NMEA

SPECIAL REPORT #3

THE OCEAN LITERACY CAMPAIGN

Special Edition • March 2010

featuring: **OCEAN LITERACY SCOPE AND SEQUENCE FOR GRADES K-12**

NATIONAL MARINE EDUCATORS ASSOCIATION

"... to make known the world of water, both fresh and salt."

THE NATIONAL MARINE EDUCATORS ASSOCIATION brings together those interested in the study and enjoyment of the world of water. Affiliated with the National Science Teachers Association, NMEA includes professionals with backgrounds in education, science, business, government, museums, aquariums, and marine research, among others. Members receive *Current: The Journal of Marine Education, NMEA News,* and discounts at annual conferences. Membership information is available from: NMEA, P.O. Box 1470, Ocean Springs, MS 39566-1470; Phone: (228) 818-8893; Fax: (228) 818-8894; email: johnette.bosarge@usm.edu, or visit our website online at **www.marine-ed.org/.**

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Front Cover: All Photos Courtesy of Craig Strang

Front Cover Photo Captions: (top right caption): Principle 2d. Most beach sand is eroded from land sources and carried to the coast by rivers, but sand is also eroded from coastal sources by surf. (left caption): Principle 5c. The diversity of major groups of organisms is much greater in the ocean than on land. (middle right caption): Principle 1g. The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. (bottom right caption): Principle 7a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored.

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Special Edition Log *This NMEA Special Edition, the Ocean Literacy Campaign Special Report #3, features the work of dozens of agencies and hundreds of individuals to bring ocean sciences into the mainstream of both formal and informal education. As a community, we have accomplished a great deal since the initial distribution of what has fondly come to be known as "The Ocean Literacy Brochure" at the 2005 NMEA Annual Conference in Maui. Number one among those accomplishments is the publication in this Report of the* Ocean Literacy Scope and Sequence for Grades K-12 *in the form of 28 conceptual flow diagrams. The report also includes several articles and resources that we hope will be informative as you begin to use the Scope and Sequence. The entire Report will be available on the Ocean Literacy website (www.oceanliteracy.net).*

Funding for this Special Report was generously provided by the National Marine Sanctuary Foundation and NOAA Office of Education. Their support is deeply appreciated.

Craig Strang and Lynn Uyen Tran, Special Report Editors

Contents

The Ocean Literacy Campaign Special Report #3 is sponsored by the National Marine Sanctuary Foundation and NOAA Office of Education.

Introduction

By Craig Strang and Lynn Uyen Tran

This NMEA Special Report on Ocean Literacy brings together seven years of dedication and collaboration among hundreds of individuals and institutions committed to promoting an ocean literate populace. In particular, this Special Report celebrates the official launch of the *Ocean Literacy Scope and Sequence for Grades K-12*, which can also be found in its entirety on the new Ocean Literacy website (www.oceanliteracy.net). It is our hope that the publication of the Scope and Sequence will propel the Ocean Literacy Campaign from the somewhat abstract world of "essential principles and fundamental concepts" directly into standards, curriculum, and classrooms nationwide. In no way does this mean the work of the Campaign is done. Instead, this Special Report serves as a reflective tool for our community to take a look back at the progress we have made together, and hopefully to offer some inspiration for the new wave of Ocean Literacy activism that lies ahead.

To begin, Sarah Schoedinger, Lynn Uyen Tran, and Lynn Whitley provide a historical overview of the making of what we are calling "The Ocean Literacy Framework," comprised of *Ocean Literacy: The Essential Principles of Ocean Sciences K-12* and the complementary *Ocean Literacy Scope and Sequence for Grades K-12*. The story they tell demonstrates how a diverse community of agencies, institutions, and committed individuals put agendas and self-interest aside to do ground-breaking work together to define and promote Ocean Literacy. Up until now, many people and organizations have contributed their time, resources, and intellect toward these documents without much credit; in the Honor Roll, we acknowledge those who have contributed to the process. We publish the Honor Roll with some trepidation since we know it is incomplete. If you know of missing names, including your own, please offer your additions at the Ocean Literacy website.

Following the Honor Roll is a compilation of several notable projects, programs, and publications that have resulted from and enacted the *Ocean Literacy Framework*. Like the Honor Roll, this compilation is not complete. Rather it exemplifies how the Ocean Literacy Campaign has been inspiring and useful. It is a tribute to the creative work and impact of marine educators around the world, most of them NMEA members, who are making tools for teachers, scientists, and informal educators. We hope many of you will add your own vignettes and accomplishments via the Ocean Literacy website.

As we continue to reflect on what we have done as a community, we consider the relationships that have evolved. Catherine Halversen and Lynn Uyen Tran take a critical look at these relationships, and propose that, perhaps, as ocean scientists and educators in this community work together on various projects within the Ocean Literacy Campaign, they are creating new rules of engagement. They offer examples to show that a new "community of practice" may be emerging from these collaborative partnerships that could redefine the ways in which scientists and educators serve society.

Promoting Ocean Literacy requires that we know how people understand the ocean. Lynn Uyen Tran, Diana Payne, and Lynn Whitley provide an abridged version of two recent literature reviews on ocean sciences education in their discussion of the limited availability of educational research on students' understanding of the ocean. They argue for the value and significance of learning research in ocean sciences, identify what is missing, and then offer insights from existing research that have significant implications for teaching.

The *Ocean Literacy Scope and Sequence for Grades K-12* is presented in this Special Report as a series of 28 conceptual flow diagrams that represent and organize the ideas of the seven Principles into four grade bands–K-2, 3-5, 6-8, and 9-12. This document provides guidance to educators, standards committees, curriculum developers, and scientists conducting outreach. This section of the Report begins with an explanation from Craig Strang, Kathy DiRanna, and Jo Topps of the theoretical underpinnings of conceptual flow diagrams, and how they are developed and used. Next, the complete 28 flows are presented, followed by four supporting resources. First, "Ideas from Teachers" is a set of possible ways the Ocean Literacy Framework can be used in classrooms that are generated by some of the teachers who have been part of the Campaign. Second, the "Ocean Literacy Alignment Matrix" shows the extent to which each of the flow aligns with the Principles and Concepts, and is organized according to the seven Essential Principles and 44 Fundamental Concepts. Third, the Ocean Literacy "Index of Topics" shows how the major ideas that are included in each of the flow builds from K-12 for each principle. Fourth, we offer an initial attempt to demonstrate how the Scope and Sequence aligns with state science standards. In this example, we align the flow for grades 3-8 with the New York State Science Standards. Future development will focus on aligning the Scope and Sequence to state and national science standards, and making this resource increasingly versatile for a variety of purposes and audiences.

Finally, we thank the National Marine Sanctuary Foundation and NOAA Office of Education for funding the publication of this Special Report. We also thank NMEA for its support of this work and providing a professional home and platform for those who have been committed to ocean literacy since long before there was a Campaign!

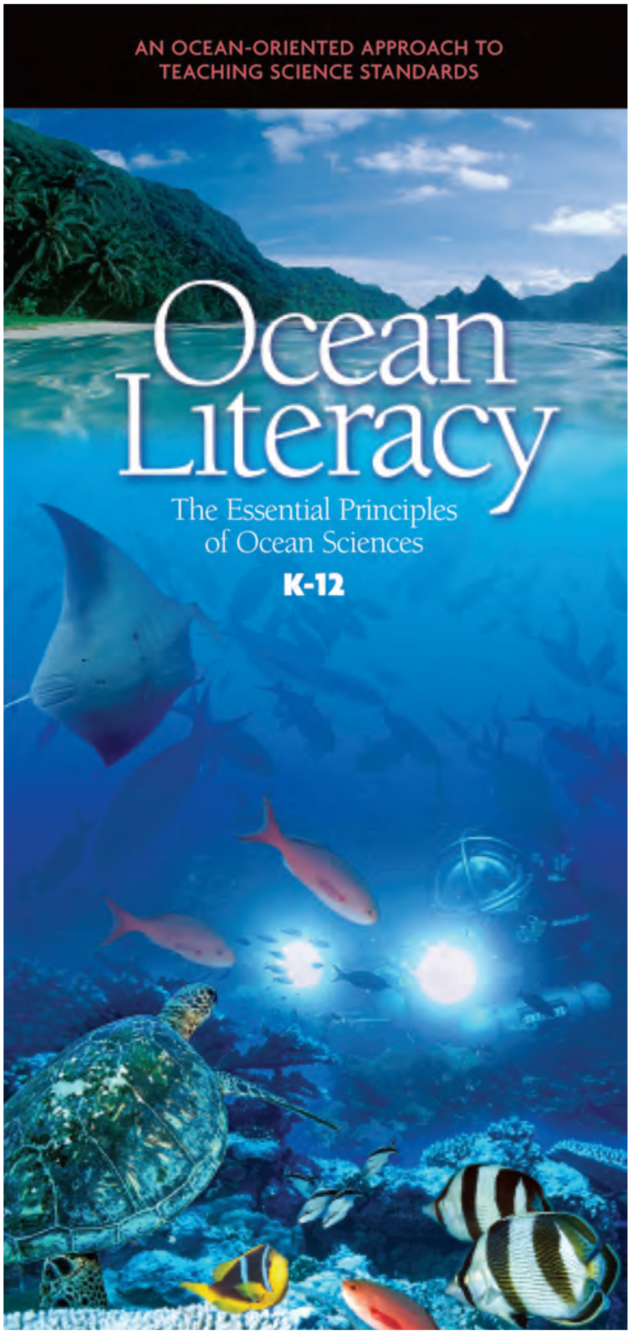
From the Principles to the Scope and Sequence: A Brief History of the Ocean Literacy Campaign

By Sarah Schoedinger, Lynn Uyen Tran, and Lynn Whitley

The Ocean Literacy Campaign is a wide-ranging, collaborative and de-centralized effort by scientists and educators to create a more ocean literate society. An important component of the Campaign is the education of our K-12 students in ocean sciences. The development of two consensus documents, *Ocean Literacy: The Essential Principles of Ocean Sciences K-12* (hereafter referred to as the Ocean Literacy Principles) and the complementary *Ocean Literacy Scope and Sequence for Grades K-12* (hereafter referred to as the Scope and Sequence), has been integral to this Campaign. The documents provide formal and informal educators and curriculum and program developers with a "roadmap" that helps them build coherent and conceptually sound learning experiences for students from Kindergarten through 12th grade. Over the years, the efforts in the Campaign have been, and continue to be, supported by many organizations and the dedicated individuals within them. In this discussion, we offer a compressed historical overview of the development of the two consensus documents to chronicle the collective endeavor of a committed community, as well as acknowledge all those who have contributed to making this ground-breaking work a success.

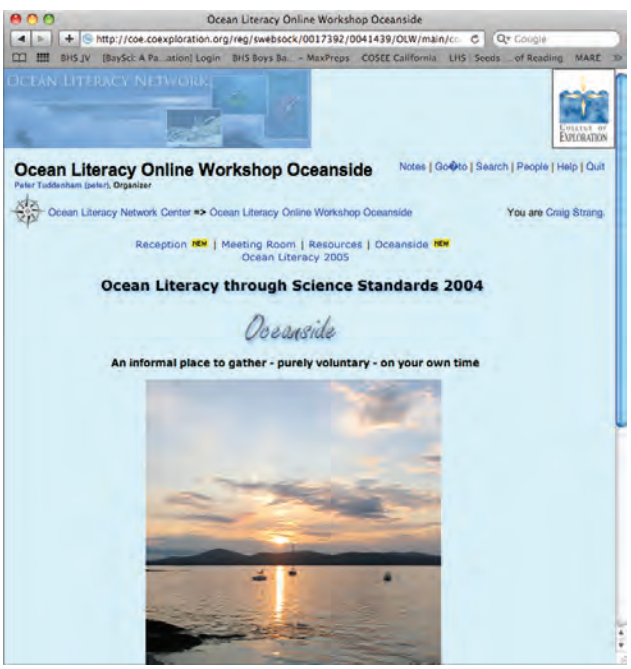
To begin, why did we need to develop a definition of, and identify essential principles and fundamental concepts for, ocean literacy? When the *National Science Education Standards* was published in 1996[1], members of the ocean sciences and ocean education communities were dismayed to find that there was little mention of ocean topics in the content standards. Additionally, most state standards did not include much about the ocean, coasts, or watersheds. Consequently, the teaching of ocean sciences was largely ignored in most K-12 classrooms. There were exceptions of course; pockets of excellence, where passionate educators and innovative programs managed to bring marine science content and experiences to some students. Without a coherent framework of concepts and messages, however, ocean educators and scientists began to realize that these topics would remain on the margins of teaching and learning about science. Additionally, there was a conviction among educators and scientists that the ocean provided an exciting context for teaching science and other disciplines in an integrated manner. Nevertheless, without consensus on what was important for people to learn about the ocean, we would continue to be hard pressed to make the case to include ocean sciences into national and state standards, and for more teaching about the ocean in K-12 classrooms.

Early works to develop a consensus position on ocean sciences education began in 2002. The College of Exploration and



Cover of *Ocean Literacy: The Essential Principles of Ocean Sciences K-12*.

National Geographic Society (NGS) led an online conference in 2002, *Oceans for Life*, which resulted in the pre-cursor[2] to the work summarized in the Ocean Literacy Principles. Additionally, two high-level commissions identified ocean education as a key strategy for achieving the policy goals identified in their reports.[3,4] It became apparent that without an ocean literate public, we would never solve our most critical ocean resource management issues. In 2003-2004, efforts across several organizations came together in a synergistic way. The Center for Ocean Sciences Education Excellence—New England, led by scientist Bob Chen, identified the concepts thought to be the most important for the public to know about the ocean in their region. The National COSEE Network, led by Craig Strang, Sarah Schoedinger, and Sharon Walker, identified Ocean Literacy to be its top strategic priority. Scientist and member of the National Marine Educators Association (NMEA), Bob Stewart, led seven of his colleagues to write and present a paper, *What Every Student Ought to Know about the Ocean on Graduation from High School*. NMEA, initially led by Elizabeth Day-Miller, Craig Strang, Bob Stewart, and Sarah Schoedinger, established an Ad Hoc Committee on Science Standards to determine how to infuse more ocean-related content into the K-12 curriculum. The NGS, the National Oceanic and Atmospheric Administration (NOAA), National Sea Grant College Program, Lawrence Hall of Science, the College of Exploration, the Ocean Project, and the Association of Zoos and Aquariums (AZA) all lent their ample support to bind these various efforts into a national campaign. The movement was ignited.



Work began on the Ocean Literacy Principles during a two-week, asynchronous, online workshop hosted by the College of Exploration.

In October 2004, the College of Exploration hosted a two-week online workshop, *Ocean Literacy Through Science Standards*, on its virtual campus (www.coexploration.org) that involved roughly 100 people representing constituencies important to improving ocean literacy. These constituencies included: formal educators (primarily from K-12 schools, but also colleges and universities); researchers from various sub-disciplines of the ocean sciences; education policymakers (from AAAS; NSTA); science coordinators from state and local departments of education; informal educators; and federal agency representatives involved in education and outreach. While some small face-to-face meetings were necessary throughout the process, we found that meeting online supported the inclusiveness, transparency, and democratic process of our work and became a useful tool in our efforts. At the end of this online workshop, we reached consensus on a definition of ocean literacy, and developed a draft set of principles, which were eventually winnowed down to the seven Essential Principles with 44 Fundamental Concepts analogous to those in the National Science Education Standards (NSES).[5,6] Small teams of scientists and educators took this draft and fleshed out the ideas through an iterative process of writing and sending out their revisions for review by members of the ocean sciences education community. The result of their diligence and commitment was the ground-breaking document *Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Sciences K-12*, which identifies the content knowledge that an ocean literate person should know by the end of 12th grade.

A matrix aligning the Ocean Literacy Principles to the content standards in the NSES was developed, but it was also recognized that more was needed. Since the *Essential Principles* and *Fundamental Concepts* are ideas students should understand by the *end* of high school, it was difficult for a teacher, curriculum developer, or standards committee to know what to include about a specific ocean concept at a particular grade band that would help students build a complete understanding by the end of 12th grade. It became apparent that a scope and sequence showing how the Ocean Literacy Principles could be taught at various grade bands (K-2, 3-5, 6-8, 9-12) was needed. We decided conceptual flow diagrams would provide the community with a more detailed and useful tool for building an understanding of each concept (for more information and theoretical underpinnings of conceptual flow diagrams, please refer to the article in this report by Craig Strang, Kathy DiRanna, and Jo Topps on page 27).

Work on the Scope and Sequence for Grades K-12 officially began in April 2006. Forty-six scientists and educators from the ocean literacy community and experts in conceptual flow development met at the Lawrence Hall of Science (LHS) at the University of California, Berkeley, hosted by COSEE California and NOAA Office of Education, for three days to conduct the initial development of the Scope and Sequence. They produced early versions of 14 of the 28 flows. From May 2006 to June 2008, members from this initial development team (Rita Bell, Tina Bishop, Francesca Cava, Beth Jewell, Judy Lemus, Sarah Schoedinger, Craig Strang, Peter Tuddenham, and Lynn Whitley) led numerous working groups across the country. Dozens of educators and scientists participated in all day working meetings, as well as in special workshops held at annual meetings for NMEA and NSTA, to write and discuss the concepts and ideas in each principle that were appropriate for each grade band. These working meetings around the country resulted in a *first draft* of each conceptual flow diagram.

Between June and November 2008, marine educators and curriculum developers at LHS/COSEE California along with ocean scientists and educators from the ocean literacy community revised the first draft of each conceptual flow diagram. Coordinated by Lynn Tran, the LHS team included Noelle Apostol, Emily Griffen, Catherine Halversen, Sarah Pedemonte, Craig Strang, Emily Weiss, and Maia Wilcox with additional assistance from Frannie Coopersmith, John Farrington, Myrna Jacobson, David Mountain, Adina Paytan, Gil Rosenthal, Bob Stewart, and Tammie Visintainer. The LHS team worked in groups of two to five individuals, in two-hour sessions, two to three times each week. Addressing each conceptual flow diagram individually, they clarified concept statements; organized and reorganized concepts; and elaborated, expanded, and further broke down the concepts identified in the first draft. They also consulted with scientists and educators in the community. This revision resulted in a *second draft* of the flows.

A two week, online *Public Review* took place from November 5-19, 2008. Members of the ocean literacy community were invited to participate in the review of the second draft of the Scope and Sequence, which comprised of 28 conceptual flow diagrams. As before, the review occurred on the virtual campus of the College of Exploration, and was open to all interested educators and scientists. Over 100 scientists and educators participated using *Caucus Space* for online asynchronous discussions and *Marratech* for synchronous virtual meetings. They scrutinized, debated, discussed, and reworked the content, language, organization, and presentation of all the flows individually. For both the synchronous and the asynchronous online discussions, one scientist and/or one educator moderated the interactions. The team of educators and curriculum developers at LHS/COSEE California spent the next few months amending the second draft of the conceptual flow diagrams in light of the feedback from the Public Review. These modifications were made one principle at a time; that is, the conceptual flow diagrams for grades K-2, 3-5, 6-8, and 9-12 in each principle were reviewed together in order to ensure progression of concepts and consistency in language across all grade bands. This revision resulted in the *third draft*.

Next, from April-June 2009, individuals with specific expertise in ocean sciences and education were invited to take part in the two-stage *Expert Review* of the third draft of the 28 conceptual flow diagrams. Stage one (April-June 2009) was a review of the science content for accuracy. Two to three ocean scientists with expert knowledge in the particular concepts within a particular principle were selected to review all four grade band conceptual flow diagrams for that principle. The scientists reviewed the flows for scientific accuracy and conceptual logic; the Scope and Sequence project manager facilitated correspondences by teleconference and email between the scientists in order to resolve disagreements and inconsistencies. The third draft of the flows was revised in accordance with suggestions from the scientists. Stage two (June 8-10, 2009) was a review for educational appropriateness of the content. Fourteen educators with expertise in conceptual flow diagrams, the Ocean Literacy Principles, classroom teaching, curriculum development, and educational research convened at LHS to scrutinize and modify the flows for accuracy as conceptual flow diagrams and their developmental appropriateness and progression without changing the scientific integrity of the statements. The educators formed teams of three to four individuals with different expert knowledge, and each team discussed and revised all four grade band conceptual flow diagrams for a particular principle. They also reviewed the conceptual flow diagrams within each grade band, across all seven principles. The team of educators and curriculum developers at LHS/COSEE California spent the next month incorporating all feedback from both Expert Reviews into a *fourth draft* in time to be showcased at the 2009 NMEA Conference in Monterey, California.

Beth Jewell, Peter Tuddenham, Lynn Whitley, Maia Wilcox, and Tammie Visintainer toasting the completion of the Scope and Sequence following the Expert Educator Review in Berkeley, California.

Craig Strang, Lynn Tran, and Lynn Whitley launched the entire *Ocean Literacy Scope and Sequence for Grades K-12* in a day-long, pre-conference workshop at the NMEA Conference in June 2009. The workshop explored the design of professional development related to the Scope and Sequence and was attended by 40 enthusiastic participants. At the same time, COSEE California, led by the College of Exploration (Scott Carley, Peter Tuddenham, Tina Bishop, and Scott Tuddenham) has been re-designing the Ocean Literacy website (http://www.oceanliteracy.net) to make the complete Scope and Sequence available online. The new website should be launched by the time you receive this NMEA Special Report.

2002	2003	2004	2005
Ocean literacy discussions initiated. ➔ College of Exploration and National Geographic host *Oceans for Life* online conference.	NMEA establishes Ad Hoc Committee on Science Standards.	National COSEE Network makes Ocean Literacy top strategic priority. October. Online Ocean Literacy workshop. ➔ National Geographic Society, COSEE, NOAA, NMEA, and the College of Exploration host online conference. ➔ Initial set of key concepts identified.	February-July. *Ocean Literacy: The Essential Principles of Ocean Literacy K-12* developed. ➔ Iterative process through public online and in-person meetings to refine concepts. ➔ Matrix to align the Ocean Literacy Principles and concepts with the National Science Education Standards (NSES).
2006	**2007**	**2008**	**2008**
April. Work on Scope and Sequence begins. ➔ Working meeting at Lawrence Hall of Science results in early versions of 14 conceptual flow diagrams. May (to June 2008). First draft of Scope and Sequence developed. ➔ Working meetings at workshops and national conferences around country, including University of California and MAMEA Conference in Maryland, result in first draft of all 28 conceptual flow diagrams.	July. Public review of Scope and Sequence Grades K-5 at NMEA Conference in New York City.	June-July. Public review of Scope and Sequence. ➔ Review of Grades 6-12 at NMEA Conference in Savannah, Georgia. ➔ COSEE West Teacher Workshop.	June-November. Second draft of Scope and Sequence developed. ➔ Working meetings at the Lawrence Hall of Science, with scientists and educators. November. Online Public Review of second draft.
2009	**2009**	**2009**	**2010**
January-April. Third draft of Scope and Sequence developed. ➔ Working meetings with scientists and educators to incorporate feedback from Online Public Review. April-June. Expert Review of third draft. ➔ Stage 1, Scientists review ➔ Stage 2, Educators review	June. Fourth draft of Scope and Sequence developed. ➔ Working meetings with scientists and educators to incorporate feedback from Expert Reviews. June. Launch of complete Scope and Sequence. ➔ Pre-conference rollout and professional development workshop at NMEA Annual Meeting in Monterey, CA.	July-September. Final edits of Scope and Sequence made. ➔ Working meetings at the Lawrence Hall of Science to refine layout and design of conceptual flow diagrams and, ensure alignment to *Ocean Literacy Essential Principles and Fundamental Concepts*. Fall. Launch of updated Ocean Literacy website with online version of Scope and Sequence.	Winter. Publication of the NMEA Special Report #3 on the Ocean Literacy Campaign featuring the *Ocean Literacy Scope and Sequence for Grades K-12*.

Table 1. Chronology of major events for developing the Ocean Literacy Framework.

Participants engage in small group discussions at the pre-conference Professional Development Workshop at the NMEA Annual Conference in Monterey, California.

From July-October 2009, the LHS/COSEE California team made the last revisions for the *final draft* of the Scope and Sequence. These revisions included: editing the layout and design for all the flows based on informal feedback from participants at the NMEA pre-conference workshop; reviewing the flows by grade bands to identify cross-references between principles; and scrutinizing the flows individually to determine alignment with the Ocean Literacy Principles. This alignment matrix is part of the supporting materials in this NMEA Special Report.

Together, the *Ocean Literacy: The Essential Principles of Ocean Sciences K-12* and the complementary *Ocean Literacy Scope and Sequence for Grades K-12* documents make up the *Ocean Literacy Framework*. As evidenced by this compressed chronology of events, the making of the Ocean Literacy Framework has been a massive collaborative and iterative undertaking that has involved hundreds of dedicated people who gave generously of their usually uncompensated time, energy, and expertise—a testament to this remarkable community. See Table 1 for a summary of the major events. It is also important to point out that many efforts within the Ocean Literacy Campaign would not be possible without the willingness of large numbers of people with diverse opinions from numerous organizations to come to consensus on some very important decisions related to the substance of ocean literacy. Why is this so amazing? Because the Ocean Literacy Campaign has been, and continues to be, a grass-roots effort by ocean scientists, science educators (formal and informal), education policy makers, and others who have been able to put aside their personal and agency-specific agendas along with their need for recognition in order to stay focused on fostering an ocean literate society. Moreover, numerous other accomplishments inside and outside the ocean sciences community have emerged from these efforts and collaborative activities (for more information on these impacts, please refer to the *Impacts of the Ocean Literacy Principles* in this NMEA Special Report). There are many individuals who have contributed to this effort since 2002, as well as organizations that played a significant leadership role in the development of the Ocean Literacy Framework. Look to the "Honor Roll" for a list of all those who have contributed their time, expertise, and good will, much of it voluntarily, to make the Scope and Sequence. To each of you, we extend our sincere appreciation.

Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms (Principle 5h).

ENDNOTES

1 National Research Council. (1996). National Science Education Standards. National Academy Press: Washington, D.C.

2 The scope and sequence that resulted from the Oceans for Life conference is available at http://www.nationalgeographic.com/seas/

3 U.S. Commission on Ocean Policy, *An Ocean Blueprint for the 21st Century. Final Report*. Washington, DC: http://www.oceancommission.gov, 2004, p.122.

4 Pew Oceans Commission, *America's Living Oceans: Charting a Course for Sea Change. A Report to the Nation*. Arlington, VA: http://www.pewoceans.org, 2003, p. ix.

5 *Ocean Literacy Essential Principles and Fundamental Concepts for K-12*, http://www.coexploration.org/oceanliteracy/documents/OceanLitConcepts_10.11.05.pdf

6 Cava, Francesca, S. Schoedinger, C. Strang, and P. Tuddenham. (2005). *Science Content and Standards for Ocean Literacy: A Report on Ocean Literacy*, http://www.coexploration.org/oceanliteracy/documents/OLit2004-05_Final_Report.pdf

Ocean Literacy Scope and Sequence Honor Roll

The people listed here contributed their time and intellect to the development and review of the *Ocean Literacy Scope and Sequence for Grades K-12*. Despite our most diligent efforts, the Honor Roll is no doubt incomplete. If you know of names that are missing, including your own, please contact the editors (cstrang@berkeley.edu or lynn.tran@berkeley.edu) or add names yourself by going to www.oceanliteracy.net.

