CORAL REEF LESSON PLAN

Caution: Do Not Bleach!

Focus

Coral reef bleaching

Grade Level

9-12 (Life Science)

Focus Question

Why are coral reefs important, and what are possible explanations for the phenomenon known as "coral bleaching?"

Learning Objectives

- Students will be able to identify and explain five ways that coral reefs benefit human beings.
- Students will be able to identify and explain three major threats to coral reefs.
- Students will be able to describe major components of the Coral Reef Early Warning System.
- Students will be able to identify and discuss actions that can be undertaken to reduce or eliminate threats to coral reefs.
- Students will be able to discuss at least one hypothesis that explains why corals under stress may expel their zooxanthellae

Materials

- Copies of either "Coral Reef Subject Review" *(fill-in-the-blank version, with or without word bank)* or "Coral Reef Subject Review Crossword Puzzle," one copy for each student or student group
- Computers with internet access

Audio/Visual Materials

None, unless students require A-V equipment for their public education programs

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Classroom style or groups of 4-6 students

Maximum Number of Students

30

Key Words

Coral reefs
Zooxanthellae
Symbiosis
Bleaching

Background

Coral reefs are one of the most biologically productive ecosystems on Earth. Most people have seen images of brightly colored fishes and other reef-dwelling organisms, yet many do not understand why these systems are personally important. Programs and articles about coral reefs typically point out benefits that include protecting shorelines from erosion and storm damage, supplying foods that are important to many coastal communities, and providing recreational and economic opportunities. These benefits are obviously important to people who live near reefs, but there is another aspect of coral reefs that can benefit everyone: the highly diverse biological communities are new sources of powerful antibiotic, anti-cancer and anti-inflammatory drugs.

The idea of coral reefs as a source of important new drugs is new to many people; but in fact, most drugs in use today come from nature. Aspirin, for example, was first isolated from the willow tree. Morphine is extracted from the opium poppy. Penicillin was discovered from common bread mold. Although almost all of the drugs derived from natural sources come from terrestrial organisms, recent systematic searches for new drugs have shown that marine invertebrates produce more antibiotic, anti-cancer, and anti-inflammatory substances than any group of terrestrial organisms. Particularly promising invertebrate groups include sponges, tunicates, ascidians, bryozoans, octocorals, and some molluscs, annelids, and echinoderms.

Some of the drugs derived from marine invertebrates are:

Ecteinascidin – Extracted from tunicates; being tested in humans for treatment of breast and ovarian cancers and other solid tumors

Topsentin – Extracted from the sponges *Topsentia genitrix*, *Hexadella* sp., and *Spongosorites* sp.; anti-inflammatory agent

Lasonolide – Extracted from the sponge *Forcepia* sp.; anti-tumor agent

Discodermalide – Extracted from deep-sea sponges belonging to the genus *Discodermia*; anti-tumor agent

Bryostatin – Extracted from the bryozoan *Bugula neritina*; potential treatment for leukemia and melanoma

Pseudopterosins – Extracted from the octocoral (sea whip) *Pseudopterogorgia elisabethae*; anti-inflammatory and analgesic agents that reduce swelling and skin irritation and accelerate wound healing

ω**-conotoxin MVIIA** – Extracted from the cone snail *Conus magnus*; potent pain-killer

Think a moment about the invertebrates in this list. Notice that most of these species are sessile, and live all or most of their lives attached to some sort of surface. Several reasons have been suggested to explain why these animals are particularly productive of potent chemicals. One possibility is that they use these chemicals to repel predators, since they are basically "sitting ducks." Since many of these species are filter feeders, and consequently are exposed to all sorts of parasites and pathogens in the water, they may use powerful chemicals to repel parasites or as antibiotics against disease-causing organisms. Competition for space may explain why some of these invertebrates produce anti-cancer agents: If two species are competing for the same piece of bottom space, it would be helpful to produce a substance that would attack rapidly dividing cells of the competing organism. Since cancer cells often divide more rapidly than normal cells, the same substance might have anti-cancer properties.

