Student Name:

Class:

Biodiversity in the Coral Reefs

Expert Pack: Grades 9-10

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The Table of Contents lists of the texts *in order of their suggested reading*, including text complexity information and a brief synopsis of the text.

A note on complexity analysis: The expert packs were created using both quantitative and qualitative considerations. The Reading Maturity Metric was used to calculate the quantitative analysis, including the CCSS grade band ratings. The CCSO rubric for informational texts was used to conduct the qualitative assessments and ratings align to the CCSSO rubric.

- Reading Maturity Metric: http://www.readingmaturity.com/rmm-web/#/
- CCSSO Rubric: included at the end of the Table of Contents

http://www.conserve-energy-future.com/top-25-coral-reef-facts.php	text accessible, and labeled facts support ease of navigation Language: Very Complex. Where discipline-specific word are used, they are often not able to be determined in context Knowledge Demands: Moderately Complex... Some discipline-specific knowledge would support comprehension, but not necessarily limit it.	
Text 3: Coral Polyps – Tiny Builders Author: Coral reef Alliance Genre: Scientific Diagram and Informational Description Cost/Access: $0.00 Link: http://coral.org/coral-reefs-101/coral-reef-ecology/coral-polyps/	**Quantitative: N/A** RMM: 8.1 CCSS: 6-8 Dale Chall: 10.74 Flesch-Kincaid 10.7 **Qualitative:** Purpose: Explicit Structure: Very Complex... Graphics essential to understanding the content Language: Very Complex... Diagram labeled with technical names of polyp structure, though accompanying article directly supports comprehension Knowledge Demands: Moderately Complex... Text provides new knowledge; prior knowledge would support understanding.	Diagram of a polyp, accompanied by a description of the structure and habits of the polyp, including the source of its beautiful colors.
Text 4: Corals Dine on Microplastics Author: Alison Pearce Stevens Genre: Informational news Article Cost/Access: $0.00 Link: https://student.societyforscience.org/article/corals-	**Quantitative:** RMM 8.2 CCSS 6-8 Dale Chall 10.34 Flesch-Kincaid 7.6 "Corals Dine On Microplastics" **Qualitative:** Purpose: Moderately Complex... While the topic is explicit, the text contains a wide-ranging amount of information, indicating multiple purposes, including conservation, scientific research, and offerings of counter claims.	A new scientific study show the polyps on the coral reef eating plastic at the same rate as other food in the water, raising concerns about the long term health and growth of the reef.

dine-microplastics	Structure: Moderately Complex. Subheading support organization and connections between concepts are complex but relatively explicit Language: Very Complex. Language is contemporary, but text contains occasional discipline specific Tier 3 vocabulary Knowledge Demands: Moderately Complex. Practical knowledge is sufficient but some domain-specific knowledge is helpful; implied references to other studies	
Text 5: Coral Reef Biodiversity Author: Coral Reef Alliance Genre: Informational Article Cost/Access: $0.00 Link: http://coral.org/coral-reefs-101/coral-reef-ecology/coral-reef-biodiversity/	**Quantitative:** RMM: 9.7 CCSS: 9-12 Dale Chall: 11.19 Flesch-Kincaid 12.1 **Qualitative:** Purpose: Moderately Complex... Easily determined with careful reading. Structure: Moderately Complex. Semi-explicit connections between ideas; no subheadings or graphics to support connections Language: Moderately Complex. Some strong academic language, as well as domain-specific words necessary to comprehension Knowledge Demands: Moderately Complex. Some discipline-specific knowledge would support comprehension.	An explanation of biodiversity, with examples from the reef.
Text 6: Coral and Coral Reefs Author: The Ocean Portal Team; reviewed by Nancy Knowlton, Smithsonian Genre: Scientific Article	**Quantitative:** RMM: 9.3 CCSS 6-10 Dale Chall: 10.9 Flesch-Kincaid: 10.5 **Qualitative:**	A detailed look at the make-up, reproduction, and threats to coral reefs.

Cost/Access: $0.00 Link: http://ocean.si.edu/corals-and-coral-reefs	Purpose: Slightly Complex... Explicit purpose of informing about coral reefs. Structure: Moderately Complex. Text features and graphics support but are not essential to understanding; somewhat complex organization supported by subheadings. Language: Very Complex. Wide range of Tier 2 and domain-specific vocabulary, some of which cannot be inferred from context. Knowledge Demands: Moderately Complex. Some discipline-specific knowledge would support comprehension, but not necessarily limit it.	
Text 7: Bizarre and Beautiful Coral Reef Animals Author: The Smithsonian Ocean Initiative Genre: Website with text and graphics Cost/Access: $0.00 Link: http://ocean.si.edu/slideshow/bizarre-and-beautiful-coral-reef-animals	**Quantitative:** RMM: 9.6 CCSS: 9-10 Dale Chall: 11.02 Flesch-Kincaid 12 **Qualitative:** Purpose: Slightly Complex... Explicit. Structure: Very Complex Feature and graphics essential to understanding the accompanying text. Language: Very Complex. Includes Latin terms and references to specific geographical locations, though sentences structure is clear and accessible. Knowledge Demands: Moderately Complex. Some discipline-specific knowledge would support comprehension, but not necessarily limit it.	Website of photographs and descriptions of the various animals that live on the reef. Slideshow includes links to other information about coral reefs – students should feel free to explore these links as well!

Text 8: The Great Barrier Reef Food Chain Author: GreatBarrierReef.co,.au Genre: Diagram Cost/Access: $0.00 Link: http://www.greatbarrierreef.com.au/information/great-barrier-reef-food-web/	**Quantitative: N/A** **Qualitative:** Purpose: Slightly Complex. Explicit Structure: Very Complex. Graphics essential to understanding the content Language: Moderately Complex. Animal names should be more familiar after exploring previous website Knowledge Demands: Very Complex. Knowledge of food chains, and biodiversity, important to understanding the food chain.	Diagram of the food chain of the Great Barrier Reef
Text 9: Why Are Coral Reefs Important? Author: Jessica Carilli Genre: Informational Article Cost/Access: 0.00 http://coralreefsystems.org/content/value-corals	**Quantitative:** RMM 10.6 CCSS: 9-12 Dale Chall: 12.5 Flesch Kincaid: 19.9 **Qualitative:** Purpose: Slightly Complex. The purpose is clearly stated in the title and all information supports the stated purpose Structure: Slightly Complex. Text features support but are not essential, and the organization is very clear Language: Very Complex. Vocabulary and sentence structure is advanced; use of the provided glossary is recommended. Knowledge Demands: Moderately complex. Working knowledge of coral reefs is necessary for access.	Students learn, briefly, why the coral reefs are so important to humans and to the earth. Sentence length and vocabulary may inhibit readers, but the organization and content of the short text is accessible and explicit.
Text 10: Status of and Threat to Coral Reefs Author: International Coral Reef Initiative (ICRI) Genre: Informational Article	**Quantitative: N/A** RMM: 11 CCSS: 9-12 Dale Chall: 12.09 Flesch-Kincaid 12.3	The article describes the threats to coral reefs, both natural and generated by humans. While

Cost/Access: $0.00 Link: http://www.icriforum.org/about-coral-reefs/status-and-threat-coral-reefs	**Qualitative:** Purpose: Slightly Complex. Explicitly state in title and content Structure: Moderately Complex. Concepts broken into clear categories with explicit connections. Language: Very Complex. Contains some academic language that may be unfamiliar; sentence length and structure makes text more readable. Knowledge Demands: Moderately Complex. Some knowledge about economic development and tourism may support understanding, but is not essential.	the most challenging text in the pack, it is very readable, and students will gain a ton of knowledge already supported by what they have read.
Text 11: Crabs Play Defense, Save Corals Author: Sarah Zielinski Genre: Informational News Article Cost/Access: $0.00 Link: https://student.societyforscience.org/article/crabs-play-defense-save-corals	**Quantitative:** RMM 9.3 CCSS 6-10 Dale Chall 10.96 Flesch-Kincaid 7.7 **Qualitative:** Purpose: Slightly Complex. Purpose of the article is explicitly stated in the title and content Structure: Moderately Complex. Connections between ideas are not supported by subheadings or other text features; connections between ideas not always explicit Language: Moderately Complex. Sentence structure is straight-forward; article contains a wide range of domain-specific vocabulary Knowledge Demands: Moderately Complex Practical knowledge is sufficient but some domain-specific knowledge is helpful; references to specific scientific terms may inhibit comprehension	In a fascinating display of mutualism, crabs defend their coral reef homes from invasive species.

Text 12: What You Can Do Author: NOAA Genre: Informational Article Cost/Access: 0.00 http://coralreef.noaa.gov/getinvolved/whatyoucando/	**Quantitative:** RMM 10.6 CCSS: 9-12 Dale Chall: 12.5 Flesch Kincaid: 19.9 **Qualitative:** Purpose: Slightly Complex. The purpose is clearly stated Structure: Slightly Complex. Text features support but are not essential, and the organization is very clear Language: Moderately Complex. Some academic vocabulary; sentence structure is accessible Knowledge Demands: Moderately complex. Working knowledge of coral reefs is necessary for access.	This articles from the NOAA explain what everyone can do to contribute to the preservation of the coral reef.

EXTENDED READING AND LEARNING	
Extended Reading, Text 1: Threatened Coral Get Fishy Rescue Author: Stephen Ornes Genre: Informational News Article Cost/Access: $0.00 Link: https://student.societyforscience.org/article/threatened-coral-get-fishy-rescue	Gobi fish respond to coral sending out SOS in the water when invasive seaweed attacks!
Extended Reading, Text 2: BBC HD Great Barrier Reef: Nature's Miracle Author: BBC Genre: Documentary Video Cost/Access: $0.00 Link: https://www.youtube.com/watch?v=AK1sfx3iGbA	Hour long video on the coral reefs, beautifully shot and well-narrated

Text Complexity: Qualitative Measures Rubric

INFORMATIONAL TEXTS

Text Title_____ Text Author_____

	Exceedingly Complex	Very Complex	Moderately Complex	Slightly Complex
TEXT STRUCTURE	○ **Organization:** Connections between an extensive range of ideas, processes or events are deep, intricate and often ambiguous; organization is intricate or discipline-specific ○ **Text Features**: If used, are essential in understanding content ○ **Use of Graphics:** If used, intricate, extensive graphics, tables, charts, etc., are extensive are integral to making meaning of the text; may provide information not otherwise conveyed in the text	○ **Organization:** Connections between an expanded range ideas, processes or events are often implicit or subtle; organization may contain multiple pathways or exhibit some discipline-specific traits ○ **Text Features**: If used, directly enhance the reader's understanding of content ○ **Use of Graphics:** If used, graphics, tables, charts, etc. support or are integral to understanding the text	○ **Organization:** Connections between some ideas or events are implicit or subtle; organization is evident and generally sequential or chronological ○ **Text Features**: If used, enhance the reader's understanding of content ○ **Use of Graphics:** If used, graphic, pictures, tables, and charts, etc. are mostly supplementary to understanding the text	○ **Organization:** Connections between ideas, processes or events are explicit and clear; organization of text is chronological, sequential or easy to predict ○ **Text Features**: If used, help the reader navigate and understand content but are not essential to understanding content. ○ **Use of Graphics:** If used, graphic, pictures, tables, and charts, etc. are simple and unnecessary to understanding the text but they may support and assist readers in understanding the written text
LANGUAGE FEATURES	○ **Conventionality**: Dense and complex; contains considerable abstract, ironic, and/or figurative language ○ **Vocabulary:** Complex, generally unfamiliar, archaic, subject-specific, or overly academic language; may be ambiguous or purposefully misleading ○ **Sentence Structure:** Mainly complex sentences with several subordinate clauses or phrases and transition words; sentences often contains multiple concepts	○ **Conventionality**: Fairly complex; contains some abstract, ironic, and/or figurative language ○ **Vocabulary:** Fairly complex language that is sometimes unfamiliar, archaic, subject-specific, or overly academic ○ **Sentence Structure:** Many complex sentences with several subordinate phrases or clauses and transition words	○ **Conventionality**: Largely explicit and easy to understand with some occasions for more complex meaning ○ **Vocabulary:** Mostly contemporary, familiar, conversational; rarely overly academic ○ **Sentence Structure:** Primarily simple and compound sentences, with some complex constructions	○ **Conventionality**: Explicit, literal, straightforward, easy to understand ○ **Vocabulary:** Contemporary, familiar, conversational language ○ **Sentence Structure:** Mainly simple sentences
PURPOSE	○ **Purpose:** Subtle and intricate, difficult to determine; includes many theoretical or abstract elements	○ **Purpose:** Implicit or subtle but fairly easy to infer; more theoretical or abstract than concrete	○ **Purpose:** Implied but easy to identify based upon context or source	○ **Purpose:** Explicitly stated, clear, concrete, narrowly focused
KNOWLEDGE DEMANDS	○ **Subject Matter Knowledge:** Relies on extensive levels of discipline-specific or theoretical knowledge; includes a range of challenging abstract concepts ○ **Intertextuality:** Many references or allusions to other texts or outside ideas, theories, etc.	○ **Subject Matter Knowledge:** Relies on moderate levels of discipline-specific or theoretical knowledge; includes a mix of recognizable ideas and challenging abstract concepts ○ **Intertextuality:** Some references or allusions to other texts or outside ideas, theories, etc.	○ **Subject Matter Knowledge:** Relies on common practical knowledge and some discipline-specific content knowledge; includes a mix of simple and more complicated, abstract ideas ○ **Intertextuality:** Few references or allusions to other texts or outside ideas, theories, etc	○ **Subject Matter Knowledge:** Relies on everyday, practical knowledge; includes simple, concrete ideas ○ **Intertextuality:** No references or allusions to other texts, or outside ideas, theories, etc.

GLE ALIGNMENT:

- Explain how the use of different energy resources affects the environment and the economy (SE-M-A6)
- Analyze positive and negative effects of human actions on ecosystems (LS-H-D4) (SE-H-A7)
- Identify resources humans derive from ecosystems (SE-M-A1)

Rationale and suggested sequence for reading:

The intent of this pack is to build knowledge round the coral reef, especially about the biodiversity with in the reef and the threats to the reef, both from humans and nature. The pack increases in complexity as the texts progress, beginning with fact statements and a diagram of a polyp, the animal the entire reef is built from, and then goes on the explore biodiversity using both written and visual sources. The most complex text describes the threats to the reef, and the pack concludes with an article that brings the concept of biodiversity and threat together, and crabs save the reef from invasive starfish.