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- Expert Educator Review June 8-10, 2009 #

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6. *Tina Bishop*, College of Exploration, COSEE California
7. *Marjorie Bollinger*, National Aquarium in Baltimore
8. *Francesca Cava*, National Geographic Society
9. *Karen Cerwin*, K-12 Alliance/WestEd #
10. *Linda Chilton*, University of Southern California Sea Grant, COSEE West
11. *Vic Chow*, Bodega Marine Laboratory, University of California, Davis *
12. *Patricia Cooper*, University of Hawaii, Manoa, COSEE California *
13. *Ann Coopersmith*, University of Hawaii, Maui Community College
14. *Kathleen Cressy*, Puente High School, Ventura, California, COSEE West Teacher
15. *Cynthia Cudaback*, Ocean Consulting
16. *Roberta Dean*, MARE, Lawrence Hall of Science
17. *Annette deCharon*, University of Maine, COSEE Ocean Systems
18. *Mark DeCrosta*, Science Teacher, J.W. Mitchell High School, New Port Richey, Florida
19. *Melissa Demetrikopoulos*, Institute for Biomedical Philosophy
20. *Kathy DiRanna*, K-12 Alliance/WestEd #
21. *Ania Driscoll-Lind*, Kula Naia Foundation, Hawaii
22. *Don Duggan-Haas*, Paleontological Research Institution and its Museum of the Earth, Ithaca, New York
23. *Kanesa Duncan*, University of Hawaii, Manoa, Curriculum Research & Development Group, COSEE California
24. *Laura Eidietis*, Eastern Michigan University
25. *Christina Engen*, Crescenta Valley High School, Glendale, California, COSEE West Teacher
26. *Dominique Evans-Bye*, Clark Magnet H.S. Glendale, California, COSEE West Teacher
27. *John Farrington*, Woods Hole Oceanographic Institute (retired) *
28. *Rosanne Fortner*, Ohio State University, COSEE Great Lakes
29. *Marc Frischer*, Skidaway Institute of Oceanography
30. *Marsha Gear*, California Sea Grant
31. *Amy Larrison Gillan*, Science Teacher, Indiana Public Schools
32. *Scott Glenn*, Rutgers University, Institute of Marine and Coastal Sciences *
33. *Gary Griggs*, University of California, Santa Cruz *
34. *Charlene Guss*, Ivy Academy Middle School, Woodland Hills, California, COSEE West Teacher
35. *Catherine Halversen*, MARE, Lawrence Hall of Science, COSEE California #
36. *Amy Hill*, Chadwick H.S., Palos Verdes, California COSEE West Teacher
37. *Christy Herren*, University of Maine, COSEE Ocean Systems
38. *Jan Hodder*, University of Oregon, COSEE Pacific Partnerships

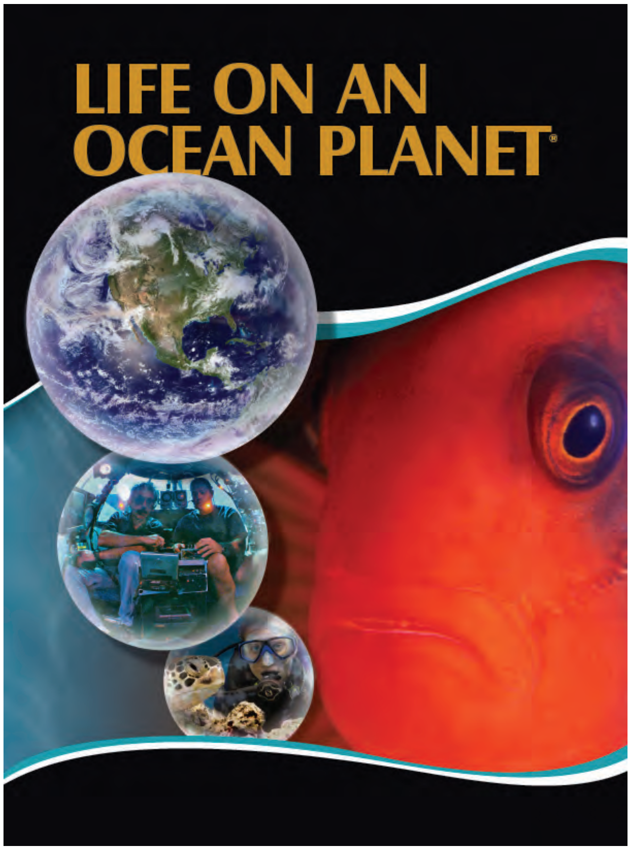
39. *Myrna Jacobson*, University of Southern California *
40. *Kris Jensen*, High School Teacher, Queen Ann's County, Maryland
41. *Beth Jewell*, West Springfield High School, Springfield, Virginia #
42. *Brandon Jones*, United States Environmental Protection Agency *
43. *Paula Keener-Chavis*, NOAA Office of Exploration and Research *
44. *Nikki Koehler*, University of Michigan, Michigan Sea Grant
45. *Julie Lambert*, University of North Carolina-Wilmington, Center for Marine Science and Science Education
46. *Beth Larson*, North Hollywood Zoo Magnet High School, North Hollywood, CA, COSEE West Teacher
47. *Alison LeBeau*, Long Beach Aquarium of the Pacific
48. *Judy Lemus*, University of Hawaii, Hawaii Institute of Marine Biology, COSEE California *
49. *Mellie Lewis*, Elementary Teacher (retired), Howard County Public Schools, Maryland
50. *Carmelina Livingston*, St. Andrews School of Science and Math, Charleston, South Carolina, COSEE South East
51. *Joan Macomber*, Downey High School, Downey, California, COSEE West Teacher
52. *Ellen Maisen*, Millikan Middle School, Sherman Oaks, California COSEE West Teacher
53. *John Manderson*, NOAA National Marine Fisheries Service *
54. *Paul Martin*, St Callistus and St. Barbara School, K-8, Huntington Beach, California COSEE West Teacher
55. *George Matsumoto*, Monterey Bay Aquarium Research Institute *
56. *David Mountain*, NOAA National Marine Fisheries Service (retired) *
57. *Ruth Musgrave*, Whale Times, Inc.
58. *Dan Najuch*, Science Teacher, Orchard Park Middle School, Orchard Park, New York
59. *William Nuckols*, W.H. Nuckols Consulting, Annapolis, Maryland
60. *Christiane Parry*, California Coastal Commission
61. *Adina Payton*, University of California, Santa Cruz *
62. *Kristina Morningstar Pego*, St. Lucie County Schools, Florida
63. *Bill Quilinan*, Dana Middle School, San Pedro, California, COSEE West Teacher
64. *Lauren Rader*, Project Oceanology
65. *Annie Richardson*, NASA Jet Propulsion Laboratory
66. *Wayne Risley*, Dana Middle School, San Pedro, California, COSEE West Teacher
67. *Gil Rosenthal*, Texas A&M University *
68. *Dan Rubenstein*, Princeton University *
69. *Stacey Rudolph*, NOAA Office of Education
70. *Tom Russel*, Dana Middle School, San Pedro, California, COSEE West Teacher
71. *Sarah Schoedinger*, NOAA Office of Education
72. *Gail Scowcroft*, University of Rhode Island, COSEE Central Coordinating Office
73. *Mike Senise*, San Diego Unified School District, COSEE California
74. *Zeenat Sheikh*, Kecoughtan High School, Hampton, Virginia, COSEE West Teacher
75. *Ann Marie Shields*
76. *Eric Simms*, Scripps Institution of Oceanography, COSEE California
77. *Melissa Smith*, K-12 Alliance/WestEd #
78. *Betsy Abbott Stefany*, The SABENS Group, Lebanon, New Hampshire
79. *Bob Stewart*, Texas A&M University, Department of Oceanography *
80. *Craig Strang*, MARE, Lawrence Hall of Science, COSEE California #
81. *Phil Stirtz*, Aliso Niguel High School, Aliso Viejo, California, COSEE West Teacher
82. *Pam Stryker*, Teacher, Barton Creek Elementary, Austin, Texas #
83. *Merrie Southgate*, Science Educator and Author
84. *Drew Talley*, University of San Diego *
85. *Donna Taylor*, Curtis Middle School, Los Angeles, California, COSEE West Teacher
86. *Jo Topps*, K-12 Alliance/WestEd #
87. *Lynn Tran*, MARE, Lawrence Hall of Science, COSEE California #
88. *Tara Treiber*, Santa Monica Pier Aquarium, Santa Monica, California
89. *Peter Tuddenham*, College of Exploration, COSEE California #
90. *Joseph Vargas*, Los Angeles Unified School District High School Teacher (retired), COSEE West Teacher
91. *Sharon Walker*, University of Southern Mississippi, J.L. Scott Marine Education Center, MS-AL and National Sea Grant, COSEE Central Gulf of Mexico
92. *Emily Weiss*, MARE, Lawrence Hall of Science, COSEE California #
93. *Lynn Whitley*, University of Southern California, Wrigley Institute for Environmental Studies and Sea Grant Program, COSEE West #
94. *Ali S. Widmar*, National Science Teachers Association
95. *Gene Williamson*, Middle School/High School Teacher (retired), Seal Rock, Oregon #
96. *Belinda Young*, Lawrence Middle School, Los Angeles, CA COSEE West Teacher

Impacts of the Ocean Literacy Principles

Ocean Literacy: The Essential Principles of Ocean Sciences K-12 (referred to as the Ocean Literacy Principles) has been a ground-breaking document, both as a product and because of its development process, both of which are creating a ripple effect across the entire ocean sciences education community and beyond. The Ocean Literacy Framework, comprised of the Ocean Literacy Principles and the Ocean Literacy Scope and Sequence, is the first consensus set of documents to identify, articulate, and organize the core concepts of ocean sciences for educational purposes. It has become a powerful rallying point for elevating the prominence of ocean sciences in the mainstream K-12 and informal science education systems. While it is not new for educators and scientists to work together on a project, the process of continued collaboration and partnership between educators and scientists in different agencies and organizations is significant, and has added to the potency of the Ocean Literacy Campaign. The Ocean Literacy Framework has been the foundation and/or inspiration for numerous significant accomplishments nationwide and in several other countries. Here we share a few of those high-impact accomplishments.

***Life on an Ocean Planet:* Current Publishing and the National Marine Educators Association (NMEA)**

Life on an Ocean Planet is a nationally distributed high school marine science textbook that evolved from two years of research and alliance with many science and science education-based organizations such as NMEA, COSEE, NOAA, and the NMEA Ocean Literacy Committee. *Ocean Literacy: The Essential Principles of Ocean Sciences K-12* provided an early framework for Current Publishing to use in developing their curriculum content for *Life on an Ocean Planet*. Moreover, the development process has been a cross-disciplinary, team effort involving: eight NMEA members serving as the Current Publishing Ocean Literacy Advisory Team; the expert curriculum writing and development skills of marine science educators; and 22 classroom teachers and research scientists across the country who provided their pedagogical and scientific expertise as reviewers. Each chapter of the 2010 edition, which prominently acknowledges NMEA as a partner, is correlated with the Ocean Literacy Essential Principles and Fundamental Concepts. These chapter correlations document where specific ocean literacy concepts are introduced and taught. They are easily identified in chart format for teachers in the Teacher Curriculum Guide. The textbook is grade-level appropriate for high school students and written in a friendly, motivational style to enhance science learning. The content is balanced with student-tested investigations and hands-on activities to ensure students achieve science understanding. *Life on an Ocean Planet* uses an interdisciplinary approach to integrate the curriculum areas of reading, math, language, and social sciences into the marine science content. For more information, please visit the website (http://www.currentpublishingcorp.com).



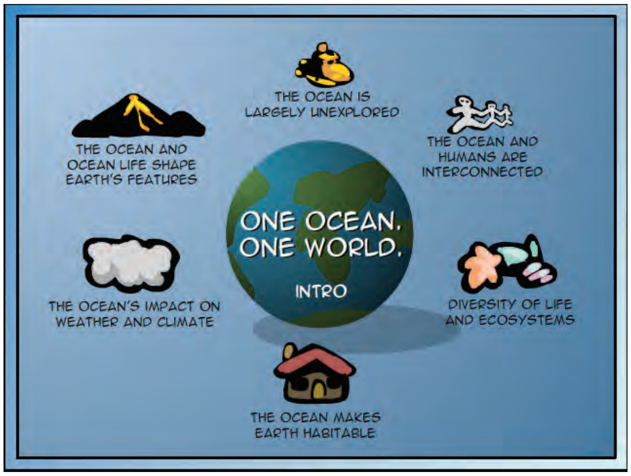
Cover of the *Life on an Ocean Planet* textbook from Current Publishing.

NOAA Environmental Literacy Grant-funded *Ocean Sciences Curriculum Sequences for Grades 3-5* and *6-8*: Lawrence Hall of Science, University of California, Berkeley; Rutgers University, Institute of Marine & Coastal Studies; and National Undersea Research Center, University of Connecticut

When focusing on standards-based content, achieving the "right" balance of depth and breadth in a curriculum is a challenge, one that teachers are often left to struggle with on their own. The *GEMS/MARE Ocean Sciences Curriculum Sequence for Grades 3-5*, funded by NOAA, brought scientists and educators together to discuss and suggest a balanced pathway through the body of ocean sciences content. *Ocean Literacy: The Essential Principles of Ocean Sciences K-12* and the Ocean Literacy Scope and Sequence for Grades K-12 formed the basis of this curriculum sequence. The curriculum sequence will also be aligned with the *National Science Education Standards* and the science standards of 20 states. Scientists and educators worked through a multi-step process drawing on current research in ocean sciences and science learning, to form the conceptual framework, the progression of concepts, and the unit topics. They applied their specialized expertise to identifying the Ocean Literacy and standards-based concepts worth more time in classrooms according to one or both of the following criteria: 1) they are concepts that underlie essential understandings of a discipline; and 2) they are concepts that need more classroom time and contexts for most effective learning by students because they are developmentally challenging to grasp. What resulted was a versatile curriculum sequence for grades 3-5, comprising 25 (60-minute) classroom sessions organized into three units of study: ocean circulation, diversity of life in the ocean, and human impact on the ocean. The curriculum sequence has been piloted, and the team made revisions in the light of those results. As of the writing of this report, the curriculum is undergoing a national field test in 70 classrooms across the country. The curriculum, which includes teacher guides, student readings, data sheets, and an instructional materials kit, will be revised further after the national field test; and by January 2011, will be available nationwide for schools to adopt from Carolina Biological. *Newsflash:* A new companion curriculum funded by NOAA, the *Ocean Sciences Curriculum Sequence for Grades 6-8* and based on the Ocean Literacy Scope and Sequence for grades 6-8, will enter into the development process in early 2010.

Ocean Literacy in New Jersey: COSEE Networked Ocean World (COSEE NOW) and Rutgers University's Institute of Marine & Coastal Sciences

COSEE NOW, with a focus on engaging ocean scientists in education and public outreach, challenged a number of ocean scientists to create a presentation or story about how they think about the content and concepts contained in the Ocean Literacy Principles. A resulting Ocean Literacy lecture series, called *Pulse of the Planet*, is held at the Liberty Science Center, the New Jersey state science museum with approximately one million visitors annually. COSEE NOW encourages scientists to tell their Ocean Literacy stories from their own perspective, highlighting their own expertise in the field, and helps scientists develop and revise their presentations for the public lectures. COSEE NOW also supports a biweekly podcast of scientists, explaining their science and its importance to society. In addition, Dr. Paul Jivoff of Rider University, New Jersey worked with COSEE NOW educators to develop the online interactive, *One World, One Ocean*. This series of animations explains each of the Ocean Literacy Principles in an engaging and comprehensible way. The COSEE NOW Director uses the seven Ocean Literacy Principles as the "ship's wheel" to guide decisions on how to spend time and resources in educational program development. *Ocean Literacy: The Essential Principles of Ocean Sciences K-12* is a mandatory handout given to scientists seeking advice and guidance about how they can write effective broader impact statements in their grant requests. (See http://coseenow.net/2008/11/ocean-literacy-interactive-animation/)



Flash animation for the Ocean Literacy Principles from COSEE NOW (see website address above).

***An Introduction to Our Dynamic Ocean:* COSEE Coastal Trends, including Laura Murray, Elizabeth Day-Miller, Angela Ward, and Kris Jensen with Queen Anne's County Public Schools (QACPS), Maryland**

COSEE Coastal Trends is partnering with Queen Anne's County Public Schools, Maryland to formalize a semester-long, entry level, secondary school ocean sciences course using the Ocean Literacy Principles as the foundation. During the summer of 2008, a course curriculum outline and associated lessons/activities based on the Ocean Literacy Principles were assembled. This course outline was tested with all incoming ninth graders in the two high schools in QACPS and in one Lee County High School in Alabama. The course curriculum was revised based on these teachers' feedback during the early summer of 2009. This revised curriculum included the integration of science-based, hands-on lab, field, and computer activities for each of the Ocean Literacy Principles. It also served as the basis of an implementation institute offered to 14 teachers in July 2009. These teachers will pilot *An Introduction to Our Dynamic Ocean* course curriculum during the 2009-2010 school year and provide feedback for the second revision. Once these revisions are made (summer, 2010), the curriculum will be posted on the COSEE Coastal Trends (http://www.coseecoastaltrends.net) website and disseminated through the COSEE network.

State Science and Environmental Education Content Standards

It is necessary for ocean sciences to be in national and state standards in order for ocean sciences to be taught in schools more broadly. The Ocean Literacy Framework is a tool that

Participants collect data on a field trip during the *Our Dynamic Ocean* Course Implementation Workshop.

standards committees can use to inform how they might include ocean sciences in the development or revision of their science or environmental education standards. Thus far, a handful of states have used these tools in such a way. For instance, Maryland, California, and Michigan have cited the use of the Ocean Literacy Principles in the development of their environmental literacy standards. South Carolina, Florida, and Georgia have used the Ocean Literacy Principles in the development of their science standards; and high school students in Georgia are now required to take an ocean sciences course. Finally, in New Jersey, committed ocean literate educators and science coordinators leveraged the Ocean Literacy Principles to play a key role when their state science standards underwent revisions. The new standards, which focus on Earth systems science and biogeochemical cycles, are a close match to the Ocean Literacy Principles 2, 3, and 6. New Jersey now has state science standards containing important concepts integral and relevant to ocean science. The Centers for Ocean Science Education Excellence (COSEE) Mid-Atlantic was integral in influencing the final document.

Informal Science Education Institutions and the Ocean Literacy Principles

- **The Aquarium of the Pacific** in Long Beach, California has taken a pro-active role in addressing the need for ocean literacy among the public. Starting in 2005, the Aquarium brought together influential stakeholders throughout the region to discuss how informal education centers can tackle the educational goals outlined in the Ocean Literacy Principles. Through this initial gathering and subsequent conferences and workshops, such as the California Conference on Ocean Literacy (CoOL Conference), the Aquarium has produced consensus documents, summarized from participating experts, which serve to inform others on best practices for using the Ocean Literacy Principles (www.aquariumofpacific.org/downloads/CACoOlReport.pdf). The Aquarium's Educational Programs and exhibits also reflect the goals outlined in the Ocean Literacy Principles. While most aquariums address the "low hanging fruit" of Principle 5, the Aquarium of the Pacific has strived to incorporate as many of the other principles as possible into its programs and exhibits. For example, the *Oceans on the Edge* gallery features exhibits on One World Ocean, Principle 1, and on Energy from the Sea, Principle 6. Through past exhibits on waves, and through current ones on El Niño and plankton, the Aquarium of the Pacific continues to utilize the guidance outlined by the Ocean Literacy Principles to bring a more holistic and broad view on how aquarium visitors impact the ocean and how the ocean influences their lives. (See also http://www.aquariumofpacific.org/newsevents/newsdetail/the_coastal_america_ocean_art_contest/ and http://www.aquariumofpacific.org/education)

The Sant Ocean Hall at the Smithsonian Institution.

- **The Smithsonian's Sant Ocean Hall** (SOH), the largest addition to the Smithsonian Institution Museum of Natural History since its opening, uses the Ocean Literacy Principles as a guide for all its public and educational programs. The Principles serve as the basis for many of the messages the Institution is focused on sharing with the public. The Principles are also incorporated into the SOH docent training program to help docents guide discoveries and answer questions in the Ocean Hall. In addition, the Ocean Literacy Principles are used to determine the content and lessons selected for inclusion in The Ocean Portal, a web-based resource dedicated to providing scientific information about the ocean. A portion of The Ocean Portal will also serve as a resource where K-12 educators can visit for assistance in developing lesson plans about ocean-related topics. All of the objectives of SOH are cross-referenced with the Ocean Literacy Principles (see Table 1).

Sant Ocean Hall Objectives	Ocean Literacy Principles
To inspire awe for how vast, diverse, and unexplored the ocean is, and for how fundamentally different it is from land.	**Principle 1.** Earth has one big ocean with many features.
To provide a unique and engaging experience that demonstrates how the ocean works and how it is interconnected with other global systems.	**Principle 2.** The ocean and life in the ocean shape the features of Earth. **Principle 3.** The ocean is a major influence on weather and climate.
To demonstrate how life evolved in the ocean over billions of years and changed dramatically over time.	**Principle 4.** The ocean makes Earth habitable.
To instill in students an awareness of the great diversity of ocean habitats and ocean life, and of how much is still being discovered.	**Principle 5.** The ocean supports a great diversity of life and ecosystems. **Principle 7.** The ocean is largely unexplored.
To inform students about the exciting technologies and other approaches used by scientists and ocean explorers to uncover the ocean's mysteries.	**Principle 7.** The ocean is largely unexplored.
To inspire and empower students to make the connection between the ocean and their daily lives, and to encourage them to continue exploring the ocean and to help conserve it.	**Principle 6.** The ocean and humans are inextricably linked.

Table 1. Cross-referencing Sant Ocean Hall objectives with the Ocean Literacy Principles.

Banana Slug String Band Music Group

The renowned children's music group, The Banana Slug String Band (http://www.bananaslugstringband.com), is producing a new album, *Only One Ocean*, entirely focused on the content found in *Ocean Literacy: The Essential Principles of Ocean Sciences K-12*. The CD is being produced with financial contributions from 10 Centers in the National COSEE Network and from the National Marine Educators Association (NMEA), the NOAA Office of Exploration and Research, The College of Exploration, and Dr. Sue Cook. The CD, available to the public in early 2010, will feature several well-known guest artists who have contributed their time to the project. Some of the artists on the CD include: Brett Dennen; Zach Gill (pianist for Jack Johnson); Grammy Award winning Michael Doucet and the band, Beausoleil; Barry Phillips (performed at the George Harrison memorial concert at the Royal Albert Hall with the surviving Beatles and Eric Clapton); and Victor Wooten (two-time winner of the Nashville Music Awards' Bassist of the Year, and member of the Grammy Award-winning supergroup, Bela Fleck and the Flecktones). Banana Slug albums have won 16 state and national awards for excellence. Thousands of Banana Slug CDs are sold each year through eight distributors such as Amazon.com, Acorn Naturalists, and Kaplan Early Learning, and as downloads through iTunes and other MP3 sites. In addition, the band plays over 20 major concerts and dozens of smaller shows each year. *Only One Ocean* will bring the importance of the ocean to a large audience of parents and children not previously reached by the Ocean Literacy Campaign.

The Banana Slug String Band.

National and International Conferences

There have been at least nine conferences (six in the U.S., one in Australia, one in Japan, and one in Chile) entirely devoted to discussing and reflecting on the Ocean Literacy Framework and/or the Ocean Literacy Campaign.

- Public Ocean Literacy (2005-Long Beach, California)
- CoOL: Conference on Ocean Literacy (2006-Washington, D.C.)
- International Pacific Marine Educators Conference (2007-Maui, Hawaii; 2008-Townsville, Australia)
- New England Ocean Science Education Consortium Conference on Ocean Literacy (2007; 2008)
- Japan Ocean Literacy Symposium (2008-Tokyo, Japan)
- Primera Feria Educativa del Océano (2008-Santiago, Chile)
- Ocean Literacy Summit—Beyond the Brochure (2009-Newport, Oregon)

Kazuya Hirai leading a teacher workshop for fisheries high school teachers following the Japan Ocean Literacy Symposium at the Tokyo University of Marine Science and Technology.

Federal Funding

At least three grant programs in two large federal agencies, NOAA and NSF, require that proposals for projects focusing on the ocean as a part of the Earth System must address the Ocean Literacy Principles in order to be considered for funding.

- NOAA Office of Education: Environmental Literacy Grant (ELG) awards support formal and informal education projects. The informal education awards support education projects designed to engage the public in activities that increase ocean and/or climate literacy and the adoption of a stewardship ethic. They support projects that involve: community outreach, citizen science, civic engagement, social networking, media campaigns, professional development for educators, interpretative training, building networks of aquariums, high-level data visualization systems, and live video feeds. The awards for formal education promote changes in K-12 education to expand the amount of Earth System Science taught in the classroom and improve student learning and application of that subject. Successful projects catalyze change in K-12 education through development of new programs and materials and/or revision of existing programs and materials and/or by supporting transformative methods that expand or lead to the expansion of the use of Earth System Science in K-12 classrooms.

- NOAA Office of Education: Bay-Watershed Education and Training (B-WET) program provides grants in support of locally relevant experiential learning through meaningful watershed educational experiences in the K-12 environment. Funded projects provide meaningful watershed educational experiences for students and related professional development for teachers in support of regional education and environmental priorities.

- NSF, Directorate for Geosciences, Ocean Science Division (OCE) Centers for Ocean Sciences Education Excellence (COSEE) provides grants to support the COSEE Network, which consists of 12 coordinated COSEE Centers, fosters the integration of ocean research into high-quality educational materials; enables ocean researchers to gain a better understanding of educational organizations and pedagogy; provides educators with an enhanced capacity to understand and deliver high-quality educational programs in the ocean sciences; and provides material to the public that promotes a deeper understanding of the ocean and its influence on each person's quality of life and our national prosperity.

Thank You Ocean Campaign

A widespread media campaign to raise awareness about the ocean has been initiated by the State of California, the NOAA Office of National Marine Sanctuaries, and the Ocean Communicators Alliance. The resulting Thank You Ocean Campaign provides videos, Public Service Announcements, podcasts, billboards, and a web presence, all based on the Ocean Literacy Principles.

Beyond Ocean Literacy Principles

What started as a good idea for ocean sciences has turned into a great idea that other disciplines of science have adopted. It is becoming apparent that educators and scientists across many disciplines recognize the significance and value of having a consensus document that articulates, organizes, and presents the critical ideas of their respective fields. To date, there are several science literacy frameworks that have been inspired by the Ocean Literacy Principles, and are based on conversations and cooperation between scientists and educators in multiple institutions and organizations. These include:

1. **The Essential Principles and Fundamental Concepts of Atmospheric Literacy**

   The Atmospheric Science Literacy Framework is intended to provide guidance to educators and the public on the big ideas of atmospheric science so that they may be able to communicate about the Earth's atmosphere in a meaningful way, and be equipped to make informed and responsible decisions about activities that impact the Earth's atmosphere. Approximately 60 participants, including diverse teachers, scientists, informal educators, and policy makers, took part in the Atmospheric Science Literacy Framework Workshop (formerly Atmospheric Sciences and Climate Literacy), which convened in November 2007 to develop this framework. NSF and NOAA provided funding for the workshop; the National Association of Geoscience Teachers (NAGT), National Earth Science Teachers Association (NESTA), American Geophysical Union (AGU), and American Meteorological Society (AMS) co-sponsored the event; and the University

Corporation for Atmospheric Research (UCAR) and Cooperative Institute for Research in Environmental Studies (CIRES) hosted it. UCAR's multimedia services enabled the workshop to offer a live and archived webcasts of the plenary presentations and discussions, as well as a simultaneous video conference of the workshop with other sites around the nation. (For more information, please visit their website, http://eo.ucar.edu/asl/index.html)

2. Climate Literacy: The Essential Principles of Climate Science

As part of a community effort to promote climate literacy, current climate scientists, formal and informal educators, and representatives of a range of U.S. agencies participated in developing and vetting a list of the most important concepts in climate science. Substantial development of the document included individuals who participated in the Framework for Climate and Weather Education Workshop, cosponsored by NOAA and AAAS Project 2061; and the Atmospheric Science and Climate Literacy Workshop, sponsored by UCAR, AGU, and CIRES, with funding from NSF and NOAA. Additionally, discussions at numerous public presentations and a period of formal review led to the final version of the document. (For more information, please visit their website, http://www.climate.noaa.gov/index.jsp?pg=/education/edu_index.jsp&edu=literacy)

3. Earth Science Literacy Principles

The primary outcome of the Earth Science Literacy Initiative is a community-based document that clearly and succinctly states the underlying principles and ideas of Earth science across a wide variety of research fields. Development of this document was an iterative process that began with a 12-day online workshop, May 2008, involving more than 350 participants from the Earth science research, education, and policy communities. Participants communicated through an asynchronous online environment in an effort to generate and organize the "Big Ideas" and supporting concepts in Earth Science. The organizing committee took the ideas and discussions from the online workshop and organized them into a structure that was useful for a writing workshop, which comprised of 36 individuals from the committee and online workshop. The committee coordinated public reviews to inform revisions of the document until its completion in May 2009. NSF provided funding support. (For more information, please visit their website, http://www.earthscienceliteracy.org/)

4. *Neuroscience Core Concepts:* The Essential Principles of Neuroscience

The Public Education and Communication Committee of the Society for Neuroscience is responsible for providing outreach activities that connect scientists, K-12 educators, media, and the general public with the advancements in understanding and research in neuroscience. In 2007, this committee led a development team involving hundreds of neuroscientists and educators nationwide to consult, review, and refine a consensus document. What resulted were the *Neuroscience Core Concepts*, which offer K-12 teachers and the general public the most important insights gained through decades of brain research and spotlight promising research paths. (For more information, please visit their website, http://www.sfn.org/index.aspx?pagename=core_concepts)

5. Key Concepts in Microbial Oceanography

The Education and Outreach Program of the Center for Microbial Oceanography: Research and Education (C-MORE) is focused on promoting scientific literacy in microbial oceanography among students, educators, and the general public. It was recognized that a first step toward promoting microbial oceanography literacy was to define the key concepts. C-MORE identified six key concepts after conducting lengthy conversations with scientists and educators, within and outside C-MORE. (For more information, please visit their website, http://cmore.soest.hawaii.edu/education.htm)

The Ocean Literacy Principles inspired other science disciplines to identify and organize their big ideas.

Scientist and Educator Partnerships and Ocean Literacy: Creating a New Community of Practice

By Catherine Halversen and Lynn Uyen Tran

Engaging scientists and educators in meaningful partnerships to transform ocean sciences education is not a new effort or ideal. Since 2002, the Centers for Ocean Sciences Education Excellence (COSEE) has made this the hallmark of their efforts and cornerstone of their mission to instill a sense of urgency for, and a greater understanding of, ocean literacy in the public. Many of the COSEE efforts create opportunities for scientists to implement education, public outreach, and broader impact in the work that they do. COSEE and other organizations, such as NOAA, have provided opportunities to create rich experiences and generalizable results upon which future collaborations between scientists and educators can be built. This paper focuses on one such effort, the Ocean Literacy Campaign, and subsequent projects in which COSEE and NOAA played the convening role that brought together scientists and educators. We propose that educators and scientists participating in the Ocean Literacy Campaign are in the process of creating a new "community of practice" with shared customs and habits, which has implications for sustaining the work to promote ocean literacy. It suggests that partnerships between scientists and educators have utility and are enduring beyond individual projects, and that these partnerships can redefine the ways science and education serve society.

The Ocean Literacy Campaign has created rich opportunities and provided a vehicle around which scientists and educators[1] can forge new relationships and build a shared community of practice to accomplish a common goal—promote ocean literacy among the public. The Campaign began with the development of the *Ocean Literacy: The Essential Principles of Ocean Sciences K-12* (hereafter referred to as the Ocean Literacy Principles) in 2004, and led to subsequent activities, including the creation of the *Ocean Literacy Scope and Sequence for Grades K-12* (hereafter referred to as the Scope and Sequence) and other materials, such as textbooks, college courses, and curricula.

Janice McDonnell and Scott Glenn with their students in the Communicating Ocean Sciences to Informal Audiences course at Rutgers University.

Bringing the expertise of scientists and educators to the same table and nurturing meaningful partnerships has been integral to the Campaign from the beginning. Scientists brought their science content knowledge and experience sharing that content with the public and their students; and educators brought their pedagogical content knowledge about how to help students and the public to make meaning of and understand the science. A remarkable, secondary result emerged from this ongoing and intensely engaging work. Scientists and educators developed a deeper understanding of each other's "community of practice" and respect for each other's expertise. From this understanding and respect, many individuals created invaluable and long-lasting relationships. This comment from a marine scientist reflected this sentiment:

> *As a scientist who specializes in education, the Ocean Literacy [Campaign]…has offered valuable opportunities to have substantive interaction with professionals in both science and education. From being one of the developers of the "Oceans for Life" Geography Scope and Sequence, through the subsequent development and review of the Ocean Literacy Principles and Scope and Sequence, I feel very fortunate to have been involved as both a scientist and an educator. My work with educators always provides me with a great deal of professional growth and personal enlightenment. And as someone trained in scientific research, I feel that my professional pathway in education has allowed me to make a much broader impact in science than I likely could have as a bench scientist.*
>
> -Dr. Judy Lemus, Hawaii Institute of Marine Biology, University of Hawaii

The continued collaborative work by scientists and educators on efforts in the Ocean Literacy Campaign, required each to cross out of their own community, and led to the development of mutually engaging scientist-educator partnerships that have fostered a new type of community of practice.

CREATING A NEW COMMUNITY OF PRACTICE

A community of practice is a group of people engaged in shared customs and habits, and is characterized by four activities of its members: *joint enterprise* towards goals and purposes, *mutual engagement* in activities, development of a *shared repertoire* of habits, rules, and traditions, and the process of *negotiating meaning* in practice (Wenger 1998).

In committing to, and participating in, the Ocean Literacy Campaign there was *joint enterprise* between ocean scientists and educators toward goals and purposes for achieving an ocean literate populace through formal and informal educational. There was *mutual engagement* in numerous activities to support these goals. These activities included: working together to develop and review the Ocean Literacy Principles and the Scope and Sequence; teaching the *Communicating Ocean Sciences* courses; developing the high school course, *An Introduction to our Dynamic Ocean* (COSEE Coastal Trends); writing the *Life on an Ocean Planet* textbook (Current Publishing and NMEA); developing curriculum, such as the NOAA-funded *Ocean Sciences Curriculum Sequence* (COSEE California); and COSEE Networked Ocean World's Ocean Literacy Interactive Animation, podcasts of the Pulse of the Planet lectures, and their *Student Summit for Ocean Literacy*. More information about these activities is described further in this NMEA Special Report. As the scientists and educators became involved in these shared activities, members from both communities learned from and about one another, crucial for forging partnerships and developing a community of practice.