For more information on drugs from the sea, visit *http://www.reefcheck.org/articles/june_03/drugs_sea.pdf* and *http://www.reefcheck.org/articles/june_03/marine_pharmacology.pdf*

Despite their numerous benefits to humans, many coral reefs are threatened by human activities. Sewage and chemical pollution can cause overgrowth of algae, oxygen depletion, and poisoning. Fishing with heavy trawls and explosives damages the physical structure of reefs as well as the coral animals that build them. Careless tourists and boat anchors also cause mechanical damage. Thermal pollution from power plants and global warming cause physiological stress that kills coral animals and leaves the reef structure vulnerable to erosion. Many of these impacts are the result of ignorance; people simply aren't aware of the importance of coral reefs or the consequences of their actions, but the damage and threats to reefs continues to increase on a global scale.

Some of the most severe damage appears to be caused by thermal stress. Shallow-water reef-building corals live primarily in tropical latitudes (less than 30° north or south of the equator). These corals live near the upper limit of their thermal tolerance. Abnormally high temperatures result in thermal stress, and many corals respond by expelling the symbiotic algae (zooxanthellae) that live in the corals' tissues. Since the zooxanthellae are responsible for most of the corals' color, corals that have expelled their algal symbionts appear to be bleached. Because zooxanthellae provide a significant portion of the corals' food and are involved with growth processes, expelling these symbionts can have significant impacts on the corals' health. In some cases, corals are able to survive a "bleaching" event and eventually recover. When the level of environmental stress is high and sustained, however, the corals may die.

Prior to the 1980s, coral bleaching events were isolated and appeared to be the result of short-term events such as major storms, severe tidal exposures, sedimentation, pollution, or thermal shock. Over the past twenty years, though, these events have become more widespread, and many laboratory studies have shown a direct relationship between bleaching and water temperature stress. In general, coral bleaching events often occur in areas where the sea surface temperature 1°C or more above the normal maximum temperature.

In 1998, the President of the United States established the Coral Reef Task Force (CRTF) to protect and conserve coral reefs. Activities of the CRTF include mapping and monitoring coral reefs in U.S. waters, funding research on coral reef degradation, and working with governments, scientific and environmental organizations, and business to reduce coral reef destruction and restore damaged coral reefs. Using high-resolution satellite imagery and Global Positioning System (GPS) technology, the National Oceanic and Atmospheric Administration (NOAA) has made comprehensive maps of reefs in Puerto Rico, the U.S. Virgin Islands, the eight main Hawaiian Islands and the Northwestern Hawaiian Islands. Maps of all shallow U.S. coral reefs are expected to be completed by 2009. NOAA monitors reefs using a system of specially designed buoys that measure air temperature, wind speed and direction, barometric pressure, sea temperature, salinity and tidal level, and transmit these data every hour to scientists. Satellites are also used to monitor changes in sea surface temperatures and algal blooms that can damage reefs. Research and restoration projects on selected coral reefs are conducted by NOAA's National Undersea Research Program.

The first part of this lesson is intended to:

- introduce students to coral reefs and improve their understanding of why these systems are important, how they are threatened, and what can be done to protect and restore these unique and valuable ecosystems; and to
- introduce students to hypotheses that explain why corals under stress may expel their zooxanthellae.

In the second part of this lesson, students design and prepare educational programs to improve public awareness of the importance of coral reefs and what needs to be done to reduce or eliminate harmful impacts from human activities. This activity offers many opportunities for cross-curricular activities, and may be extended over several weeks or months. If time is limited, you may choose to use the first part alone.

Learning Procedure

Part 1

1\.

Direct students to the coral reef tutorials at *http://www.nos.noaa.gov/education/welcome.html*. You may want to assign different tutorial sections to each student group. Have each student or student group complete one version of the Coral Reef Subject Review and lead a discussion to review the answers. Be sure that students understand the relationship between coral animals and their symbiotic algae (zooxanthellae), and that under thermal stress many corals will expel their zooxanthellae.

Briefly explain the purpose and activities of the U. S. Coral Reef Task Force (CRTF), and highlight the monitoring functions that are intended to identify reef areas threatened by thermal stress or algal blooms.

2\.

Tell students that their assignment is to investigate possible explanations for zooxanthellae expulsion by corals under stress, and prepare a written report outlining at least one hypothesis that explains this behavior. The report should explain:

- the symbiotic relationship between corals and their zooxanthellae;
- how corals obtain their zooxanthellae; and
- how environmental stress may alter the symbiosis.

