A Reef of Your Own

Coral Reef Biology / 9-12 / Life Science

Focus Question

What physiological, ecological, and behavioral strategies contribute to the success of reef-building corals?

Learning Objectives

- Students will be able to describe and explain the importance of asexual and sexual reproductive strategies to reef-building corals.
- Students will be able to explain why is it important that reef-building corals have a nutritional strategy that includes both photosynthesis and carnivory.
- Students will be able to describe two behaviors that reef-building corals use to compete for living space with other species.
- Students will be able to explain how coral reefs can produce high levels of biological material when the waters surrounding these reefs contain relatively small amounts of the nutrients normally needed to support biological production.

Links to Overview Essays and Resources Useful for Student Research

http://oceanservice.noaa.gov/topics/ocean/coralreefs
http://www.coris.noaa.gov/about/biology
http://oceanservice.noaa.gov/education/kits/corals/coral01_intro.html

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 (from the Corals Tutorial at http://oceanservice.noaa.gov/education/kits/corals)
- (optional) Computers with internet access; if students do not have access to the internet, direct them to local library resources, and/or download copies of materials cited under "Learning Procedure" and provide copies of these materials to each student or student group

Audio/Visual Materials

- None

Teaching Time

Two or three 45-minute class periods, plus time for student research; additional time will be needed if you decide to set up a model coral reef ecosystem

Seating Arrangement

Groups of 3-4 students

Maximum Number of Students

30

Key Words

Coral reefs
Aquarium
Symbiosis
Zooxanthellae
Broadcast spawning

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Background Information

Coral reefs are among the most biologically diverse and productive ecosystems on Earth. Coral reefs protect shorelines from erosion and storm damage, supply foods that are important to many coastal communities, and provide recreational and economic opportunities. In addition, the highly diverse biological communities associated with coral reefs are new sources of powerful antibiotic, anti-cancer and anti-inflammatory drugs that have the potential to benefit the entire human race (for more information on drugs from coral reefs, see the Background section of *http://oceanservice.noaa.gov/education/kits/corals/lessons/coral_bleach.pdf*, and *http://oceanexplorer.noaa.gov/explorations/03bio/background/medicines/medicines.html*

Unfortunately, coral reefs are regularly damaged by a variety of natural stresses. Hurricanes and cyclones can break corals loose and scatter them into areas where they cannot survive. Storm damage to coastal areas can increase the inflow of sediments that can smother living reefs and reduce light needed by many shallow-water corals. Freshwater runoff may cause additional stress by lowering the salinity of water surrounding reefs. Unusually low tides can leave corals exposed to high temperatures, solar radiation, and the risk of drying out. High temperatures associated with phenomena such as El Nino and prolonged periods of unusual warmth cause severe damage through thermal stress and may be lethal. Corals are also subject to predation and disease. Coral reefs have survived these types of threats for millions of years. Some reefs have become extinct, but others have flourished.

Corals are also threatened by human activities. These stresses may have a much greater impact than natural stresses. Sewage and chemical pollution can cause overgrowths of algae, oxygen depletion, and poisoning. Poor land management and deforestation can lead to excessive runoff and sedimentation. Fishing with heavy trawls, poisons, and explosives damages the physical structure of reefs as well as the coral animals that build them. Careless tourists, boat anchors, and collection for the aquarium trade also cause mechanical damage. Thermal pollution from power plants and other human activities that raise water temperatures cause physiological stress that kills coral animals and leaves the reef structure vulnerable to erosion. Oil spills, fuel discharges, and anti-fouling chemicals from boats add additional stress. 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. There is also evidence that impacts caused by humans may be increasing the severity of natural threats. Many researchers have noticed an increase in coral diseases and believe that at least part of the reason is that the corals have been weakened by other stress factors.