Students will find the Tier 2 and domain-specific vocabulary increasingly accessible as they move through the pack as the words repeat in different contexts, and discovering the delicate balance of this ecosystem will support their ability to learn about other ecosystems, ocean life, and natural and human impact on the environment.

The Common Core Shifts for ELA/Literacy:

1. Regular practice with complex text and its academic language
2. Reading, writing and speaking grounded in evidence from text, both literary and informational
3. *Building knowledge through content-rich nonfiction*

Though use of these expert packs will enhance student proficiency with most or all of the Common Core Standards, they focus primarily on Shift 3, and the highlighted portions of the standards below.

College and Career Readiness Anchor Standards for Reading Literary and/or Informational Texts *(the darkened sections of the standards are the focus of the Expert Pack learning for students)***:**

1. ***Read closely to determine what the text says explicitly and to make logical inferences from it;*** cite specific textual evidence when writing or speaking to support conclusions drawn from the text.
2. ***Determine central ideas or themes of a text*** *and analyze their development*; summarize the key supporting details and ideas.
3. **Read and comprehend complex literary and informational texts independently and proficiently**

TEXT #1

Coral Reefs

National Geographic

http://video.nationalgeographic.com/video/coral-reefs

A beautiful introduction to some basic facts about reef structure and environment!

TEXT #2

Top 25 Coral Reef Facts

Conserve Every Future

http://www.conserve-energy-future.com/top-25-coral-reef-facts.php

Coral reefs are some of the most beautiful places on Earth to visit. Even just watching an underwater documentary film about them will show you how lively and beautiful they are. Coral reefs are more than beautiful, they are fascinating ecosystems, and important to all of life on Earth. It almost isn't fair to call a coral reef a "biome" or "ecosystem," it may be more important to their survival to begin to see them for what they are – living communities.

25 Interesting Facts About Coral Reefs

Here are the top 25 coral reef facts you should know.

Fact 1: Any reef that is called a "barrier" reef gets its name because its presence protects the shallow waters along the shore from the open sea. That protection promotes the survival of many types of sea plant and animal life.

Fact 2: A coral reef isn't a "thing," it's actually a community of life that lives and thrives in one location. What we think of as the base of the reef (and what we see when it is dry and removed from the water) is only one small aspect of a living reef.

Fact 3: The hard shell you see when coral is removed from water is the hard shell of an animal called a polyp. It is the cluster of polyps growing together that gives reefs their shape.

Fact 4: Reefs that are noticeable in size, like the Great Barrier Reef in Australia, are between 5 and 10,000 years old.

Fact 5: The Great Barrier Reef is actually made up of 900 smaller reefs.

Fact 6: The Great Barrier Reef covers 2,600 miles. It also crosses over 500 islands and is one of the most visited reefs in the world.

Fact 7: Reefs are very important to the fishing industry because they are the natural habitat of the bait fish which is used to fish for tuna and other large species.

Fact 8: Reefs are where many fish and sea creatures choose to spawn. The protected environment of the reef means their eggs will be safe from predators.

Fact 9: The algae that typically covers and grows around a reef isn't a plant, it's a living creature. There are many different kinds of algae, from the microscopic to ones with leaf like appendages several feet in length.

Fact 10: Benthic Diatoms are microscopically small and vastly abundant algae type lifeforms that live in the reef ecosystem. They are a huge reason why a living coral reef has such a dense biomass.

Fact 11: Scientists have discovered that many parts of a coral reef can be harvested to make medications to treat cancers and other illnesses.

Fact 12: The numerous types of seaweed, plankton and algae type growths that thrive on a coral reef provide food for an amazing amount of fish – fish that are also safe to feed in the protected structure of the reef.

Fact 13: Coral reefs can also be started on the shells of sunken boats. In fact, to help preserve different sea biomes, the navy will sink old ships to allow a coral reef to grow.

Fact 14: Wherever coral reefs grow, the sea bed is more stable. Reefs help seagrass and other sea plants survive in the area. The more plants are growing on the sea bed, the less impact storms and surges will have on seabed too. All of the plants that are protected by the coral reef prevent the bottom of the bed from being washed out deeper, changing the depth and temperature of the water near the shore. The sea bed washing out can also cause significant erosion of the shoreline.

Fact 15: Coral reefs also help to improve the surrounding water quality. They act as a kind of filter that traps things floating in the water, which makes for cleaner water all around.

Fact 16: Did you know that because the coral reef can stabilize the seabed for seagrasses, it provides a space for feeding and raising babies for many of the sea mammals? A seagrass meadow acts like a nursery for manatee and dugongs, where they can feed and raise their calves in a protected environment.

Fact 17: Villages tend to appear wherever there is a coral reef because it can provide a major food source for people without them having to venture out into unprotected waters, or too far inland.

Fact 18: There are three types of reefs, and one gets mistaken for an island. There are barrier reefs, fringing reefs and atolls. The last is often called an island when it is really a reef.

Fact 19: A coral reef needs sunlight to grow, that is why they hardly ever grow in waters deeper than 45 feet. They also are more likely to be found in tropical oceans, as the water is clearer and warmer.

Fact 20: Fringing reefs get their name from being closer to shore than a barrier reef. They are arranged like a fringe around the shallow waters. Barrier reefs are further out to sea, and in deeper waters. Atolls are mistaken for islands because they are island like and grow on the outer edges of lagoons.

Fact 21: Oddly enough, reefs usually grow up on the east shore of land masses. The temperature there is thought to be warmer than the western side. The ideal temperature for a coral reef is between 68 and 82 degrees Fahrenheit.

Fact 22: Reefs also grow where there are stronger wave patterns and currents. The stronger currents and waves deliver more food for the ecosystem that creates the reef structure.

Fact 23: Coral reefs also play an important role in helping to manage carbon monoxide levels. This makes them of great benefit to the world's population.

Fact 24: There are more types of fish living in a two acre area of coral reef than there are kinds of birds in all of North America.

Fact 25: The shape of a coral reef forms a natural protective barrier against storm waves. The waves break apart on the reef, so they don't hit the shore at full force. Any reef that is called a "barrier" reef gets its name because its presence protects the shallow waters along the shore from the open sea. That protection promotes the survival of many types of sea plant and animal life.

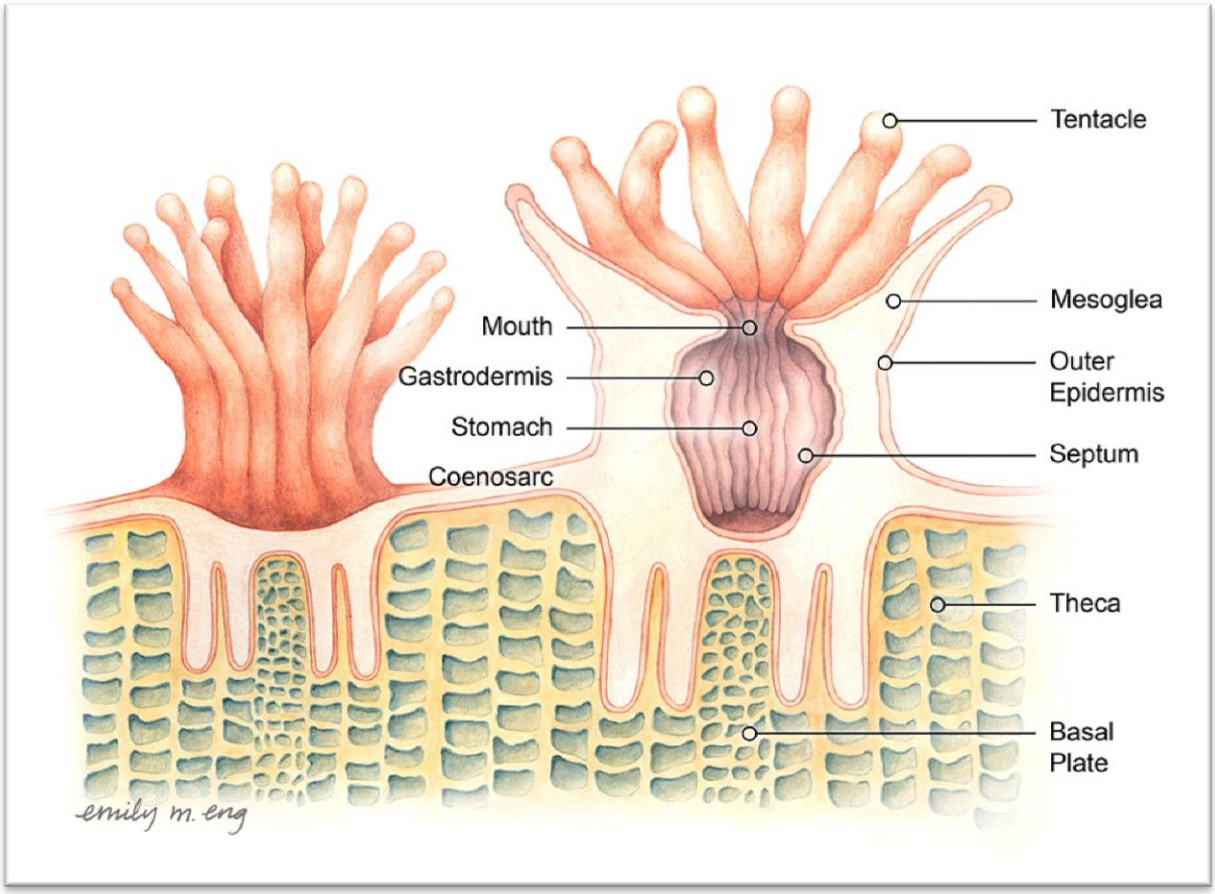
The coral reef isn't just something pretty to look it; it plays an important role in the survival of our planet. It directly supports a marine ecosystem, but it also provides important benefits for mankind.

TEXT #3

Coral Polyps—Tiny Builders

Coral Reef Alliance

http://coral.org/coral-reefs-101/coral-reef-ecology/coral-polyps/



Cross-section of a coral polyp.

Coral reefs are built by and made up of thousands of tiny animals—coral "polyps"—that are related to anemones and jellyfish. Polyps can live individually (like many mushroom corals do) or in large colonies that comprise an entire reef structure.

Close up of polyps are arrayed on a coral, waving their tentacles. There can be thousands of polyps on a single coral branch.

A polyp has a sac-like body and an opening, or mouth, encircled by stinging tentacles called nematocysts or *cnidae*. The polyp uses calcium and bicarbonate ions from seawater to build itself a hard, cup-shaped skeleton made of calcium carbonate (limestone). This limestone skeleton protects the soft, delicate body of the polyp. Coral polyps are usually nocturnal, meaning that they stay inside their skeletons during the day. At night, polyps extend their tentacles to feed.

Most coral polyps have clear bodies. Their skeletons are white, like human bones. Generally, their brilliant color comes from the zooxanthellae (tiny algae) living inside their tissues. Several million zooxanthellae live and produce pigments in just one square inch of coral. These pigments are visible through the clear body of the polyp and are what gives coral its beautiful color.

TEXT #4

Corals Dine on Microplastics

Alison Pearce Stevens

https://student.societyforscience.org/article/corals-dine-microplastics

Coral reefs such as this one may be at risk because the young polyps that build reefs ingest super-small bits of plastic. These pollutants may interfere with a coral's ability to obtain real food.

Plastic trash is washing off of land and into the seas. And that pollution may be harming some of the ocean's most important habitats: coral reefs. That's the conclusion of a new Australian study.

Coral reefs are the most biologically diverse habitats in the ocean. Their nooks and crannies provide shelter for thousands of species of animals, both big and small. That huge variety of reef organisms also provides food for a wide range of other critters. If the corals die, though, lots of those other species will have trouble surviving. The new

study raises concerns about the survival of some coral species — and the complex ecosystems that depend on them.

The animals that build reefs are called polyps. Coral polyps are small. Their soft bodies also lack a hard outer covering to protect them from potential predators. So the polyps make their own protective home out of calcium carbonate. Coral polyps continually add to these homes. And over time, communities of millions of polyps craft the large, rocky apartment complexes that we know as reefs.

Polyps hide in their homes by day. At night, they extend their arm-like appendages out to snatch small snacks, usually *plankton*, from the water. Those snacks are truly tiny — a mere 400 micrometers (0.016 inch) in diameter or less, notes Mia Hoogenboom. She is a marine biologist at James Cook University in Townsville, Australia.

Unfortunately, she points out, scientists are finding more and more bits of plastics in the ocean ecosystem. Those microplastic pieces are less than 5 millimeters (0.2 inch) in size. That makes many just the right size for corals to gobble up.

Hoogenboom's team lives and works near the Great Barrier Reef, the world's largest coral system. It stretches across more than 2,000 kilometers (1,240 miles) of Australia's northeast coast. It's also home to the greatest diversity of species in the world. But that *biodiversity* could be at risk from plastics. Hoogenboom and her co-workers wanted to find out how plastics might be affecting those reef corals.

Food or plastic?

Corals get some energy from single-celled algae that live amidst the corals' tissues. These algae produce their energy through photosynthesis. But corals also must eat plankton and other foods to obtain certain vital nutrients important for growth and reproduction. So Hoogenboom's team started its investigation by probing whether corals might be mistaking plastics for food. This is a concern because many other marine animals make that error.

The team brought pieces of one type of coral into their lab. The species is known as brain coral because its round shape and fold-like pattern make it resemble the human brain. Then the researchers shredded a blue ice cream tub made of polypropylene (PAAH-lee-PRO-pih-leen). This is one of the plastics most commonly found in the ocean. The scientists added the plastic microbits to the water in which the corals were being kept.

Two days later, the researchers examined the polyps' stomachs. One out of every five of the coral animals had eaten plastic. What's more, pieces of the blue plastic had gotten stuck deep in the animals' stomachs. That suggests the polyps cannot get rid of the plastic once it is swallowed, says Hoogenboom.

Next, the researchers added a precise amount of microplastics to the corals' water. Twelve hours later, the scientists measured how much had disappeared. This showed the polyps had eaten microplastic bits at the same rate they normally eat plankton.