If you want to provide a starting point for this research, the following resources will be useful:

http://www.nos.noaa.gov/education/corals/supp_coral_roadmap.html (Roadmap to Resources: Corals)

http://www.gbrmpa.gov.au/corp_site/info_services/publications/reef_research/issue2_98/2rmn1.html (article: Bleaching The Great Unknown)

http://www.oneocean.org/overseas/200009/coral_bleaching_the_hows_and_whys_and_whats_next.html (article: Coral Bleaching: the Whys, the Hows and What Next?)

http://www.biology.ualberta.ca/courses.hp/zool250/CoolPapers/Cnidaria/Anthozoa/AnemoneZooxanth.pdf (article: Feeding behavior and acquisition of zooxanthellae by planula larvae of the sea anemone *Anthopleura elegantissima*)

http://ioc.unesco.org/coralbleaching/Hughes%20et%20al.pdf (article: Climate Change, Human Impacts, and the Resilience of Coral Reefs)

http://www.crc.uri.edu/comm/download/Coral_1-4.pdf (article: Coral Bleaching: Causes, Consequences and Response)

http://www.breeders-registry.gen.ca.us/Reprints/Misc/macna_VII/tyree.htm (article: Scleractinian Corals in Nature and Captivity)

3.

Lead a discussion of students' research results. Written reports should include most of the following points:

- Zooxanthellae are single-celled motile algae (dinoflagellates).
- Many marine invertebrates in addition to corals have symbiotic algae.
- Photosynthesis by zooxanthellae provides a significant source of nutrition for many host symbionts; as much as 90% of the total energy requirement in some coral and giant clam species.
- Zooxanthellae are also involved in calcium carbonate deposition (skeletal growth) in some corals.
- Some zooxanthellae produce an ultraviolet-absorbing pigment that may act as a sort of "sunscreen" for host corals.
- The mechanism by which corals obtain zooxanthellae (or, from a slightly different perspective, become infected with zooxanthellae) is not known, but sea anemone larvae have been reported to indiscriminantly ingest zooxanthellae along with other particulate materials. The algal cells become incorporated into the larvae's endodermal cells, while other particulate materials are either digested or expelled.
- "Bleaching" has been observed in most marine organisms that host zooxanthellae.
- It is not known whether bleaching happens because the algae leave their host animal or because the host expels the algae.

- Bleaching can also occur when algae expel their pigments.
- Bleaching appears to be the result of various types of environmental stress, including high temperature, exposure to excessive irradiance, lowered salinity, and pollution.
- Combinations of different stresses may result in bleaching, even though corals might be tolerant of the individual conditions (for example, if corals are near their upper thermal limit, even small increase in irradiance can result in bleaching).
- Elevated temperatures reduce the photosynthetic ability of zooxanthellae.
- Increased atmospheric carbon dioxide may lead to an increased in dissolved carbon dioxide in seawater, which will increase the solubility of calcium and reduce calcification.
- While there is no absolute proof that bleaching events are the result of global warming, many scientists consider the link to be incontrovertible.
- Different species of corals have different tolerance levels for various environmental factors. Similarly, different strains of zooxanthellae have different tolerance levels.
- Different strains of zooxanthellae are found within and among coral species.
- Coral genera with fast growth rates and high metabolic rates are most susceptible to bleaching.
- The "adaptive bleaching hypothesis" proposes that corals expel their zooxanthellae under stress so that they can be replaced with other strains that are better suited to the stress conditions. There is no evidence, however, that corals can simply take up more tolerant strains of algae. In addition, high mortality, reduced growth rates, and decreased fecundity in bleached corals do not suggest an effective adaptation to stress conditions.
- If the stress conditions that cause bleaching do not persist for more than about six weeks, most bleached corals recover.
- Some scientists have predicted that persistent temperature increases coupled with other stresses will lead to widespread loss of coral reefs, which may require 500 years or more to recover.
- Marine protected areas are currently the most effective management tool for protecting coral reefs and other marine resources, but they cannot stop temperature increases or other adverse climate changes.

Ask students to discuss why coral reefs are at risk, and what they think can or should be done to reduce or eliminate the negative impacts of human activity on coral reefs. There is a strong possibility that a significant part of the current risk to coral reef systems is the result of human activity, particularly as it relates to global warming. Meaningful actions to address this type of issue depend upon widespread understanding of the problem and commitment to workable solutions. Public education is an important step toward building this sort of understanding and commitment. Have students brainstorm what "key messages" might form part of a public education program about coral reefs, what audiences should be targeted to receive these messages, and how these messages might be most effectively delivered to these audiences.