One of the most striking responses to thermal stress is known as "bleaching." Most reef-building corals have single-cell algae called zooxanthellae living within their tissues. These algae play an important role in the corals' nutrition and growth. Pigments in the algae are also responsible for most of the corals' color. Under thermal stress, some corals may expel these algae, causing the corals to appear bleached. Some corals may recover and acquire replacement algae, but many others die.

In 1998, the President of the United States established the Coral Reef Task Force (CRTF) to protect and conserve coral reefs. The CRTF has identified six problem areas for priority action:

- Land-based sources of pollution;

- Overfishing;
- Lack of public awareness;
- Recreational overuse and misuse;
- Climate change and coral bleaching; and
- Disease.

As co-chair of the CRTF, and as directed by the Coral Reef Conservation Act of 2000, NOAA has the responsibility to conserve coral reef ecosystems. NOAA's coral reef conservation efforts are carried out primarily through its Coral Reef Conservation Program (CRCP). Under this program, NOAA works with scientific, private, government, and nongovernmental organizations at the local, federal, and international levels to address conservation actions.

All of these areas the CRTF has identified for action can benefit from broad public involvement, even from people who live thousands of miles from a living reef. The first step toward effective action to protect and manage coral reefs is to understand the biology of the organisms that create the reef structure.

In this activity, students will explore biology of reef-building corals, and use this knowledge to design a miniature coral reef system. If time permits, students may implement their design with live corals and other reef organisms.

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Learning Procedure

1. Direct students to the Corals Tutorials at : *http://oceanservice.noaa.gov/education/kits/corals/coral01_intro.html*. You may want to assign different tutorial sections to each student group. Have each student or student group complete one version of the Corals Subject (downloadable), and lead a discussion to review the answers. Be sure students grasp the following points:
Almost all reef building corals are sessile (they remain in one place and do not move), and are adapted to their environment through specific physiological and behavioral characteristics.

Particularly important are:

- Reproductive strategies (both sexual and asexual modes, including mass spawning events);
- A combination of photosynthetic and carnivorous nutrition; and
- Behavioral interactions with other species that allow corals to successfully compete for living space.

2. Tell students that they are going to design a functioning model of a coral reef ecosystem that could be put together in your classroom. To prepare for this task, their assignment is to research relevant aspects of

- Nutritional strategies used by corals;
- How corals compete with other species for space;
- How corals reproduce;
- How coral reefs can support large numbers of plants and animals when the waters surrounding these reefs contain so little of the nutrients needed to support biological production that these waters are often called "biological deserts"; and
- Key physical factors (temperature, water movement, etc.) required by corals.
- You may want to brainstorm some of these functions to get things started. Students may recognize the need for a source of energy (which implies one or more food chains), some means for disposing of wastes, a source of oxygen, etc. In addition to the coral reef tutorials, you may want to direct students to the Roadmap to Resources: Corals at *http://www.oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html*.

3. Lead a discussion of students' research results in the context of designing a model coral reef ecosystem. Students should recognize photosynthesis as the primary source of energy in coral reef systems and the role of the algae living within the coral tissues (zooxanthellae). Ask students to identify organisms that could provide an energy source

for their miniature coral reef ecosystem. Corals with their associated zooxanthellae are one possibility. Algae (both microscopic and macroscopic) are another possibility, and on natural reefs compete directly with corals for space. Since the algae can grow more quickly than corals, they could overrun a reef ecosystem unless there was a way to keep the algae in check. On natural reefs, grazing fishes and invertebrates fill this niche. You may want to point out that coralline algae have hard surfaces similar to the surfaces of corals. Coralline algae are very important to reef growth, since the larvae of many corals can only settle on surfaces that have been previously colonized by coralline algae.