Educators reported making personal connections and generating relationships that were, and will continue to be, worthwhile on many levels. For instance, in working on the Scope and Sequence, a high school science teacher commented about how the community contributed to his work back in the classroom:

> *It was great to unite with a diverse and talented group of… marine educators in a workshop environment to help develop the Scope and Sequence for the Ocean Literacy Principles.…I worked on [the flow for Principle 1, which] was particularly useful to me as a young marine science teacher because I got to rationalize and reflect upon the order in which I have been teaching the material in the classroom.*
>
> –Benjamin Kay, High School Science Teacher, Santa Monica High School, California

In some cases, educators and scientists had worked in relatively close geographic and conceptual proximity for years but previously, had not experienced each other's work, much less collaborated with one another. In this instance, the college course, Communicating Ocean Sciences to Informal Audiences (COSIA), served as the shared activity where scientists and educators forged meaningful relationships:

Kristopher Jensen, Paul Martin, and Kathleen Cressy at a COSEE-West Ocean Observing Systems workshop building models to explore circulation patterns.

> *When we [educators] partnered with [scientists] in other universities before, we'd have a meeting and come up with great ideas that never went anywhere. But the COSIA course structured those partnerships so that we could actually be successful.…There was a deliverable, there was an outcome, so that was a really good part of [the successful partnership].*
>
> –Aquarium Director[2]

These connections among educators and scientists have broadened the audience for their respective work and will likely lead to future opportunities to work together.

As they carried out these shared activities, scientists and educators entered into different forms of engagement (how we interact), different endeavors (what we do together) with different definitions of what matters, different habits and routines, and different reward systems (Wenger 1998). Collaborators engaged in collective learning about each other's valued practices, tools, guiding principles and goals, and then developed a *shared repertoire of habits, rules, and traditions* for their new community. For instance, some of these repertoires emerged from determining the criteria for what concepts should be included in the Ocean Literacy Principles and the Scope and Sequence, and what form those documents would take. Members were *negotiating meaning in practice* as they met online and face-to-face to discuss, debate, and explain the inclusion, exclusion, or placement of each concept, and eventually to produce the finished Ocean Literacy Principles and the Scope and Sequence. While they did not always agree, there was mutual professional respect and attempts toward consensus and resolution.

Additionally, they encountered discrepancies and entered into new and unknown domains that challenged their claims to expertise (Engeström, Engeström, and Karkkainen 1995). For instance, a fisheries scientist and an oceanographer, respectively, offered the following comments:

> *Working with LHS [Lawrence Hall of Science] has made me feel that the work I do is much more relevant than I usually feel it is. The emphasis around [here], as in most research institutions, is on writing papers for technical journals, that in truth, few people read. We, as scientists, generally just talk amongst ourselves, and it is a pretty small world. I have enjoyed being pushed to identify unique characteristics of the ocean that kids might not think about because of their experiences as "terrestrial organisms" and to attempt to communicate that understanding in a way kids might be able to understand. Some of the ideas I thought about as a result of my engagement with your project are becoming part of a paper and presentation I am going to be giving at the International Council for the Exploration of the Sea science conference in Berlin.*
>
> –Dr. John Manderson, National Marine Fisheries Service

> *It was interesting to see the science concepts from an educator's perspective with an emphasis on the importance of bringing the concepts to a "communicable level" without losing content. It was important to clarify for educators—and for myself—not only the Planet Ocean concept, that the ocean is an important part of the world, but also the importance of the order that concepts are presented in and their relationships to each other. The impact on my work is that I now have a greater consciousness about how I present new concepts to my university students.*
>
> –Dr. Myrna Jacobson, University of Southern California

Consequently, there was a shift from viewing knowledge as distributed hierarchically (or vertically) among people who possessed different levels of skill and competency (i.e. expert or novice) to "knowledge as distributed across actors who [were] competent in different types of practices" (Anagnostopoulos, Brass, and Subedi 2007). This shift was evidenced by the following comments from educators:

> *Whether it is in my work on the Ocean Literacy Campaign, the National Ocean Sciences Bowl, or the daily operations of the Northwest Aquatic and Marine Educators, I revel in the opportunity to share ideas with scientists. They no longer scare me. They know more about some things; I know more about other things. I hope that young teachers will avail themselves of the new climate of cooperation between the scientific and educational communities to strengthen their own work with students. "Just do it."*
>
> –Gene Williamson, Retired Junior High/Intermediate School Teacher, Beaverton, Oregon

> *In my experiences with the [COSIA] course, the participation of scientists provides direct access to the latest research and results, offers valuable current and historical insights into the process and culture of science, and adds an important personal dimension to the practice of science (i.e., scientists are people, too!). Likewise, educators contribute to the partnership by sharing their practical experiences, their knowledge of current learning theory and pedagogy, and an understanding of the practice of education as both an art and a science—all of which reinforce the approach that effective teaching and learning experiences go well beyond simply telling people what you know, or what you think they should know. Forging effective partnerships between scientists and educators not only allow them to learn from one another, it also benefits other audiences by creating a learning community exponentially more powerful than either could alone.*
>
> –Eric Simms, Scripps Institution of Oceanography and Birch Aquarium

The work on the Ocean Literacy Campaign thus far necessitated scientists and educators to share their respective expertise across what sometimes seemed to be very distinct communities, each built to reflect the purposes of those making the decisions, and characterized by their very different, historically based institutionalized norms (Rowan and Miskel 1999; Scott 2001; Tyack 1974; Weick 1995). It became evident that the Campaign was offering scientists and educators opportunities to develop a community of practice that enveloped those who worked on the project from its inception, and those just recently joining the effort. Next, we briefly share insights from this process on developing strong partnerships that serve as the foundation for sustaining this community.

FOUNDATIONS FOR STRONG PARTNERSHIPS

There are several underlying principles for initiating and growing partnerships between scientists and educators that have contributed to developing this community of practice for the Ocean Literacy Campaign.

1. Draw on existing relationships and connections, and ask colleagues to contact their colleagues to join in the effort as well. It is helpful to select partners who have shared values, goals, and/or ideologies.
2. Think of knowledge and tools as assets to be shared, and that these can be built on and revised by the community. Encourage ownership of these assets among all the members of the community.
3. Cultivate mutual respect by encouraging a culture of honesty, open dialogue, careful listening, and recognizing distributed expertise.

Judy Lemus is one of many scientists who have played an integral role in developing the whole Ocean Literacy Framework.

4. Define goals and processes clearly and, very importantly, have a shared activity around which all partners can do meaningful work together toward those goals.

Successful application of these principles is reflected in long-lasting partnerships that extend beyond any one project, as members strive to work together and sustain the new community. One such success is indicated by the continued collaborations between scientists and educators at Hampton University and Virginia Aquarium (COSEE Coastal Trends):

> *Dr. [Deidre] Gibson and I have had the benefit of co-teaching [COSIA] for the past three years. That consistency has allowed us to get to know each other's strengths and areas of expertise, which makes the overall teaching experience a positive one. It is truly a partnership when we teach this class.…COSIA…has been a catalyst for initiating additional partnerships between Hampton University [HU] and Virginia Aquarium. Staff and students in HU's marine science department serve as mentors in the Aquarium's* Mentoring Young Scientists (MYS) *enrichment program for middle school students, while Aquarium educators provide activities for HU's High School Open House Day. The COSIA course and the* MYS *program were both woven into the COSEE-Coastal Trends grant in which the Aquarium and HU are partnering with the University of Maryland Center for Environmental Studies. Hampton is also a partner in the Aquarium's recent NOAA grant proposal* Sea Sojourn, *which requests funds to develop ocean literacy strategies for reaching early learners.*
>
> –Karen Burns, Education Specialist for Bay & Ocean Literacy, Virginia Aquarium

Thus, there are "ripple effects" emerging from these personal connections that take on a life of their own and create momentum as scientists and educators talk, collaborate, and learn from each other.

The most telling outcome of our work together has been that nearly all members of the community find the relationship to be mutually beneficial and of great value to them personally and professionally. A marine ecologist remarked:

> *Working on the Ocean Sciences Curriculum Sequence has enriched me both as an educator and as a scientist—it is a rare opportunity to sit with top-notch scientists and brilliant educators to think deeply about what is important in ocean science, and what we feel a young student really needs to know to interpret and appreciate the world around them. It not only helps the students, but it helps us to see the world and our science through fresh eyes.*
>
> –Dr. Drew Talley, University of San Diego and Ocean Discovery Institute

The efforts from the Ocean Literacy Campaign have generated opportunities to build partnerships between professional communities with complementary expertise to achieve a goal that neither community could achieve on its own. The development of this community of practice clearly indicates the potential for both scientists and educators to join in the community. Moreover, shared activities continue to emerge from these successful scientist and educator collaborations around Ocean Literacy. These efforts have shown that meaningful and long-standing partnerships are based on discrete, transferable principles that can be shared by the community and incorporated into other efforts to ensure that collaborations are mutually beneficial and lead to ongoing partnerships and opportunities. This has been, and continues to be, an inspiring experience for all of us currently involved in the community.

ENDNOTES

[1] For the purposes of this article, we are using the term 'scientist' to describe someone who works as faculty or researcher at a university, college, or research facility, with expertise and training in science. The descriptor 'educator' is used to describe someone working as a K-12 teacher or instructor in formal or informal environments, with expertise in learning and teaching. The lines between educator and scientist are often blurred, and certainly many science faculty members are also educators and well-versed in educational pedagogy; and educators may have science degrees and substantial science knowledge.

[2] This statement was excerpted from the 2008 evaluation report for COSIA [Inverness Research Associates. (2008)/ (See http://www.inverness-research.org/abstracts/ab2008-12_Rpt-COSIA-interim-eval-rpt.html)]. All quotes reported therein were anonymous.

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From the Mountains to the Sea: NMEA 2010!

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The Tennessee Educators of Aquatic and Marine Science (TEAMS) invite you to Gatlinburg, Tennessee at the foothills of the Great Smoky Mountains National Park.

The conference begins Monday afternoon with an exhibit preview and reception. Before taking it to the top of Mount Harrison aboard the Gatlinburg Aerial Tramway, we will enjoy the Stegner Lecture performance. Tuesday through Thursday are jam-packed with general and concurrent sessions. Tuesday will conclude with a fun-filled night at Ripley's Aquarium of the Smokies. The annual auction will take place Wednesday evening so be sure to bring your checkbook! The highlight of the afternoon is the awards presentation followed by a real Tennessee Hoedown at Dumplin Valley farm; and Friday is full of field trips that will take you to exciting destinations around East Tennessee and concludes with a stampede at Dolly Parton's Dixie Stampede. For more information, visit www.nmeaweb.org/gatlinburg2010.

Research on Learning and Teaching Ocean and Aquatic Sciences

By Lynn Uyen Tran, Diana L. Payne, and Lynn Whitley

To achieve an ocean and aquatic literate society, ocean and aquatic sciences must be valued and integrated into educational practice, research, standards, curricula, textbooks, and assessments. In addition, the ocean and aquatic sciences education community must draw upon research and theory in the learning and teaching of science, and ocean and aquatic sciences in particular. In this article, we summarize two publications that explore these arguments (Payne and Zimmerman, in press; Tran 2009), and situate the findings within the discussion of the Ocean Literacy Scope and Sequence for Grades K-12.

A DEARTH OF EDUCATIONAL RESEARCH: WHAT IS MISSING AND WHY IT IS IMPORTANT [a]

Earth systems science as a discipline, and ocean and aquatic sciences in particular, are poorly represented in K-12 national and state frameworks and standards (Hoffman and Barstow 2007; McManus et al. 2000), which often drive the curriculum, instruction, and assessment at the local, state, and national levels. Moreover, educational research has paid little attention to teaching and learning of ocean and aquatic science concepts in contrast to other well-studied areas of science such as chemistry, physics, and biology. The effects of this omission and oversight are reflected in a citizenry that has low knowledge and awareness of the concepts and environmental issues pertaining to ocean and aquatic ecosystems (Steel, Smith, Opsommer, Curiel, and Warner-Steel 2005; The Ocean Project 2009).

In a time when we are expected to comprehend and respond to increasingly complex socio-scientific issues (e.g., global climate change, environmental pressures on coastal and ocean resources, and biotechnology potential within the ocean), many people often do so with no more than a sixth grade understanding of how the natural world works and with a non-scientifically accurate understanding of the ocean (The Ocean Project 2009). Despite their limited knowledge, people, especially young people, are willing and interested to take action to protect the health of the ocean and the environment; they just need to know how (The Ocean Project 2009). Indeed, "improving the knowledge base of citizens should be the first step in establishing a nationwide effort to preserve the oceans (Steel, Smith et al. 2005). Furthermore, scientific literacy and technical knowledge are not the only factors influencing the public's decision making on environmental issues. It is important to note that while understanding the science is important for decision making, people also need to have and recognize personal and emotional connections to the phenomena (Steel, Lovrich, Lach, and Fomenko 2005). While 50% of the U.S. population lives within coastal counties, 50% have had little to no exposure to the ocean other than second-hand images (U.S. Commission on Ocean Policy's Report to the President and Congress 2004). Moreover, personal experiences, along with adequate resources and reliable educational research, are important to assist teachers in teaching ocean and aquatic sciences and related environmental stewardship.

There is, however, scant educational research specifically investigating students' understanding of ocean sciences concepts. Brody and Koch (1989-1990) reported that more than 86% of the elementary, middle, and high school students they studied did not know concepts essential to understanding ocean science and ocean resources. The students in this study also held non-normative ideas that would significantly impact their ability to make informed decisions about ocean resources. Ballantyne (2004) found students in South Africa had difficulties understanding ocean concepts, such as sources of salinity, wave propagation, and human impacts. Studies can be found describing particular components of the water cycle and/or climate, but few studies address larger system comprehension, including the interdependence and interactions of the multiple components that comprise the ocean system. However, recent educational research indicates that ocean and aquatic sciences, when integrated into curriculum and instruction, can be used as a model of a large-scale coherent theme to assist in student understanding of complex systems (Fortner, Corney, and Mayer 2005; Lambert 2006). In the absence of additional educational research focused specifically on ocean and aquatic sciences, we look instead to a systems-based approach to teaching and learning.

LEARNING AND TEACHING OCEAN SCIENCES: A COMPLEX SYSTEMS APPROACH [b]

Water and Carbon Cycles

While there is limited educational research on learning related to the seven Ocean Literacy Principles specifically, there is a body of literature on students' (Kindergarten to university) understanding of the scientific concepts and ideas underlying the principles that can be used to infer about their ocean literacy. These studies have investigated students' understanding of the water cycle, carbon cycle, density, evolution, and photosynthesis. This review concentrates on the water and carbon cycles in particular, as there is a larger collection of research pertaining to students' understanding of these processes, which allows for a depth rather than breadth of analysis. In addition, these processes are critical to understanding several Ocean Literacy Essential Principles and Fundamental Concepts, most notably Principle 1-c, f, g; Principle 2-a; Principle 3-a, b, c, d, e, f, g; and Principle 6-1.

A review of learning research in chemistry, physics, geology, ecology, environmental education, and systems dynamics provided several major insights. The research showed that having knowledge of conservation of matter and basic particle theory helped students understand the water cycle as the circular movement of water between sources and the atmosphere (Bar and Galili 1994; Johnson 1998; Tytler 2000). Most students, however, did not think of the water cycle as a complex system that occurred over great distances or time (Ben-zvi-Assarf and Orion 2005; Dickerson and Dawkins 2004; Shepardson, Wee, Priddy, Schelleberger, and Harbor 2008). Research on students' understanding of the carbon cycle primarily focused on phenomena—the greenhouse effect, global warming, and climate change. Studies revealed that students did not understand how carbon in the atmosphere affected climate and weather, with most thinking the depletion of the ozone layer led to global warming (Andersson and Wallin 2000; Boyes and Stanisstreet 1993; Groves and Pugh 1999; Lee, Lester, Ma, Lambert, and Jean-Baptiste 2007).

Only a few of these investigations examined students' understanding of the cycles as complex, global systems. These studies reported that when students considered the cycles at a localized place, water and carbon moved from one place to another but did not disappear into oblivion; when thinking about these cycles on a global scale or over time, however, even university students did not understand that water and carbon also should not disappear into oblivion. In other words, students held the concept of conservation of matter when thinking of the cycles locally, but not when considering the cycles as global systems (Ben-zvi-Assarf and Orion 2005; Sterman and Sweeney 2002). Understanding the water and carbon cycles as complex systems may be particularly important to ocean and aquatic science literacy, as the interrelations and interconnections of these processes, over distance and time, are fundamental to the concepts in the seven Ocean Literacy Principles. Emphasis on only individual processes leaves students to make connections between the cycles in a global system on their own, which they may not be able to do. Systems thinking is valued and supported in the National Science Education Standards (National Research Council [NRC] 1996). Studies on systems thinking offer insight to the challenges and strategies for learning and teaching about ocean and aquatic sciences in this way.

Complex Systems: Cognitive Challenge, Pedagogical Support

A complex system is an aggregate of components, all of which are necessary for the system to function (Ben-zvi-Assarf and Orion 2005). Complex systems are hierarchical in nature and have multiple interacting levels (Wilensky and Resnick 1999).

Sylvia Vitazkova and Claudio Vargas use a model of Earth to demonstrate ocean circulation during a Communicating Ocean Sciences Instructors' Workshop in Berkeley, California.

Put differently, the idea and entity of the system at higher levels (e.g., a traffic jam, respiratory system, water cycle) emerge from interactions of objects at lower levels (the cars, cells, water molecules), and is more than an accumulation of the parts. The system maintains stability through self-correcting feedback loops, and even small changes can have significant effects. Systems thinking is the ability to understand and interpret complex systems, and comprises numerous types and levels of thinking skills (Richmond 1993). Thinking in this manner is challenging and students need practice and experiences to become adept at looking at the world as an interconnected system.

The studies in this review reported that students and novices tended to have *a centralized mindset*; that is, they preferred explanations that assumed a single cause or an ultimate controlling factor (Penner 2001; Perkins and Grotzer 2000; Raia 2005; Resnick 1990, 1996; Wilensky and Resnick 1999). Students tended to offer simplified, direct cause-effect explanations for complex events, such as a lead goose causing geese to fly in a "V" formation (Penner 2000), tilt of Earth causing glaciation in the Northern Hemisphere (Raia 2005), and change in temperature can eliminate a species in a food web causing the web to collapse (White 2000). Researchers argued that such a mindset hindered students' ability to consider the effects of the interdependence and interconnection of components in a complex system. Additionally, in this mindset, students neglected emergent properties of complex systems (Penner 2000). Emergent properties are the features, characteristics, or objects of a system that "emerge" from interactions among the lower level properties, such as weather patterns arising from movement of water and air molecules. Students failed to recognize the importance of such factors as time and space when considering causal explanations of complex systems (Feltovich, Spiro, and Coulson 1993; Grotzer 2003), for instance, that it would take years to reduce the amount of carbon in the atmosphere even if anthropogenic input was significantly reduced instantaneously.

Furthermore, comparison studies between experts (scientists) and novices (students) revealed that in noticing the interconnectedness of components in a system, students tended to identify the parts within the system, while experts talked about how the parts worked and their roles in the system as a whole (Hmelo, Holton, and Kolodner 2000; Hmelo-Silver, Marathe, and Liu 2007; Hmelo-Silver and Pfeffer 2004).

Despite these learning challenges, researchers found several teaching methods that facilitated systems thinking skills. First, opportunities for students to use models, and more specifically, to create, manipulate, and revise models helped students think about complex systems. As a critical condition of this first point, students showed improvements when they had the chance to work with models over several iterations so that they could design their model, test out their ideas, rethink, revise, and retest multiple times (Edelson 2002; Hmelo et al. 2000; Kawasaki, Herrenkohl, and Yeary 2004; Penner, Giles, Lehrer, and Schauble 1997). There were also student gains in activities where they used computer-based learning environments (virtual models), such as virtual environments and hypermedia (Barab, Hay, Barnett, and Keating 2000; Evagorou, Korfiatis, Nicolaou, and Constantinou 2008; Kali, Orion, and Eylon 2003). Thus, models—virtual and physical—made the invisible, abstract, and intangible elements of the dynamic processes in complex systems visible, concrete, and tangible for students as they learned. Second, researchers noted that structure and guidance from knowledgeable and skilled classroom teachers was critical for learning. The teachers had systems thinking skills, understood the complex system, and provided support to the students as they struggled in doing the tasks. Third, opportunities for students to have control over their own learning experiences, as well as to talk about and reflect on their ideas with their peers helped students develop systems thinking skills.

The studies in this article provide three major suggestions for the ocean and aquatic sciences education community. First, a systems approach to critical concepts and processes, such as the water and carbon cycles, may support ocean literacy. Systems thinking has great explanatory and predictive power and it is worth the time and effort it takes to help our students achieve this skill. Second, understanding global processes from a systems perspective requires types of thinking skills that are challenging to develop. Strategies that can support systems thinking include: 1) ensuring that teachers have advanced pedagogical knowledge to scaffold student thinking; 2) designing activities that give students control to create and manipulate models (virtual and physical); and 3) providing opportunities for students to talk with peers to reflect on, articulate, and share their thinking. And finally, though not summarized above, informal learning environments (e.g., aquariums, museums, science centers) provide access to objects, organisms, and phenomena that create personal connections for learners. These personal connections have long-lasting effects on individuals' interests and motivations to learn and act (National Research Council [NRC] 2009). While the strategies described here might simply be considered "good teaching" for any science concepts, they may well be especially and disproportionately important, compared to other "good teaching" strategies, for helping students to understand concepts related to the ocean.

CONCLUSION

In sum, the Ocean Literacy Scope and Sequence for Grades K-12 is an instructional tool that shows how concepts in ocean sciences are interconnected, and thus it supports a systems approach for teaching and learning about the ocean. The conceptual flow diagrams for each principle guide users (including educators, curriculum and program developers, administrators) through a potential teaching and learning sequence. The ordering and building of these ideas across grade bands within each Ocean Literacy Principle illustrates how student thinking can be scaffolded from one developmental level to the next. Cross-references between principles within each grade band emphasize the interrelationships of concepts at a particular developmental level. Concepts conveyed by use of the conceptual flow diagrams and engaging learning experiences will allow students to reflect, articulate, and share their thinking; build personal connections that will have a long-lasting effect on their motivations to learn and act; and ultimately to become ocean literate.

AUTHORS' NOTES

[a] This first section is a summary of a chapter (Payne and Zimmerman, in press) in the upcoming monograph *The Inclusion of Environmental Education in Science Teacher Education*, set for publication in 2010 by the Association for Science teacher Education (ASTE).

[b] This second section is a summary of a paper commissioned (Tran 2009) by the National Research Council's Committee to Review NOAA's Education Programs. The paper reviewed the corpus of literature on students' understanding of the water and carbon cycles in order to offer insight on their ocean literacy, as these processes are critical to ocean literacy.

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Developing the Ideas of Ocean Literacy Using Conceptual Flow Diagrams

By Craig Strang, Kathy DiRanna, and Jo Topps

Upon publication of *Ocean Literacy: the Essential Principles of Ocean Sciences K-12*, there was broad recognition of the potential power of a consensus document describing what every person should know about the ocean to be considered science literate. There was also recognition of the limitations of such a document that describes the ideal end state, yet provides no road map for how to get there. We knew that ultimately we would need to craft a road map to provide an answer to the question, "If students are to understand the Ocean Literacy Principles by the end of grade 12, what would we need to teach them in grades K-2, in grades 3-5, in grades 6-8, and in grades 9-12 to help them reach that goal?" The answer to that question—a scope and sequence—would be of great interest to teachers and informal science educators, but also to national and state standards committees, curriculum developers, textbook writers, and assessment specialists. But what would be an effective way to represent this complex information so that it would be comprehensive, understandable, and accessible for these different end users? For this answer, we turned to literature in learning, teaching, and teacher professional development.

Research in the learning sciences (Bransford et al. 1999) reveal that to develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge; (b) understand facts and ideas in the context of a conceptual framework; and (c) organize knowledge in ways that facilitate retrieval and application. Thus to facilitate the development of students' conceptual understanding and organization of ocean sciences ideas, the scope and sequence should have a logical and coherent approach to building the complex ideas of the Ocean Literacy Principles from one grade band to the next. Conceptual flow diagrams (as shown on pages 33-62) offer a way to present and organize such a progression of ideas, and can be a versatile tool for several reasons: they describe the developmentally appropriate concepts at each grade band, as well as the relationships among the concepts, in a graphical format; they provide a research-based example of a sequence in which the concepts can be taught, beginning at the earliest grades; and the diagrams balance the need for accessibility and utility with fidelity to learning theory and cognitive science.

CONCEPT MAPS VERSUS CONCEPTUAL FLOWS

Conceptual flow diagrams are a specialized and distinct form of concept maps. Concept maps are graphical tools for organizing and representing knowledge that were developed in 1972 in the course of Joseph Novak's research program at Cornell University, where he sought to follow and understand changes in children's knowledge and understanding of science (Novak and Musonda 1991). The data from Novak's study indicated "the lasting impact of early instruction in science and the value of concept maps as a representational tool for cognitive developmental changes." Novak's concept maps include concepts, usually enclosed in circles or boxes, and relationships between concepts indicated by a connecting line linking two concepts. Text on the connecting line, referred to as linking words or linking phrases, specify the relationship between the two concepts. Concepts are generally represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map, and more specific concepts arranged below. The hierarchical structure for a domain of knowledge may be somewhat relative as it often depends on the context in which that knowledge is being applied or considered (Novak and Cañas 2008; Novak and Gowin 1984). The use of concept maps generally represents a constructivist approach to learning and teaching, as it assists the learner in developing and displaying the trajectory of their understanding of new concepts and ideas.

Conceptual flow diagrams were developed by the K-12 Alliance/WestEd in California in 1989, for use with teachers during professional development institutes conducted for an NSF-funded statewide systemic initiative. In that setting and dozens of others since, teachers developed conceptual flow diagrams to improve their content knowledge, their curriculum planning, and their instruction of complex science concepts. As a product, a conceptual flow diagram resembles a map of nested concepts. The biggest ideas are supported by small ideas, and those small ideas are maintained by even smaller ideas that become learning sequence concepts (see Figure 1). The conceptual flow diagram differs from a concept map in that it addresses concepts in a unit of instruction, and has both a hierarchy of ideas (indicating the relationship between and among the ideas) and a direction (i.e., the sequence for instruction of the unit). Conceptual flow diagrams are intended to be read and taught from top to bottom and from left to right. Concepts nested beneath other concepts serve to elucidate and support the concepts above. Concepts to the right build on those to the left, and often move in a developmental sequence, especially in the early grades, from more concrete to more abstract.

The process of guiding teachers through the development of conceptual flow diagrams is described at length in the book, *Assessment Centered Teaching: A Reflective Practice* (DiRanna et al. 2008). The process of making conceptual flow diagrams has also been adapted for a variety of purposes, including planning for classroom instruction and assessment simultaneously, assisting in school district analysis, selection and adoption of instructional materials, and helping curriculum developers to design instructional materials. Given these versatile uses of conceptual flow diagrams to display and organize big ideas and concepts in a well-thought-out progression of learning and teaching for different educational purposes, we decided to use conceptual flow diagrams to represent the scope and sequence.

PURPOSE OF CONCEPTUAL FLOW DIAGRAMS

The conceptual flow diagram is a "backward-planning" tool. Starting with the end in mind and planning backwards (Wiggins and McTighe 2005) is a means for setting comprehensible goals and designing better instruction. Teachers can array the big ideas that are important for students to know, the standards they are responsible for teaching, and the content presented in the instructional materials into one comprehensive, sequential chart. As teachers identify and integrate these three elements, the process of constructing a conceptual flow diagram enables teachers to clearly identify specific goals for student learning and progress. The conceptual flow diagram assists learners by making them aware of the links in the concepts they are addressing. Too often it is a mystery to students why they are learning what they are learning. As one teacher put it:

> *The conceptual flow diagram is a determination of where you are going in your teaching and what you're going to reflect on. You have to know what concepts are important and the order in which they go to conceptualize the whole learning. I put my conceptual flow on the wall for the kids so they learn where they're going, too.*
>
> –Teacher Leader 1, NSF Center for Assessment & Evaluation of Student Learning

Developing conceptual flow diagrams helps teachers build foundational knowledge about the importance of helping students to construct conceptual frameworks rather than "learn" factual information. When a conceptual flow is displayed in the classroom, it allows both teachers and students to connect new ideas and information, providing opportunities to learn with deeper understanding.

A completed conceptual flow diagram serves the following four purposes:

1. details the important concepts and linkages to other ideas;
2. identifies an instructional sequence for which resources (e.g., textbooks, instructional materials) can be used to support teaching;

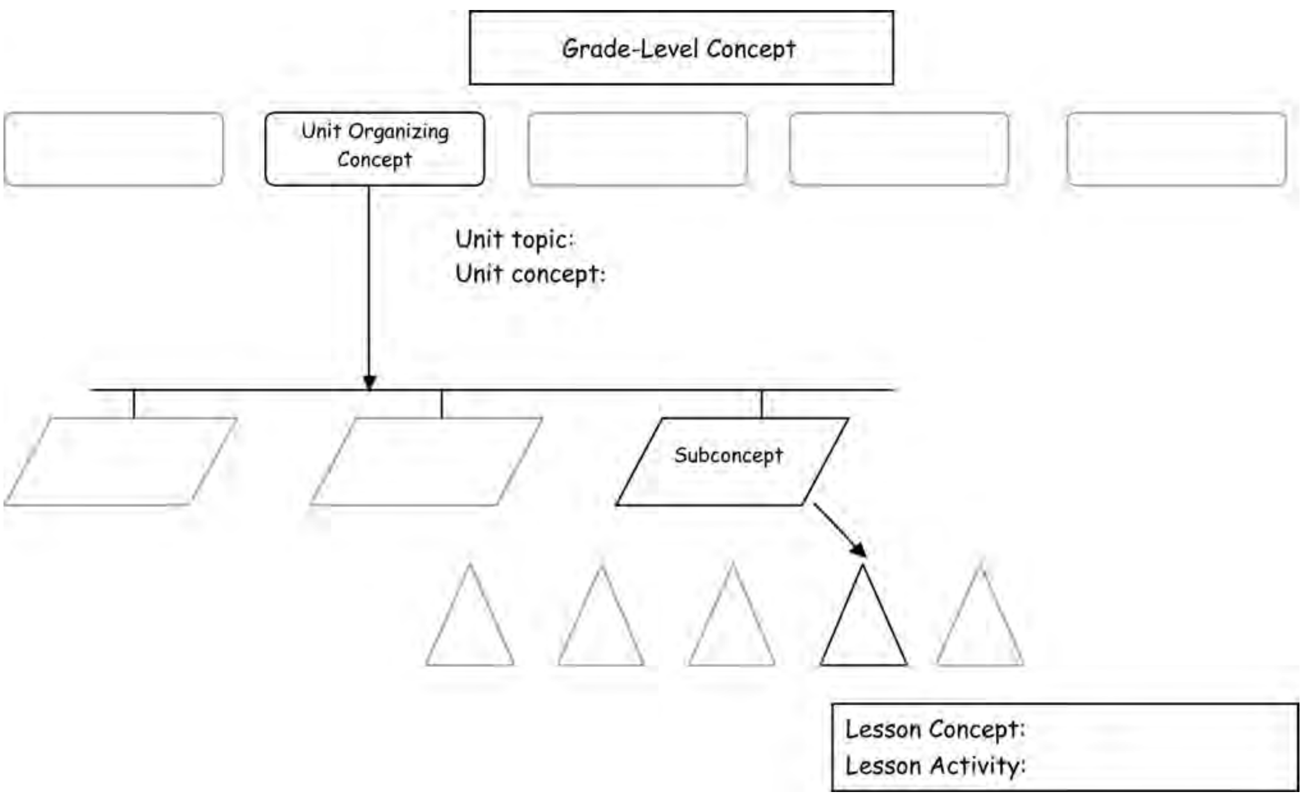

Figure 1. Shows the generic layout of conceptual flow diagrams developed by teachers to describe an instructional sequence.