Part 2

Have students or student groups prepare one or more public education programs about coral reefs, based on the results of their brainstorming sessions in Step 3. Encourage students to consider various media, including publications, visual presentations, drama, music, etc. You may want to have an entire class work on a single program, or have smaller groups work on multiple programs using the medium (or media) or their choice. There are many possibilities, depending upon the target audiences. These presentations also offer cross-curricular opportunities, particularly with social studies, English language arts, and fine arts. Whatever media students choose to work with, their final presentation should be accompanied by a list of sources for the information they present. A good starting point for this activity is the Roadmap to Resources: Corals *(http://www.nos.noaa.gov/education/corals/supp_coral_roadmap.html)*, which provides links to many other sources of coral reef data and information.

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics" in the navigation menu to the left, then "Habitat," then "Coral Reef."

The "Me" Connection

Have students write a short essay on why coral reefs are personally important, what personal actions may contribute to human-caused threats to coral reefs, and what they could do to reduce these threats.

Extensions

1. The symbiotic relationship between zooxanthellae and coral polyps can be a springboard for discussing other types of cellular symbionts. Many biology students tend to overlook microbial associations in natural communities, but there is mounting evidence that eukaryotic organisms were (and are) the result of symbiotic associations between prokaryotic organisms. At some point in these associations, one (or more) species (called endosymbionts) entered the cells of another species, and performed useful functions. Each species had its own DNA, and when these organisms reproduced, both were replicated. Eventually, the individual identities of the species disappeared, resulting in a new type of organism. This sort of transformation has actually been seen in the laboratory, and is described in Margulis and Sagan (1986). For more information and a lesson plan devoted to this topic, visit *http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_CellMates.pdf*.

2. Have students or student groups prepare a report on a specific aspect of coral biology, ecology, or management. Some possible topics include:
   - coral diseases
   - natural and anthropogenic hazards
   - oil spills on coral reefs
   - coral reef restoration
   - species diversity on coral reefs
   - benthic habitats associated with coral reefs
   - relationships between coral reefs and seagrass or mangrove ecosystems

See Roadmap to Resources: Corals *(http://www.nos.noaa.gov/education/corals/supp_coral_roadmap.html)* for links to information on these and other relevant topics.

Resources

http://www.nos.noaa.gov/education/corals/supp_coral_roadmap.html
– National Ocean Service website's Roadmap to Resources about corals, with links to many other sources of coral reef data, background information, and reports

Anonymous, 1998. Bleaching The Great Unknown. Reef Research volume 8. *http://www.gbrmpa.gov.au/corp_site/info_services/publications/reef_research/issue2_98/2rmn1.html*

Ariadne, D. and D. Diamante-Fabunan. 2000. Coral Bleaching: the Whys, the Hows and What Next? OverSeas, The Online Magazine for Sustainable Seas. *http://www.oneocean.org/overseas/200009/coral_bleaching_the_hows_and_whys_and_whats_next.html*

Schwarz J.A., V.M. Weis, and D.C. Potts. 2002. Feeding behavior and acquisition of zooxanthellae by planula larvae of the sea anemone Anthopleura elegantissima. Marine Biology 140:471-478. (available on-line at *http://www.biology.ualberta.ca/courses.hp/zool250/CoolPapers/Cnidaria/Anthozoa/AnemoneZooxanth.pdf*)

http://www.coral@coral.aoml.noaa.gov – website with a bulletin board on coral bleaching

Hughes, T.P., et al. 2003. Climate Change, Human Impacts, and the Resilience of Coral Reefs. Science 301:929-933. Available online at *http://ioc.unesco.org/coralbleaching/Hughes%20et%20al.pdf*

http://www.crc.uri.edu/comm/download/Coral_1-4.pdf – "Coral Bleaching: Causes, Consequences and Response;" a collection of papers presented at the Ninth International Coral Reef Symposium, October 2002.

Margulis, L. and D. Sagan. 1986. Microcosmos. University of California Press. Berkeley.

