided for this on the **Read It! Blue, You Say?** student worksheet.
3. Ask students to analyze the blog to determine the elements (like tone or visual design) and content that they like and dislike. Remind students to explain why they like or dislike each element they mention. There is also a space provided for these answers on the student worksheet.
4. Have students answer the questions on their worksheet. When they are looking for definitions, they should use the context from the blog, our glossary, or other online resources. You may want to set rules distinguishing other websites or resources that they are allowed to access.
5. If you set up an online community for your class, have the students post their comment(s) from the last question and allow them to respond to each other. If you do not have an online community, have the students share their comment(s) with each other, either orally or by passing their written responses around the classroom.

Name: ____________________ Date: __________

Khaled bin Sultan Living Oceans Foundation

READ IT! BLUE, YOU SAY?

INSTRUCTIONS:

1. Read *Blue, You Say?*, a blog from our Palau mission (http://www.lof.org/blue-coral/).
2. While reading the blog, take notes and connect it to your prior learning. Note things that you agree or disagree with. There is a space, below, for this.
3. Next, document what you like and dislike about this blog in the space below. Be sure to pay attention to things like style and tone, along with the content and visual design. Be sure to *explain* what it is that you do or do not like about each element.
4. Answer the questions.

NOTES

LIKES	DISLIKES

1. What is the central idea of this blog?

2. What are the mystery corals that the author found during this dive? Cite specific textual evidence to support this.

3. Did the author fully support his identification? Explain why you think this.

4. *Taxonomically*, *living fossil*, and *overexploitation* are specific vocabulary for the topic of this blog. Define them below.

5. Write a sentence of your own creation that connects the three words from #4, above.

6. Is this blog a reliable source for scientific information? Why or why not?

7. Do you notice any bias in this writing? If so, what?

8. Compare and contrast the information on Blue Coral in this blog to what you have learned about the anatomy of other soft corals (octocorals) and hard corals (hexacorals).

9. Describe three things that you learned while reading this blog entry (they do not have to relate to the central idea).

10. Construct a comment to post in response to this blog. Remember that a good comment makes connections, asks a question, or gives an opinion in a respectful manner. You might want to quote the part of the blog that you are specifically referring to. Don't be afraid to disagree with another writer, but be sure to explain yourself and remain polite.

1. What is the central idea of this blog?

   Blue Coral is different from other soft corals and comes in many shapes and colors.

2. What are the mystery corals that the author found during this dive? Cite specific textual evidence to support this.

   All of the mystery corals are Blue Coral. Students should have specific quotes to back up this claim, which may vary but might include the following:

   - **"…extract iron from the surrounding seawater which it forms into a blue salt which is incorporated into its skeleton, turning it a sky blue color…"**
   - **"…it is the only octocoral known to produce a massive skeleton…"**
   - **"…shows only faint hints at the tips of the underlying blue skeleton…"**

3. Did the author fully support his identification? Explain why you think this.

   Answers may vary.

4. *Taxonomically*, *living fossil*, and *overexploitation* are specific vocabulary for the topic of this blog. Define them below.

   - **Taxonomically: the science of classifying organisms based off of shared characteristics.**
   - **Living fossil: an organism that still exists today which is also found in the fossil record.**
   - **Overexploitation: Removing too many of an organism so that it cannot maintain its population.**

5. Write a sentence of your own creation that connects the three words from #4, above.

   Blue Coral is a soft coral *taxonomically* speaking, although it produces a hard skeleton, it is a *living fossil* that is at risk of *overexploitation*.

6. Is this blog a reliable source for scientific information? Why or why not?

   Yes. This is a first-hand account of what the author has seen. It is from a reputable organization that is based on scientific research. It also links you to the author's credentials.

7. Do you notice any bias in this writing? If so, what?

   Answers may vary, but should mention the author works with conservation scientists.

8. Compare and contrast the information on Blue Coral in this blog to what you have learned about the anatomy of other soft corals (octocorals) and hard corals (hexacorals).

   Answers may include some or all of the following:

Soft Corals	Both Octocorals	Blue Coral	All Corals	Hard Corals
• Lack a hard skeleton • Sclerites	• 8 tentacles	• Hard skeleton made of aragonite	• Made of polyps	• Hard skeleton made of calcium carbonate • 6 tentacles

9. Describe three things that you learned while reading this blog entry (they do not have to relate to the central idea).
   Answers may vary.

10. Construct a comment to post in response to this blog. Remember that a good comment makes connections, asks a question, or gives an opinion in a respectful manner. You might want to quote the part of the blog that you are specifically referring to. Don't be afraid to disagree with another writer, but be sure to explain yourself and remain polite.
    Answers may vary.

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.

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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.