None of this matters if microplastics are not polluting the waters of the Great Barrier Reef. So the final step by Hoogenboom's group was to sample water at various reef sites. And at each one, they found bits of plastic that had broken off of larger pieces of packaging or items used in fishing. So corals definitely are at risk of eating plastic, the

researchers conclude. The Australian team published its findings online February 4 in *Marine Biology*.

It's an interesting study, says Stephanie Wright. A marine biologist at the University of Exeter in England, she was not involved with the study. The new study did not give corals a choice of foods, she points out. They could only eat microplastics. Future steps should look at how easily corals ignore plastic when true food is around. But, she notes, the study does add to a growing body of knowledge about the risks that microplastics in the sea may pose.

TEXT #5

Coral Reef Biodiversity

Coral Reef Alliance

http://coral.org/coral-reefs-101/coral-reef-ecology/coral-reef-biodiversity/

Parrotfish actually eat the reef itself!

Biodiversity is the variety of living species that can be found in a particular place—region, ecosystem, planet, etc. Coral reefs are believed by many to have the highest biodiversity of any ecosystem on the planet—even more than a tropical rainforest. Occupying less than one percent of the ocean floor, coral reefs are home to more than twenty-five percent of marine life.

Why is that important? A highly biodiverse ecosystem, one with many different species, is often more resilient to changing conditions and can better withstand significant disturbances.

In addition, ecosystem services—benefits that humans receive from natural environments—are often greater in highly diverse places. Coral reefs, thanks to their diversity, provide millions of people with food, medicine, protection from storms, and revenue from fishing and tourism. An estimated six million fishermen in 99 reef countries and territories worldwide—over a quarter of the world's small-scale fishermen—harvest from coral reefs.

The biodiversity of reefs can also be appreciated simply for the wonder and amazement it inspires. Brightly colored, spotted, striped, speckled, or otherwise eccentrically patterned fish swim in and around coral reefs; some specialize in eating different kinds of algae, keeping corals from being smothered by their potentially deadly competitors. Sharks, groupers, and other predatory fish keep populations of smaller fish and other organisms in balance.

Parrotfish actually eat the reef itself. They scrape at the coral to get to the small algae (zooxanthellae) living inside the coral polyp, then grind up the coral skeleton with teeth in their throats and excrete it as sand. Those beautiful, white sand beaches? Thank parrotfish. "Cleaner" fish (and shrimp) keep other fish healthy by freeing them of parasites, while crabs and sea cucumbers crawl about, scavenging and cleaning up detritus on the reef and ocean floor.

Even marine worms and snails perform important roles in the reef ecosystem. Worms filter organic matter in the water and sediments, while snails such as limpets and conchs graze on algae. The snails sometimes become food for sea stars—while sea stars can in

turn be eaten by giant snails! Other creatures in the "spiny-skinned" or echinoderm family—such as feather stars and basket stars—capture plankton from the current.

Sea anemones—like the clownfish anemone—have formed symbiotic, or mutually beneficial, relationships with fish and crabs. The sea anemones hide and protect the fish and crabs while the fish and crabs in turn protect the anemones. Sea anemones are related to corals and are also predatory animals; they do not produce calcareous skeletons and are usually solitary.

Animals that help filter and clarify the water on a reef include sea squirts and salps ("tunicates"), and giant clams (mollusks), which sieve and eat phytoplankton. And even primitive animals like sea sponges are important to reef health, providing habitat for crustaceans, marine worms, and young fish in their intricate aquiferous canals, and for barnacles and tiny mollusks in their complex surfaces.

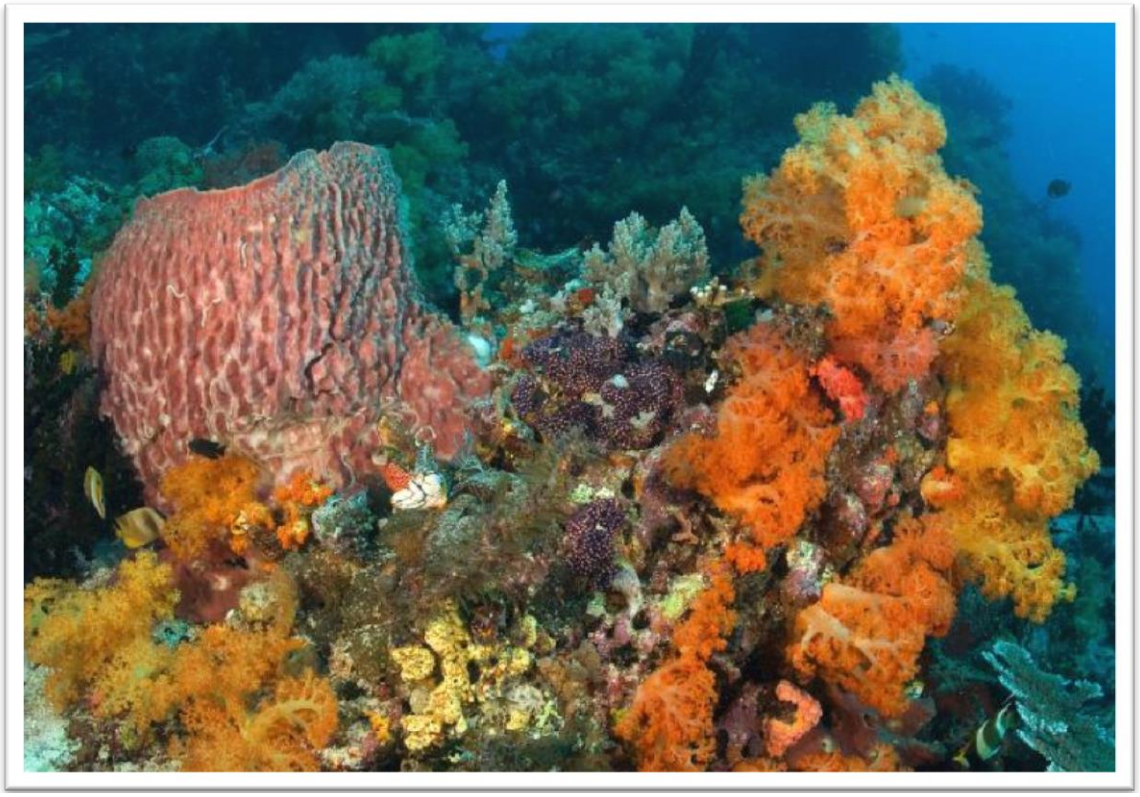
They are also "recyclers"—taking in nutrients they filter from the water and producing waste products that feed lots of other reef species. Sponges themselves become food for nudibranchs, sea stars, turtles, and fish. And they are valuable to humans as well, producing diverse chemical compounds that are being explored for human medicines.

TEXT #6

Coral and Coral Reefs

The Ocean Portal Team; Reviewed by Nancy Knowlton, Smithsonian NMNH

http://ocean.si.edu/corals-and-coral-reefs



Corals, sponges and seaweeds cover most of the surface of many coral reefs. Credit: Wolcott Henry

Coral reefs are the most diverse of all marine ecosystems. They teem with life, with perhaps one quarter of all ocean species depending on reefs for food and shelter. This is a remarkable statistic when you consider that reefs cover just a tiny fraction (less than one percent) of the earth's surface and less than two percent of the ocean bottom. Because they are so diverse, coral reefs are often called the rainforests of the sea.

Coral reefs are also very important to people. The value of coral reefs has been estimated at 30 billion U.S. dollars and perhaps as much as 172 billion U.S. dollars each year**,** providing food, protection of shorelines, jobs based on tourism, and even medicines.

Unfortunately, people also pose the greatest threat to coral reefs. Overfishing and destructive fishing, pollution, warming, changing ocean chemistry, and invasive species are all taking a huge toll. In some places, reefs have been entirely destroyed, and in many places reefs today are a pale shadow of what they once were.

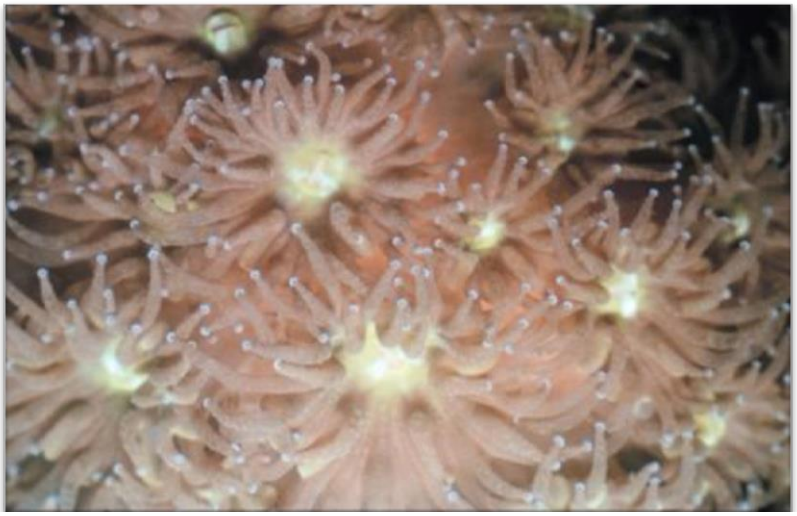
What Are Corals?

Animal, Vegetable & Mineral

Corals are related to sea anemones, and they all share the same simple structure, the polyp. The polyp is like a tin can open at just one end: the open end has a mouth surrounded by a ring of tentacles. The tentacles have stinging cells, called nematocysts, that allow the coral polyp to capture small organisms that swim too close. Inside the body of the polyp are digestive and reproductive tissues. Corals differ from sea anemones in their production of a mineral skeleton.

Shallow water corals that live in warm water often have another source of food, the zooxanthellae (pronounced zo-o-zan-THELL-ee). These single-celled algae photosynthesize and pass some of the food they make from the sun's energy to their hosts, and in exchange the coral animal gives nutrients to the algae. It is this relationship

that allows shallow water corals to grow fast enough to build the enormous structures we call reefs. The zooxanthellae also provide much of the color that corals have.



Flower-like clusters of pink polyps make up this coral colony.
Credit: Photo Collection of Dr. James P. McVey, NOAA Sea Grant Program.

Coral Diversity

In the so-called true stony corals, which compose most tropical reefs, each polyp sits in a cup made of calcium carbonate. Stony corals are the most important reef builders, but organpipe corals**,** precious red corals**,** and blue corals also have stony skeletons. There are also corals that use more flexible materials or tiny stiff rods to build their skeletons—the seafans and sea rods, the rubbery soft corals, and the black corals.

The family tree of the animals we call corals is complicated, and some groups are more closely related to each other than are others. All but the fire corals (named for their strong sting) are anthozoans which are divided into two main groups. The hexacorals (including the true stony corals and black corals, as well as the sea anemones) have smooth tentacles, often in multiples of six, and the octocorals (soft corals, seafans, organpipe corals and blue corals) have eight tentacles, each of which has tiny branches running along the sides. All corals are in the phylum Cnidaria, the same as jellyfish.

Reproduction

A purple hard coral releases bundles of pink eggs glued together with sperm. **Credit:** Chuck Savall

Corals have multiple reproductive strategies – they can be male or female or both, and can reproduce either asexually or sexually. Asexual reproduction is important for increasing the size of the colony, and sexual reproduction can be far from the parents.

Asexual Reproduction

Asexual reproduction results in polyps or colonies that are clones of each other - this can occur through either budding or fragmentation. Budding is when a coral polyp reaches a certain size and divides, producing a genetically identical new polyp. Corals do this throughout their lifetime. Sometimes a part of a colony breaks off and forms a new colony. This is called fragmentation, which can occur as a result of a disturbance such as a storm or being hit by fishing equipment.

Sexual Reproduction

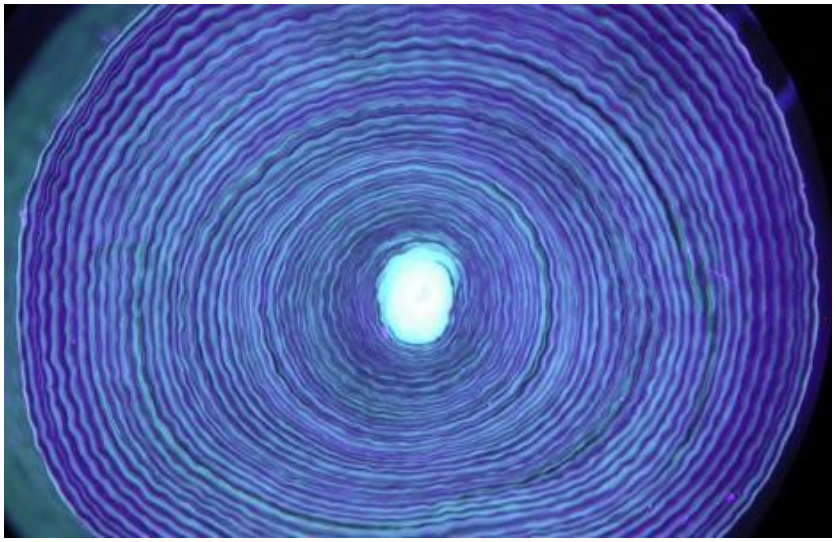
In sexual reproduction, eggs are fertilized by sperm, usually from another colony, and develop into a free-swimming larva. There are two types of sexual reproduction in corals, external and internal. Depending on the species and type of fertilization, the

larvae settle on a suitable substrate and become polyps after a few days or weeks, although some can settle within a few hours!

Most stony corals are broadcast spawners and fertilization occurs outside the body (external fertilization). Colonies release huge numbers of eggs and sperm that are often glued into bundles (one bundle per polyp) that float towards the surface. Spawning often occurs just once a year and in some places is synchronized for all individuals of the same species in an area. This type of mass spawning usually occurs at night and is quite a spectacle. Some corals brood their eggs in the body of the polyp and release sperm into the water. As the sperm sink, polyps containing eggs take them in and fertilization occurs inside the body (internal fertilization). Brooders often reproduce several times a year on a lunar cycle.

From Corals to Reefs

Coral Growth



Credit: Owen Sherwood Ultraviolet light illuminates growth rings in a cross-section of 44-year-old *Primnoa resedaeformis* coral found about 400 m (1,312 ft) deep off the coast of Newfoundland.