Tyree, S. 1995. Scleractinian Corals in Nature and Captivity. Available online at *http://www.breeders-registry.gen.ca.us/Reprints/Misc/macna_VII/tyree.htm*

Faulkner, D. J. 2000. Marine pharmacology. Antonie van Leeuwenhoek 77: 135-145. Available online at *http://www.reefcheck.org/articles/june_03/marine_pharmacology.pdf*

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- The cell
- Interdependence of organisms
- Behavior of organisms

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

CORAL REEF LESSON PLAN

Coral Reef Subject Review

1. ____________ organisms are composed of hundreds to hundreds of thousands of individual animals.

2. Individual coral animals are called __________.

3. The mouth of individual coral animals is surrounded by a circle of _____________.

4. After food is consumed by corals, waste products are expelled through the ______________.

5. Time of day when most corals feed: _____________

6. To capture their food, corals use stinging cells called ____________________.

7. Nematocysts are capable of delivering powerful, often lethal, _____________.

WORD BANK

plants	digitate	erosion	pollution
clear	table	weather	algae
productive	elkhorn	algae	fishing
calcium carbonate	colonial	tidal emersions	fringing
habitats	zooplankton	El Niño	barrier
encrusting	planulae	zooxanthellae	cm
calyx	broadcast	mutualistic	flat
theca	mortality	photosynthesis	crest
basal plate	synchronized	poor	buttress
feed	lunar	atoll	seaward
branching	tentacles	stresses	slope
foliase	mouth	temperatures	below
metamorphose	night	CREWS	euphotic
massive	nematocysts	mucous	sessile
polyps	toxins	recycling	asexual
mushroom	species	zooxanthellae	millions
larvae	medicines	physical stress	
sunset	tourism	predation	
phototaxis	food	anthropogenic	

8. A coral's prey ranges in size from nearly microscopic animals called ________________ to small fish.

9. Many corals collect fine organic particles in films and strands of _____________.

10. Most reef-building corals contain photosynthetic algae called __________________ which live in their tissues.

11. Corals and algae have a ___________ relationship.

12. Symbiotic algae supply corals with glucose, glycerol, and amino acids, which are the products of ____________.

13. Tropical ocean waters are generally [rich or poor] ___________ in nutrients.

14. The relationship between the algae and coral polyp facilitates a tight __________ of nutrients, which is the driving force behind the growth and productivity of coral reefs.

15. The unique and beautiful colors of many stony corals are caused by ________________.

16. ___________ can cause coral polyps to expel their algal cells.

17. Coral _____________ occurs when coral polyps expel their algal cells, causing the colony to take on a stark white appearance.

18. Because of their intimate relationship with symbiotic algae, reef-building corals respond to the environment like _________.

19. Because their algal cells need light for photosynthesis, reef corals require ___________ water.

20. Although coral reefs require nutrient-poor water, they are among the most ___________ and diverse marine environments.

21. Reefs form when polyps secrete skeletons of __________.

22. As they grow, coral reefs provide structural __________ for hundreds to thousands of different vertebrate and invertebrate species.

23. The skeletons of stony corals are secreted by the lower portion of the polyp. This process produces a cup, or ________, in which the polyp sits.

24. The walls surrounding the corals' skeletal cup are called the ____________.

25. The floor of the corals' skeletal cup is called the ____________.

26. __________ is a system of specially designed buoys that measure conditions that may cause bleaching on coral reefs.

27. When polyps are physically stressed, they contract into their calyx so that virtually no part is exposed above their skeleton. At other times, polyps extend out of the calyx. Most polyps extend the farthest when they __________.

28. __________ corals have primary and secondary branches.

29. __________ corals look like fingers or clumps of cigars and have no secondary branches.

30. __________ corals form table-like structures and often have fused branches.

31. __________ coral has large, flattened branches.

32. __________ corals have broad plate-like portions rising in whorl-like patterns.

33. __________ corals grow as a thin layer against a substrate.

34. __________ corals are ball-shaped or boulder-like and may be small as an egg or as large as a house.

35. __________ corals resemble the attached or unattached tops of mushrooms.

36. Coral reefs begin to form when free-swimming __________ attach to submerged rocks or other hard surfaces along the edges of islands or continents.

37. __________ reefs project seaward directly from the shore, forming borders along the shoreline and surrounding islands.

38. __________ reefs border shorelines, but are separated from their adjacent land mass by a lagoon of open, often deep water.

39. An ____________ is formed when a reef has developed around a volcanic island that subsides completely below sea level while the coral continues to grow upward.