3. identifies important concepts for assessment of student understanding; and

4. eventually serves as the foundation of an assessment plan for the unit of instruction.

CONSTRUCTION OF CONCEPTUAL FLOW DIAGRAMS

Conceptual flow diagrams are designed by a team, often led by a facilitator knowledgeable of the process. The process for a team of two to five people to build a conceptual flow diagram for a unit of instruction includes these five steps:

1. Individuals write a narrative response to the question, "What should students know about (blank) by the time they leave grade (blank)?

2. Individuals re-write and transfer each concept statement in complete sentences from their narrative responses onto separate post-it notes of three different sizes using the larger size for the larger, more important concepts.

3. Team members share their concepts on post-it notes with one another. They arrange the notes into a collaborative draft conceptual flow diagram with larger concepts at the top, and smaller, nested, supporting concepts below. This step can take several hours.

4. Team members match their collaborative, draft conceptual flow diagram to the concepts addressed in the instructional materials and to the science content standards used by team members.

5. Team members review the progression of concept clusters (each cluster is comprised of a large concept and the nested, smaller concepts below it) and place them in an instructional sequence that provides strong links for student understanding (see Figure 2).

CONCEPTUAL FLOW AND TEACHER CHANGE

In addition to aiding teachers in curriculum development, conceptual flow diagrams have been used as a foundational process for developing classroom assessment plans. A research study of teachers who received professional development on the building of conceptual flow diagrams found that most grade-level teams shifted over time toward a greater focus on big ideas by removing, adding, or reorganizing learning goals to focus on what was most important for students to learn. Another common shift was toward more coordinated relationships among big ideas and smaller supporting concepts. Most teams increasingly represented conceptual relationships among unit goals rather than as a list of sequential lesson topics. Paralleling organizational shifts in the conceptual flow diagrams, all of the teachers' assessment plans were more coherently organized in later portfolios. Assessment plans shifted from long lists of possible assessments toward judicious selection of a few key assessments for tracking student progress. Teachers indicated generally strong understandings of how to use conceptual flow diagrams to guide assessment decisions and to select their "juncture" assessments (Gearhart and Osmundson 2009).

> *I think teachers need to understand the conceptual flow of their curriculum…what concepts they want students to learn; what concepts to assess with their students...then they can plan for teaching.*
>
> *[Developing the Conceptual Flow] moved us from a list of topics to…nesting of important ideas. Identifying what really matters for student understanding drives decisions about…questions in the assessment.*
>
> –Teacher Leader 2, NSF Center for Assessment & Evaluation of Student Learning

In a political climate that stresses coverage of material in preparation for state testing, teachers appreciate that building

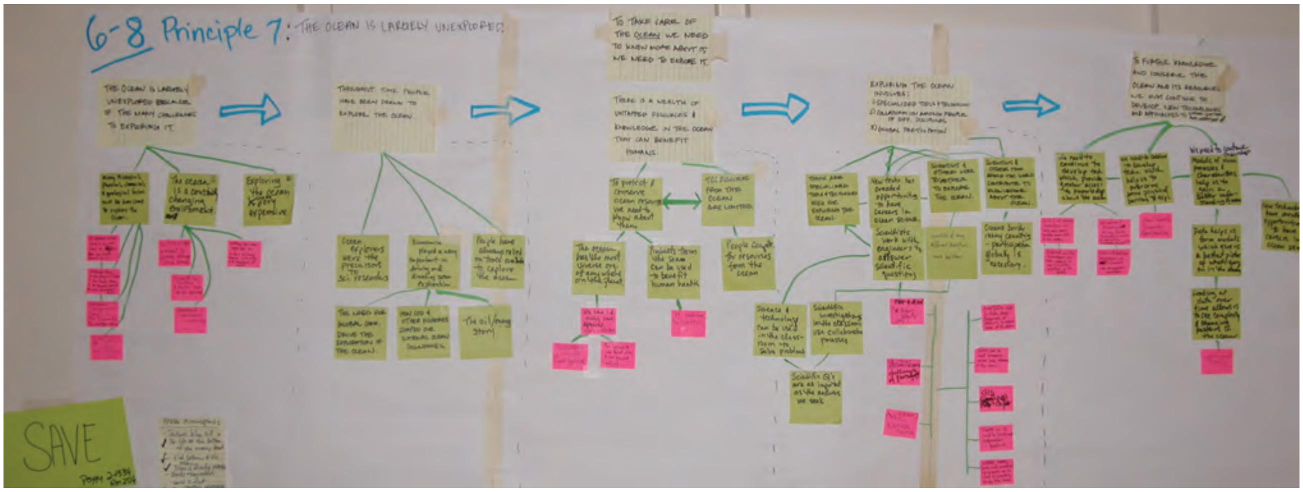

Figure 2. Sample of a first draft of the conceptual flow diagram for Principle 7 grades 6-8 developed at the first Ocean Literacy Scope and Sequence working meeting in 2006.

conceptual flow diagrams provides them with a process to think beyond standards checklists and pacing guides, and focus on conceptual understanding. One teacher explained:

> *My district is into curriculum mapping and…I'm trying to cover the standards, but (by using conceptual flow diagrams) you have to go deeper into the standards to assess the concepts that are actually behind the understanding, instead of just checking off standards.*
>
> –Teacher Leader 3, NSF Center for Assessment & Evaluation of Student Learning

Based on the findings of Gearhart and Osmundson, the benefits of conceptual flow diagrams appear to go beyond assessment planning: teachers *take ownership* of their instruction by becoming better consumers of instructional materials. As they grapple with important concepts and how they should be arranged in a meaningful sequence, teachers gain insight into how instructional materials are organized, which materials are designed to support students' understanding of the big ideas, and which lessons, resources, and assessments need to be revised. Teachers can then modify their instruction and assessment practice to address any gaps or weaknesses.

> *With a new focus on the concepts in the conceptual flow diagram, I was able to really see my instructional materials. I mean, I knew that our instructional materials were not often perfect, but this really brought out where the holes are, where I need to revise, and what I need to put in there to make sure the students understand the concept that I'm trying to teach.*
>
> –Teacher Leader 4, NSF Center for Assessment & Evaluation of Student Learning

> *I always look at a unit now and make sure that it does flow conceptually. If not, then I rearrange to make sure I include ideas that build upon one another. I always make that a part of my science teaching and I want to incorporate conceptual flow diagrams into other content areas.*
>
> –Teacher Leader 5, NSF Center for Assessment & Evaluation of Student Learning

While collaborative development of working versions of conceptual flow diagrams has been demonstrated as an effective teacher professional development activity, involving hundreds of people in the development of a set of 28 completed conceptual flow diagrams has, to say the least, never been accomplished before. *The Ocean Literacy Scope and Sequence for Grades K-12* represents a new use of conceptual flow diagrams. In 2006, the authors and several other colleagues led a group of 46 ocean scientists and educators through the development of the first Ocean Literacy conceptual flow diagrams. The process was uplifting and invaluable. Achieving a final product, however, took considerable revision, iteration, and review before consensus was reached on all 28 diagrams. Now published, we hope that the Scope and Sequence will become a catalyst for future research about how students form and revise their understanding of complex ocean sciences concepts. Further, we anticipate that the Scope and Sequence will become a driving force in defining the content that students will encounter in future standards, textbooks, curriculum materials, and assessments.

The freeware CmapTools was used in developing the conceptual flow diagrams (http://cmap.ihmc.us/conceptmap.html).

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Introduction to Conceptual Flow Diagrams: Ocean Literacy Scope and Sequence

The Ocean Literacy Scope and Sequence is comprised of 28 conceptual flow diagrams (hereafter referred to as flows). There is one flow for each principle for each grade band (K-2, 3-5, 6-8, and 9-12). Each flow represents one possible way of breaking down and organizing the major concepts and supporting ideas for each principle for a grade band. They can be used as a suggested instructional sequence, organizer of ideas, and/or indicator of learning progression. The following two figures (see below and page 32) label the major components of each flow, using the flow for Principle 1 Grades 3-5 as an example.

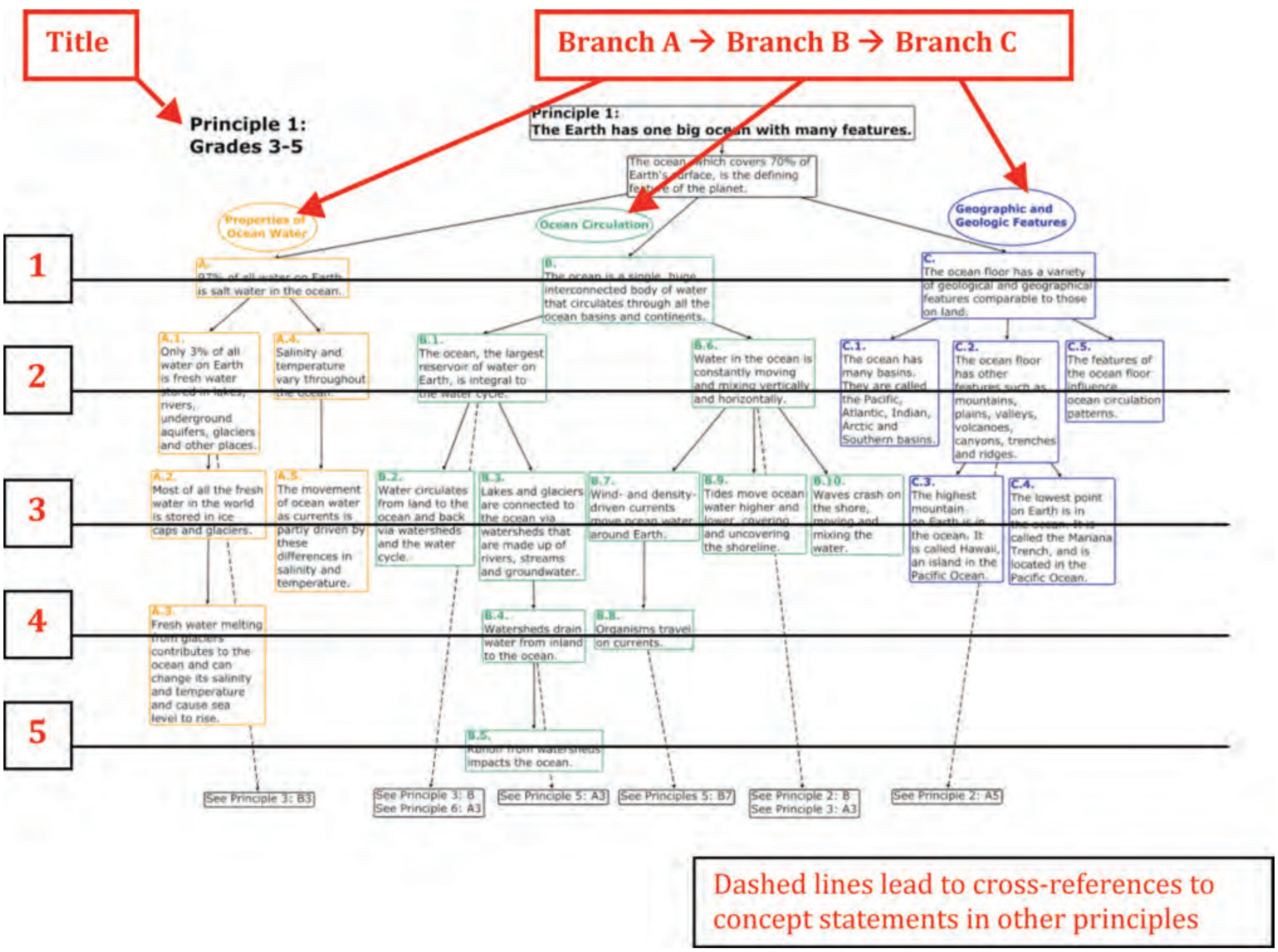


Figure 1. In this flow, there are three branches of topics and five levels of ideas. Read the flow from top to bottom and left to right, from Branch A (A1-A5) to Branch B (B1-B10) to Branch C (C1-C5). Some of the concepts cross-reference other concepts in other principles within that same grade band. These cross-references are connections between principles.

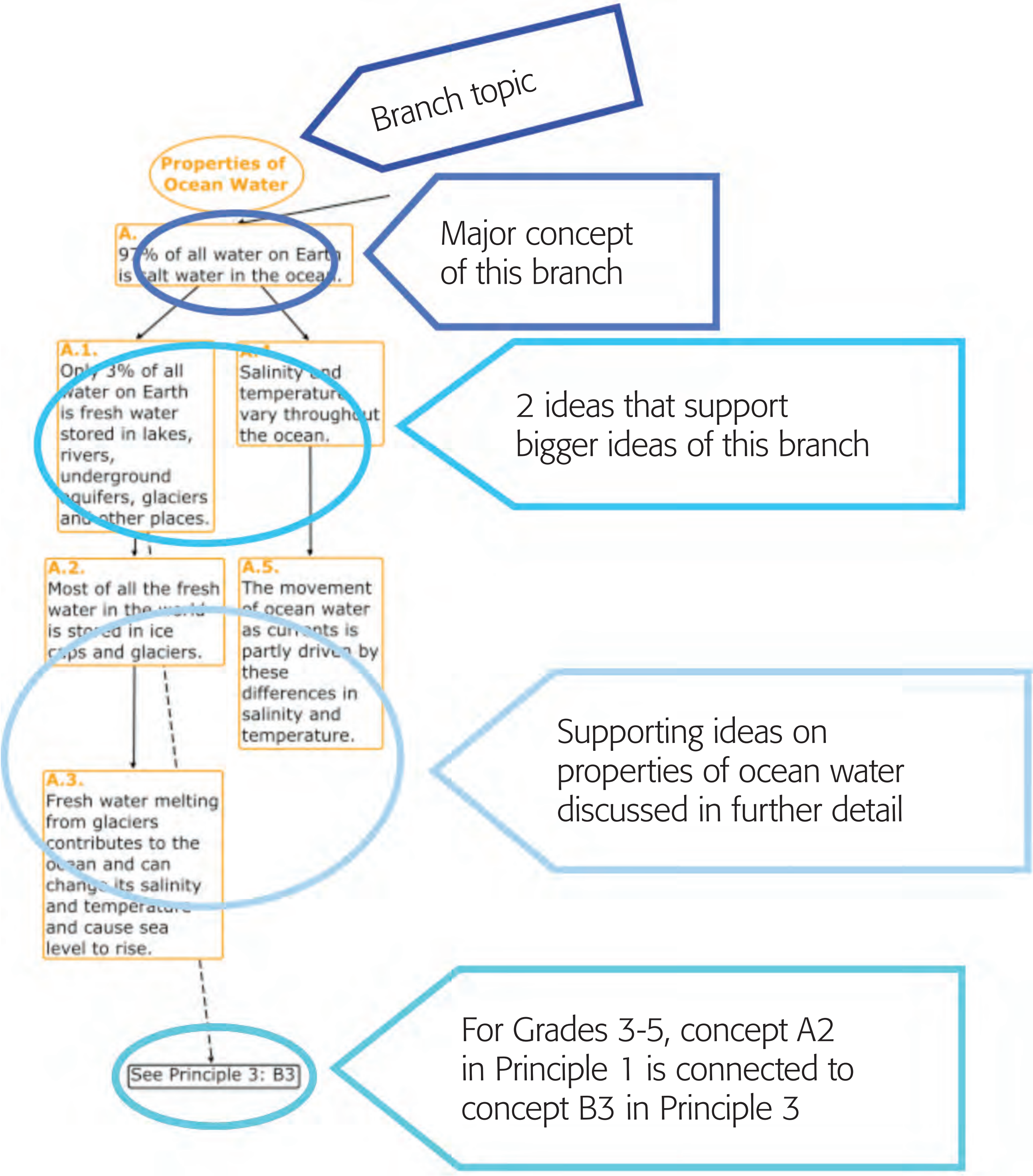
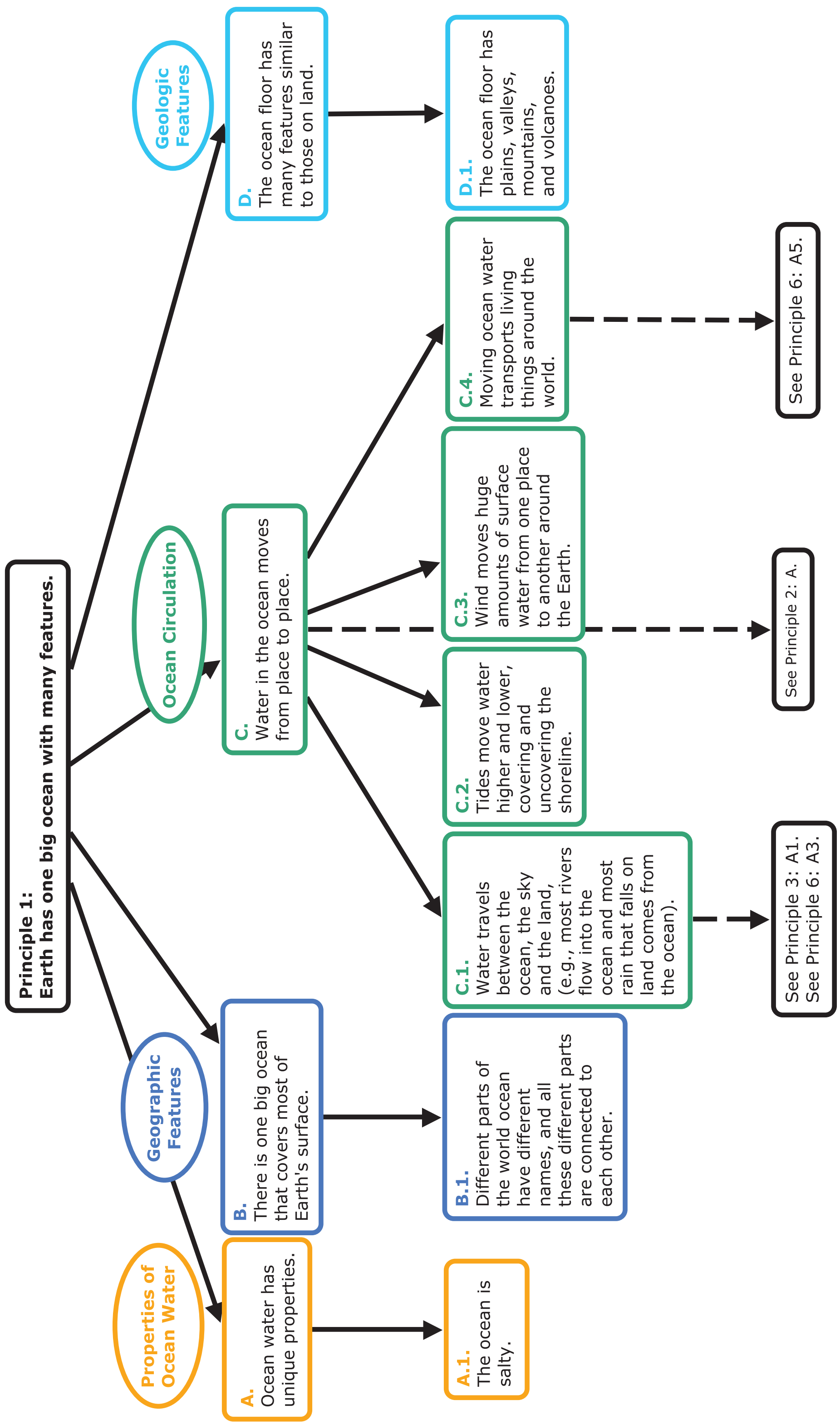
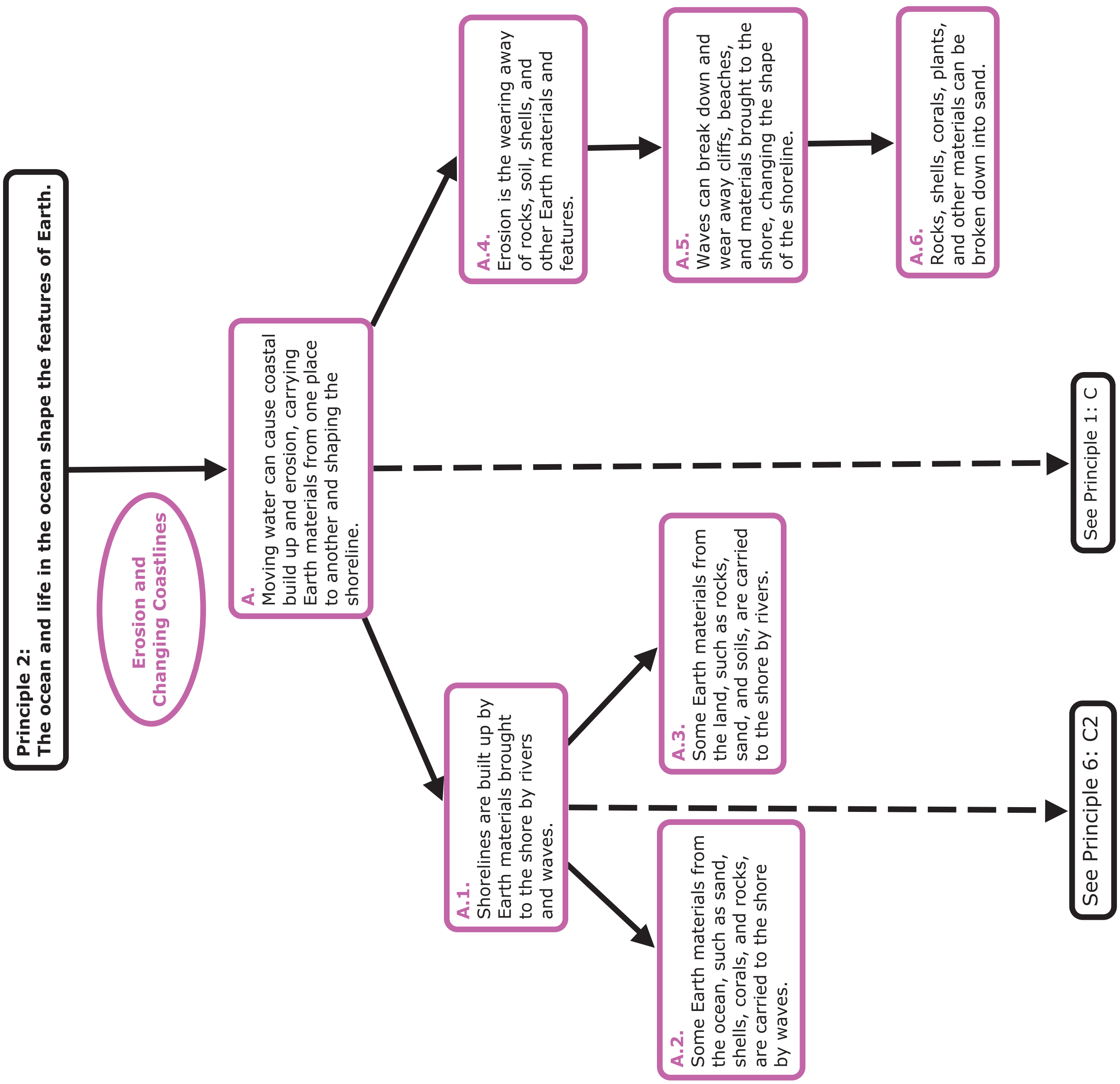


Figure 2. Branch A of conceptual flow diagram of Principle 1 for Grades 3-5. Here is a breakdown of the components in a branch. The branch is identified by topic for easy reference. The branch begins with a major concept and then nested below are two levels of ideas that support the bigger idea. Supporting ideas can be examples, but not always.