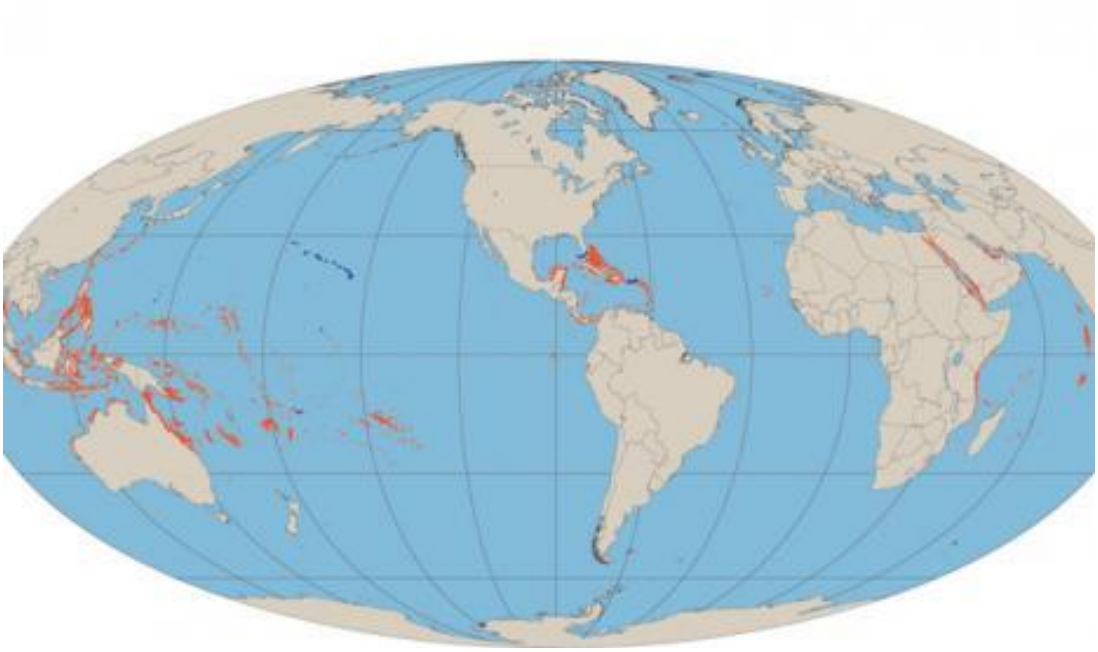
Individual coral polyps within a reef are typically very small—usually less than half an inch (or ~1.5 cm) in diameter. The largest polyps are found in mushroom corals, which can be more than 5 inches across. But because corals are colonial, the size of a colony can be much larger: big mounds can be the size of a small car, and a single branching colony can cover an entire reef.

Reefs, which are usually made up of many colonies, are much bigger still. The largest coral reef is the Great Barrier Reef, which spans 1,600 miles (2,600 km) off the east coast of Australia. It is so large that it can be seen from space!

It takes a long time to grow a big coral colony or a coral reef, because each coral grows slowly. The fastest corals expand at more than 6 inches (15 cm) per year, but most grow less than an inch per year. Reefs themselves grow even more slowly because after the corals die, they break into smaller pieces and become compacted. Individual colonies

can often live decades to centuries, and some deep-sea colonies have lived more than 4000 years. One way we know this is because corals lay down annual rings, just as trees do. These skeletons can tell us about what conditions were like hundreds or thousands of years ago. The Great Barrier Reef as it exists today began growing about 20,000 years ago.

Where are Reefs Found?



Shallow water coral reefs straddle the equator worldwide.
Credit: ©UNEP World Conservation Monitoring Centre/Global 1KM Version 7.0 Dataset

Corals are found across the world's ocean, in both shallow and deep water, but reef-building corals are only found in shallow tropical and subtropical waters. This is because the algae found in their tissues need light for photosynthesis and they prefer water temperatures between 70-85°F (22-29°C).

There are also deep-sea corals that thrive in cold, dark water at depths of up to 20,000 feet (6,000 m). Both stony corals and soft corals can be found in the deep sea. Deep-sea

corals do not have the same algae and do not need sunlight or warm water to survive, but they also grow very slowly. One place to find them is on underwater peaks called seamounts.

Credit: Klaus Jost, www.jostimages.com

Reefs as Ecosystems

Scientists have been studying why populations of crown-of-thorns sea stars (*Acanthaster planci*) have mushroomed in recent decades. Coral reefs can suffer when the sea star's numbers explode; the echinoderm has a healthy appetite and few predators.Reefs are the big cities of the sea.
They exist because the growth of corals matches or exceeds the death of corals – think of it as a race between the construction cranes (new coral skeleton) and the wrecking balls (the organisms that kill coral and chew their skeletons into sand).

When corals are babies floating in the plankton, they can be eaten by many animals. They are less tasty once they settle down and secrete a skeleton, but some fish, worms, snails and sea stars prey on adult corals. Crown-of-thorns sea stars are particularly voracious predators in many parts of the Pacific Ocean. Population explosions of these predators can result in a reef being covered with tens of thousands of these starfish, with most of the coral killed in less than a year.

Corals also have to worry about competitors. They use the same nematocysts that catch their food to sting other encroaching corals and keep them at bay. Seaweeds are a particularly dangerous competitor, as they typically grow much faster than corals and may contain nasty chemicals that injure the coral as well.

Corals do not have to only rely on themselves for their defenses because mutualisms (beneficial relationships) abound on coral reefs. The partnership between corals and their zooxanthellae is one of

These bleached corals in the Gulf of Mexico are the result of increased water temperatures. **Credit:** Emma Hickerson/NOAA

many examples of symbiosis, where different species live together and help each other. Some coral colonies have crabs and shrimps that live within their branches and defend their home against coral predators with their pincers. One kind of goby chews up a particularly nasty seaweed, and even benefits by becoming more poisonous itself.

Global Threats

The greatest threats to reefs are rising water temperatures and ocean acidification linked to rising carbon dioxide levels. High water temperatures cause corals to lose the microscopic algae that produce the food corals need—a condition known as coral bleaching.

Severe or prolonged bleaching can kill coral colonies or leave them vulnerable to other threats. Meanwhile, ocean acidification means more acidic seawater, which makes it more difficult for corals to build their calcium carbonate skeletons. And if acidification gets severe enough, it could even break apart the existing skeletons that already provide the structure for reefs.

Compare the healthy coral on the left with the bleached coral on the right.
Credit: Wolcott Henry

Local Threats

Unfortunately, warming and more acid seas are not the only threats to coral reefs. Overfishing and overharvesting of corals also disrupt reef ecosystems. If care is not taken, boat anchors and divers can scar reefs. Invasive species can also threaten coral reefs. The lionfish, native to Indo-Pacific waters, has a fast-growing population in waters of the Atlantic Ocean. With such large numbers the fish could greatly impact coral reef ecosystems through consumption of, and competition with, native coral reef animals.

Even activities that take place far from reefs can have an impact. Runoff from lawns, sewage, cities, and farms feeds algae that can overwhelm reefs. Deforestation hastens soil erosion, which clouds water—smothering corals.

Coral Bleaching

"Coral bleaching" occurs when coral polyps lose their symbiotic algae, the zooxanthellae. Without their zooxanthellae, the living tissues are nearly transparent, and you can see right through to the stony skeleton, which is white, hence the name coral bleaching.

Many different kinds of stressors can cause coral bleaching – water that is too cold or too hot, too much or too little light, or the dilution of seawater by lots of fresh water can all cause coral bleaching. The biggest cause of bleaching today has been rising

temperatures caused by global warming. Temperatures more than 2 degrees F (or 1 degree C) above the normal seasonal maximum can cause bleaching. Bleached corals do not die right away, but if temperatures are very hot or are too warm for a long time, corals either die from starvation or disease. In 1998, 80 percent of the corals in the Indian Ocean bleached and 20 percent died.

Credit: ©James D. Watt/Ocean Stock.

A bluefin trevally swims in Hawaii's Maro Coral Reef, part of the Papahānaumokuākea Marine National Monument.

Protecting Coral Reefs

There is much that we can do locally to protect coral reefs, by making sure there is a healthy fish community and that the water surrounding the reefs is clean.

Well-protected reefs today typically have much healthier coral populations, and are more resilient.

Fish play important roles on coral reefs, particularly the fish that eat seaweeds and keep them from smothering corals, which grow more slowly than the seaweeds. Fish also eat the predators of corals, such as crown of thorns starfish. Marine protected areas (MPAs) are an important tool for keeping reefs healthy. Large MPAs protect the Great Barrier Reef and the Northwestern Hawaiian Islands, for example, and in June 2012, Australia created the largest marine reserve network in the world. Smaller ones, managed by local communities, have been very successful in developing countries.

Clean water is also important. Erosion on land causes rivers to dump mud on reefs, smothering and killing corals. Seawater with too many nutrients speeds up the growth

of seaweeds and increases the food for predators of corals when they are developing as larvae in the plankton. Clean water depends on careful use of the land, avoiding too many fertilizers and erosion caused by deforestation and certain construction practices. In the long run, however, the future of coral reefs will depend on reducing carbon dioxide in the atmosphere, which is increasing rapidly due to burning of fossil fuels. Carbon dioxide is both warming the ocean, resulting in coral bleaching, and changing the chemistry of the ocean, causing ocean acidification. Both make it harder for corals to build their skeletons.

TEXT #7

Bizarre and Beautiful Coral Reef Animals

The Smithsonian Ocean Initiative

http://ocean.si.edu/slideshow/bizarre-and-beautiful-coral-reef-animals

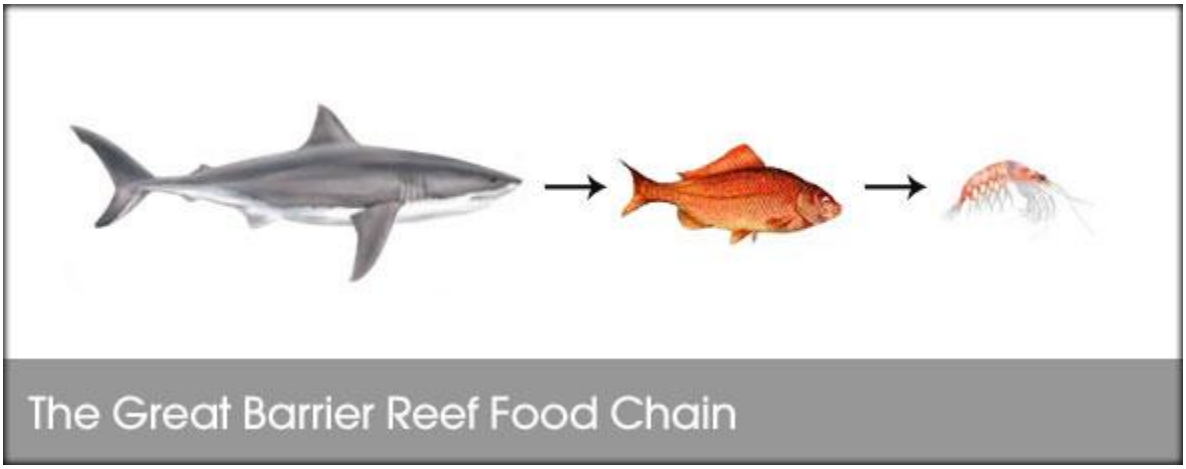
This website contains photographs and descriptions of the various animals that live on the reef as well as a slideshow that includes links to other information about coral reefs – students should feel free to explore these links as well!

TEXT #8

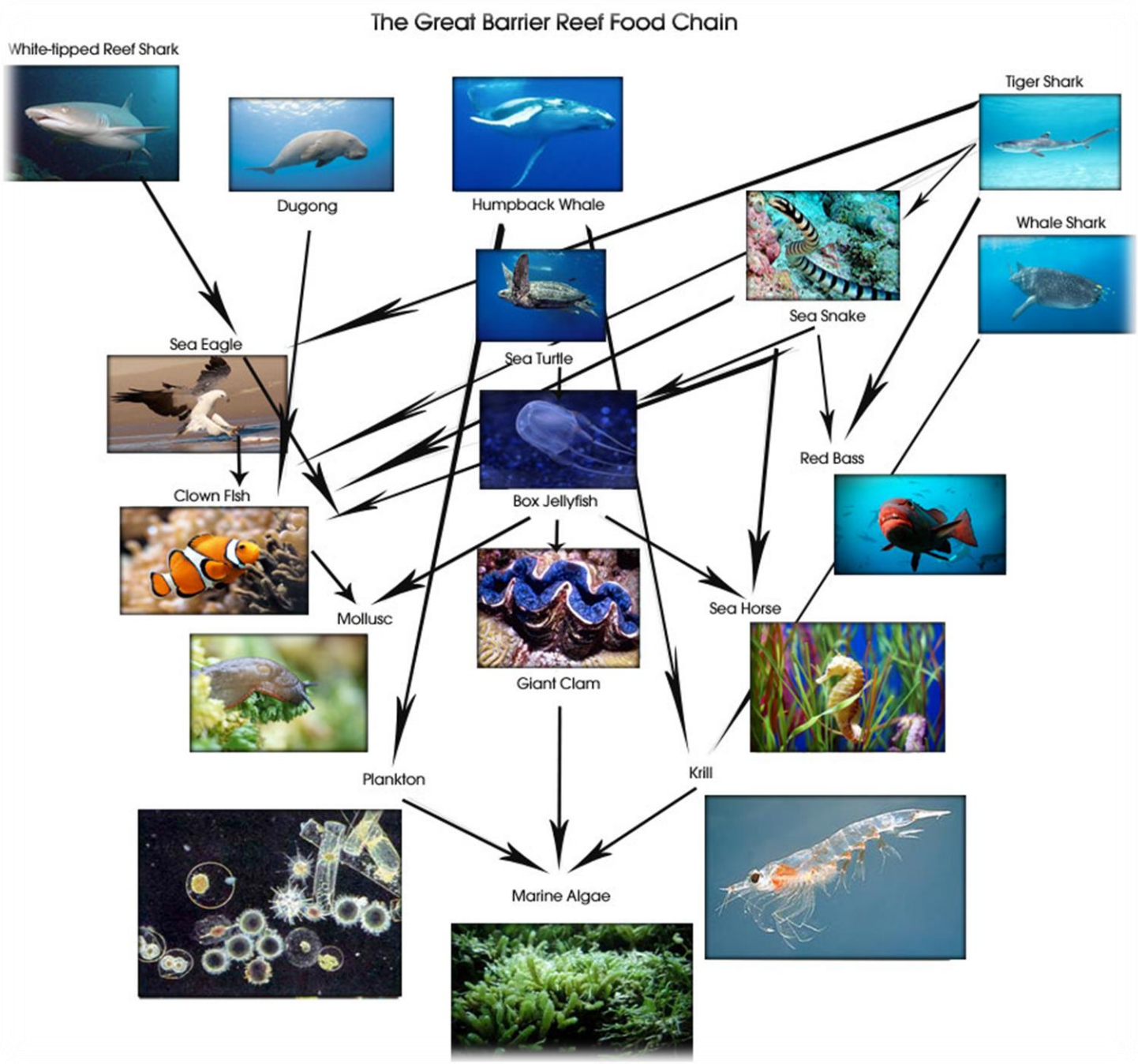
The Great Barrier Reef Food Chain

GreatBarrierReef.co.au

http://www.greatbarrierreef.com.au/information/great-barrier-reef-food-web/



The ecosystem of the Great Barrier Reef is a delicate and fragile balance, with a food chain that has multiple levels in which every part is reliant on everything else. From the largest apex predators such as the White-tipped Reef Shark all the way down to microscopic organisms called Phytoplankton, no one marine creature could exist without another, and this is reflected in that if one life form becomes endangered, the rest of the reef suffers. Below is a visual diagram style representation of the food web of the Great Barrier Reef featuring some of the core marine animals that can be found in its waters that provides a basic overview, with the arrows pointing in the direction of one animal that eats another. It is this food web that makes the Great Barrier Reef what it is, and is an example of why the influence of man is one of the main threats to the future of the reef and its continued survival as the world's largest living organism.