40. Massive corals have growth rates of 0.3 to 2 __________ per year

41. Bottom topography, depth, wave and current strength, light, temperature, and suspended sediments act on coral reefs to create horizontal and vertical zones of living species. The reef __________ is usually the zone closest to shore, followed by the reef __________ or algal ridge, then the __________ zone, and finally the __________.

42. Reef-building corals cannot tolerate water temperatures [above or below] __________ 18° Celsius (C).

43. Most reef-building corals require very saline water.

44. Reef-building corals' requirement for high light explains why most reef-building species are restricted to the ______ ____ zone, the region in the ocean where light penetrates to a depth of approximately 70 meters.

45. As adults, almost all corals are __________, which means that they remain on the same spot on the sea floor for their entire lives.

46. In __________ reproduction, new polyps bud off from parent polyps to expand or begin new colonies.

47. In sexual reproduction, coral eggs and sperm join to form free-floating, or planktonic, larvae called __________.

48. Species that release massive numbers of eggs and sperm into the water to distribute their offspring over a broad geographic area are called __________ spawners.

49. The time between planulae formation and settlement is a period of exceptionally high __________ among corals.

50. Along many reefs, spawning occurs as a __________ event, when all the coral species in an area release their eggs and sperm at about the same time.

51. The long-term control of spawning may be related to temperature, day length and/or rate of temperature change (either increasing or decreasing). The short-term (getting ready to spawn) control is usually based on __________ cues.

52. The final release of gametes during spawning is usually based on the time of __________.

53. Planulae exhibit positive ___________.

54. Once planulae settle on the bottom, they __________ into polyps and form colonies that increase in size.

55. Coral reefs support more __________ per unit area than any other marine environment.

56. Scientists estimate that there may be ____________ of undiscovered species of organisms living in and around reefs.

57. Coral reef biodiversity is considered key to finding new __________ for the 21st century.

58. Healthy reefs contribute to local economies through __________.

59. In developing countries, coral reefs provide critical __________ resources for tens of millions of people.

60. Coral reefs buffer adjacent shorelines from wave action and prevent __________, property damage and loss of life.

61. Natural damage to coral reefs frequently occurs because of __________.

62. Slow-growing corals that are damaged by storms may be overgrown by __________ before they can recover.

63. Reefs also are threatened by __________ that can cause shallow water coral heads to overheat and dry out.

64. Increased sea surface temperatures, decreased sea level and increased salinity from altered rainfall can all result from weather patterns such as __________.

65. Corals are vulnerable to __________ by fishes, marine worms, barnacles, crabs, snails and sea stars.

66. Human-caused, or __________ activities are major threats to coral reefs.

67. One of the most significant human-caused threats to reefs is __________.

68. When some contaminants enter the water, nutrient levels can increase, promoting the rapid growth of __________ and other organisms that can smother corals.