Be sure to discuss the food chains (or webs) that will exist in the model system, and how many steps in the chain (trophic levels) might reasonably be included in the system. You may need to remind students that it takes at least 10 grams of primary producers to support 1 gram of herbivores, and 1 gram of herbivores can support less than 0.1 gram of primary carnivores, and so forth (i.e., energy transfer efficiency between trophic levels is less than 10%). This means that the number of trophic levels in your model ecosystem will be quite limited unless an external source of energy (i.e., supplemental feeding) is provided. Similarly, large or highly active organisms (including many fishes) will probably require supplemental feeding, and leftover artificial food is a major cause of pollution in small aquaria.

Students should understand that while zooxanthellae supply a major part of corals' energy needs through photosynthesis, most corals must feed on other animals as well. When feeding, the individual coral animals (polyps) extend their tentacles, sting living prey with toxic microscopic darts produced by cells called nematocysts, then draw the victims into their mouths. Most corals also produce strands of mucous that extend from the mouth. Floating particles of dead plants and animals stick to the mucous strands, which are periodically drawn back into the mouth. Some species feed entirely on these particles. Carnivory is essential to most corals, because food from animal sources provides nitrogen to corals and their zooxanthellae. This element is essential to both organisms, and is cycled back and forth between them.

This cycling process is a key to why coral reefs are often called "oases of productivity in biological deserts." The tropical ocean waters that surround coral reefs are generally nutrient-poor, and consequently support much less biological production than most temperate waters. The relationship between corals and zooxanthellae is a classic example of a mutualistic symbiosis (a symbiosis is a relationship between two organisms; a mutualistic symbiosis benefits both). This relationship overcomes the problem of limited nutrients by cycling key nutrients between the symbionts, and provides the basis for a highly productive and biologically diverse ecosystem. Similar cycling is involved with various metabolic by-products. In human societies we often call these by-products "waste," but in nature they are raw materials for other organisms. The resulting linkages are the basis for many material cycles. Since much of this work is done by microorganisms, these also need to be present in the model system.

Another consideration is the reproductive strategy used by coral species that are candidates for the model system. Students should recognize that most (about 75%) stony coral species form hermaphroditic colonies that produce both male and female gametes, while the remainder are gonochoristic (the colonies produce either male or female gametes, but not both). In many coral species (and other sessile organisms such as sponges), neighboring individuals of the same species release their gametes almost simultaneously, a process known as "broadcast spawning." Discuss the advantages of broadcast spawning, which is found in about 75% of reef-building coral species. In nature, spawning time is correlated with lunar cycles. The exact moment at which gametes are simultaneously released by hundreds of individual corals appears to be triggered by the time of sunset. The gametes fuse in the water column to form floating larvae (planulae). Planulae usually swim toward the surface then settle within two days, although the larval stage of some species may last several weeks or even months. The time between planulae formation and settlement is typically a period of very high mortality (mortality is lower in some coral species that brood the planulae within their bodies after internal fertilization).

This is also a good context in which to discuss competition. Remind students that corals require hard substrates (often coralline algae) for settlement and growth. Fast-growing corals compete for space using a strategy known as "overtopping," in which the faster-growing species shades its competition from light and currents bearing food particles, so the slower-growing species eventually starves. But the slow-growers have their own strategies. Nematocysts can be used for defense as well as feeding, and some corals are able to directly attack and kill nearby polyps of other species by extending tentacles and parts of their digestive system onto the polyps. Obviously, it would not be a good idea to locate an aggressive species near another species in the model system, unless one wants to see what happens.

Students should identify at least four key physical factors. Because most shallow-water corals are tropical, they need water temperatures between 18°C and 32°C. Salinity should be that of normal seawater (about 35 parts per thousand). Zooxanthellae obviously require light for photosynthesis, and students should recognize that the wavelengths present should resemble those of natural sunlight filtered through one to two meters of water. Water movement is essential to the transport of food particles to sessile organisms, as well as for the removal of byproducts of metabolism that will be toxic if allowed to accumulate.