The Great Barrier Reef Food Chain
White-tipped Reef Shark
Dugong
Humpback Whale
Tiger Shark
Whale Shark
Sea Snake
Sea Turtle
Sea Eagle
Box Jellyfish
Red Bass
Clown Fish
Mollusc
Giant Clam
Sea Horse
Plankton
Krill
Marine Algae

TEXT #9

Why Are Coral Reefs Important?

Jessica Carilli

http://coralreefsystems.org/content/value-corals

The Value of Corals

Healthy coral reefs are among the most biologically diverse and economically valuable ecosystems on earth, providing valuable and vital ecosystem services. Coral ecosystems are a source of food for millions; protect coastlines from storms and erosion; provide habitat, spawning and nursery grounds for economically important fish species; provide jobs and income to local economies from fishing, recreation, and tourism; are a source of new medicines, and are hotspots of marine biodiversity.

Biodiversity: Coral reefs are essential spawning, nursery, breeding, and feeding grounds for numerous organisms. In terms of biodiversity, the variety of species living on a coral reef is greater than in any other shallow-water marine ecosystems and is one of the most diverse on the planet, yet coral reefs cover less than one tenth of one percent of the ocean floor. Coral reefs support more than 800 hard coral species and more than 4,000 species of fish.

Coastal Protection: Healthy coral reefs have rough surfaces and complex structures that dissipate much of the force of incoming waves; this buffers shorelines from currents, waves, and storms, helping to prevent loss of life, property damage, and erosion. Coastlines protected by reefs are more stable, in terms of erosion, and are also a source of sand in natural beach replenishment

Fisheries: The fish that grow and live on coral reefs are a significant food source for over a billion people worldwide—many of whom live far from the reefs that feed them. Approximately half of all federally managed fisheries in the United States depend on coral reefs and related habitats for a portion of their life cycles. The NOAA National Marine Fisheries Service estimates the annual commercial value of US fisheries from coral reefs to be over $100 million. Reef-based recreational fisheries generate over $100 million annually in the US. Globally, one estimate shows fisheries benefits account for $5.7 billion of the total $29.8 billion global net benefit provided by coral reefs. Sustainable coral reef fisheries in Southeast Asia alone are valued at $2.4 billion per year.

These numbers do not take into account the value of deep-sea corals, which are themselves home for many commercially valuable species and thus additional fisheries value.

Medicine: Many species found in coral ecosystems produce chemical compounds for defense or attack, particularly the slow-moving or stationary species like nudibranchs and sponges. Searching for potential new pharmaceuticals, termed bioprospecting, has been common in terrestrial environments for decades. However, bioprospecting is relatively new in the marine environment and is nowhere close to realizing its full potential. Creatures found in coral ecosystems are important sources of new medicines being developed to induce and ease labor; treat cancer, arthritis, asthma, ulcers, human bacterial infections, heart disease, viruses, and other diseases; as well as sources of nutritional supplements, enzymes, and cosmetics. The medicines and other potentially useful compounds identified to date have led to coral ecosystems being referred to as the medicine cabinets of the 21st century by some, and the list of approved and potential new drugs is ever growing.

Tourism and Recreation: Every year, millions of scuba divers and snorkelers visit coral reefs to enjoy their abundant sea life. Even more tourists visit the beaches protected by these reefs. Local economies receive billions of dollars from these visitors to reef regions

through diving tours, recreational fishing trips, hotels, restaurants, and other businesses based near reef ecosystems. One estimate places the total global value of coral-reef based recreation and tourism at $9.6 billion of the total global net benefit of coral reefs.

TEXT #10

The Status of and Threat to Coral Reefs

International Coral Reef Initiative (ICRI)

http://www.icriforum.org/about-coral-reefs/status-and-threat-coral-reefs

Why are coral reefs threatened?

The majority of reef loss or damage is not deliberate. Coral reefs are being degraded by an accumulation of stresses arising from human activities. In simple terms, stresses can be grouped by the actions of people extracting material from, and placing materials upon, coral reefs. Overfishing, pollution and coastal development top the list of chronic stressors. In many situations chronic stresses are overwhelming the resilience, (or the capacity for self-repair), of reef communities. Some coral reefs are covered with sand, rock and concrete to make cheap land and stimulate economic development. Others are

dredged or blasted for their limestone or to improve navigational access and safety. In addition to this, long-term changes in the oceans and atmosphere (rising sea temperatures and levels of CO2), and acute stresses from highly variable seasons, severe storms, earthquakes and volcanic eruptions also affect coral reefs.

So what are the different things we are doing to damage coral reefs?

- **Overfishing:** Increasing demand for food fish and tourism curios has resulted in over fishing of not only deep-water commercial fish, but key reef species as well. Overfishing of certain species near coral reefs can easily affect the reef's ecological balance and biodiversity. For example, overfishing of herbivorous fish can also lead to high levels of algal growth. From subsistence level fishing to the live fish trade, inadequate fisheries management is forcing the decline of fish stocks. Choose seafood products that come from certified, well-managed and sustainable fisheries. Certified products are available at most supermarkets - check out the product label, or visit: www.fishonline.org

- **Destructive fishing methods:** Fishing with dynamite, cyanide and other methods that break up the fragile coral reef are highly unsustainable. Dynamite and cyanide stun the fish, making them easier to catch. Fishermen say they have no other option if they are to compete with trawlers and overcome a smaller

supply of fish because of previous overfishing. These practices generally do not select or target particular fish species and often result in juveniles being killed in the process. Damaging the coral reef habitat on which the fish rely will also reduce the productivity of the area, with further impacts on the livelihoods of fishermen.

- **Unsustainable tourism:** Tourism generates vast amounts of income for host countries. Where unregulated however, tourism pressures can cause damage to the very environment upon which the industry depends. Physical damage to the coral reefs can occur through contact from careless swimmers, divers, and poorly placed boat anchors. Hotels and resorts may also discharge untreated sewage and wastewater into the ocean, polluting the water and encouraging the growth of algae, which competes with corals for space on the reef.

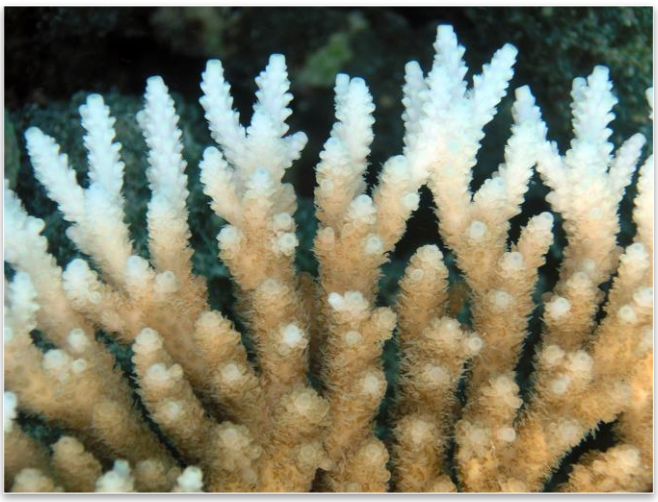
- **Coastal development:** The growth of coastal cities and towns generates a range of threats to nearby coral reefs. Where space is limited, airports and other construction projects may be built on land reclaimed from the sea. Sensitive habitats can be destroyed or disturbed by dredging activities to make deep-water channels or marinas, and through the dumping of waste materials. Where land development alters the natural flow of water, greater amounts of fresh water, nutrients and sediment can reach the reefs causing further degradation. Within the last 20 years, once prolific mangrove forests, which absorb massive

amounts of nutrients and sediment from runoff caused by farming and construction, have been destroyed. Nutrient-rich water causes fleshy algae and phytoplankton to thrive in coastal areas in suffocating amounts known as algal blooms. Coral reefs are biological assemblages adapted to waters with low nutrient content, and the addition of nutrients favours species that disrupt the balance of the reef communities.

- **Pollution:** Coral reefs need clean water to thrive. From litter to waste oil, pollution is damaging reefs worldwide. Pollution from human activities inland can damage coral reefs when transported by rivers into coastal waters. Do your bit - do not drop litter or dispose of unwanted items on beaches, in the sea, or near storm drains.

- **Global Aquarium Trade:** It is estimated that nearly 2 million people worldwide keep marine aquariums. The great majority of marine aquaria are stocked with species caught from the wild. This rapidly developing trade is seeing the movement of charismatic fish species across borders. Threats from the trade include the use of cyanide in collection, over-harvesting of target organisms and high levels of mortality associated with poor husbandry practices and insensitive shipping. Some regulation is in place to encourage the use of sustainable collection methods and to raise industry standards.

How are corals affected by climate change?



Coral Bleaching: Coral bleaching occurs when the symbiosis between corals and their symbiotic zooxanthellae breaks down, resulting in the loss of the symbionts and a rapid whitening of the coral host (thus the term "bleaching"). This is a stress response by the coral host that can be caused by various factors, but more severe and frequent cases are being caused by a rise in sea surface temperature (SSTs). If the temperature decreases, the stressed coral can recover; if it persists, the affected colony can die. The impacts from coral bleaching are becoming global in scale, and are increasing in frequency and intensity. Mass coral bleaching generally happens when temperatures around coral reefs exceed 1oC above an area's historical norm for four or more weeks. Sea surface temperature increases have been strongly associated with El Niño weather patterns. However, light intensity, (during doldrums, i.e. flat calm conditions), also plays a critical role in triggering the bleaching response. If temperatures climb to more than 2o C for similar or longer periods, coral mortalities following bleaching increase.

Mass coral bleaching was not documented in the scientific literature before 1979; however, significant mass bleaching events have since been reported in 1982, 1987, 1992 and the strongest sea surface warming event ever recorded occurred in 1998, where an estimated 46% of corals in the western Indian Ocean were

heavily impacted or died. In 2005 sea surface temperatures in the Caribbean were the highest reported in more than 100 years, and there was also significant coral bleaching following this warming. This year, coral bleaching is being reported in several locations around the world. If sea surface temperatures continue to rise, then the frequency and severity of coral bleaching will also increase, likely affecting the ability of coral reefs, as we have known them, to adapt and to provide many of the services that people rely upon.

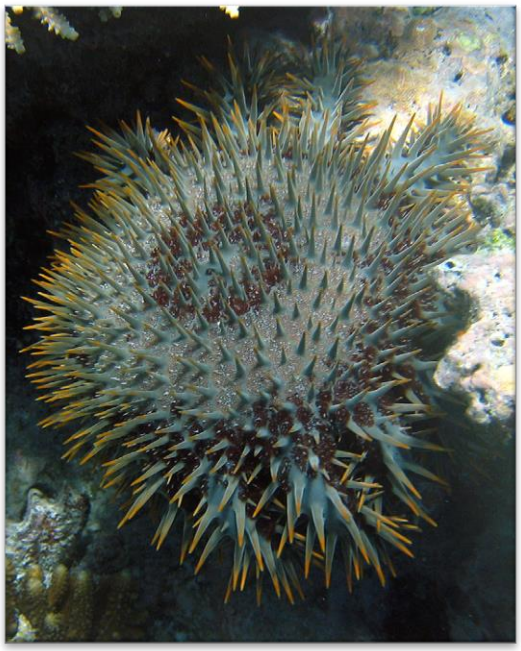
Rising sea levels: Observations since 1961 show that the average temperature of the global ocean has increased even at depths of 3000m (IPCC report), and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes sea level rise and creates problems for low lying nations and islands.

- **Ocean Acidification:** This is the name given to the ongoing decrease in the pH of the Earth's oceans, caused by their uptake of anthropogenic carbon dioxide from the atmosphere. Although the natural absorption of CO2 by the world's oceans helps mitigate the climatic effects of anthropogenic emissions of CO2, it is believed that the resulting decrease in pH, (i.e. making the water acidic), will have negative consequences, primarily for oceanic calcifying organisms such as coral reefs.

What other causes are damaging coral reefs?

- **Coral Disease:** During the last 10 years, the frequency of coral disease appears to have increased dramatically, contributing to the deterioration of coral reef communities around the globe. Most diseases occur in response to the onset of bacteria, fungi, and viruses. However, natural events and human-caused activities may exacerbate reef-forming corals' susceptibility to waterborne pathogens.

  More information is needed to identify the mechanisms by which most diseases kill their hosts, and how they are transmitted. The onset of coral disease has been shown to spread following coral bleaching events, so the evidence of a connection between warmer-than-normal water and coral disease is growing stronger. There is also evidence to indicate that low water quality increases incidence. It is critical that governments and managers continue their efforts to reduce (or stop) the effects of other major reef threats (sediments, pesticides, nutrients, overfishing, etc.) while this scientific information is gathered, if we are to give coral reefs a fighting chance of survival.