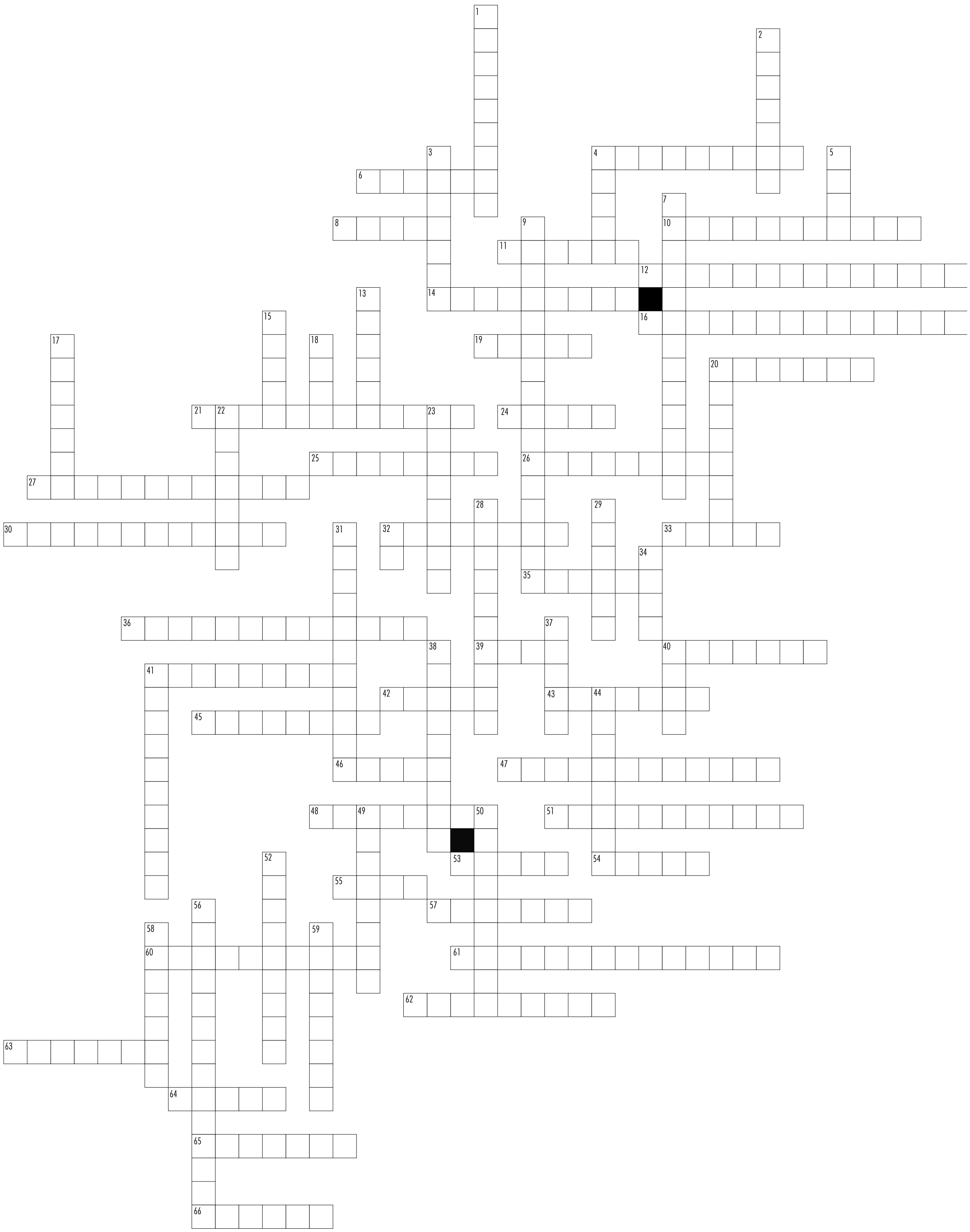
69. In many areas, coral reefs are destroyed when cyanide or dynamite are used for __________ activities.

70. Coral diseases generally occur in response to biological __________, such as bacteria, fungi and viruses, and non-biological stresses, such as increased sea surface temperatures, ultraviolet radiation and pollutants.

71. Many scientists believe that the increased frequency of coral diseases over the last 10 years is related to deteriorating water quality and increased __________ that may allow for the proliferation and colonization of microbes.

CORAL REEF LESSON PLAN

Coral Reef Subject Review: Crossword Puzzle



Across

4. The mouth of individual coral animals is surrounded by a circle of ____.
6. Many corals collect fine organic particles in films and strands of ______.
8. The long-term control of spawning may be related to temperature, day length and/or rate of temperature change (either increasing or decreasing). The short-term (getting ready to spawn) control is usually based on __________ cues.
10. To capture their food, corals use stinging cells called _____ _____.
11. Coral reefs begin to form when free-swimming __________ attach to submerged rocks or other hard surfaces along the edges of islands or continents.
12. __________ can cause coral polyps to expel their algal cells.
14. Coral reef biodiversity is considered key to finding new __________ for the 21st century.
16. Most reef-building corals contain photosynthetic algae called _________which live in their tissues.
19. After the food is consumed by corals, waste products are expelled through the __________.
20. __________ corals have broad plate-like portions rising in whorl-like patterns.
21. The __________ is usually the zone farthest from shore.
24. plate The floor of the corals' skeletal cup is called the __________.
25. As they grow, coral reefs provide structural __________ for hundreds to thousands of different vertebrate and invertebrate species.
26. Coral __________ occurs when coral polyps to expel their algal cells, causing the colony to take on a stark white appearance.
27. Once planulae settle on the bottom, they __________ into polyps and form colonies that increase in size.
30. Many scientists believe that the increased frequency of coral diseases over the last 10 years is related to deteriorating water quality and increased __________ that may allow for the proliferation and colonization of microbes.
32. __________ organisms are composed of hundreds to hundreds of thousands of individual animals.
33. Slow-growing corals that are damaged by storms may be

overgrown by __________ before they can recover.