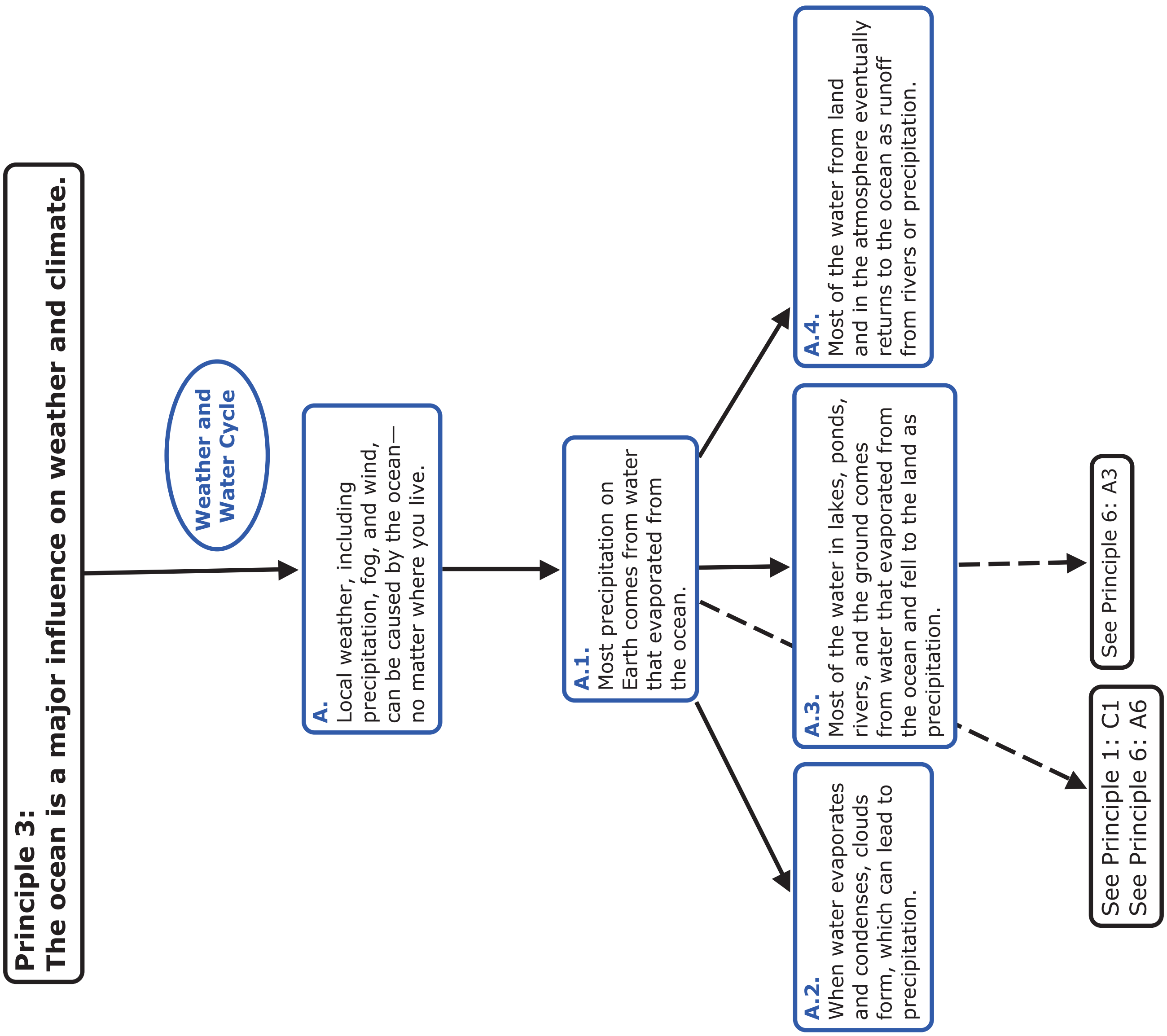
Principle 1: Grades K-2



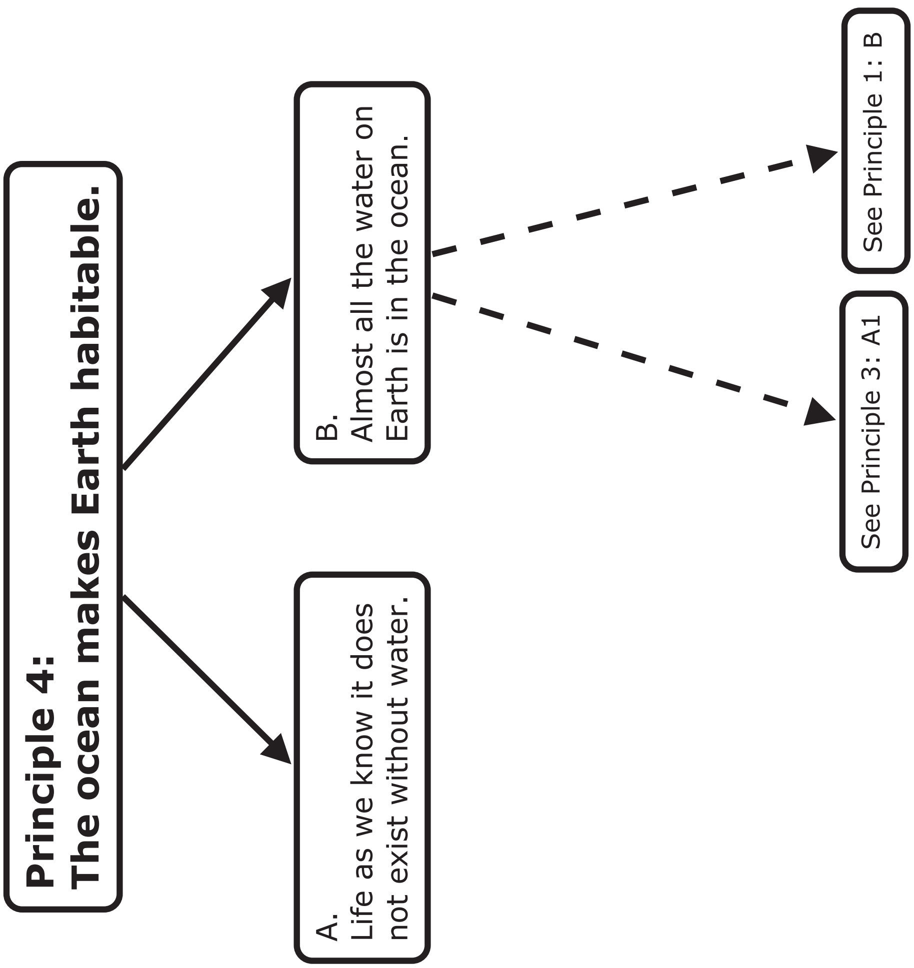
Principle 2: Grades K-2



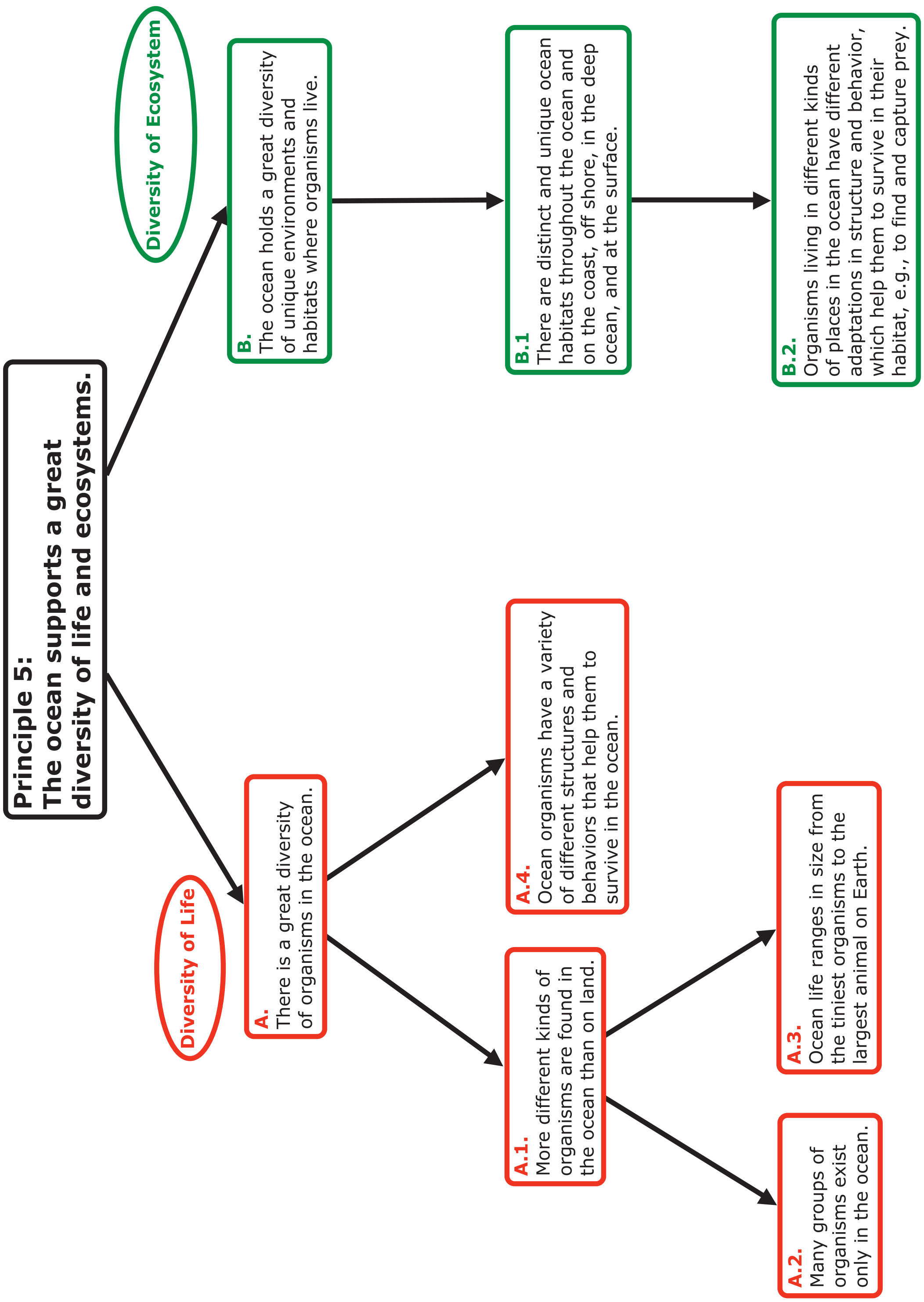
Principle 3: Grades K-2



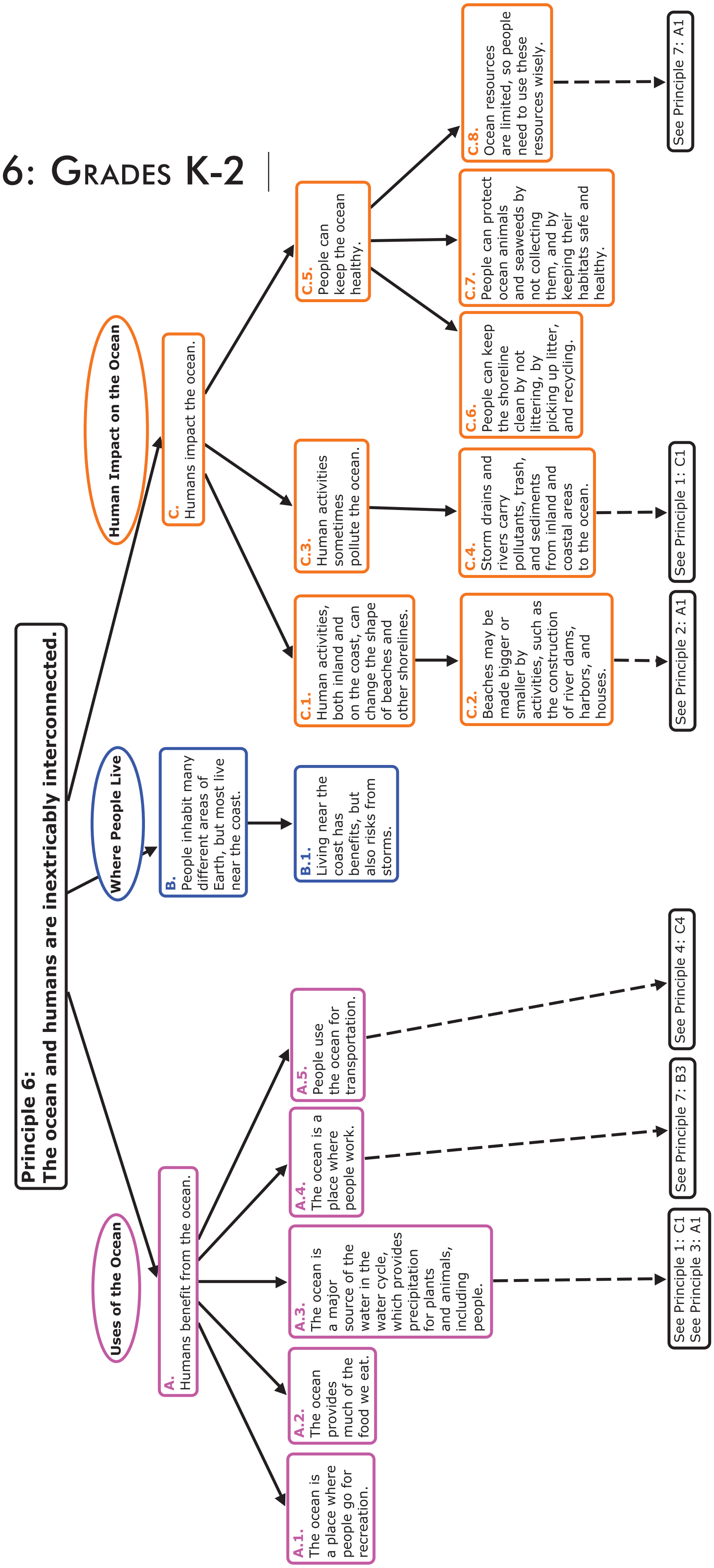
Principle 4: Grades K-2



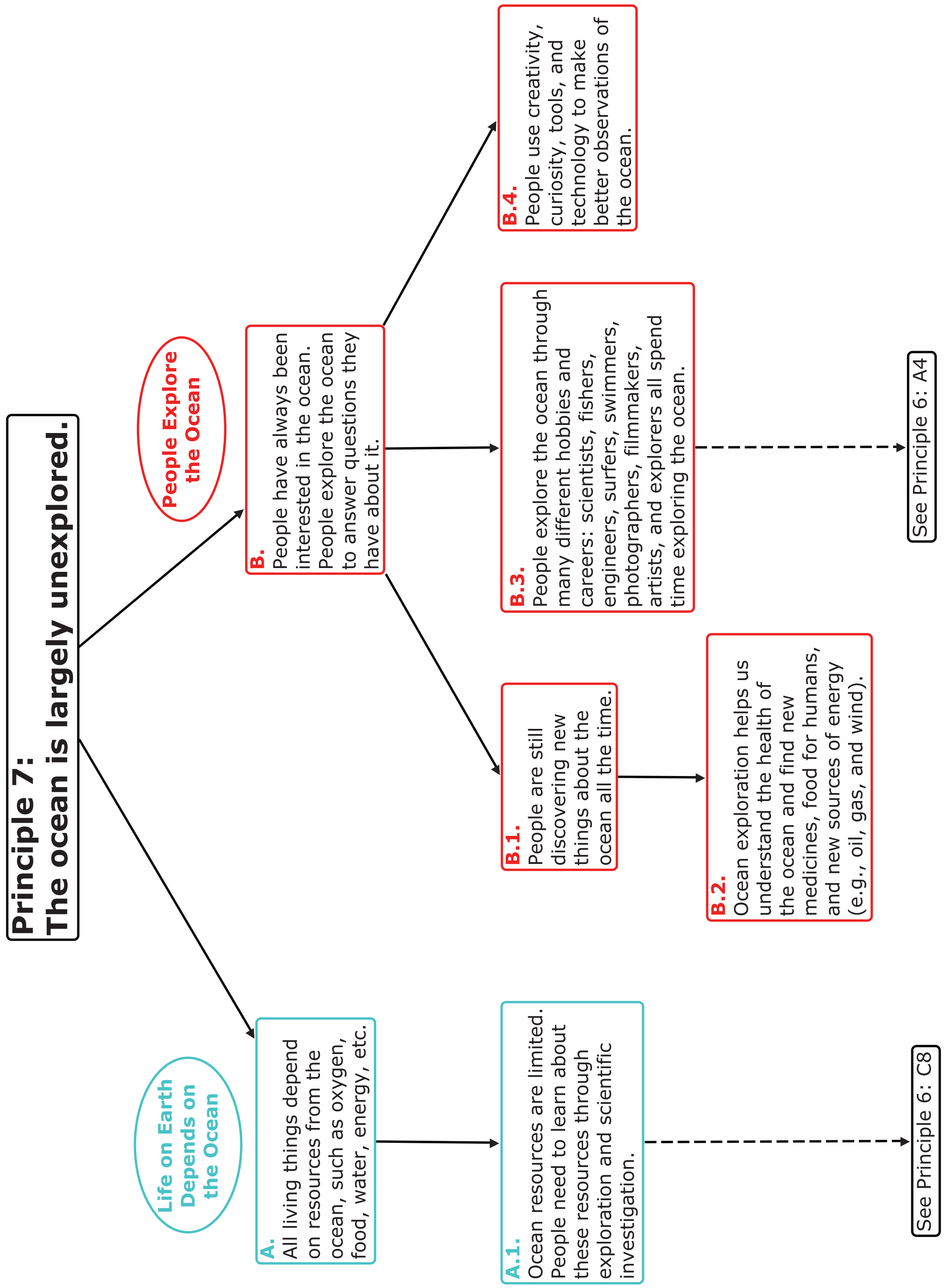
PRINCIPLE 5: GRADES K-2



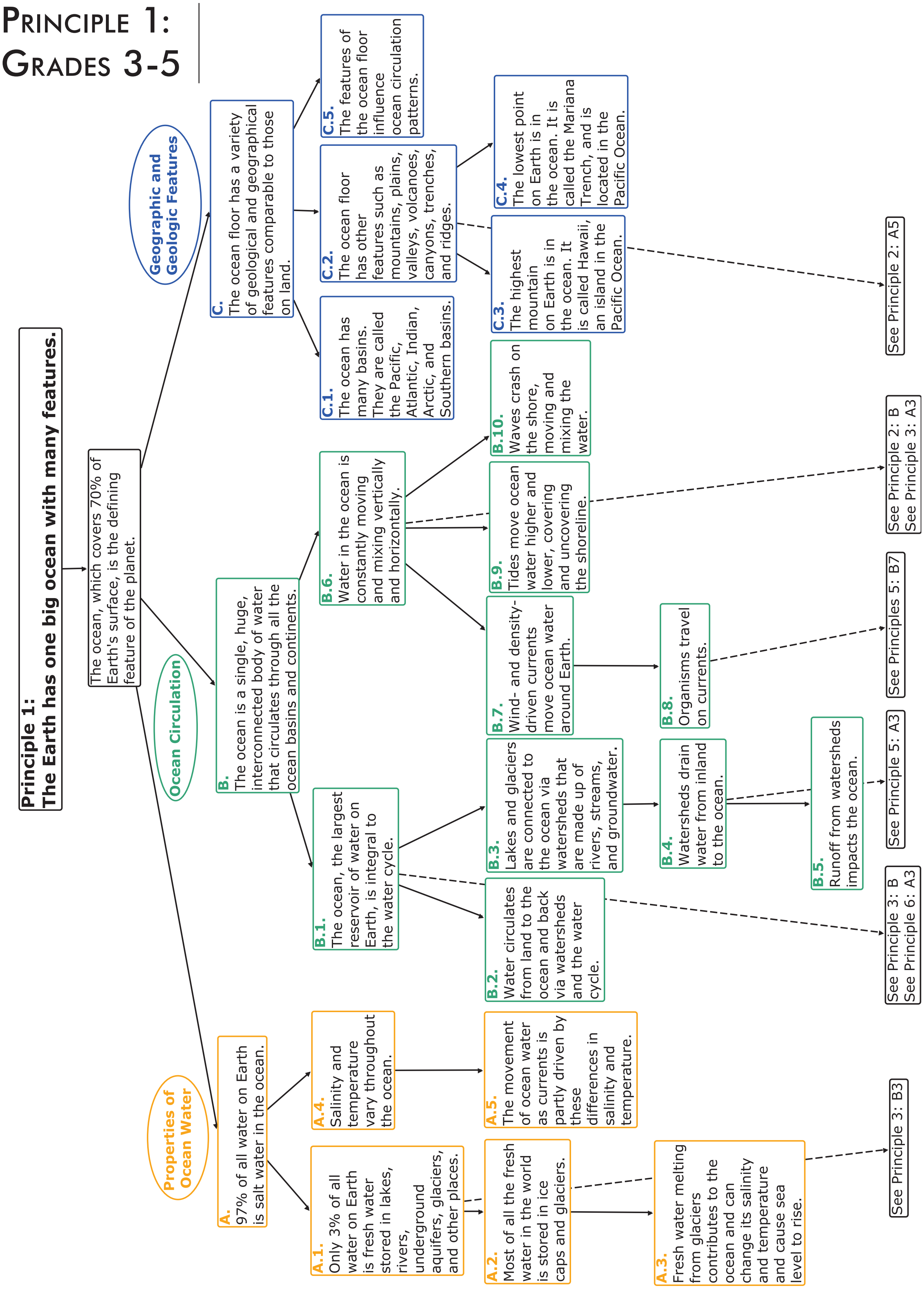
Principle 6: Grades K-2



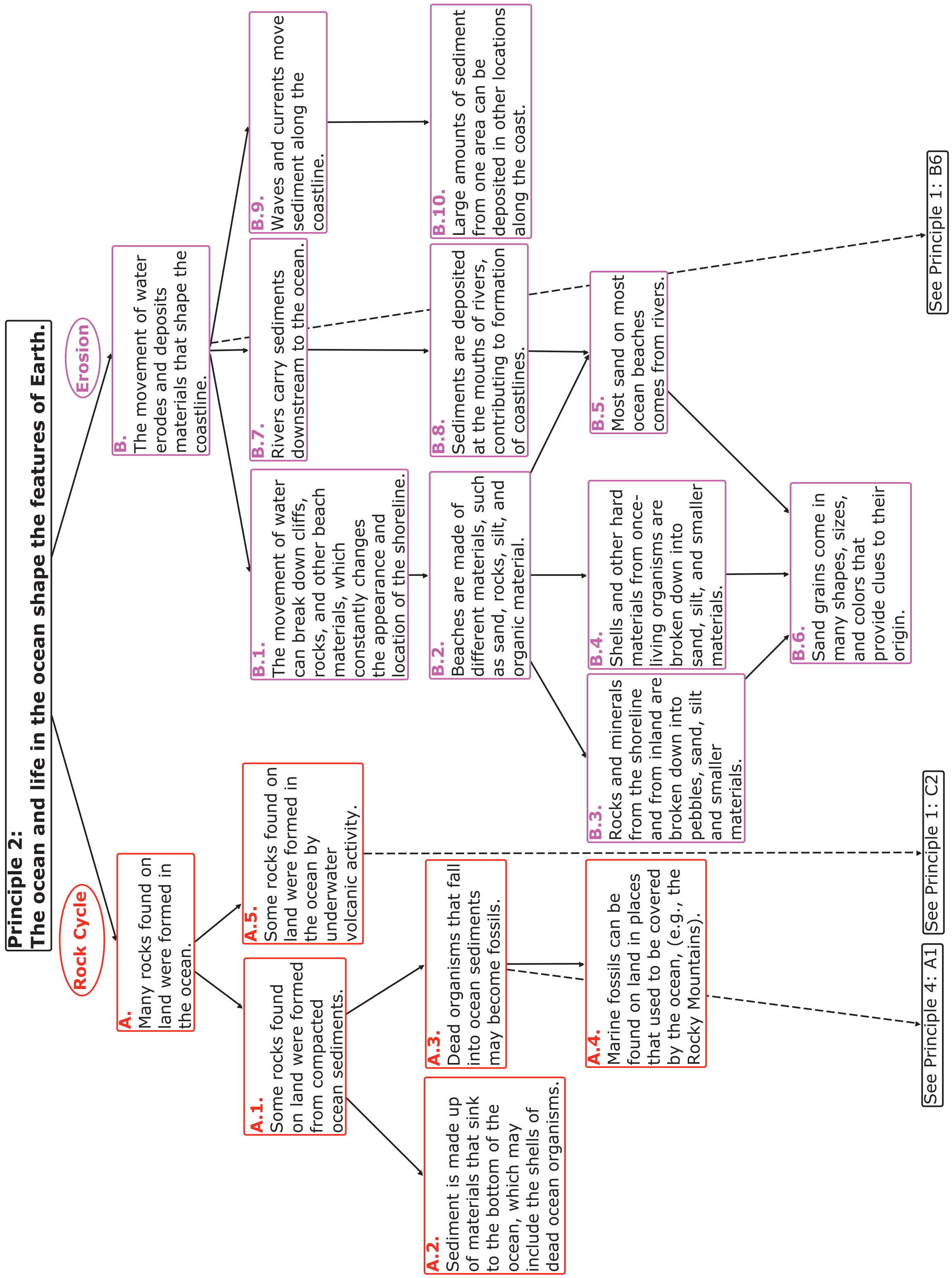
Principle 7: Grades K-2



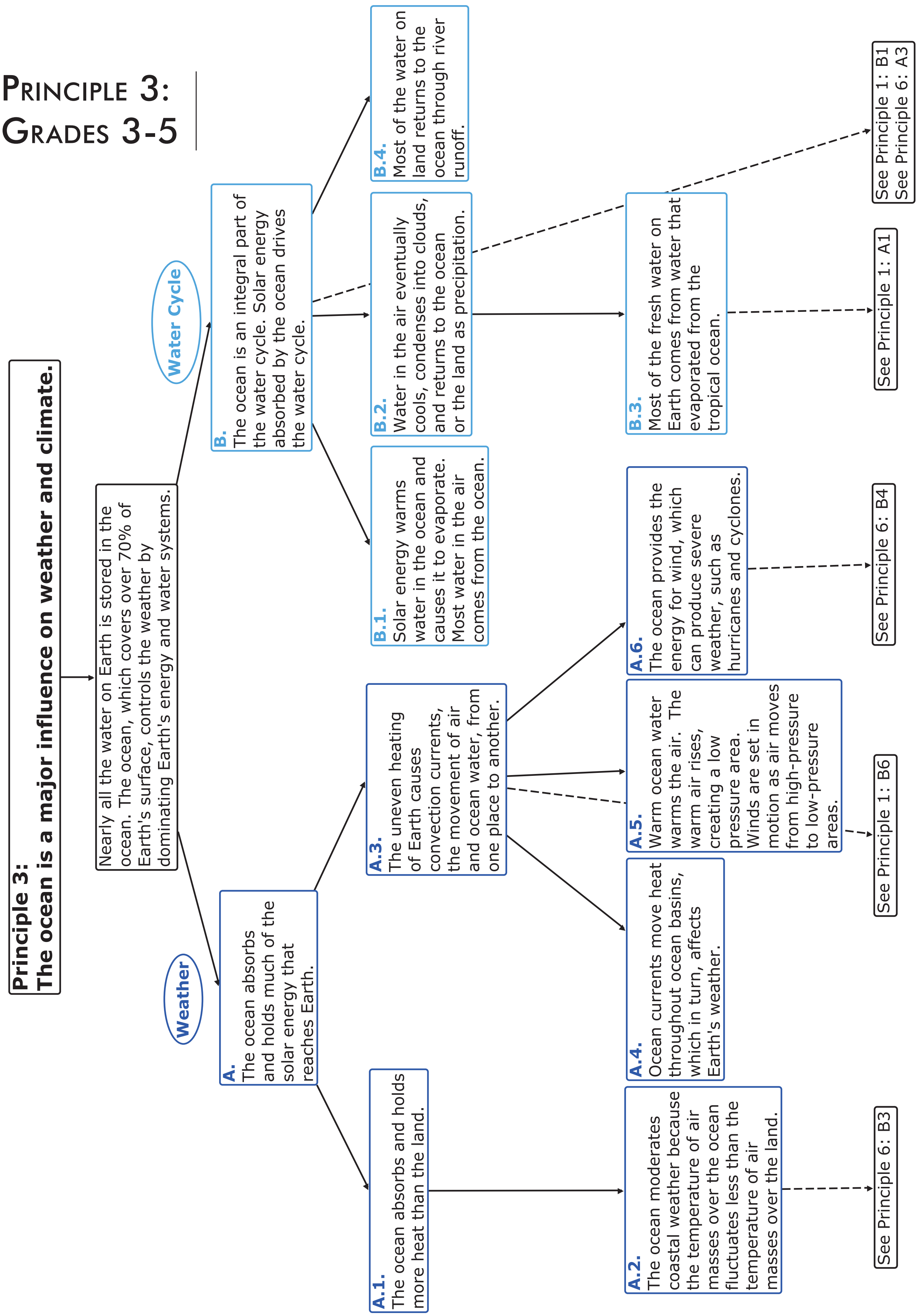
Principle 1: Grades 3-5



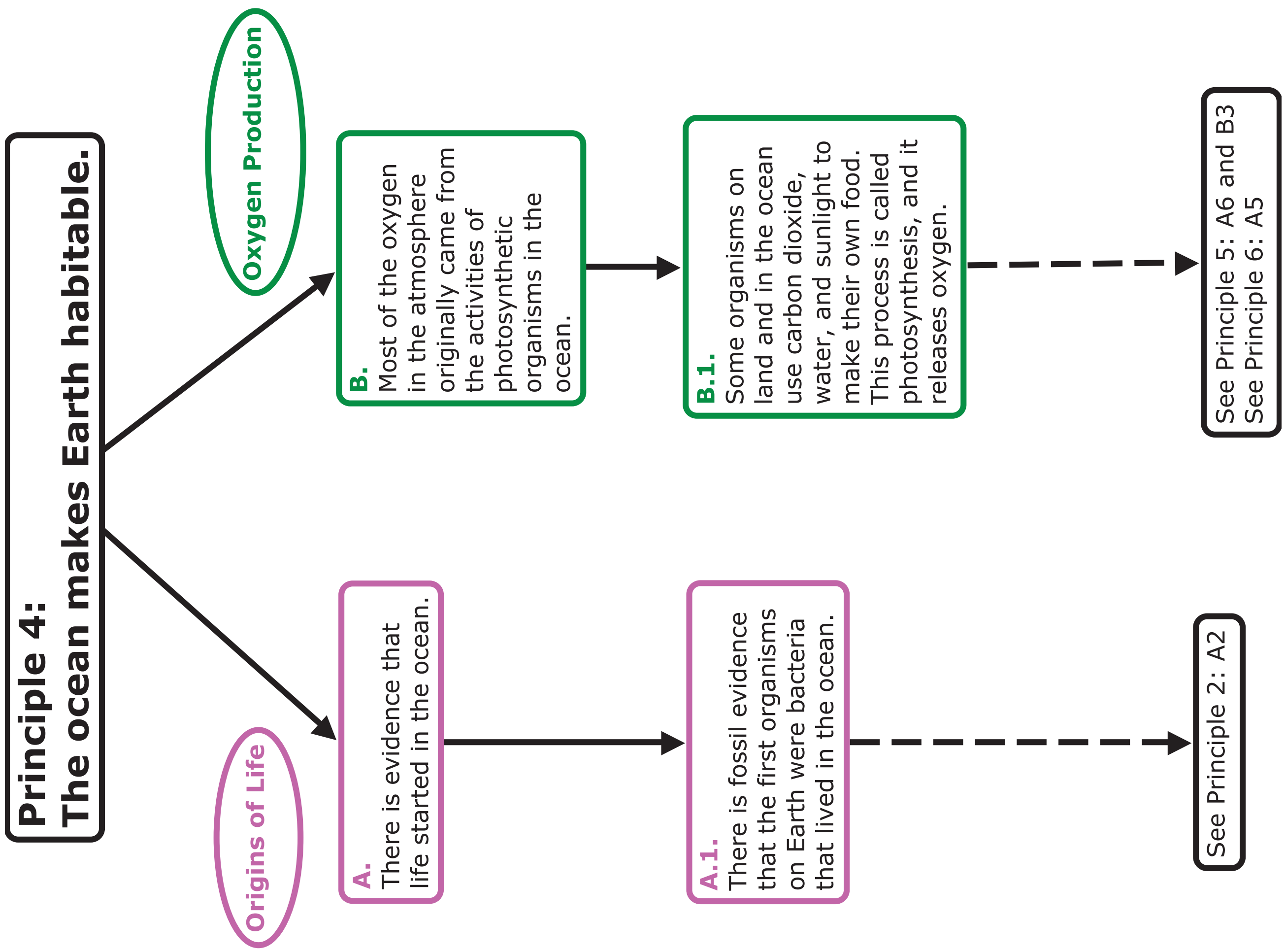
Principle 2: Grades 3-5



Principle 3: Grades 3-5



PRINCIPLE 4: GRADES 3-5



Principle 5: Grades 3-5

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

Diversity of Ecosystem

A. The ocean supports a great diversity of interconnected and interdependent ecosystems, each defined by the interaction of the physical environment and the community of organisms living there.

A.1. Coastal ocean ecosystems, (e.g., rocky seashores, kelp forests, and surface waters around the Arctic and Antarctic) that support the most life are mainly located in sunlit areas where the water is cold and nutrient-rich.

A.2. Phytoplankton, the base of most ocean food webs, flourish in coastal surface waters where there are plenty of nutrients and sunlight.

A.3. Estuaries—shallow coastal ecosystems where fresh water from rivers mixes with salt water from the ocean—are important nursery grounds for many different ocean organisms.

See Principle 1: B4

A.4. Coral reefs are productive ecosystems found in clear, warm, nutrient-poor, tropical water. Algae living inside the coral provide them with some of the nutrients they need to survive.

A.5. The open ocean ecosystem consists of the surface, mid-water, and deep parts of the ocean away from the coast and sea floor bottom. Each of these areas is made up of entirely different physical characteristics and diverse communities of organisms.

A.6. The sunlit surface layers of the ocean are where the sun's energy is captured by photosynthetic phytoplankton (algae and bacteria). This layer only extends down about 200 meters.

A.7. The middle ocean layers are important living spaces for for many organisms, such as large fish and jellyfish. There is not enough light to support photosynthesis here. This zone extends from 200 meters down to 1,000 meters.

A.8. Deep water ecosystems below 1,000 meters are in complete darkness and under extreme pressure.

A.9. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms.

See Principle 4: B1

Diversity of Life

B. The ocean provides most of Earth's living space and supports a great diversity of life from the surface, through the water column, and down to the sea floor.

B.1. The great diversity of ecosystems in the ocean provides opportunities for organisms to develop a great diversity of adaptations, many of which are unique to organisms living in the ocean.

B.2. There are adaptations and life histories that exist only in the ocean, due to unique environmental and physical properties, such as salinity, pressure, temperature, light, and density, that are associated with living in a liquid environment.

B.3. Adaptations that help some organisms survive in the ocean include: blubber to retain heat, fins for swimming, gills for removing oxygen from water, collapsible lungs for deep diving, and acute hearing under water.

B.4. Migration (both horizontal and vertical) is a strategy used by marine organisms to help them respond to daily and seasonal changes in ecosystems, such as the seasonal availability of food, high and low tides, and escape from predators.

See Principle 1: B8

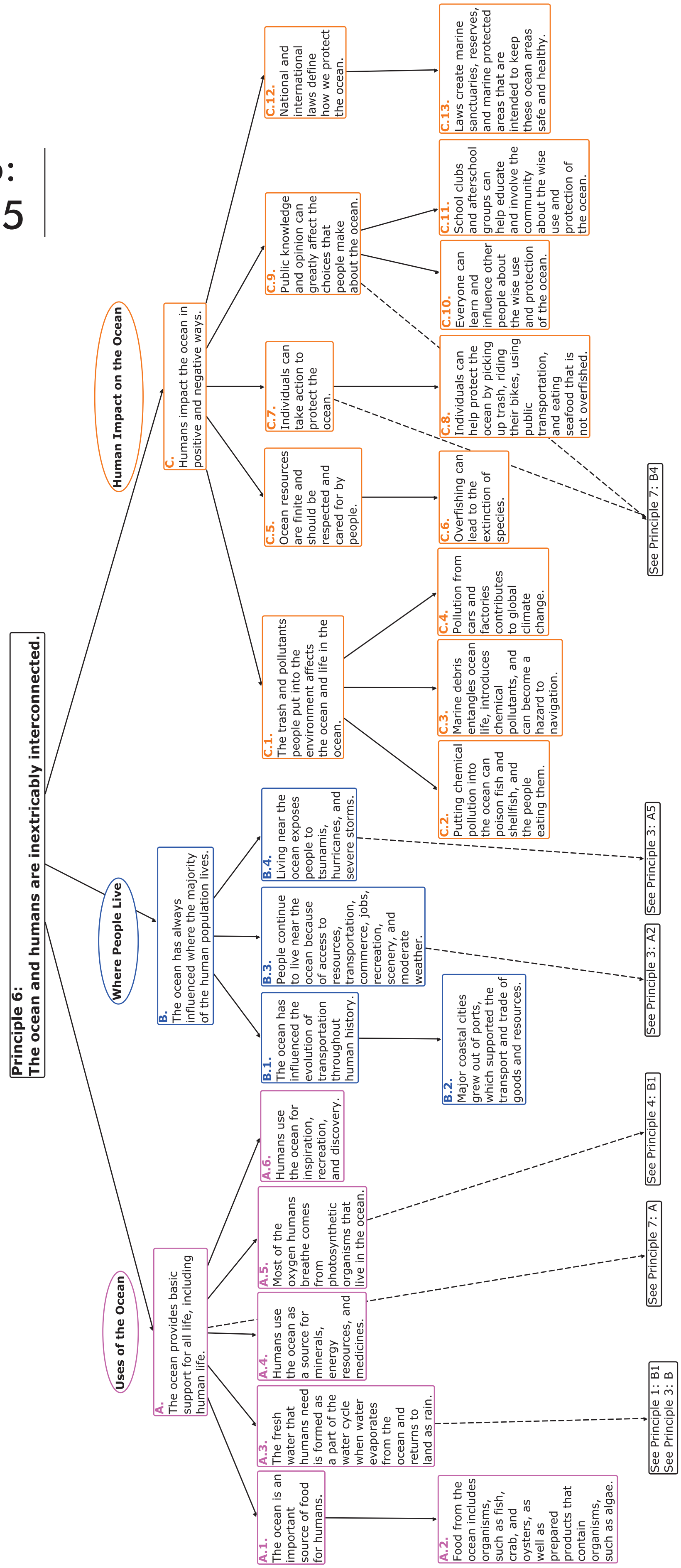
B.5. Organisms in the ocean exhibit an amazing variety of life cycles. Some undergo metamorphosis and have planktonic phases, some lay eggs, and others nurse their young.