Crown of Thorns Starfish (COTs): The Crown of Thorns Starfish is a voracious coral reef predator. Populations of the COTs have increased since the 1970s and large outbreaks of starfish can occur wiping out huge tracks of coral reef. Few animals in the sea are willing to attack the spiny and toxic crown-of-thorns starfish, but some shrimp, worms and species of reef fish do feed on

larvae or small adults. The decline of these predators, through over-harvesting and pollution, is one factor contributing to the rise in the population of the starfish.

- **Alien invasive species:** Species that, as a result of human activity, have been moved, intentionally or unintentionally, into areas where they do not occur naturally are called "introduced species" or "alien species". In some cases where natural controls such as predators or parasites of an introduced species are lacking, the species may multiply rapidly, taking over its new environment, often drastically altering the ecosystem and out-competing local organisms. The damage caused by invasive species can be devastating, through alteration of ecosystem dynamics, biodiversity loss, reduction of the resilience of ecosystems, and loss of resources, with environmental, economic as well as socio-cultural impacts.

TEXT #11

Crabs Play Defense, Save Corals

Sarah Zielinski

https://student.societyforscience.org/article/crabs-play-defense-save-corals

Crabs, like the tiny one at center, nestle within the branches of some stony corals. These crabs can protect their hosts from killer snails and starfish.

Some small but feisty crabs live among the branches of stony coral. And that's a good thing — at least for the corals. Although tiny, the crabs can fend off coral-eating starfish up to 18 times their size, a new study finds.

In 2008, for instance, an outbreak of crown-of-thorns starfish overran corals in Mo'orea, an island in French Polynesia. The large, spiky starfish (or sea stars) quickly devastated the local coral reefs in this part of the southern Pacific Ocean. But corals defended by one species of guard-crab survived. The new research shows why.

"The guard-crabs are tough," says C. Seabird McKeon. When their corals are under

attack, the crabs become quite defensive. "They pinch off tube feet and spines, and go after the sea star in all of its softest spots," he notes. McKeon is a marine biologist at the Smithsonian Marine Station in Fort Pierce, Fla. He worked on the new study, which was published September 30 in *PeerJ*.

Large crown-of-thorn starfish can overwhelm and eat undefended corals.

In some parts of the Indian and Pacific oceans, *Trapezia* (Tra-PEE-zee-uh) crabs nestle inside the arms of stony corals. These corals belong to the genus *Pocillopora* (PAH-sill-ah-POR-ah). Even the largest crabs that hang out in them are only a few centimeters (roughly 1 inch) wide. At night, these mini crabs feed on fats that they harvest from the tips of the tentacles of coral polyps. (Polyps are the living part of corals.)

In return for this food, the crabs remove dirt (sediment). They also guard their host coral from predators. Scientists refer to this type of relationship as mutualism. In it, both species benefit from being together.

Typically, a single mating pair of *Trapezia* crabs — and maybe some young crabs — nestle within the arms of a branching coral. But if the coral colony is big enough, it can host multiple species of crabs. Especially large colonies of these corals may become home to as many as five different species.

During the 2008 Mo'orea outbreak, the local population of crown-of-thorns starfish soared. These starfish can grow to 45 centimeters (18 inches) across. The multi-armed animals dined heavily on the reef, dramatically reducing the area covered by living coral.

Prior to the outbreak, 80 percent of the reef had been live coral. Afterward, a measly 3.4 percent was living.

But one species of stony coral took a much smaller hit. McKeon and his colleague Jenna M. Moore were curious how these *Pocillopora* beat the odds. To test the possible role of *Trapezia* crabs, they removed one of the largest species of these crabs: *T. flavopunctata*. They kidnapped the crustaceans from 45 of the coral colonies. Another 45 colonies got to keep their crabs. Over the next few weeks, the researchers compared what happened when corals were visited by starfish.

When populations of these voracious starfish soar every few decades, they can devastate coral reefs. The coral isn't completely helpless, however: Some crabs that live with the corals can fend off the starfish, new data show.

The predators attacked 64 percent of the unguarded corals. But the hungry starfish left 82 percent of the crab-hosting corals alone. In other words, fewer than one-third as many of the guarded corals were attacked. Unguarded corals lost an average of 22 percent of their tissues, compared with only 2 percent in a crab-guarded colony.

A crown-of-thorns starfish (Acanthaster planci).

The protective effect even extended to other coral species. The starfish tended to leave alone neighboring corals — even when they hosted no guard-crabs.

Many undefended corals housed other, smaller species of guard-crabs. Lab experiments showed that these crabs can play their own, different roles in coral defense. Members of

one of these crab species, just 4 to 6 millimeters (0.15 to 0.24 inch) across, could fend off small, coral-eating snails. Crabs from a slightly larger species grow 9 to 11 millimeters across. They couldn't defeat the snails but could protect the coral from *Culcita* starfish.

When corals have several different-sized species of crabs tucked into their arms, they may stave off several threats. That may help to explain why large *Pocillopora* colonies tend to survive better than small ones, the researchers say. After all, these corals are big enough to make room for several species at once.

McKeon says his team's study also points to the value of biodiversity. "The study is a good demonstration of how animals that appear very similar can be playing different ecological roles," he says. "If we change our starting point to 'each species is probably doing something different' instead of 'these species are all probably doing the same thing,' it means that our perception of the importance of biodiversity may change."

TEXT #12

What You Can Do

NOAA

http://coralreef.noaa.gov/getinvolved/whatyoucando/

Even if you don't live near a reef, you can help protect coral reefs in the U.S. and around the world. There are many actions, little and big, that you can take in your life to help conserve coral reefs; a selection of these are listed below.

Long-lasting light bulbs are a bright idea. If every household in the U.S. replaced a burned-out bulb with an energy-efficient, ENERGY STAR-qualified compact fluorescent bulb, it would prevent greenhouse gas emissions equivalent to that from at least 800,000 cars. Climate change is one of the leading threats to coral reef survival, so let your conservation light shine.

It stinks to send chemicals into our waterways. Whether you live one mile or one thousand miles from a coral reef, the chemicals we use to clean our houses and beautify our lawns end up in our waterways and are carried to the oceans. Just one pound of phosphorus in water produces an estimated five hundred pounds of algae, blocking sunlight and starving coral reefs. Do your part by using naturally-derived and biodegradable detergents and cleaning products. Outside the house, minimize the impacts of fertilizer by using zero-phosphorus products or no more than one pound per 1,000 square feet of turf area for nitrogen (you need just half that amount in shade).

Corals are already a gift. Don't give them as presents. Corals are popular as souvenirs, for home decor and in costume jewelry, yet corals are living animals that eat, grow and reproduce. It takes corals decades or longer to create reef structures, so leave corals and other marine life on the reef.

Don't drag the reef into this. Use reef mooring buoys when available. Or, anchor in sandy areas away from coral and sea grasses so that the anchor and chain do not drag on nearby corals or tear-up sea grass beds. Once broken, corals can take decades or longer to redevelop, and a damaged reef is less able to provide food, habitat and shoreline protection.

The ocean floor is not a dance floor. Coral reefs are alive. Stirred-up sediment can smother corals, and each inch of reef can take decades to redevelop once broken. Divers and snorkelers can do their part by maintaining proper buoyancy control, never touching reefs and spreading the word about coral reef stewardship.

Choose Sustainable Seafood. Visit NOAA Fish Watch to get to know your seafood from ocean to plate. NOAA FishWatch provides science-based facts to help consumers make smart sustainable seafood choices. Also let restaurants and grocers in your community know that you, their customer, care about where your seafood comes from. Encourage them to shift their seafood purchases towards more sustainable choices.

Conserve water. The less water you use, the less runoff and wastewater eventually find their ways back into the oceans.

Be a wastewater crusader. Make sure that sewage from your boat and home is correctly treated. Excess nutrients in wastewater can negatively impact coral reef ecosystems.

Be a marine debris crusader. In addition to picking up your own trash, carry away the trash that others have left behind. More than just an unsightly nuisance, beach and boating litter poses a significant threat to the health and survival of marine organisms,

which can swallow or get tangled in beverage containers, plastic bags, six-pack rings, and other debris.

Be an informed fish tank owner. Only buy marine fish and other reef organisms when you know they have been collected in an ecologically sound manner. Do not release store-bought fish into local waterways and ask store managers where the organisms come from and how they were collected. Does the country have a management plan to insure the harvest was legal and sustainable over time?

Become a volunteer monitor. Participate in community coral reef monitoring programs. If you do not live near a coast, get involved in protecting your watershed.

Educate yourself about coral reefs and the creatures they support. How many different species live in reefs? What new medicines have been developed from reef organisms? Participate in training or educational programs that focus on reef ecology. When you further your own education, you can help others understand the fragility and value of the world's coral reefs.

Hire local guides when visiting coral reef ecosystems. This will help you learn about local resources, and protect the future of the reef by supporting the local economy.

If you dive, don't touch! Take only pictures and leave only bubbles. Keep your fins, gear, and hands away from the reef, as this contact can hurt you and will damage the delicate coral animals.

Participate in the Great Annual Fish Count. What better way to enjoy your vacation than snorkeling or diving in America's coral reefs? The Fish Count helps scientists better understand coral reef fish populations.

Recycle. This helps keep trash out of the oceans and also out of landfills where it can have an adverse impact on the water quality of our rivers and oceans.

Report dumping or other illegal activities. Help be the eyes and ears of the reef! Your involvement can make a big difference.

Respect local guidelines when you visit a reef. Help keep coral reefs healthy by respecting local customs, recommendations, and regulations. Ask local authorities or your dive shop how to be a reef-friendly tourist.

Spread the word. Remember your own excitement at learning the value and importance of coral reef ecosystems. Sharing this excitement gets everyone involved.

Stay informed. Find out about existing and proposed laws, programs, and projects that could affect the world's coral reefs. Many Web sites provide information about coral reefs and what you can do to get involved.

Support organizations that protect coral reefs. Many groups have coral reef programs, and your support will make a big difference.

Support reef-friendly businesses. Ask what your dive shop, boating store, tour operator, hotel and other coastal businesses are doing to save coral reefs. This is especially important in coastal areas with reefs. Let them know you are an informed consumer and care about reefs.

Visit your local aquarium or zoo. Ask what they are doing and how you can help conserve our coral reefs. The answer may pleasantly surprise you. Visit the Association of Zoos and Aquariums to find a zoo or aquarium near you.

Volunteer for a reef or beach cleanup. Don't live near a coral reef? Then consider volunteering for a beach, river, or stream cleanup, if you live near one. Trash, especially plastic, is a great traveler once in the water and can end up in a far-away coral reef. Project AWARE Foundation is one of many organizations that coordinates global beach and underwater cleanups year round. The International Coastal Cleanup is another annual event that occurs at multiple locations worldwide, typically in the month of September.

EXTENDED READING TEXT #1

Threatened Coral Get Fishy

Stephen Ornes

https://student.societyforscience.org/article/threatened-coral-get-fishy-rescue

When toxic seaweed gets too close to this coral, gobies fight and bite back!

When toxic seaweed (green at right) gets too close to a type of coral (yellow structure), this fish, a broad-barred goby (Gobiodon histrio), responds to a distress signal sent by the coral and nibbles the seaweed away.

Organisms called coral have hard skeletons that anchor them to the skeletal remains of other, dead coral. These sea creatures, which form stony communities called reefs, are fighting to survive. They're under attack from overfishing, pollution and climate change. And they have to compete for space and sunlight with seaweed — some of which is

poisonous to coral. But new research shows that when threatened by that seaweed, some corals release a chemical that may bring an army of fish to the rescue.

When the seaweed gets too close, the coral emits a chemical that attracts gobies, a type of fish. They nibble back the invaders, protecting the reef's corals. The finding is a bright spot in an otherwise gloomy field of science that shows many clusters of coral around the world are dying.

"We've lost about 80 percent of the living coral in the Caribbean and 50 percent in the western Pacific," Nancy Knowlton told *Science News*. "So a better understanding of what keeps corals healthy is essential," the biologist says. Knowlton, who studies coral as part of her work at the Smithsonian Institution in Washington, D.C., did not work on the new study.

With fewer corals, fish and other creatures living in and near reefs have fewer places to call home. This leads to a decrease in populations of fish — including the gobies that would normally keep invasive seaweed away. That leaves the reef with fewer protectors.

"Without these, you have these algae-covered parking lots," says study author Mark Hay. A marine ecologist, he works at the Georgia Institute of Technology in Atlanta.

Along with Danielle Dixson, Hay studied a type of coral called *Acropora nasuta*. It resembles a tight tangle of deer antlers. The researchers put some of the corals into different cages along with some — or none — of the fish that often live in their reefy neighborhood.

Finally, the scientists added the toxic, emerald-green seaweed (*Chlorodesmis fastigiata)*. As it brushes against coral, this seaweed releases a poison that can slay the animal within days.

That seaweed is "really pretty and really nasty," Hay told *Science News*. Some types of fish were no help and left at the first sign of danger. But two types of a colorful fish called gobies responded to the coral's distress call and acted "like little hedge trimmers," Hay said. Hay and Dixson identified what recruited the gobies: It was a chemical the corals released into the water.

The scientists suggest that the gobies also benefit. Biologists knew that the fish produce a mucus on their skin that acts like a poison to their predators. Hay and Dixson found that when the gobies snacked on the toxic seaweed, they produced a stronger poison, one that acted twice as fast on predators. So when gobies help protect corals, they're protecting themselves, too.