35. Increased sea surface temperatures, decreased sea level and increased salinity from altered rainfall can all result from weather patterns such as __________.
36. The unique and beautiful colors of many stony corals are caused by __________.
39. __________ corals form table-like structures and often have fused branches.
40. In many areas, coral reefs are destroyed when cyanide or dynamite are used for __________ activities.
41. Corals are vulnerable to __________ by fishes, marine worms, barnacles, crabs, snails and sea stars.
42. Most reef-building corals require very __________ water.
43. In __________ reproduction, new polyps bud off from parent polyps to expand or begin new colonies.
45. __________ corals look like fingers or clumps of cigars and have no secondary branches.
46. Time of day when most corals feed [__________]
47. Along many reefs, spawning occurs as a __________ event, when all the coral species in an area release their eggs and sperm at about the same time.
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51. Corals and algae have a __________ relationship.
53. __________ is a system of specially designed buoys that measure conditions that may cause bleaching on coral reefs.
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57. Natural damage to coral reefs frequently occurs because of __________.
60. Although coral reefs require nutrient-poor water, they are among the most __________ and diverse marine environments.
61. Reefs also are threatened by __________ that can cause shallow water coral heads to overheat and dry out.
62. The relationship between the algae and coral polyp facilitates a tight __________ of nutrients, which is the driving

force behind the growth and productivity of coral reefs.

63. As adults, almost all corals are __________, which means that they remain on the same spot on the sea floor for their entire lives.
64. An __________ is formed when a reef has developed around a volcanic island that subsides completely below sea level while the coral continues to grow upward.
65. Coral reefs buffer adjacent shorelines from wave action and prevent __________, property damage and loss of life.
66. The final release of gametes during spawning is usually based on the time of __________.

Down

1. Species that release massive numbers of eggs and sperm into the water to distribute their offspring over a broad geographic area are called __________ spawners.
2. __________ reefs border shorelines, but are separated from their adjacent land mass by a lagoon of open, often deep water.
3. Healthy reefs contribute to local economies through __________.
4. The walls surrounding the corals' skeletal cup are called the __________
5. Individual coral animals are called __________
7. Human-caused, or __________ activities are major threats to coral reefs.
9. Reefs form when polyps secrete skeletons of __________
13. Because of their intimate relationship with symbiotic algae, reef-building corals respond to the environment like __________.
15. Reef-building corals cannot tolerate water temperatures [above or below] 18° Celsius (C).
17. __________ corals are ball-shaped or boulder-like and may be small as an egg or as large as a house.
18. Tropical ocean waters are generally [rich or poor] in nutrients.
20. __________ reefs project seaward directly from the shore, forming borders along the shoreline and surrounding islands.
22. __________ coral has large, flattened branches.
23. In sexual reproduction, coral eggs and sperm join to form free-floating, or planktonic, larvae called __________.

28. __________ corals grow as a thin layer against a substrate.
29. Nematocysts are capable of delivering powerful, often lethal, __________
31. A coral's prey ranges in size from nearly microscopic animals called __________ to small fish.
32. Massive corals have growth rates of 0.3 to 2 __________ per year
34. In developing countries, coral reefs provide critical _______ __ resources for tens of millions of people.
37. Because their algal cells need light for photosynthesis, reef corals require __________ water.
38. One of the most significant human-caused threats to reefs is __________.
40. The reef __________ is usually the zone closest to shore.
41. Planulae exhibit positive __________
44. Reef-building corals' requirement for high light explains why most reef-building species are restricted to the ______ ____ zone, the region in the ocean where light penetrates to a depth of approximately 70 meters.
49. Coral diseases generally occur in response to biological __ ________, such as bacteria, fungi and viruses, and nonbiological stresses, such as increased sea surface temperatures, ultraviolet radiation and pollutants.
50. The time between planulae formation and settlement is a period of exceptionally high __________ among corals.
52. __________ corals have primary and secondary branches.

56. Symbiotic algae supply corals with glucose, glycerol, and amino acids, which are the products of __________.
58. Coral reefs support more __________ per unit area than any other marine environment.
59. Scientists estimate that there may be __________ of undiscovered species of organisms living in and around reefs.