B.6. There are many groups of organisms that occur in the ocean that do not occur on land or in fresh water, such as sea stars, squid, jellyfish, corals, many types of worms, and seaweeds.

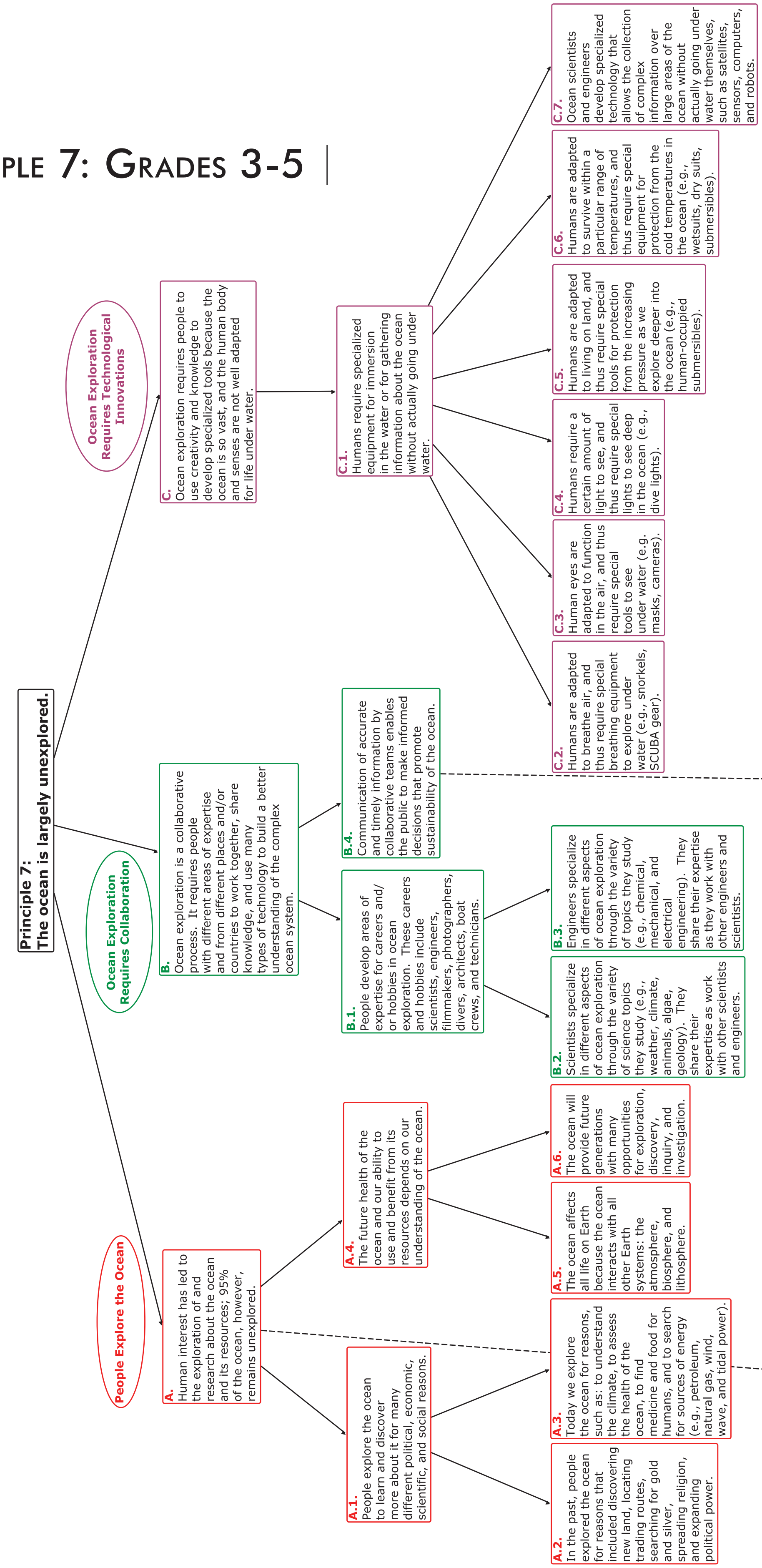
B.7. The ocean supports a tremendous variety of sizes of organisms, from extremely small to the largest animal ever to live on Earth.

B.8. Most of the organisms in the ocean are microscopic. Photosynthetic microbes are the most abundant forms of life in the ocean.