4. Have each student group prepare a written report describ;ing how they would set up a miniature coral reef ecosystem, including a description of the key system functions, and how these functions will be provided. Students should compare and contrast the processes for providing these functions in their model system with the processes that provide these functions in natural coral reef systems. A typical model system would probably include a thermostat-controlled heater, a full-spec;trum light with a time switch, and a circulating water pump capable of providing good flow rates (usually 5 to 10 times the volume of the aquarium per hour). Supplemental aeration may also be needed, depending upon the configuration of the water pump (a water circulating system that includes a fountain-like device will provide aeration as well as flow). Have each group present their designs, and lead a discussion to select the best features for an "optimum" model coral reef.

If you want to actually set up a model coral system, turnkey kits are commercially available (e.g., from Carolina Biological Supply Company *http://www.carolina.com*). It is important to remember that a significant amount of damage is done to reefs by collectors who supply (often illegally) unscrupulous aquar;ium dealers. So be certain to verify the sources of any corals and other reef species brought into the classroom.

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The Bridge Connection

The Bridge is a growing collection online marine education resources. It provides educators with a convenient source of useful information on global, national, and regional marine science topics. Educators and scientists review sites selected for the Bridge to insure that they are accurate and current.

http://www.vims.edu/bridge/reef.html

The "Me" Connection

Have students write a brief essay describing what an individual could do to protect and/or restore coral reefs, and why this sort of action is important. If they donít think this is important, have them justify their opinion.

Extensions

1. Review and discuss "Things You Can Do to Protect Coral Reefs" at *http://coralreef.noaa.gov/outreach/thingsyoucando.html*. Even if you don't live near a reef, you can help protect coral reefs in the U.S.A. and around the world.

2. For more lesson plans and activities related to coral reefs, visit the education web pages for NOAA's Ocean Explorer Cayman Islands Twilight Zone 2007 Expedition at http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/edu.html.

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Resources

http://coralreef.noaa.gov/ – Home page for NOAA's Coral Reef Conservation Program

http://www.oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html – Roadmap to Resources: Corals; a guide for educators and students to specific online coral data offerings within the NOS and NOAA family of products

http://www.coris.noaa.gov/activities/actionstrategy – National Coral Reef Action Strategy

http://coralreef.noaa.gov/outreach/thingsyoucando.html – Things you can do to help protect coral reefs

http://www.coris.noaa.gov – NOAA's Coral Reef Information System (CoRIS) designed to be a single point of access to NOAA coral reef information and data products

http://www.coralreef.gov/taskforce/las.html – Coral Reef Local Action Strategies

http://www.nmfs.noaa.gov/habitat/habitatconservation/publications/Separate%20Chapters/Cover%20and%20Table%20of%20Contents.pdf – "The State of Deep Coral Ecosystems of the United States," 2007 report from NOAA providing new insight into the complex and biologically rich habitats found in deeper waters off the U.S. and elsewhere around the world.

http://www.latimes.com/news/local/oceans/la-oceans-series,0,7842752.special – "Altered Oceans," five-part series from the *Los Angeles Times* on the condition of Earth's ocean; published July 30 – August 3, 2006

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

- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Science and technology in local, national, and global chal;lenges

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Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1. The Earth has one big ocean with many features.

- Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 5. The ocean supports a great diversity of life and ecosystems.

- Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Essential Principle 6. The ocean and humans are inextricably interconnected.

- Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
- Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
- Fundamental Concept c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
- Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7. The ocean is largely unexplored.

- Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
- Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

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Corals 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

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

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 _________ 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. [how many?]

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 __________.