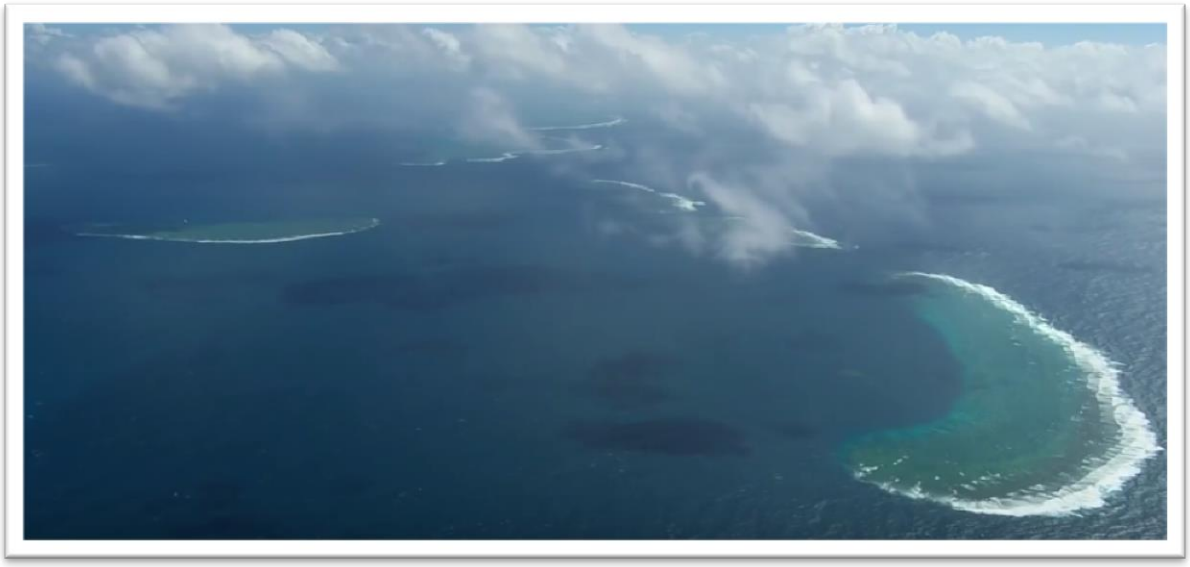
Scientists don't understand the chemistry behind the coral-goby partnership. But it does show that biologists have a lot to learn about the complex relationships among animals in a reef.

EXTENDED READING TEXT #2

BBC HD Great Barrier Reef: Nature's Miracle

BBC Documentary Video

https://www.youtube.com/watch?v=AK1sfx3iGbA



Hour long video on the coral reefs, beautifully shot and well-narrated.

APPENDICES

APPENDIX A: GLOSSARY

Words selected for the glossary are words that either cannot be determined from context, may inhibit student understanding of the text, or are essential to deep understanding of the expert pack. **The packs are designed to have words repeat for multiple exposures; words are provided in the glossary only once.** Students should reference the glossary before beginning each new text, in order to familiarize themselves with the words.

Text Title	Words and informal definitions that explain the meaning of the word in the context of the text at hand
Text 2: Top 25 Coral Reef Facts	**Biomass**—Organic matter or organisms; often refers to plants or plant-based materials. **Ecosystem**—A system formed by the interaction of a community of organisms and their environment. **Harvested**—Gathering for use or consumption. Pieces of the coral reef can be harvested to make medicine. **Microscopic**—Too tiny to be seen with the human eye. **Promote** – supports and help continue; the barrier reef supports the survival of plant and animal life.
Text 3: Coal Polyps – Tiny Builders	**Anemones**—Water-dwelling animals with many tentacles (long, waving arms used to trap food). **Pigment** – the color zooxanthellea (tiny algae and the food source of polyps) produce, giving the polyp its color.
Text 4: Corals Dine on Microplastics	**Calcium carbonate –** The main chemical compound in limestone, a rock made from the tiny shells of ancient marine organisms. Its formula is $CaCO_3$ (meaning it contains one calcium atom, one carbon atom and three oxygen atoms). **Ecosystem—** A group of interacting living organisms — including microorganisms, plants and animals — and their physical environment within a particular climate. Examples include tropical reefs, rainforests, alpine meadows and polar tundra. **Habitat—** The area or natural environment in which an animal or plant normally lives, such as a desert, coral reef or freshwater lake. A habitat can be

	home to thousands of different species. **Marine biologist—** A scientist who studies creatures that live in ocean water, from bacteria and shellfish to kelp and whales. **Microplastics—** A small piece of plastic, 5 millimeters (0.2 inch) or smaller in size. Microplastics may have been produced at that small size, or their size may be the result of the breakdown of water bottles, plastic bags or other things that started out larger. **Photosynthesis— (**verb: photosynthesize) The process by which green plants and some other organisms use sunlight to produce foods from carbon dioxide and water. **Plankton—** A small organism that drifts or floats in the sea. Depending on the species, plankton range from microscopic sizes to organisms about the size of a flea. Some are tiny animals. Others are plantlike organisms. Although individual plankton are very small, they form massive colonies, numbering in the billions. The largest animal in the world, the blue whale, lives on plankton. **Pollutant—** A substance that taints something — such as the air, water, our bodies or products. Some pollutants are chemicals, such as pesticides. Others may be radiation, including excess heat or light. Even weeds and other invasive species can be considered a type of biological pollution. **Polypropylene—** The second most common plastic in the world. It is tough and durable. Polypropylene is used in packaging, clothing and furniture (such as plastic chairs). **Predator—** A creature that preys on other animals for most or all of its food. **Species—** A group of similar organisms capable of producing offspring that can survive and reproduce. **Tissue—** Any of the distinct types of material, comprised of cells, which make up animals, plants or fungi. Cells within a tissue work as a unit to perform a

	particular function in living organisms. Different organs of the human body, for instance, often are made from many different types of tissues. And brain tissue will be very different from bone or heart tissue.
Text 5: Coral Reef Biodiversity	**Biodiversity—** (short for biological diversity) The number and variety of species found within a localized geographic region. **Competitor –** Another species that competes with the coral for environment or food resources. Here, the biodiversity protects the coral reef in many ways from competitors who would move in and destroy the reef. **Excrete –** to expel as waste. Parrotfish wat coral and excrete sand. **Solitary –** To live alone; sea anemone are often solitary, rather than living in large groups like the polyps that make up the coral
Text 6: Coral and Coral Reefs	**Acroporid**—One of the most dominant organisms that build the coral reefs **Algae—** Single-celled organisms, once considered plants (they aren't). As aquatic organisms, they grow in water. Like green plants, they depend on sunlight to make their food. **Asexual reproduction** – A type of reproduction in which a plant or animal can reproduce itself, without needing another male or female animal. **Brood** – To hold eggs inside the body of a polyp. These polyps allow sperm to fall in from the water and they fertilize inside the polyp. **Encroaching** – Moving in too closely. Competitors may encroach on a coral's space or food, or Crown-of-thorns starfish encroach upon coral and eat them! **Fragmentation –** A type of reproduction in which part of the coral breaks off, and forms a new colony elsewhere. **Larvae**—The immature form of an animal, such as an insect. Caterpillars are the larvae of butterflies. **Mushroomed**— Exploded rapidly; grew. **Mutualism—** A type of symbiosis in which both organisms benefit from the relationship.

	Nematocysts— A jellyfish is part of this family **Organism**— A singular form of life, whether plant or animal **Sexual reproduction –** A type of reproduction in which eggs and sperm interact to make new animals; most sexual reproduction for polyps happens in the water, outside of the animal! **Spawning** – Producing and/or laying eggs in water. In this case, polyps sexually reproduce by releasing (spawn) eggs and sperm into the water at the same time. **Substrate**— The surface or material on or from which an organism lives, grows, or obtains its nourishment. **Synchronized** – Happening at the same time **Teem**— To be overflowing with; the coral reef teems with life
Text 9: Why Are Coral Reefs Important	**Biologically—** Relating to living matter or the science of living organisms. The coral reef is biologically diverse, meaning it supports multitudes of plants and animals. **Buffer—** A protective shield or wall. The coral reef is a buffer between land and dangerous waves. **Dissipate**— To scatter into different directions; coral reefs dissipate dangerous waves that could damage land and people. **Economically**— Valuable/important: Important to the money or financial situation of a community. **Erosion**— When soil or sand washes away into the water; coral reefs prevent the erosion of beaches and land, keeping the land and humans safer from tsunamis and dangerous weather **Federally**— Having to do with the national government. **Hotspot**— A popular, important location. **Induce**— To help or cause to happen, such as labor (giving birth to a baby). **Pharmaceutical**—Drugs or medicine you would purchase at a **pharmacy** **Replenishment**— To add to what is lacking, or put back to make whole

	again. Coral reefs replenish the beach with sand, as parrot fish and other organism break them down, covert them to sand, which washes up on the beach **Spawning** –Releasing a mass of eggs – usually in the water **Sustainable**— An action or event able to be maintained or supported without severe damage to something else. Sustainable fisheries do not damage corah reefs, so that coral reefs can produce more fish. It is not sustainable to damage the reef when fishing, because then fish will have no place to live and breed.
Text 10: Status of and Threat to Coral Reefs	**Alteration** – A significant change **Anthropogenic** – The results of the influence of human being son nature. For example, carbon dioxide produced by humans from cars and industry has caused global warming, which in turn causes sea temperatures to rise, which kills coral reefs. **Cyanide** – A deadly poison, dumped into the water to spun or kill fish, making them easy to catch. **Degraded** – Broken down and destroyed over time. The coral reefs are being degraded by human activities (degradation is the noun). **Herbivorous** – Animals that eat only plants – if the herbivorous fish are gone because of fishing, too much algae grows because they aren't there to eat it **Husbandry practice** – Raising plant or animals for human use, such as food or, here, for aquariums. **Mitigate** – To make less severe or harmful. **Symbiosis/Symbiotic** – A relationship where two different living things live together and depend on each other for survival. **Voracious** – A living being that eats a tremendous amount of food – Crown-of-thorn starship are voracious eaters of coral reefs. **Unregulated** – No rules to manage a system. Here, unregulated tourism means that business take advantage of the coral reef, without thinking about the permanent harm they are causing.

Text 11: Crabs Play Defense, Save Corals	**Crustaceans—** Hard-shelled water-dwelling animals including lobsters, crabs and shrimp. **Ecology—** A branch of biology that deals with the relations of organisms to one another and to their physical surroundings. A scientist who works in this field is called an **ecologist**. **Genus—** A group of closely related species. For example, the genus *Canis* — which is Latin for "dog" — includes all domestic breeds of dog and their closest wild relatives, including wolves, coyotes, jackals and dingoes. **Starfish—** A type of sea creature that is shaped like a star. Starfish, also known as sea stars, are not true fish. They are related to sand dollars, sea urchins and sea cucumbers. **Sediment—** Material (such as stones and sand) deposited by water, wind or glaciers.
Text 12: What You Can Do	**Adverse—**Harmful or unfavorable. **Conserve**— Protect or save from destruction. **Equivalent**—Equal to. **Fragility**—The quality of being delicate, breakable, or vulnerable; the coral reefs are **fragile** – they have fragility. **NOAA** — National Oceanic and Atmospheric Administration. A federal agency that works to study and educate about the changing environment. **Phosphorous**— A chemical that encourages algae growth on the top of the ocean, which blocks sunlight and kills the coral reefs. **Unsightly**— Ugly or unpleasant to look at. **Watershed**— Describes the area where water and land touch; often, this areas becomes polluted from human actions, which then flows out to the ocean and to coral reefs.

APPENDIX B: STUDENT ACTIVITIES AND JOURNALS

Cumulative and Singular Activities to Accompany your Expert Pack!

Cumulative Activities - The following activities should be completed and updated ***after reading each resource in the set***. The purpose of these activities is to capture knowledge building from one resource to the next, and to provide a holistic snapshot of central ideas of the content covered in the expert pack. *As a developing expert, you are **required** to complete the Rolling Knowledge Journal and Sensational 6 Journals.*

Rolling Knowledge Journal

1. Read each selection in the set, one at a time.

2. After you read *each* resource, stop and think what the big learning was. What did you learn that was new *and important* about the topic from *this* resource? Write, draw, or list what you learned from the text about the topic.

3. Then write, draw, or list how this new resource added to what you learned from the last resource(s).

4. Include at least 2 entries per article or resource.

Please see the example on the following page.

Rolling Knowledge Journal EXAMPLE

Title	Write, Draw, or List	
Title of the text	**New and important learning about the topic and quotes**	**How does this resource add to what I learned already?**
TEXT 1: "Incident"	• This poem is about Baltimore, which tells me that discrimination did not take place just in the South. • I am surprised at the people blaming the little kids.	• *(Connect to anything else you have read or learned for THIS TEXT ONLY – all other responses must connect to the texts that came before in the series*) • I know that part of the reason the civil rights movement got started was because people got fed up with discrimination.
TEXT 2: "1960: Sitting Down to Take A Stand"	• Four teenagers in Greensboro, NC, sat at a countertop in a department store that was only meant for white customers. • More and more people sat at the countertops in "sit-ins," which was a peaceful way to protest. • Sit-ins were a new way to protest discrimination. • "I felt that this could be the last day of my life" recalls Franklin McCain, now 67 and living in Charlotte, North Carolina. "But I thought that it was well worth it. Because to continue to live the way we had been living—I questioned that. It's an incomplete life. I'd made up my mind that we absolutely had no choice."	• This makes me think more about the text "Incident" because both the girl in the poem and the students who sat at the lunch counter experienced racism and name-calling. • Both the narrator of ""Incident" and the students had to wait a long time for discrimination to get better. • The students in Greensboro handled discrimination differently than the narrator. • The quote from this article also makes me think of "incident" because if I had experienced what she did, I would feel that I did not have a choice either.
TEXT 3: … and so on…		• *Make connections across both texts!*

Rolling Vocabulary: "Sensational Six"

1. Read each resource then determine the 6 words from each text that *most exemplify the central idea of the text.*
2. Next, use your 6 words to write about the most important idea of the text. You should have as many sentences as you do words.
3. Continue this activity with EACH selection in the Expert Pack.
4. After reading all the selections in the Expert Pack, go back and review your words.
5. *Now select the "Sensational Six" words from ALL the word lists.*
6. Use the "Sensational Six" words to summarize the most important learning from this Expert Pack.

Please see the example on the following page.

EXAMPLE: Rolling Vocabulary: "Sensational Six"

Title	Six Vocabulary Words & Sentences
"1960: Sitting Down to Take A Stand"	**Words:** 1. Supreme Court 2. Sit-ins 3. Inspired 4. Demonstrations 5. Landmark 6. Exhibit **Sentences:** 1. The Supreme Court is the highest Federal court and set an important precedent when ruling on Brown vs The Board of Education. 2. Sit-ins were a form of peaceful protest that gained popularity during the civil rights movement. 3. The author describes this peaceful protest as one that inspired others to get involved in the movement. 4. Demonstration… (And so on…)
Sensational Six – selected from all the articles read!	1. Segregation 2. Integration/Desegregation 3. Protests/(Protestors) 4. Brown vs. Board of Ed. 5. Discrimination 6. Equality

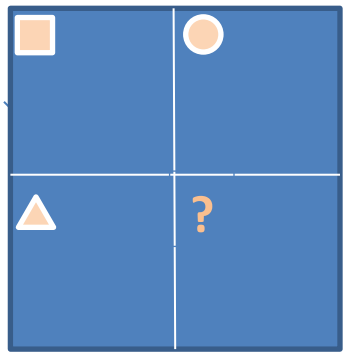
Sensational Summary:

Protests and lawsuits like Brown vs. the Board of Education sought to get rid of all racial segregation. Segregation in schools, freedom rides, and sit-ins received a lot of attention as people fought for equality and integration. The landmark decision to desegregate schools put many young people in the positon to be courageous and be a part of the protests that made history even if it was dangerous and very difficult.