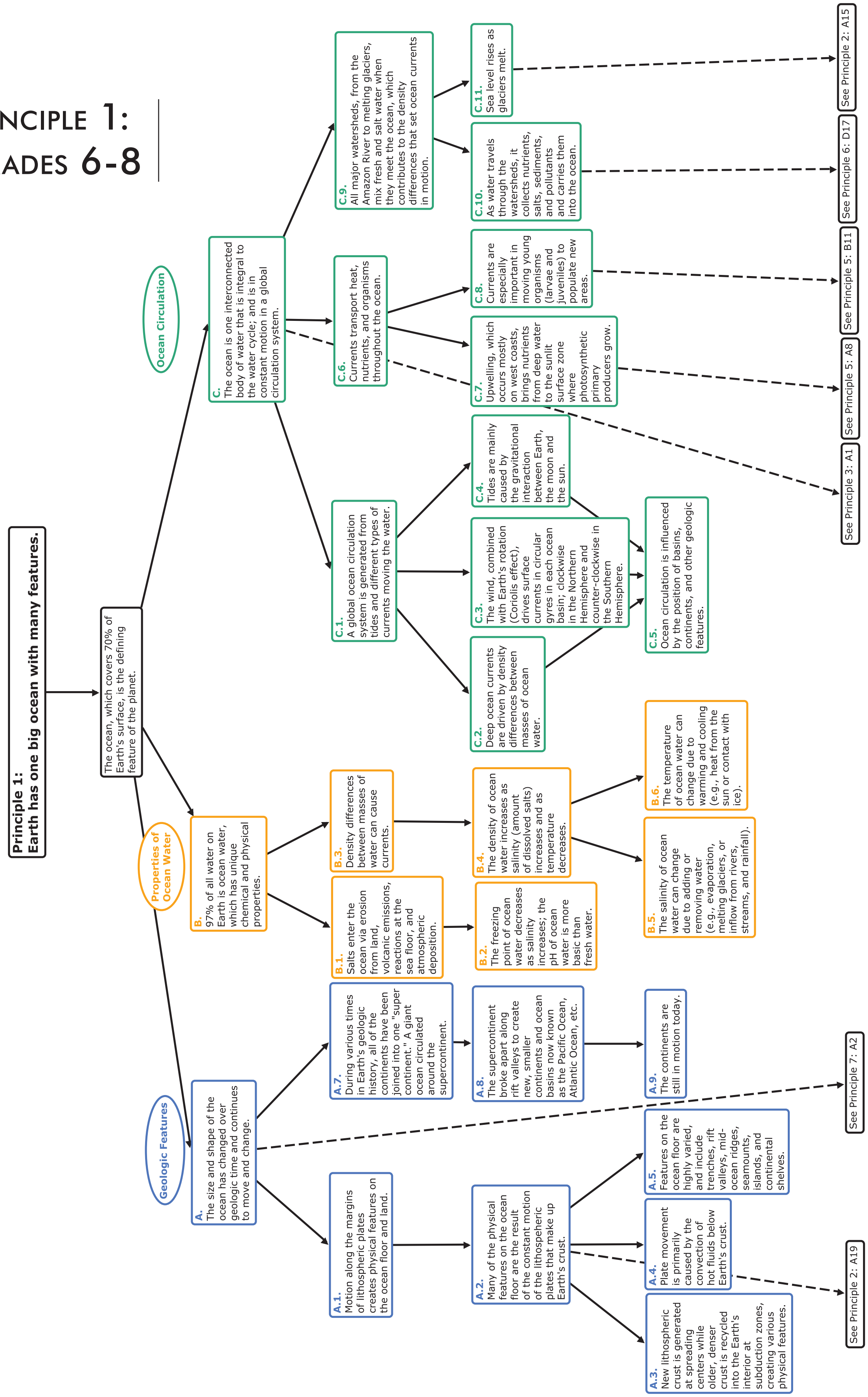
PRINCIPLE 6: GRADES 3-5



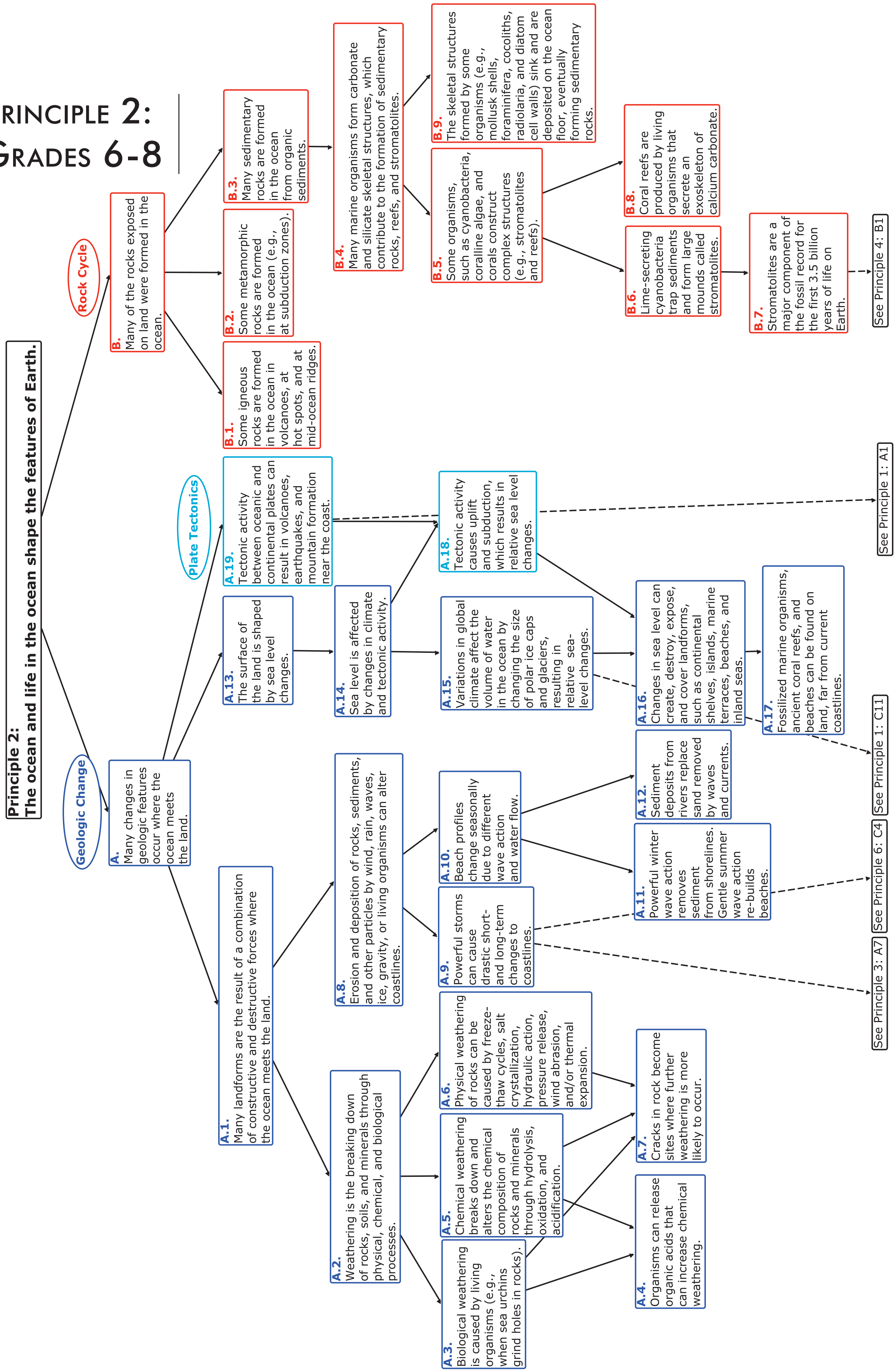
Principle 7: Grades 3-5



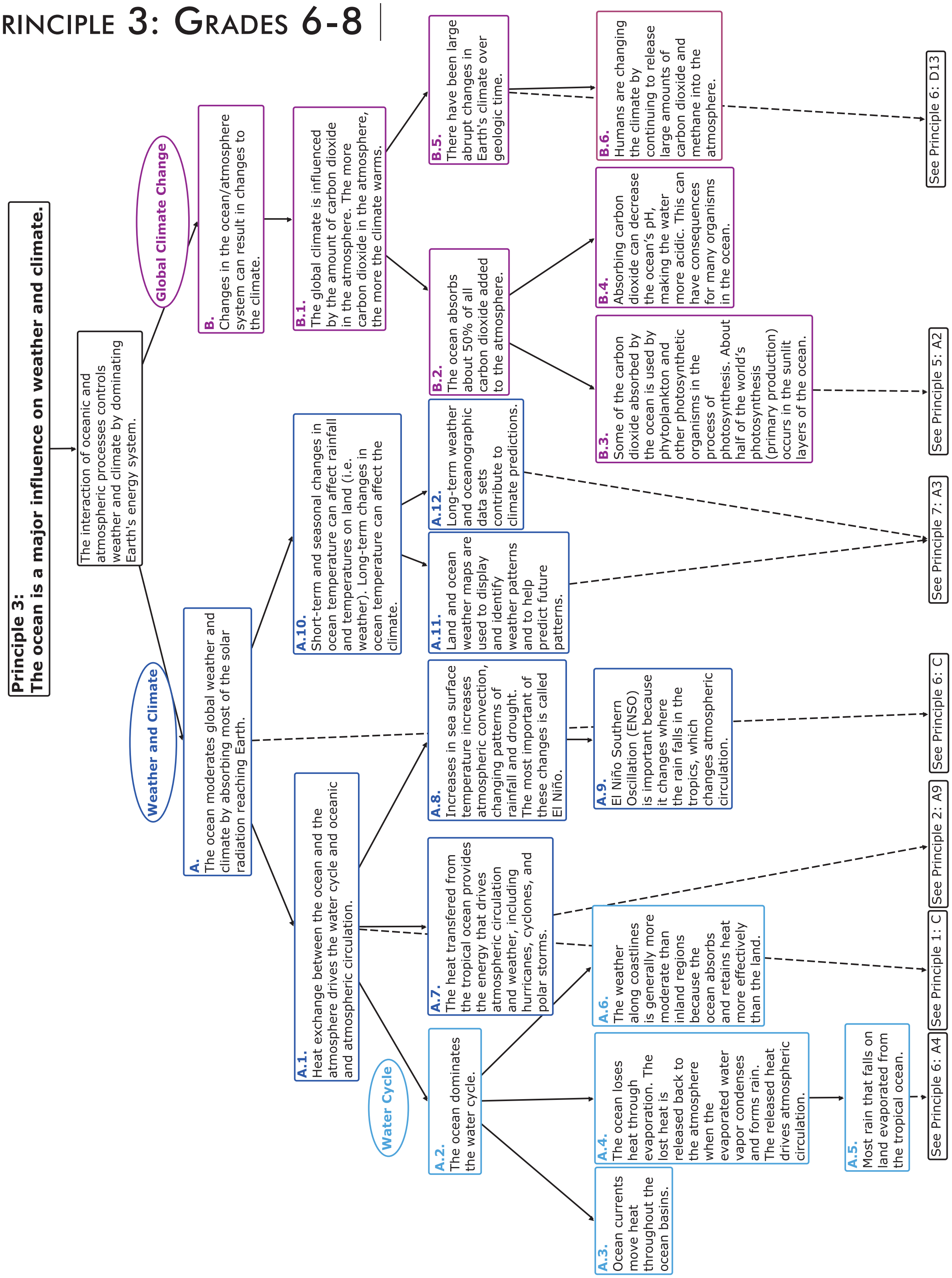
Principle 1: Grades 6-8



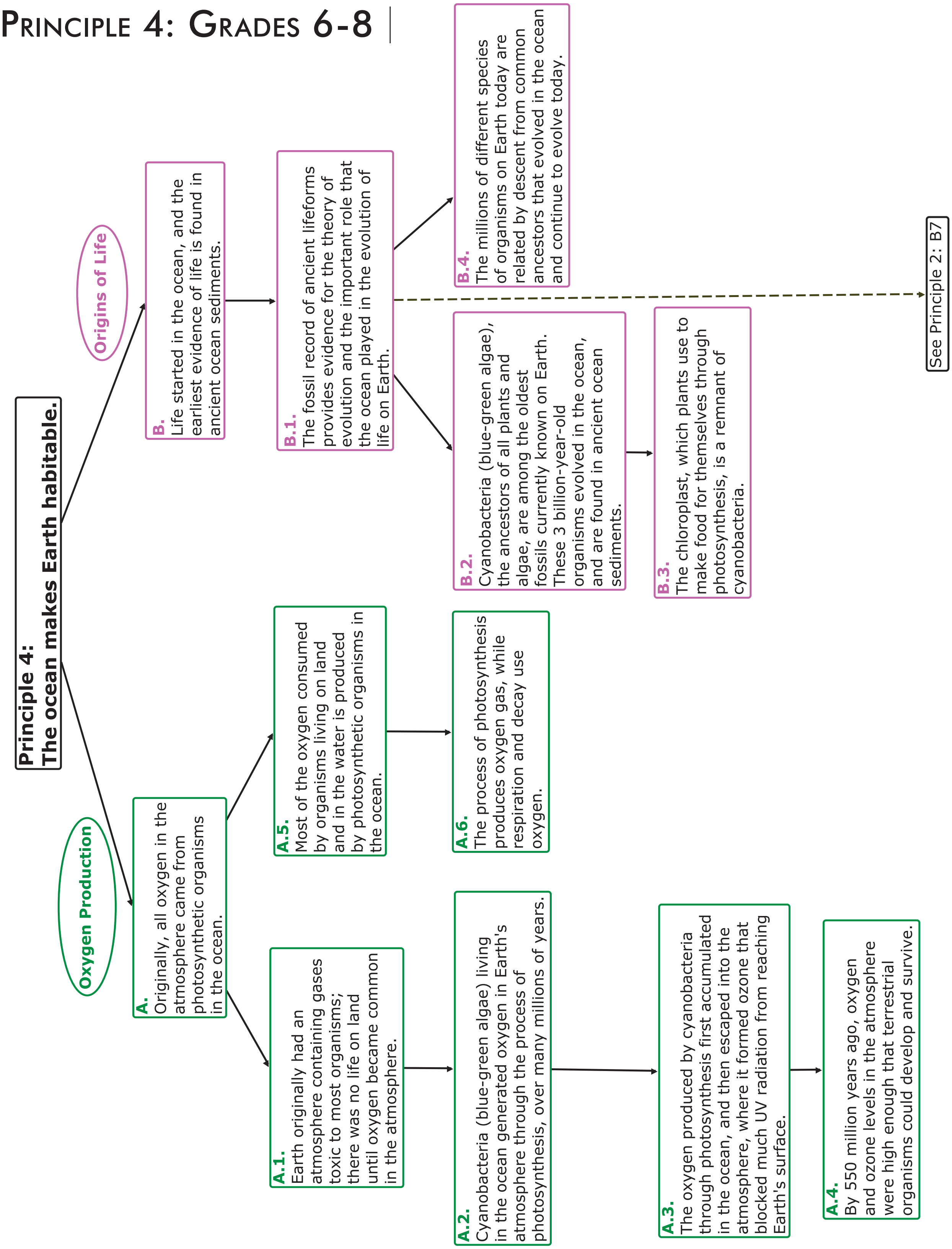
Principle 2: Grades 6-8



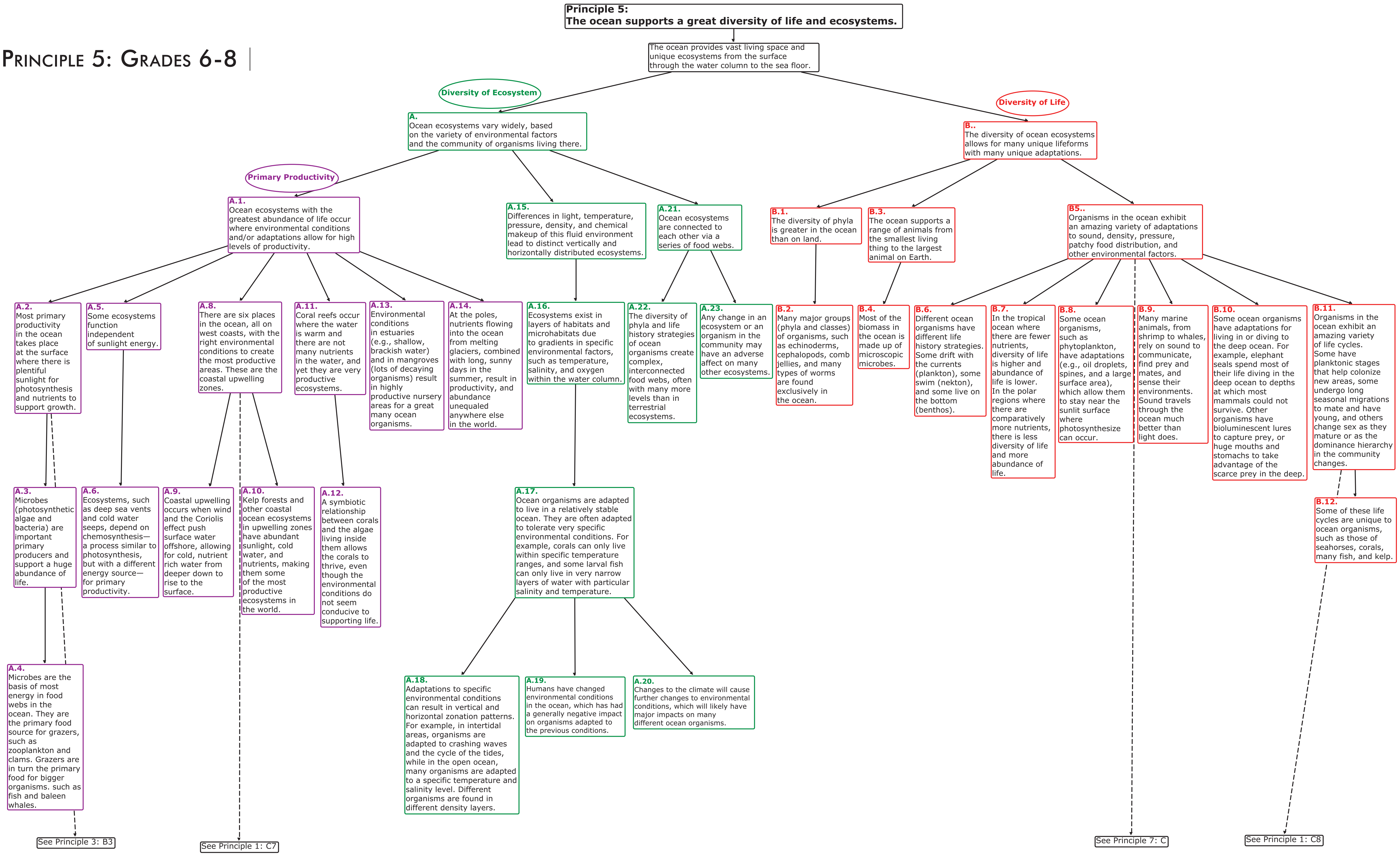
PRINCIPLE 3: GRADES 6-8



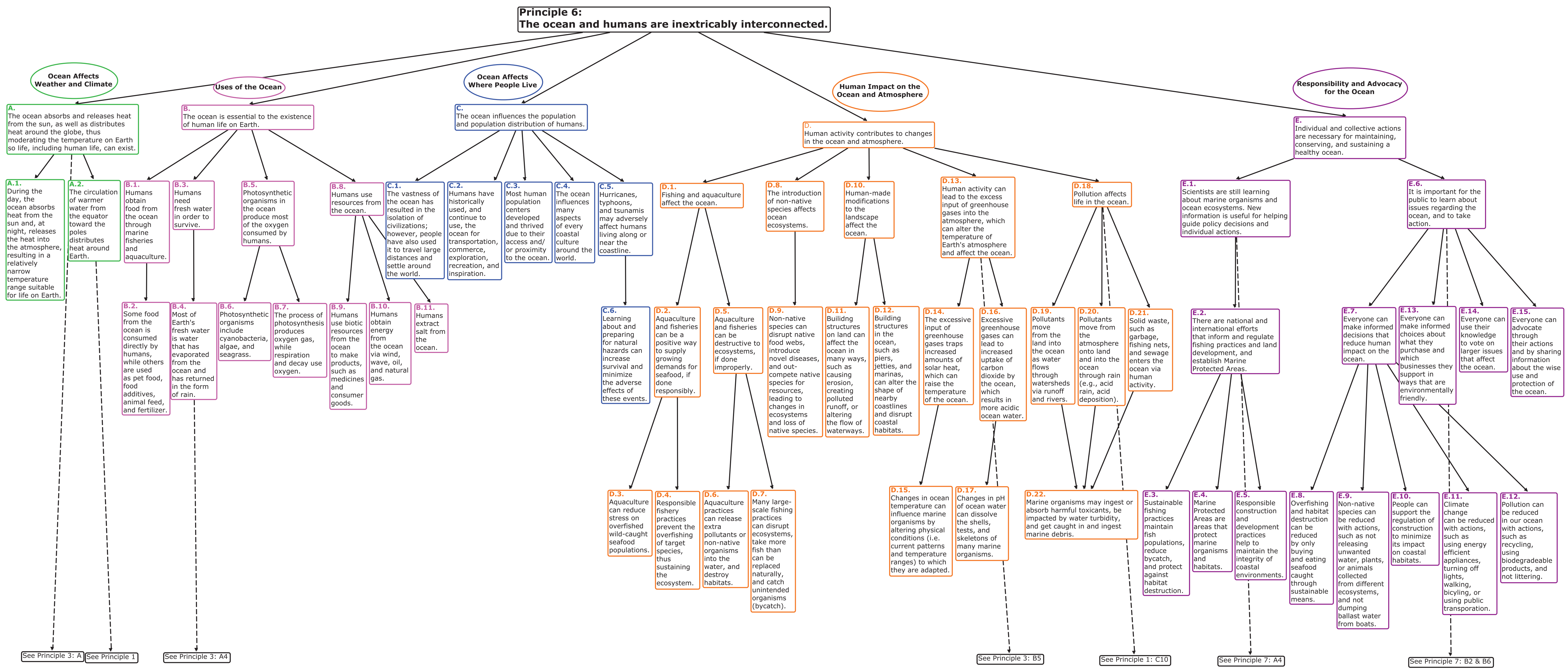
Principle 4: Grades 6-8



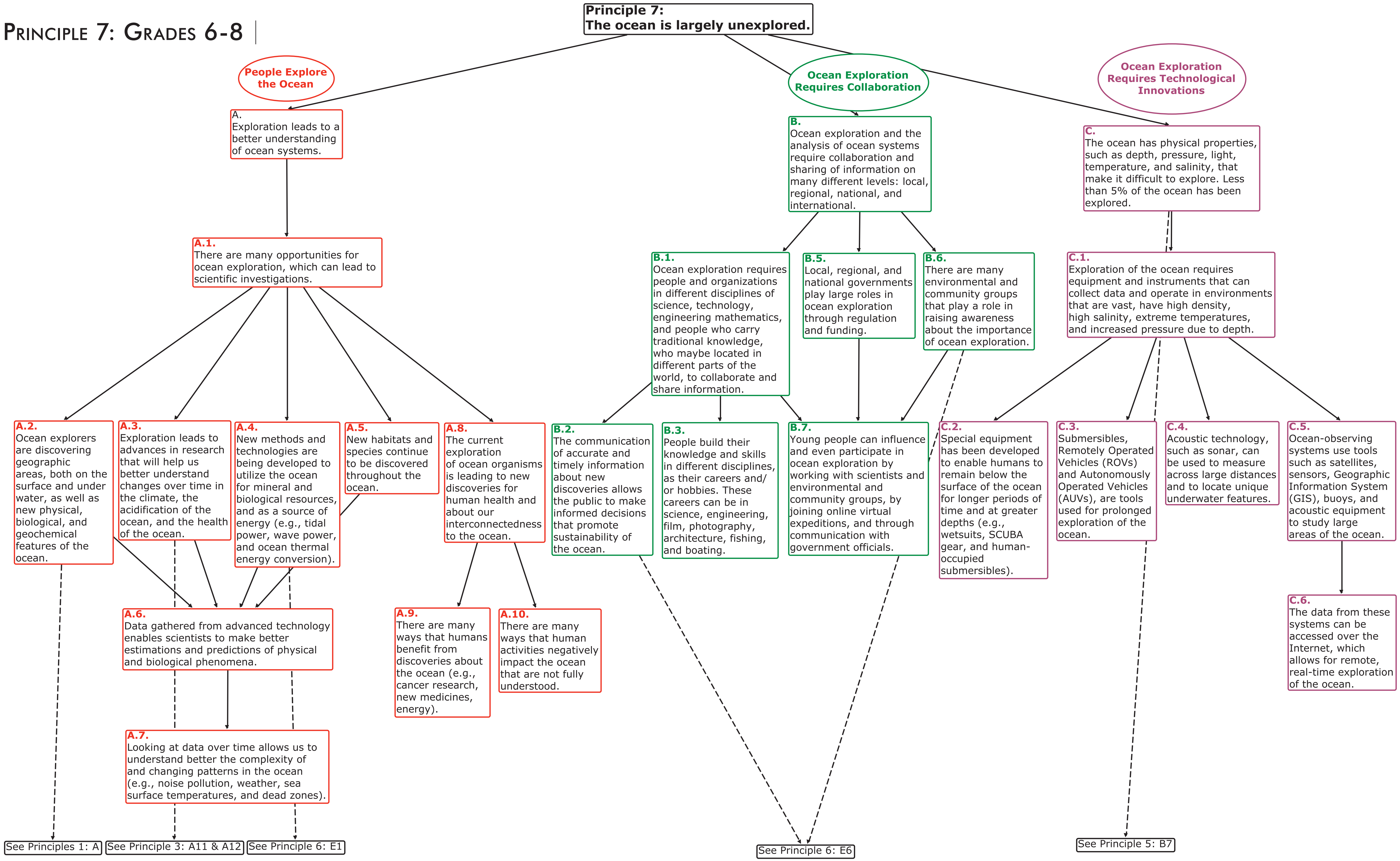
Principle 5: Grades 6-8



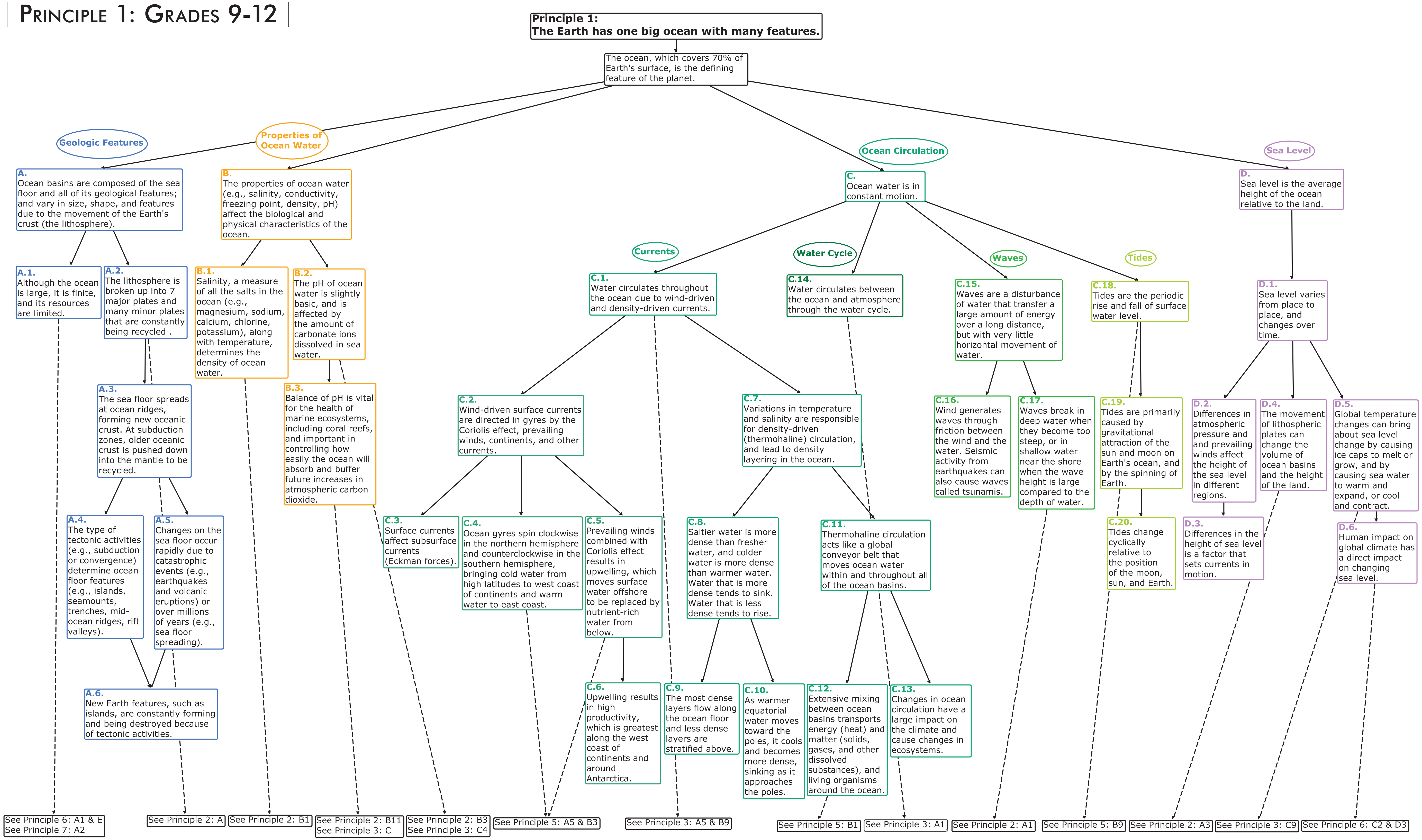
PRINCIPLE 6: GRADES 6-8



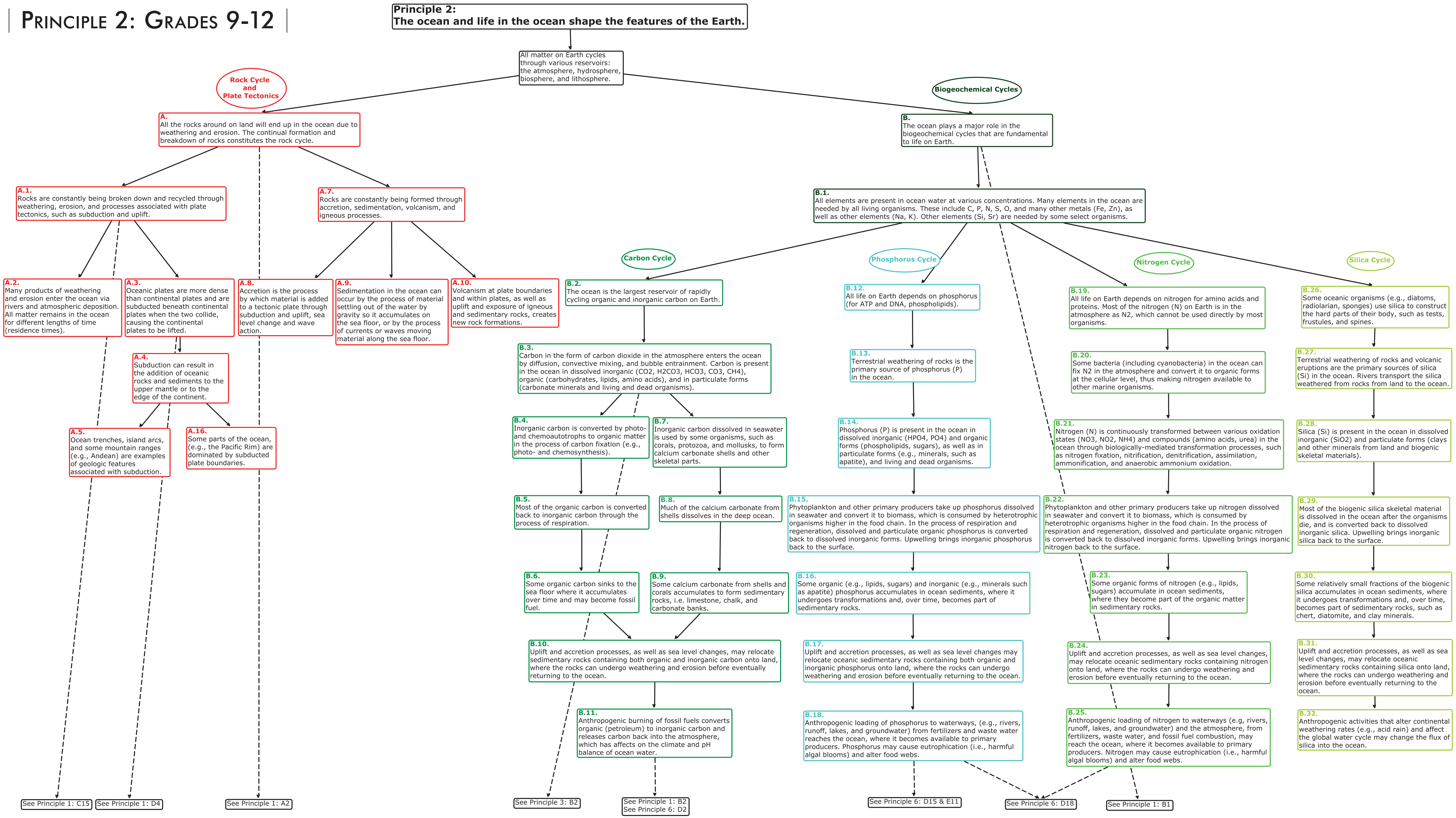
Principle 7: Grades 6-8



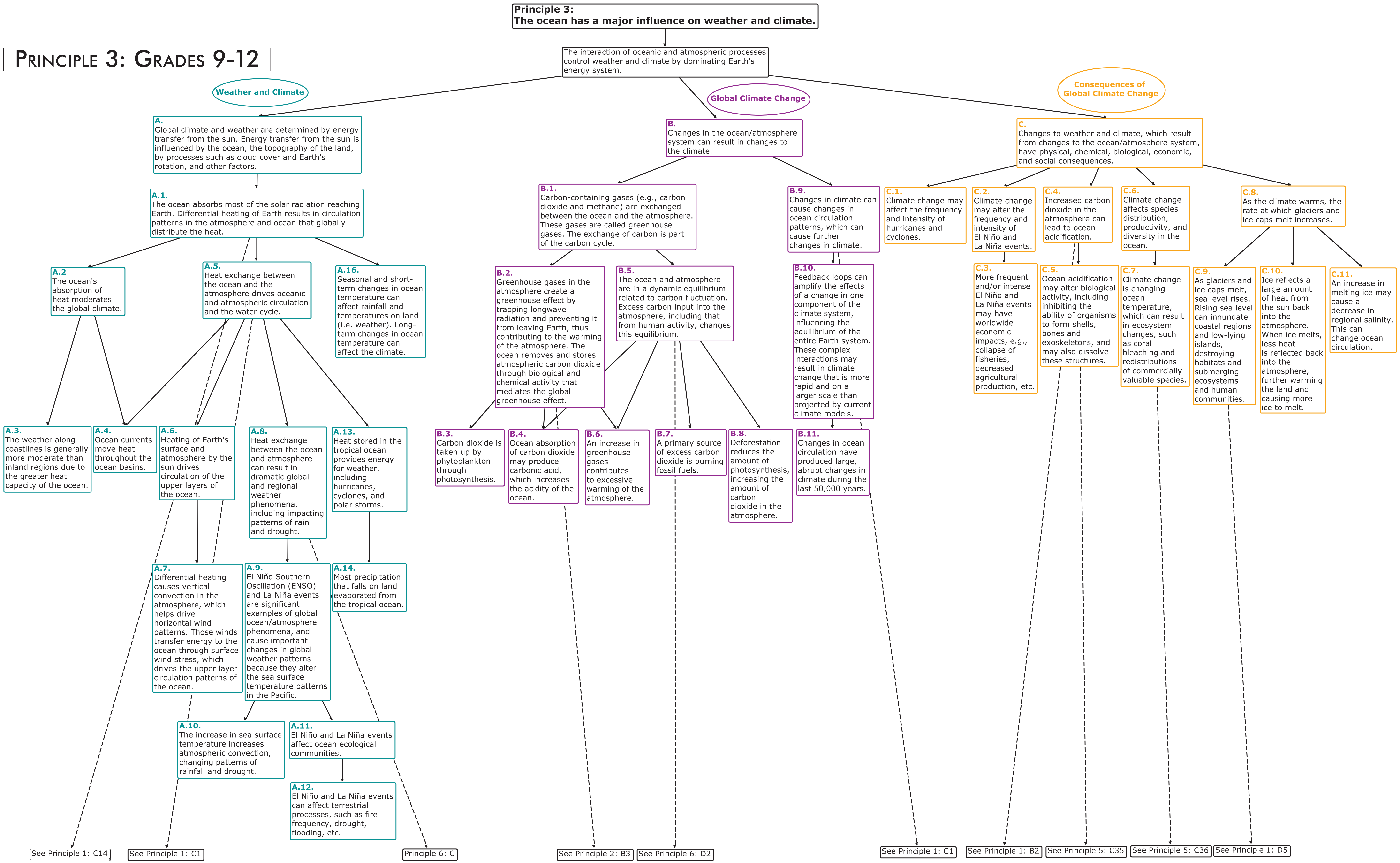
Principle 1: Grades 9-12



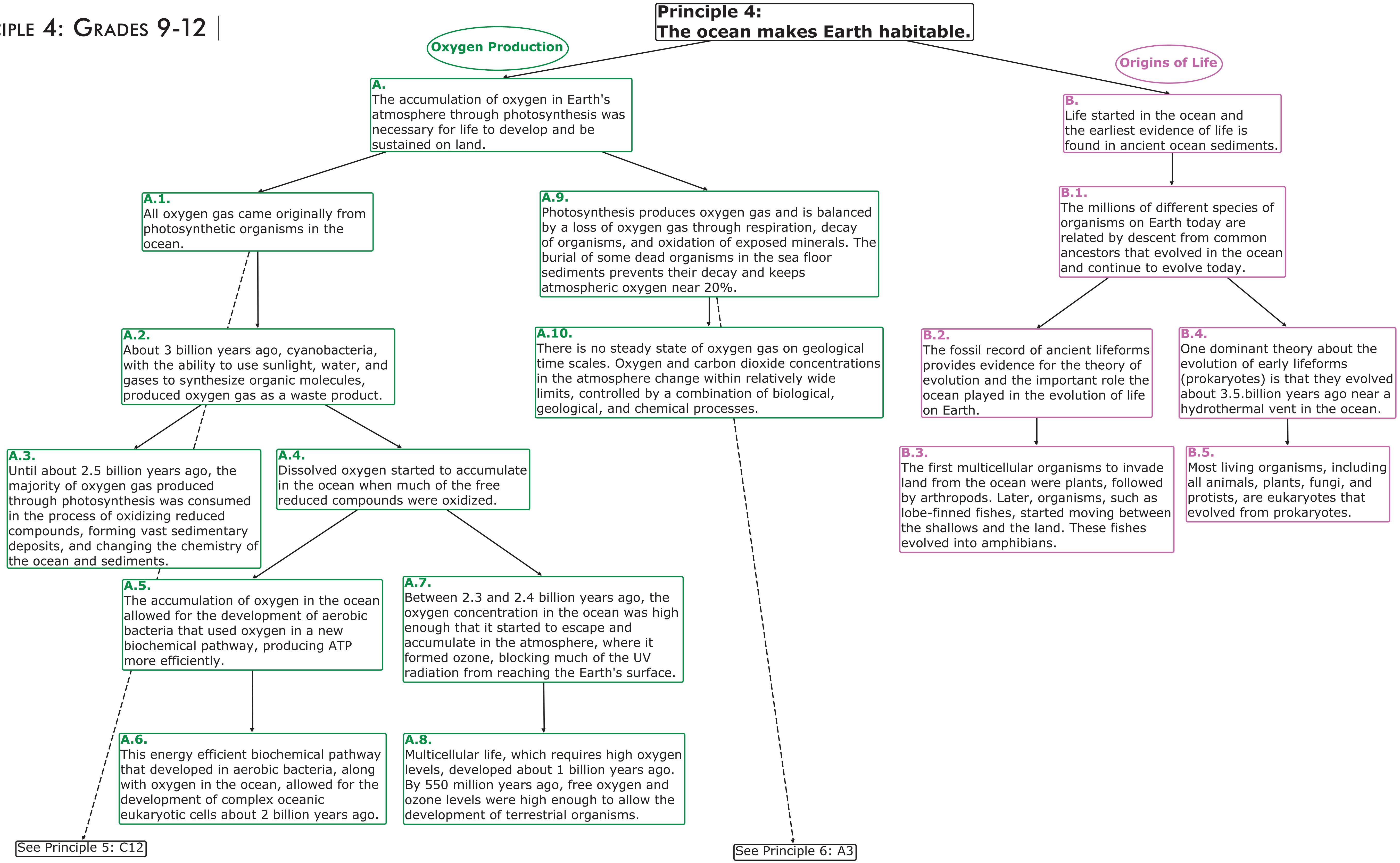
Principle 2: Grades 9-12



PRINCIPLE 3: GRADES 9-12

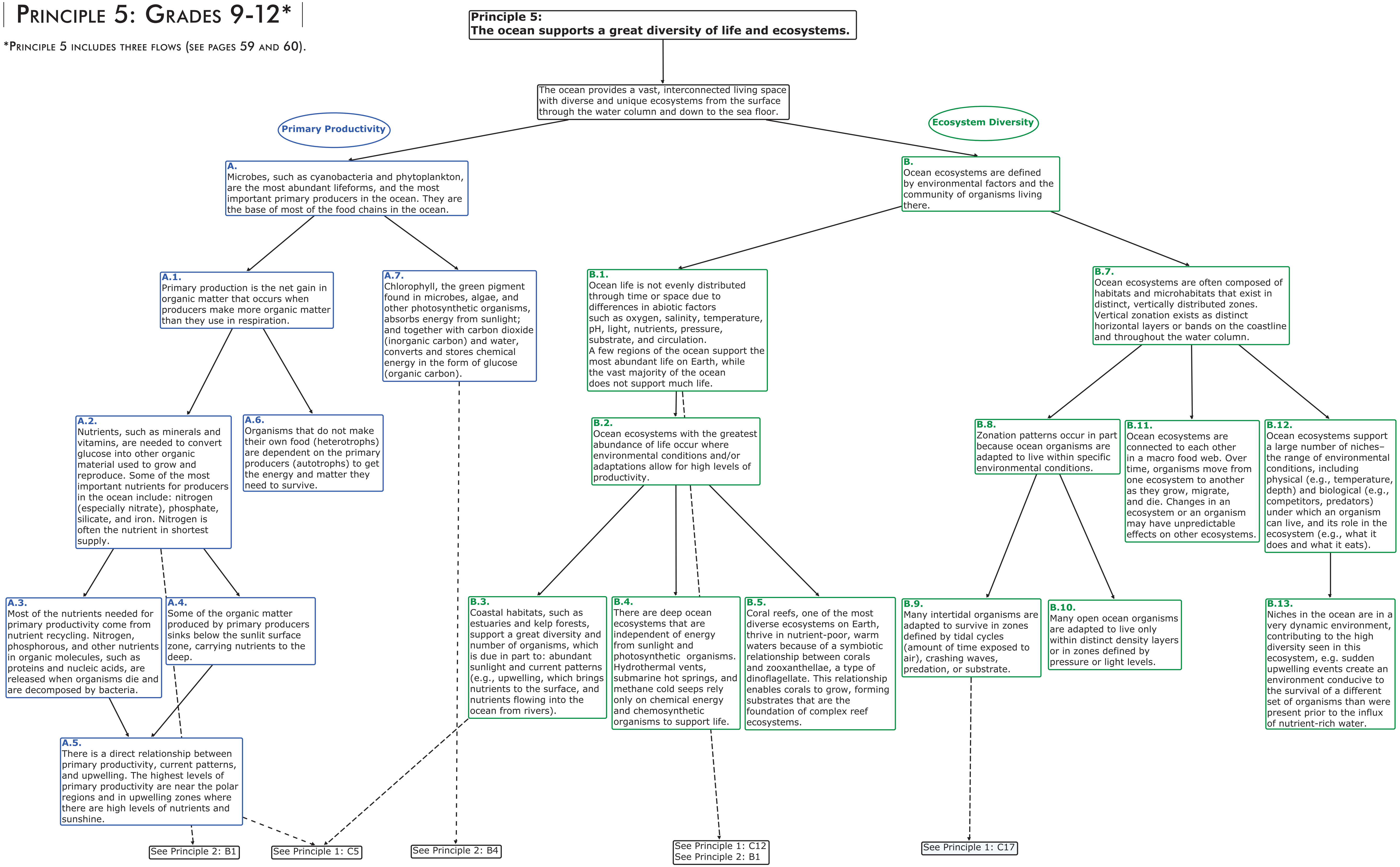


Principle 4: Grades 9-12



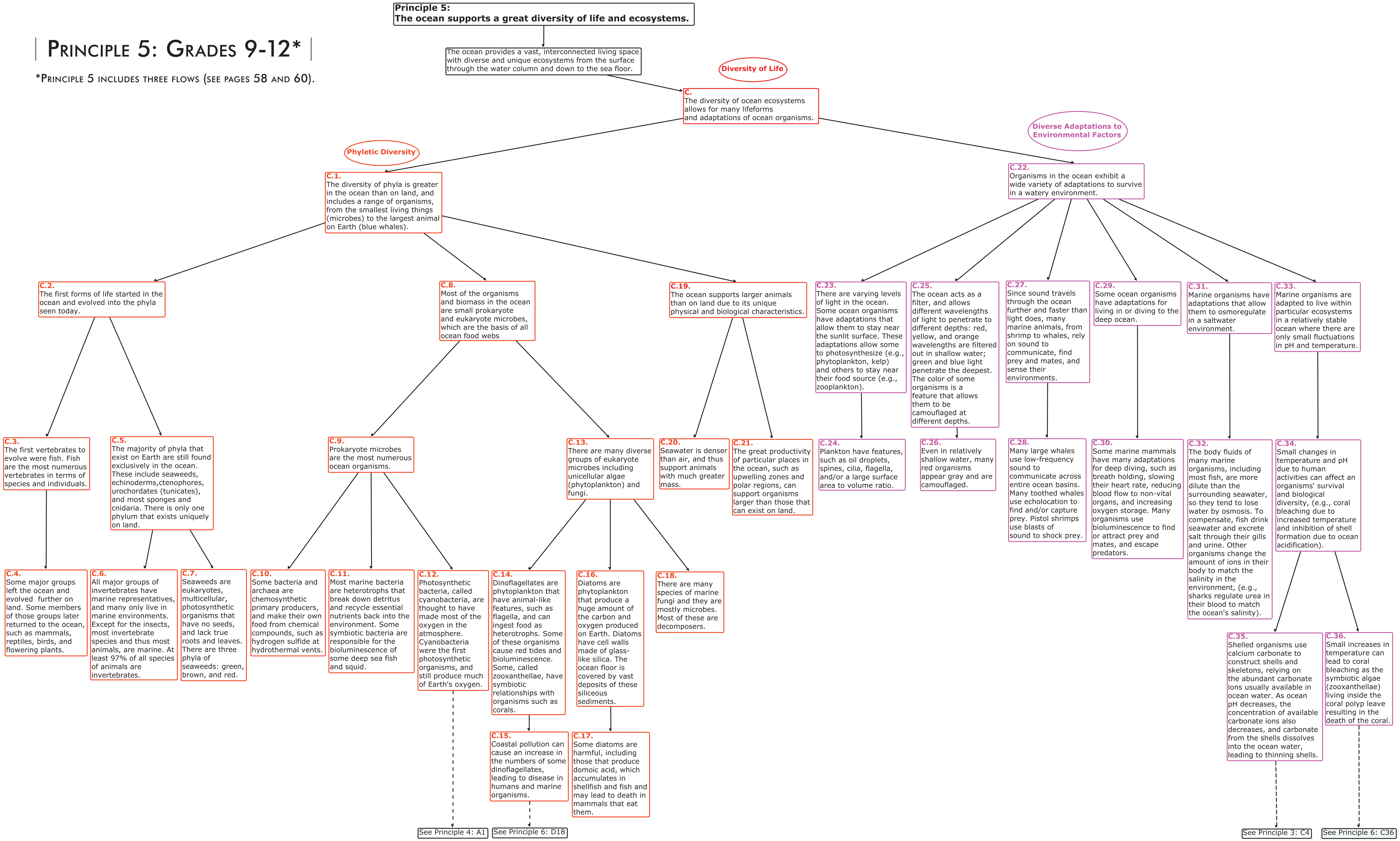
Principle 5: Grades 9-12*

*Principle 5 includes three flows (see pages 59 and 60).



Principle 5: Grades 9-12*

*Principle 5 includes three flows (see pages 58 and 60).



Principle 5: Grades 9-12*

*Principle 5 includes three flows (see pages 58 and 59).

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

The ocean provides a vast, interconnected living space with diverse and unique ecosystems from the surface through the water column and down to the sea floor.

Diversity of Life

C.
The diversity of ocean ecosystems allows for many lifeforms and adaptations of ocean organisms.

Diversity of Feeding Behaviors

C.37.
Many marine organisms have adaptations for feeding, capturing prey, and avoiding predators.

C.38.
Some marine organisms have strategies and/or structures for finding food in the vast ocean where there is: varied abundance of food in specific locations like in coastal regions and upwelling zones; or scarcity of food in large expanses like the open ocean and deep sea.

C.39.
For exploiting patchy distribution of food, some strategies includes: migrating long distances (e.g., Gray whales, chambered nautili, and zooplankton); and having fat reserves (e.g., marine marine mammals and sea birds). For surviving in environments where prey are hard to find, some strategies include: having large stomachs and mouths (e.g., deep-sea hatchet fish and gulper eels) to take advantage of prey when they find it; and hydrodynamic tuna that chase down prey at high speeds.

C.40.
Marine organisms have strategies and/or structures for capturing food in a watery environment where: food may be suspended in the water column; the organism has to contend with the fluid friction of water and buoyancy.

C.41.
These strategies include: catching food in suspension (e.g., cnidarians, crinoids); filtering large quantities of water to strain out smaller organisms (e.g., baleen in whales, siphons in claims, modified legs in barnacles); and having strong muscles or fast reflexes to chase down and snatch prey (e.g., fast swimming tuna and marlin, tentacles of squids and octopuses.

C.42.
Some marine organisms have symbiotic relationships that help them acquire energy.

C.43.
Dinoflagellates called zooxanthellae live in the tissues of coral polyps. Coral gets sugars and oxygen from photosynthesis by the zooxanthellae and the zooxanthallae gets carbon dioxide, nutrients, and shelter from the coral. Other examples of mutualism include clown fish living among anemone tentacles and cleaner fish removing parasites from other fish.

Diversity of Life Cycles and Reproductive Strategies

C.44.
Organisms in the ocean have a variety of reproductive strategies and life cycles.

C.45.
Marine organisms have different lifestyles (i.e., planktonic, nektonic, benthic), and many transition between lifestyles as part of their life cycle, which allow them to survive in different ecosystems at different stages in their development. This is advantageous for a variety of reasons, such as: juveniles accessing different resources than adults (e.g., food and space); limiting competition between juveniles and adults; decreased predation rates on, and increased available nutrients for, juveniles.

C.46.
Some examples of these changes between lifestyles include: benthic adult crabs in the intertidal with a juvenile planktonic larval form; and sessile adult mollusks with a planktonic larval form.

C.47.
Marine organisms have a range of life cycles and reproductive modes from simple, asexual reproduction to complex sexual reproduction, and some species shift between asexual and sexual (alternation of generation).

C.48.
Some common forms of asexual reproduction among marine organisms include: splitting or fission (e.g., anemones) and budding (e.g., sponges). Organisms that reproduce asexually can have extremely fast growth rates under favorable environmental conditions (e.g., microbes, algae).

C.49.
Some marine organisms have alternation of generations, switching between sexual and asexual reproduction each generation (e.g., jellyfish, seaweed). For seaweeds, diploid sporophyte generation produces haploid spores through meiosis, and a haploid gametophyte generation produces haploid gametes. The fertilized gametes produce the sporophyte. In some green and brown algae, the gametophyte and the sporophyte look identical, while in kelps the large organism we see is the sporophyte. The kelp gametophyte is microscopic.

C.50.
Sexual reproduction may involve separate males and females; or switching between male and female or vice versa or have both male and female reproductive organs simultaneously (i.e., hermaphroditic). Some hermaphroditic species change sex in response to age, population changes, and shifts in environmental factors (e.g., brittlestars, coral reef fish).

C.51.
Reproductive strategies of marine organisms tend to be related to population density of the species, and thus are connected to mate competition and chances of finding mates.

C.52.
In places with high-population density where there is high mate competition, organisms may change sex (e.g., blue head wrasse) or have multiple mates (e.g., squid). In places with low-population density, organisms may be monogamous (e.g., pelagic species like mahimahi), or develop parasitic relationships (e.g., anglerfish and isopods).

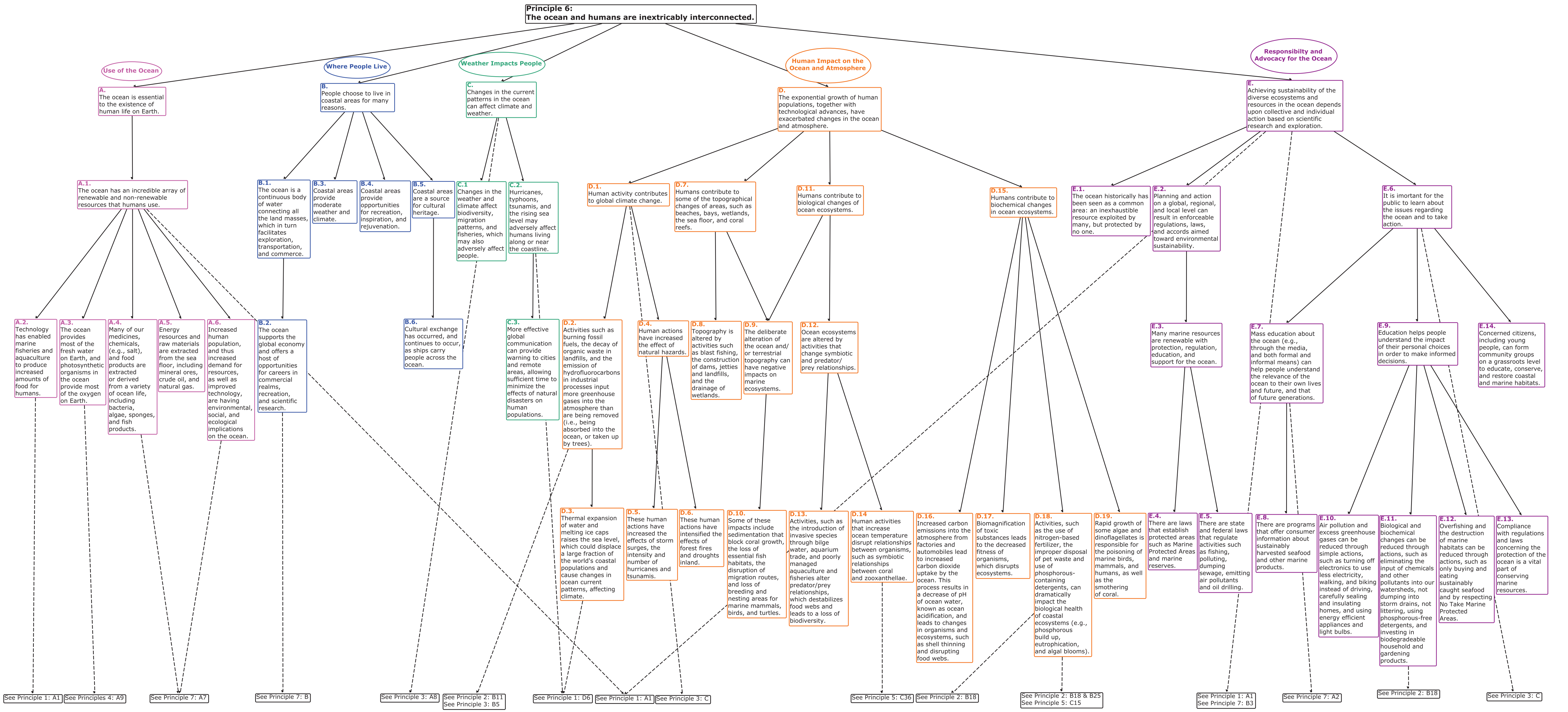
C.53.
Marine organisms have strategies for finding mates and maximizing fertilization of eggs in the vast ocean.

C.54.
These strategies include: using mulitple environmental cues, such as day length, tidal cycles, seasonal variations in current patterns, to synchronize their breeding or spawning cycles (e.g., grunions, elephant seals, and butterfly fish). For species that have external fertilization, females and males produce millions of eggs and sperms (e.g., sea urchins, squids); and for deep sea and pelagic species, producing bioluminescent signals to attract mates (e.g., some pelagic octopuses).