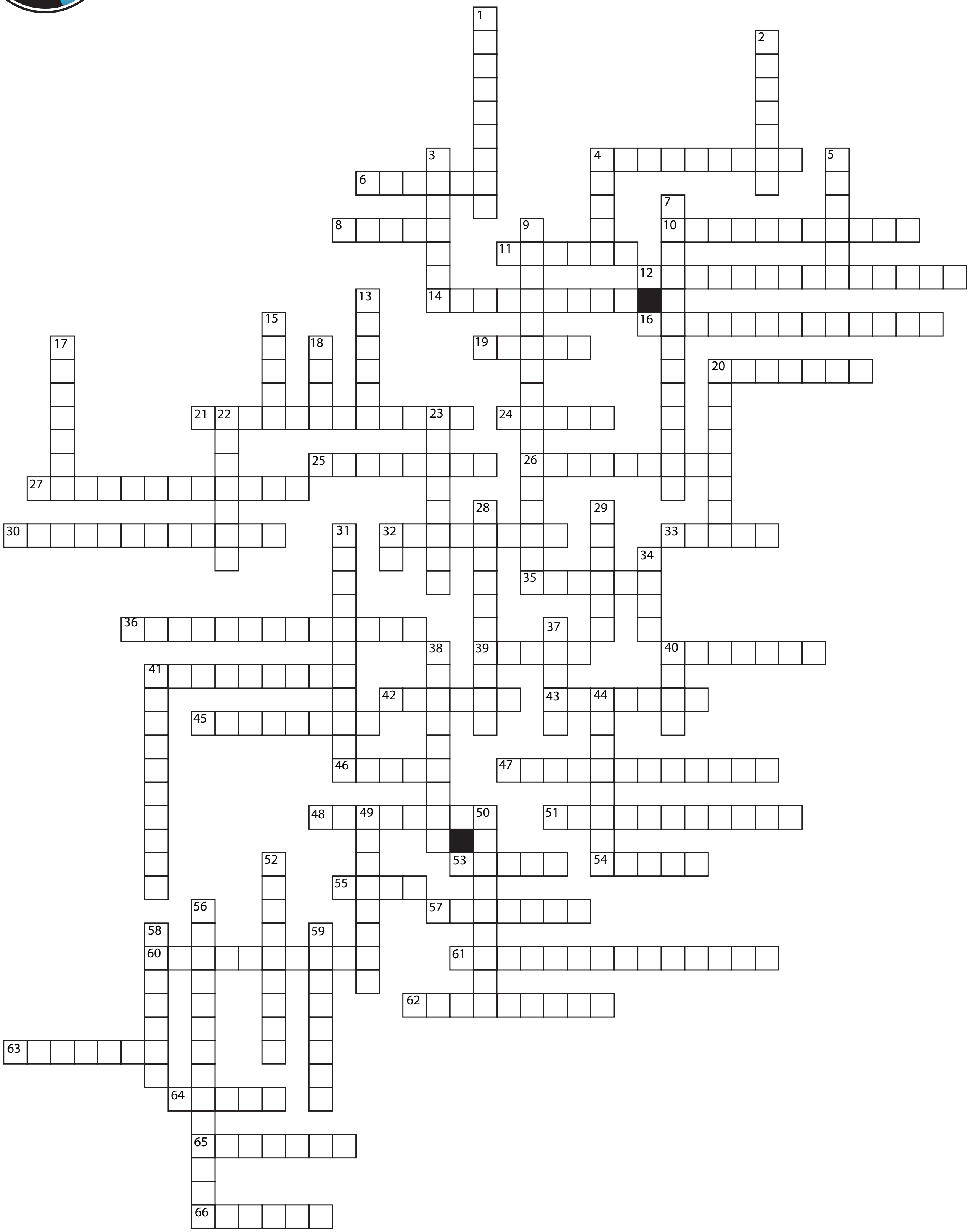
68. When some contaminants enter the water, nutrient levels can increase, promoting the rapid growth of __________ and other organisms that can smother corals.

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.

Corals 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. The skeletons of stony corals are secreted by the lower portion of the polyp. This process produces a cip or _________ in which the coral sits.
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.
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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 __________.
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46. Time of day when most corals feed [__________]
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53. __________ is a system of specially designed buoys that measure conditions that may cause bleaching on coral reefs.
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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 non-biological 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.