****Please note that the Sensational Summary comes at the end of the entire expert pack –] the Sensational Six words are chosen from all of them.****

Singular Activities – You'll do the following activities for at least two of your texts. The purpose of these activities is to check for understanding, capture knowledge gained, and provide a variety of ways for you to interact with each text.

Picture of Knowledge: Take a piece of paper and fold it two times: once across and once top to bottom so that it is divided into 4 quadrants, and draw in these shapes:



Then, write in each square:

Square: What one thing did you read that was interesting to you?

Triangle: What one thing did you read that taught you something new?

Circle: What did you read that made you want to learn more?

Question Mark: What is still confusing to you? What do you still wonder about?

Find at least one classmate who has read [selection] and talk to each other about what you put in each quadrant.

Quiz Maker (Recommended for [Insert Text/Resource Titles])

- Make a list of questions that would make sure another student understood the information.

- Your classmates should be able to find the answer to the question *from the resource*.
- Include answers for each question.
- Include where you can find the answer in the resource.
- Find someone to take your quiz and then go over the answers with them!

Wonderings

I'm a little confused about:	**This made me wonder:**
On the left side, track things you don't understand from the article as you read	*On the right side, list some things you still wonder (or wonder now) about this* ***text OR topic***
EXAMPLE from "Incident": • What does it mean to be a "Baltimorian?"	• Was Baltimore considered the South? • Does this have a connection to the famous bus protest? • Where did that protest happen (can't recall right now!)

APPENDIX C: OTHER STUDENT ACTIVITES

Peer Summaries:

Break students into pairs. One of them is the reporter, and the other is the interviewee. The reporter will conduct an interviews about the text or texts, and take notes as the interviewee speaks. You may provide questions for them to ask, or they may generate their own. The reporter should try to ask follow-up questions

Word and Knowledge Wall:

Create a bulletin board of a tree with no leaves. At the end of each class period, have students select a new word or piece of knowledge that they acquired from the day's reading, and they pin it to a bulletin board or wall. Over time, this will grow into a veritable tree of knowledge – and also provide a CFU into what students are pulling from the texts on a daily basis.

TED Talks

At the end of a pack, students should be given the opportunity to display their new expertise! A 2-3 minute "TED Talk" is a great wat for students to collaborate on knowledge, create visuals to support their talk, and provide extra exposure to speaking and listening standards, in particular SL4.

Socratic Circles

Develop several big questions for student to discuss and debate about once they have completed the pack. Pair students up and organize chairs into two circles: pairs will sit in either the inner or outer circle. Those on the inner circle are the ones debating or speaking; those in the outer ring are taking notes and preparing. Give each student three talking chips – they "spend" a chip each time they speak and once they have spent their chips, their partner enters in their place and takes over. This ensures that everyone has the opportunity to share and speak.

APPENDIX D: FOR TEACHERS: SUGGESTIONS FOR IMPLEMENTING EXPERT PACKS

Through our wide-ranging experience supporting teachers with expert pack implementation, we've discovered a few actions that have been directly related to student success. They are recommended action steps for teachers when implementing expert packs.

Note that while students have the opportunity to select their own packs, teachers should do the following for every pack they put in front of students – teachers should "become the expert" before they ask their students to do the same.

Before Starting the Pack:

1. Read the Pack: Read the pack, first as a reader. Annotate it using your classroom strategy (see below) and write your own notes.. Begin to "become the expert."

2. Complete the exemplar Rolling Knowledge and Sensational Six Vocabulary Journals: Read the pack again, and create your own, exemplar set of journals. This serves two important purposes: one, to ensure you know the content well in order to help your students and two, to develop the bar of what you would like to see from them in their own journals. Without this bar of excellence, it is easy to accept mediocre journal entries.

3. Select additional activities: Which additional activities may work well with specific articles in the pack? When will you do these activities?

4. Make a calendar: While students should be working at their own pace, teachers should establish some benchmarks for pace-setting. When should students be halfway through the pack? When should the pack be complete? When might it be beneficial to have a TED Talk or Socratic Circle?

5. Plan for selection and structure: How will students select their packs so that they choose based on their actual interest, rather than on what their friends pick? How can you introduce the topics in engaging ways? Many teachers develop 5 minute presentations on the packs or have students who have already completed other packs try to "sell" the packs to others! How will the room be organized for effective small group work? How will you transition in and out of expert pack time each day? Successful expert pack implementation depends upon strong organization, especially in the beginning –how will you model for students what you want to see from them?

During Expert Pack Time:

1. Teach annotation: Students should be taught a standard annotation format, and should annotate in this way, allowing the teacher to see what they are annotating and why as well as preventing the massive blocks of highlighting with no purpose. Here are our suggestions.

    - *Underline* major points, and state why you underlined it in the margin.
    - Circle keywords or phrases that are confusing, and jot down a potential definition in the margin.
    - *Use a* **question mark (?)** for questions that you have during the reading. Write the question in the margin.

- *Use an* **exclamation mark (!)** for things that surprise you, and write what surprised you or stood out to you in the margin.
- ***Draw an arrow (↲)*** when you make a connection to something inside the text, or to an idea or experience outside the text, and write that connection in the margin.
- Every 3-5 paragraphs, jot down the gist of what you just read in a sentence or two.

2. Students should work with each other - not with the teacher: Students should be working in small groups, according to the pack. When they have a question, they should first ask each other. If no one in the group can answer, only then can students ask the teacher for help.

3. Rooms are quiet and collegiate: *Expert packs, with their focus on information, intense reading about a topic, and collection of notes and evidence, is very much an opportunity for students to practice the work and collaboration they will do in college.* Classrooms should feel like a college library – small groups of students, occasionally speaking quietly, but mostly working with their texts. Teacher should set these expectations, monitor, circulate, and offer support when necessary. That said, students should be encouraged to grapple with the information largely on their own.

4. Students need to receive regular feedback: Students will work hard on their journals, and deserve regular feedback on them. Included in the appendix is a suggested rubric, which includes a section for self-assessment. Students should grade themselves, as well as receiving ratings from the teacher, which can open objective conversations about where to improve and grow, as well as allowing the teacher to keep careful tabs on students' knowledge and vocabulary development as they move through the pack. Remind students to focus on growth – where can they get better? How can these journals show off what they are learning in meaningful ways? Use your exemplar rubric as the bar for high expectations. Read student work carefully for copying directly from the text, as well as for ideas that range wildly away from them.

Concluding an Expert Pack:

1. Provide the opportunity for students to show off! Students need the opportunity to display their new expertise in engaging ways that are still rigorous. TED Talks, including visuals, are an excellent way to do this, but there are a myriad of other ways to allow students to teach each other, showcase their knowledge, and use their vocabulary.

2. Provide time for reflection and feedback: Give students the opportunity to reflect on their experience with the pack. What went well? What could have gone better? What do they still want to learn? Teachers should do their own self-reflection at this time, as well, thinking constantly about how to involve themselves less in the process and allow students to develop expertise and independence with each other.

APPENDIX E: GRADING RUBRIC

The suggested use of this rubric is as a tool for student reflection and goal-setting as well as a support to help teachers monitor student progress and provide feedback on student efforts. At the end of each week, students should complete the rubric on their own, assigning numerical scores on their week's work and writing and short reflection on the second page. The teacher can then look over their work and respond with her/his own scores and feedback, and students can set goals for improvement.

Annotations	• Using symbols correctly and effectively • Writes notes in margins when annotating symbols • Periodically writes the gist of what is being read • Writing is readable and annotations make sense with the content	1 2 3 4 5
Rolling Knowledge	• Knowledge collected demonstrates new knowledge about the text • Knowledge is not randomly selected – it makes sense and shows developing thoughts about the topic • Connections to previous readings are logical and not haphazard • Knowledge is not copied from the text – it is paraphrased and, whenever possible, uses the vocabulary words! • Journal section is neatly structured and readable	1 2 3 4 5
Sensational Six	• Words selected exemplify the gist and big ideas of the text • Definitions adhere to the word's meaning in context (not just looking it up in the dictionary • Sentences are about the reading topic, not random • Journal section is neatly structured and readable	1 2 3 4 5
Summary	• Summary of each article includes usage of all sensational six words, but is not limited to 6 sentences! • Summary includes direct quotes from the text if possible, but definitely includes evidence and important details • Summary includes knowledge that is included in the Rolling Knowledge journal • Journal section is neatly structured and readable	1 2 3 4 5
Participation and Group Work	• Reading independently at own pace – not rushing • Asking partner or group before asking the teacher • Not wasting time and Persevering! • Journals are neat and allow you to track your new knowledge and vocabulary across the whole expert pack • Improving based on feedback each week.	1 2 3 4 5

Weekly Feedback	STUDENT SELF SCORE AND RATIONALE: • What went well… • Action Steps for next week… TEACHER SCORE AND RATIONALE: • What went well… • Action Steps for next week…

Name: Class: Date:

APPENDIX F: SUPPORTS FOR STRUGGLING STUDENTS

By design, the **gradation of complexity** within each Expert Pack is a technique that provides struggling readers the opportunity to read more complex texts. Listed below are other measures of support that can be used when necessary.

- Provide a brief **student-friendly glossary** of some of the academic vocabulary (tier 2) and domain vocabulary (tier 3) essential to understanding the text.
- Download the Wordsmyth widget to classroom computers/tablets for students to access student-friendly definitions for unknown words. http://www.wordsmyth.net/?mode=widget
- Provide brief **student friendly explanations** of necessary background knowledge
- Include **pictures or videos** related to the topic within and in addition to the set of resources in the pack.
- Select a small number of texts to **read aloud** with some discussion about vocabulary work and background knowledge.
- Provide **audio recordings** of the texts being read by a strong reader (teacher, parent, etc.)
- **Chunk the text** and provide brief questions for each chunk of text to be answered *before* students go on to the next chunk of text.
- Pre-reading activities that focus on the **structure and graphic elements** of the text.
- Provide **volunteer helpers** from the school community during Expert Pack time.
- **Expert Pack Glossary** For each TEXT a glossary has been provided based on the major words that might inhibit comprehension, or that cannot be determined from context. Please note that, while challenging words may reoccur in text, they will not repeat in the glossary.

The following sections are additions made by Student Achievement Partners to help users better support English Language Learners in engaging with the text set.

Why Text Sets Support English Language Learners

Those acquiring English as a second language have to learn many words in English to catch up with their English-only peers. Vocabulary builds at a much quicker pace when reading a set of connected texts. Text sets are an adaptable resource perfect for building knowledge and vocabulary. Student use of text sets can vary in terms of independence or teacher supports based on the individual needs of the students in the room. Activities found within the text set resources reflect several best practices for English Language Learner instruction including:

- Providing brief, engaging texts that provide a high volume of reading on a topic.
- Providing web-based resources and/or videos that are tied to the content of the texts students are reading.
- Providing opportunities for students to learn new vocabulary through the use of student-friendly definitions in resource-specific glossaries.
- Allowing for options to reinforce newly learned vocabulary and/or content through graphic organizers.
- Providing opportunities for students to reinforce new vocabulary through multi-modal activities including written work, group discussion, viewing visual content, and reading texts that feature the vocabulary.

Teachers of ELLs may use the protocols on the following pages to provide additional support to students who are struggling to access the content within text sets because they are new to English.

ELL Text Set Protocol Grades 3-12

The goal of text sets is to help students build knowledge through a volume of independent reading, and it is important that educators provide scaffolds to allow English Language Learners to be successful in engaging meaningfully with the texts, even as students are still developing English language skills. The protocol below can be used for teaching with text set resources as a full class. Students can also be trained on the protocol so that they can utilize text sets in small groups or partnerships as a resource for independent or reciprocal reading and study.

Please note that this protocol includes options for teachers. Individual decisions should be made considering the needs of the students and the demands of the content, keeping in mind that the goal of each scaffold is to allow students to meaningfully access the text and move toward independent, knowledge-building reading.

Step one: Build knowledge and vocabulary.

Introduce students to the overall topic/content of the text set, including knowledge demands needed to engage in the content, and domain-specific vocabulary necessary for comprehension. This should be done prior to engaging with the texts themselves; time allotted to this activity should reflect student needs (anywhere from 5 minutes prior to reading, to a full day's lesson is appropriate).

Options for this step include:

- Engage students in reading and discussing auxiliary texts (of lesser complexity) and resources (illustrations, photographs, video clips) on the topic of the text set.
- Pre-teach a few key content-specific terms prior to students engaging with a text set. (Ideas for text-focused vocabulary instruction can be found here.)
- Provide the student-friendly glossary included in the text set prior to reading each text.
- When possible, allow students to read texts in their home language about the topic under study.

Step two: Read text orally.

Focusing on one resource at a time, allow students to listen to a fluent read of the resource, while following along with their own copy of the text.

Options for this step include:

- Have a fluent reader model the first read of a text or resource.
- Have students engage in a buddy/partner read.
- Use recordings of the text to provide additional opportunities to hear expert reading.

Step three: Engage in group discussion about the content.

Allow students time in partnerships or small groups to discuss the content of the resource.

Options for this step include:

- Allow for discussion/conversation (in the students' home language if possible) with a small group of students reading the same text set prior to writing or provide heterogeneous language groupings to talk about content and discuss what students are learning.
- Have students refer to the student-friendly glossary included with each text set to identify meanings for new vocabulary necessary for comprehension.

Step four: Write about what was read.

Options for this step include:

- Use the "Rolling Knowledge Journal" and/or "Rolling Vocabulary Journal" as a shared writing routine/ graphic organizer to help to scaffold the writing process and capture student knowledge over time.

- Provide students with several supports to help students engage in writing/drawing about what they read:
    - Use mentor texts about which students can pattern their writing.
    - Allow them to write collaboratively.
    - Show students visual resources as prompts, etc.
    - Provide language supports such as strategically chosen sentence starters.

Repeat steps one through four with each resource in the text set as appropriate.