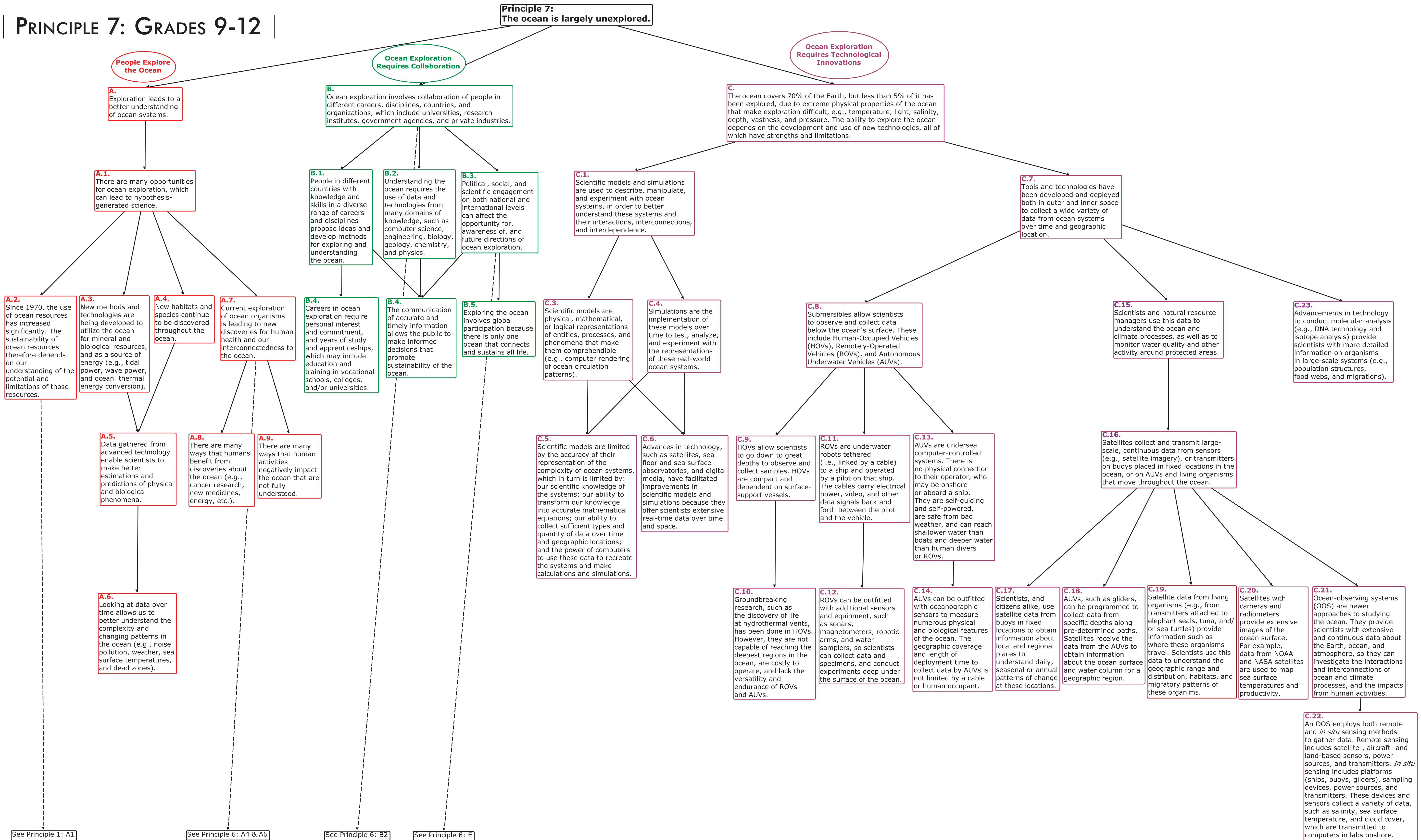
C.55.
Marine organisms have strategies for maximizing survival and dispersal of offspring that has a range of parental care levels, thus the strategies entail different amounts of energy resources and investments from the parents.

C.56.
These strategies include: releasing millions of eggs and sperm into the water (broadcast spawning), which offers no parental care, but increase probability for survival and dispersal of offspring by ocean currents (e.g., clams, corals, and most fish); brooding young inside male or female adults or defending patches of fertilized eggs, which offers some parental care (e.g., seahorse, octopus, some sharks, and surf perch); and intense parental care where one or both parents invest tremendous energy to nurture young until they are large enough to fend for themselves (e.g., marine mammals, sea birds).

Principle 6: Grades 9-12



PRINCIPLE 7: GRADES 9-12



Ideas from Teachers: Using the Ocean Literacy Framework

From the initial drafts to the final review, and every step along the way, classroom teachers have been integral to developing the Ocean Literacy Scope and Sequence for Grades K-12. They shared their pedagogical content knowledge—their professional judgment on how to transform subject-matter knowledge into forms accessible to the students being taught. This expertise was critical for breaking down the Ocean Literacy Essential Principles and Fundamental Concepts appropriately for each of the grade bands, showing connections between concepts, and then organizing the concepts in ways that represent increasingly sophisticated understanding. Several of these teachers offer insights on how they have or plan to use the Ocean Literacy Principles and the Scope and Sequence.

Pam Stryker, Elementary Teacher, Barton Creek School, Austin, Texas

All students love the ocean (and I love teaching it); but when I began teaching (38 years ago) there was very little guidance as to what was important for students to know about the ocean. Ocean units tended to be random collections of unrelated topics: whales, shells, sharks, etc. Slowly through attending marine education workshops and conferences, I began to see the big picture: the diversity of life that it supports, its function in so many of Earth's natural cycles, and the role it plays in all of our lives (even if you live 200 miles from the shore). Ocean literacy is for everyone. The national and state standards act as general guides to the big concepts that need to be taught at each grade with little specificity. It is left to the districts and schools to interpret. With no guiding documents as to what is important to know about the ocean, ocean studies were usually relegated to coastal areas. The Ocean Literacy Principles show how the ocean impacts all of us, as well as how we impact the ocean. There is a global need to know and understand the ocean. The Ocean Literacy Scope and Sequence breaks down those big ideas into manageable pieces that can easily be aligned into local curriculums. Within our own district, we will be revising our science scope and sequence to the new Texas Essential Knowledge and Skills. As a part of the committee, I will be providing both the Ocean Literacy Principles and the Scope and Sequence documents and encouraging each grade level to incorporate them into their curriculum. After all, our Colorado River does flow right into the Gulf of Mexico, so what we do here, 200 miles away, does impact the ocean. We probably should know a little about it!

Mellie Lewis, Elementary Teacher, Howard Public Schools, Maryland

I will use the Ocean Literacy Scope and Sequence in two ways. First, as a fifth grade science resource teacher developing an enrichment program for accelerated students, I will use the

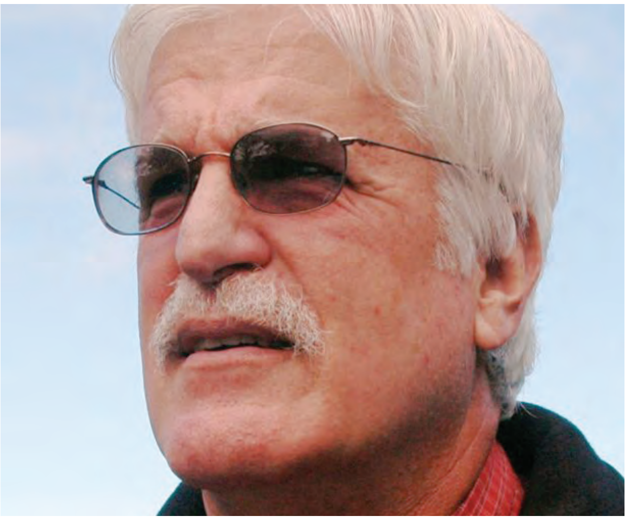
Mellie Lewis

Scope and Sequence to extend the regular instruction of the Fifth Grade Elementary Science Curriculum. For example, one of the curriculum objectives is for students to identify components of the Chesapeake Bay ecosystem. Using the Scope and Sequence, and referring to Principle 5: *The ocean supports a great diversity of life and ecosystems*, I have a resource that will aid in developing grade-level appropriate and sequential lessons to extend the regular fifth grade science curriculum. Second, I will use the Scope and Sequence to develop curriculum and an instructional program for our before-school enrichment class for students in grades 3-5. Since I have not taught many of these students in the past, I am unaware of their science experience and background. I plan to use the Scope and Sequence to design a pre-assessment knowledge indicator, which will provide me with an understanding of my students' background knowledge, so that I can build upon this to develop appropriate and sequential lessons.

Carmelina Livingston, Lead Science Teacher, St. Andrew's School of Math and Science, Charleston, South Carolina

As a science teacher for elementary (K-5th) grades, the Ocean Literacy Scope and Sequence is a "blueprint of concepts that is both developmentally age and grade appropriate" for all students. The Scope and Sequence models the "basic to specific" and the "concrete to abstract" method of learning. When I plan for classroom instruction, both the Ocean Literacy Principles and the State Science Curriculum Standards are incorporated. The Ocean Literacy Principles are not considered as an extra set of standards or guidelines to teach students, but an integration of concepts that are age and grade appropriate in a sequential manner. For instance, in the state standards, students in grades K-2nd observe objects by using the senses and compare and classify objects based on properties. According to the Ocean

Literacy Principle 1, students observe the properties of ocean water. In this particular lesson, my goal for students is to apply the process skill of observation with the properties of ocean water. I design an investigation for students to explore salt water during a science lab lesson as one concrete way to practice this kind of learning. The Ocean Literacy Principles are a valuable asset for designing science experiences, and teachers are encouraged to use them to include ocean science in daily science instruction.



Gene Williamson

Gene Williamson, Retired Junior High/Intermediate schoolteacher, Beaverton, Oregon

In my 30 years of teaching, I never had any problem figuring out what to teach about ocean science. I've always been passionate about the subject matter and have kept up on the content. The thing that kept me up late at night—every year—was trying to decide in what sequence to present the concepts and topics that I wanted to teach. There are so many ways to organize instruction, and I learned the hard way that not all of them are good. I would have loved to have had the Ocean Literacy Scope and Sequence when I was teaching. It provides a map that shows how the ideas build on one another. It is an invaluable resource to beginning and experienced teachers.

Barbara Walton-Faria, Middle School Science Teacher and Curriculum Developer, Thompson Middle School, Newport, Rhode Island

I use the Ocean Literacy Principles to help develop curriculum and units of study for public school students in grades 6-8. By using the matrix to cross-reference specific Ocean Literacy Essential Principles and Fundamental Concepts with the National Science Education Standards, educators are able to expand their teachings about our ocean environment. It is not only possible, but easy to teach an entire middle school earth, life, or physical science course from an ocean perspective, using the matrix attached to the Ocean Literacy Principles.

Barbara Walton-Faria

Beth Jewell, High School Biology and Oceanography Teacher, Fairfax County Public Schools, Virginia

As a high school biology teacher, I use the Ocean Literacy Principles as I prepare my lessons and course of study for my students. Wanting to emphasize the importance of the ocean, I try to incorporate ocean topics in many of my biology lessons. The Ocean Literacy Scope and Sequence will make it easy for me to see where students have been and where I can take them. For instance, when teaching about photosynthesis I can follow Principle 4: *The ocean makes the Earth habitable* through the grade bands to build on what students have been taught in middle school and the direction I should be taking them. I can also use the Scope and Sequence as a guide, as my students and I plan and prepare grade-appropriate activities for 150 elementary students. In the fall of each school year, we organize an oceanography day camp for elementary students. My expertise is not at the K-5 level; however, this document steers me as I develop suitable learning experiences for the campers that build on what is being taught in their classrooms.

Beth Jewell

How to Use the Ocean Literacy Alignment Matrix

This set of matrices show how the Scope and Sequence aligns with the seven Essential Ocean Literacy Principles and 44 Fundamental Concepts. There is one matrix for each principle. For each matrix, the grade bands run horizontally across the top; the fundamental concepts for that principle run vertically along the left column. There are three levels of alignment (see bottom of page).

1	The Earth has one big ocean with many features.			
	K-2nd	3rd-5th	6th-8th	9th-12th
a	x	x	XX	XX
b	x	XX	XX	XX
c	XX	XX	XX	XX
d			x	XX
e	x	x	XX	XX
f	x	XX	x	
g	x	XX	XX	
h				x

2	The ocean and life in the ocean shape the features of the Earth.			
	K-2nd	3rd-5th	6th-8th	9th-12th
a		XX	XX	XX
b			XX	x
c	XX	XX	XX	XX
d	x	XX	XX	x
e	x		XX	XX

3	The ocean is a major influence on weather and climate.			
	K-2nd	3rd-5th	6th-8th	9th-12th
a	x	XX	XX	XX
b	XX	XX	XX	XX
c			XX	XX
d	x	x	x	x
e			XX	XX
f			XX	XX
g			x	XX

4	The ocean makes Earth habitable.			
	K-2nd	3rd-5th	6th-8th	9th-12th
a		x	XX	XX
b		x	XX	XX

5	The ocean supports a great diversity of life and ecosystems.			
	K-2nd	3rd-5th	6th-8th	9th-12th
a	x	x	XX	XX
b		x	XX	XX
c	x	x	XX	XX
d	x	XX	XX	XX
e		XX	x	x
f	x	XX	XX	XX
g	x	x	x	x
h			XX	XX
i		x	x	x

6	The ocean and humans are inextricably interconnected.			
	K-2nd	3rd-5th	6th-8th	9th-12th
a	x	x	XX	x
b	x	XX	XX	XX
c	x	x	x	x
d	x	XX	XX	XX
e	XX	XX	XX	XX
f	x	x	XX	XX
g	XX	XX	XX	XX

7	The ocean is largely unexplored.			
	K-2nd	3rd-5th	6th-8th	9th-12th
a		XX	XX	XX
b	x	x	XX	XX
c	x	x	XX	
d		XX	XX	XX
e				XX
f	x	XX	XX	XX

[blank]	**= no alignment**
x	**= mentions concepts**
XX	**= addresses concepts in depth**

Index of Topics

The following seven charts are an index of the topics in all 28 conceptual flow diagrams of the Scope and Sequence. There is one chart for each principle. For each chart, the major branches of topics on the conceptual flow diagrams for that principle run horizontally across the top; the grade bands run vertically along the left column.

1	The Earth has one big ocean with many features.			
	Properties of Ocean Water	**Geographic and Geologic Features**	**Ocean Circulation**	**Sea Level**
K-2nd	• The ocean is salty	• Ocean basins • Ocean floor features • Only one ocean	• Tides • Transportation of living things • Watersheds • Wind-driven currents	
3rd-5th	• Density-driven currents • Salinity • Temperature • Where fresh water is • Where salt water is	• Highest mountain on Earth • Lowest point on Earth • Ocean basins • Ocean floor features	• Currents • Only one ocean • Tides • Transportation of living things • Water cycle • Watersheds • Waves	
6th-8th	• Density • Density-driven currents • Freezing point • How ocean became salty • pH • Salinity • Temperature	• Change over geologic time • Convection • Generation of Earth's crust • Motion of lithospheric plates • Ocean basins • Ocean floor features • Supercontinent	• Density-driven currents • Only one ocean • Sea level rising • Tides • Transportation of living things • Watersheds • Wind-driven currents • Upwelling	
9th-12th	• Density • Effect on life processes • pH • Salinity • Temperature	• Generation of Earth's crust • Motion of lithospheric plates • Ocean basins • Ocean floor features • Tectonic activities	• Coriolis effect • Currents • Density-driven currents • Eckman forces • Effect on climate • Gyres • Prevailing winds • Tides • Transportation of living things • Upwelling • Water cycle • Waves • Wind-driven currents	• Atmospheric pressure • Change over time • Effect on currents • Global temperature change • Movement of lithospheric plates • Prevailing winds • Regional differences

2	The ocean and life in the ocean shape the features of the Earth.			
	Coastal Erosion	Plate Tectonics	Rock Cycle	Biogeochemical Cycle
K-2nd	• Deposition of Earth materials • Erosion of Earth materials			
3rd-5th	• Beach composition • Currents as agents of sedimentation • Erosion of biotic materials • Erosion of Earth materials • Formation of sand • Rivers as agents of sedimentation • Sedimentation • Water as an agent of erosion • Waves as agents of sedimentation		• Marine fossils • Marine organisms contribute to rock formation • Ocean sediments • Sedimentary rock composition • Volcanic rock formation	
6th-8th	• Biological weathering • Chemical weathering • Changing coastlines • Changing sea level • Erosion • Deposition • Landforms uncovered by sea level change • Physical weathering	• Earthquakes • Mountain formation • Subduction • Sea level change • Tectonic activities • Volcanoes • Uplift	• Coral reef formation • Igneous rock formation • Marine organisms contribute to rock formation • Metamorphic rock formation • Stromatolites • Sedimentary rock formation	
9th-12th		• Continental plates • Erosion • Geologic features from subduction • Oceanic plates • Residence times • Subduction • Tectonic activity • Weathering	• Accretion • Igneous processes • Sedimentation • Volcanism	• Carbon cycle • Elements in ocean water • Nitrogen cycle • Phosphorus cycle • Silica cycle

3	The ocean is a major influence on weather and climate.			
	Weather and Climate	Water Cycle	Global Climate Change	Consequences of Global Climate Change
K-2nd		• Condensation • Evaporation • Precipitation • Runoff • Watersheds		

3	The ocean is a major influence on weather and climate.			
	Weather and Climate	**Water Cycle**	**Global Climate Change**	**Consequences of Global Climate Change**
3rd-5th	• Convection currents • Creation of wind • Energy absorption • Ocean currents • Temperature fluctuation • Wind energy	• Condensation • Energy absorption • Evaporation • Precipitation • Runoff • Where fresh water comes from		
6th-8th	• Atmospheric convection • El Niño • Energy absorption • Heat exchange • Weather and climate patterns	• Condensation • Evaporation • Energy absorption • Ocean currents move heat • Precipitation	• Atmospheric carbon dioxide • Human effects • Ocean absorption of CO_2 • pH • Photosynthetic organisms	
9th-12th	• Atmospheric convection • Differential heating • El Niño and La Niña • Energy absorption • Energy transfer • Evaporation • Heat capacity • Ocean currents move heat • Precipitation • Weather and climate patterns • Wind energy		• Atmospheric warming • Carbon cycle • Carbon dioxide balance • Greenhouse gases • Greenhouse effect • Human effects • Ocean absorption of CO_2 • Ocean circulation pattern • pH • Photosynthesis	• Change in ocean circulation • Change in ocean temperature • Decreased solar reflection • El Niño and La Niña • Frequency and intensity of weather events • Melting of glaciers and ice caps • Ocean acidification • Rising sea level

4	The ocean makes Earth habitable.	
	Origins of Life	**Oxygen Production**
K-2nd	• Water is necessary for life • Where water is on Earth	
3rd-5th	• Bacteria • Fossil evidence • Life started in the ocean	• Earth's atmosphere • Photosynthesis
6th-8th	• Chloroplast • Cyanobacteria • Fossil evidence • Life started in the ocean • Ocean sediments • Theory of evolution	• Cyanobacteria • Earth's atmosphere • Oxygen consumption • Ozone • Photosynthesis • Respiration and decay

4	The ocean makes Earth habitable.	
	Origins of Life	**Oxygen Production**
9th-12th	• Fossil evidence • Life started in the ocean • Hydrothermal vents • Prokaryotes and eukaryotes • Theory of evolution	• Aerobic respiration • Balance of oxygen and carbon dioxide • Cyanobacteria • Decay • Dissolved oxygen • Earth's atmosphere • Photosynthesis • Oxidation • Ozone

5	The ocean supports a great diversity of life and ecosystems.			
	Primary Productivity	**Diversity of Ecosystems**	**Diversity of Life**	**Diversity of Life: Adaptations to Environmental Factors (9-12 only)**
K-2nd		• Adaptations • Habitats	• Adaptations • Organism diversity • Size and scale of life	
3rd-5th		• Coastal ecosystems • Conditions for photosynthesis • Coral reefs • Deep water ecosystems • Estuaries • Open ocean • Physical properties of the ocean • Phytoplankton	• Adaptations • Adaptations for living in the ocean • Life cycles • Metamorphosis • Migration organism diversity • Physical properties of the ocean • Size and scale of life	
6th-8th	• Abundance of life • Chemosynthesis • Chemosynthetic ecosystems • Conditions for photosynthesis • Coral reefs • Coriolis effect • Estuaries • Food webs • Kelp forests • Mangroves • Photosynthetic organisms • Polar seas • Symbiosis • Upwelling	• Abiotic factors • Adaptations for living in the ocean • Climate change effect on environments • Ecosystems • Food webs • Habitats • Habitat zonation • Human effect on environments • Physical properties of the ocean	• Adaptations for living in the ocean • Biomass • Conditions for diversity • Life cycles • Life histories • Migration • Organism diversity • Physics of sound • Reproduction • Size and scale of life	

5	The ocean supports a great diversity of life and ecosystems.			
	Primary Productivity	**Diversity of Ecosystems**	**Diversity of Life**	**Diversity of Life: Adaptations to Environmental Factors (9-12 only)**
9th-12th	• Autotrophs • Chlorophyll • Carbon fixation • Heterotrophs • Microbes • Nutrient cycling • Nutrients in photosynthesis • Organic molecules • Primary production definition • Upwelling	• Abiotic factors • Abundance of life • Adaptations to environmental conditions • Chemosynthetic organisms • Coral reefs • Diversity of life • Estuaries • Food webs • Habitat zonation • Hydrothermal vent communities • Intertidal habitats niches • Kelp forests • Niches • Open ocean • Physical properties of the ocean • Productivity • Upwelling	• Diversity of adaptations to environmental factors • Diversity of feeding behaviors • Diversity of life cycles and reproductive strategies • Phyletic diversity	• Adaptations for diving • Adaptations to varying light levels • Bioluminescence • Camouflage • Coral bleaching • Features of sound • Light filtration • Human effects on organisms • Ocean acidification and its effects • Osmoregulation • Physical characteristics of the ocean • Plankton adaptations • Sound as communication

5	The ocean supports a great diversity of life and ecosystems.		
	Diversity of Life: Life Cycles and Reproductive Strategies (9-12 only)	**Diversity of Life: Feeding Behaviors (9-12 only)**	**Diversity of Life: Phyletic Diversity (9-12 only)**
9th-12th	• Alternation of generations • Asexual reproduction • Broadcast spawning • Hermaphroditism • Parasitism as a reproductive strategy • Parental care strategies • Population density effects on reproductive strategies • Sexual reproduction • Strategies for maximizing dispersal • Strategies for maximizing fertilization • Transitions between lifestyles	• Buoyancy • Filter feeding • Mutualisms • Physical characteristics of the ocean • Strategies for capturing food • Strategies for exploiting patchy distribution of food • Symbiosis	• Bioluminescence • Biomass • Chemosynthetic organisms • Cyanobacteria • Diatoms • Dinoflagellates • Eukaryotes • Fish diversity • Fungi • Heterotrophs • Invertebrate diversity • Land to ocean transition • Phyla found in the ocean • Physical characteristics of the ocean • Phytoplankton • Productivity • Prokaryotes • Ocean to land transition • Origins of life • Seaweed diversity • Size and scale of life • Symbiosis • Vertebrate evolution

6	The ocean and humans are inextricably interconnected.				
	Uses of the Ocean	**Where People Live**	**Human Impact on the Ocean and Atmosphere**	**The Ocean Affects Weather and Climate which Impacts People**	**Responsibility and Advocacy for the Ocean**
K-2nd	• Commerce • Food resources • Human benefits from the ocean • Recreation • Source of fresh water • Transportation • Water cycle	• Human population distribution • Weather impacts on humans	• Human impacts on changing shorelines • Pollution • Human efforts to protect the ocean • Recycling • Resource availability		
3rd-5th	• Food resources • Natural resources • Source of fresh water • Source of oxygen • Recreation • Water cycle	• Commerce • Human population distribution • Recreation • Resources • Transportation • Weather impacts on humans	• Chemical pollution • Human efforts to protect the ocean • Human impacts on global climate change • Legal efforts to protect the ocean • Making informed decisions • Marine debris • Marine Protected Areas • Marine reserves • Marine sanctuaries • Ocean resources are finite • Overfishing		
6th-8th	• Biotic resources • Food resources • Process of photosynthesis • Photosynthetic organisms • Marine fisheries • Sources of energy • Source of fresh water • Source of medicines • Source of oxygen • Source of salt	• Commerce • Exploration • Human cultures • Human history • Human population centers • Human population distribution • Recreation • Transportation • Weather impacts on humans	• Acid rain • Acid deposition • Aquaculture • Bycatch • Changing coastlines • Changing ocean temperature • Fisheries • Greenhouse gases • Human-made structures • Introduced species • Ocean acidification • Overfishing • Pollution • Watersheds	• Distribution of energy (heat) • Energy (heat) absorption	• Climate change • Introduced species • Influencing policy decisions • Making informed decisions • Marine Protected Areas • Modifications to the landscape • Pollution • Reducing overfishing • Reducing habitat destruction • Sustainability

6	The ocean and humans are inextricably interconnected.				
	Uses of the Ocean	**Where People Live**	**Human Impact on the Ocean and Atmosphere**	**The Ocean Affects Weather and Climate which Impacts People**	**Responsibility and Advocacy for the Ocean**
9th-12th	• Aquaculture • Fisheries • Food resources • Human impacts on the ocean • Non-renewable resources • Renewable resources • Sources of energy • Source of fresh water • Source of medicines • Source of mineral ores • Source of natural gas • Source of oil • Source of oxygen • Source of salt	• Careers • Climate • Commerce • Exploration • Global economy • Human cultures • Recreation • Transportation	• Algal blooms • Biomagnification • Burning fossil fuels • Changing ocean temperature • Effect of techno-logical advances • Eutrophication • Greenhouse gases • Human effect on global climate change • Impact on humans of natural hazards • Human impact on ocean ecosystems • Human impact on topography • Human population growth • Hydrofluorocarbon emissions • Introduced species • Ocean acidification • Rising sea level	• Effect of changing weather and climate • Effect of natural disasters • Effective natural disaster warnings	• Education • Legal efforts to protect the ocean • Making informed decisions • Marine Protected Areas • Marine reserves • Protecting marine resources • Reducing biological and biogeochem-ical changes • Reducing overfishing • Reducing pollution • Sustainability • The ocean is finite

7	The ocean is largely unexplored.			
	Life on Earth Depends on the Ocean	**People Explore the Ocean**	**Ocean Exploration Requires Collaboration**	**Ocean Exploration Requires Technological Innovations**
K-2nd	• Requirements for life • Scientific investigation	• Asking questions • Ecosystem health • Hobbies and careers • Making observations • Natural resources • Tools and technology		
3rd-5th		• Atmosphere • Biosphere • Ecosystem health • Ecosystem interactions • Lithosphere • Natural resources • Reasons for exploring • Spirit of exploration	• Communication of information • Engineering careers • Making informed decisions • Ocean hobbies • Science careers • Sustainability • Technology	• Human immersion • SCUBA • Tools for exploration • Tools for seeing underwater • Tools for exploring ocean depths • Tools for remotely collecting information • Tools for surviving cold temperatures

7	The ocean is largely unexplored.			
	Life on Earth Depends on the Ocean	**People Explore the Ocean**	**Ocean Exploration Requires Collaboration**	**Ocean Exploration Requires Technological Innovations**
6th-8th		• Advances in research and technology • Climate research • Collecting long-term data • Discovering natural resources • Discovering new habitats • Discovering new species • Human benefits from discovery • Human impacts on the ocean • Ocean geography	• Communication of information • Community groups • Environmental groups • Governmental roles in ocean exploration • Making informed decisions • Role of youth in ocean exploration • Science careers • Sustainability	• Internet as a tool • Ocean-observing systems • Physical properties of the ocean • Remote exploration • Sonar • Tools for exploration • Tools for exploring under the water • Tools for prolonged exploration
9th-12th		• Advances in research and technology • Collecting long-term data • Discovering new habitats • Discovering new species • Human benefits from discovery • Human impacts on the ocean • Sustainability of resources • Use of resource	• Careers in ocean exploration • Communication of information • Global participation in ocean exploration • Higher education in ocean exploration • Making informed decisions • Political engagement • Science careers • Sustainability • Technology	• Computer technology • Continuous data collection technology: sensors and transmitters • Molecular analysis • Ocean-observing systems • Physical properties of the ocean • Satellites • Satellite image technology • Scientific models • Simulations • Submersibles: HOV, ROV, AUV

Join us in Developing Supplements to Expand Ocean Literacy

There are two active efforts to develop supplements that will expand the scope of *Ocean Literacy: The Essential Principles of Ocean Sciences K-12*. The Traditional Knowledge Committee of the National Marine Educators Association is spearheading the development of a guide to Traditional Ecological Knowledge about the Ocean. If you are interested in joining this effort, please contact committee co-chairs Sylvia Spalding and Don Hudson at sylvia.spalding@noaa.gov or donhudson@chewonki.org.

COSEE Great Lakes is developing a Great Lakes supplement that will describe the essential principles and fundamental concepts necessary to understand this complex aquatic ecosystem in the center of the continent. Please contact Rosanne Fortner, Director, COSEE Great Lakes at fortner.2@osu.edu for additional information.

Alignment of Scope and Sequence with New York State Standards for Grades 3-8

The following chart shows how the Scope and Sequence aligns with the science standards for grades 3-8 for New York State. The columns are the principles and major strands of concepts on the conceptual flow diagram for that principle; the rows are the state standards. For New York, there are multiple standards underlying each key question. There are three levels of alignment:

- [blank] = no alignment
- x = aligns with one standard
- XX = aligns with multiple standards

New York State Standards	Principle 1			Principle 2		Principle 3		Principle 4		Principle 5		Principle 6			Principle 7		
Grade 3	A	B	C	A	B	A	B	A	B	A	B	A	B	C	A	B	C
What are some of the properties of matter?	x				x												
What are some ways that energy can be transformed from one form to another?						x	x	x		x							
How do simple machines help us move objects?																	
How are plants and animals well-suited to live in their environments?									x	x	XX						x
Grade 4	A	B	C	A	B	A	B	A	B	A	B	A	B	C	A	B	C
What role do plants and animals play in their environment?									x	x	x	x		x	x		x
What are the properties of electricity and magnetism?																	
What makes water so special?	x	x					x					x					
How do natural events affect our world?	x	x		x	XX												
Grade 5	A	B	C	A	B	A	B	A	B	A	B	A	B	C	A	B	C
How do scientists gather and share information?																	
What are the processes that help shape the land?			x		x												
How does nutrition and exercise affect our health?																	
How are plants and animals in an ecosystem connected?									x	x	x	x		XX	x		x

NY State Standards	Principle 1			Principle 2			Principle 3			Prin. 4		Principle 5			Principle 6					Principle 7		
Grade 6	A	B	C	A	B	C	A	B	C	A	B	A	B	C	A	B	C	D	E	A	B	C
How does energy play a role in our lives? How do machines impact our lives?			x	x																		
How do matter and energy interact to produce weather patterns?	x	x					XX	XX							x		x					
How does the transfer of matter and energy through biological communities support diversity of living things?									x	x	x	XX	x	x		x						
How is interdependence essential in maintaining life on Earth?									x	x			x					x				
Grade 7	A	B	C	A	B	C	A	B	C	A	B	A	B	C	A	B	C	D	E	A	B	C
How do we as scientists gather and interpret evidence that Earth is continually changing?	XX			XX	x	XX	x				x											
How do the properties and interactions of matter and energy explain physical and chemical change?		x																				
How do human body systems function to maintain homeostasis?																						
How is homeostasis maintained in other organisms?											x	x		XX								
Grade 8	A	B	C	A	B	C	A	B	C	A	B	A	B	C	A	B	C	D	E	A	B	C
How does life on Earth continue and adapt in response to environmental change?											x		x	x								
How do we apply the laws of motion to explain the movement of objects on Earth?																						
What roles do forces play in the patterns and stability of the solar system?			x									x										
How does human consumption of resources impact the environment and our health?			x						x							x		XX	x	XX		

About the Contributors and Credits

CONTRIBUTORS

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Catherine Halversen is Co-Director of the Marine Activities, Resources & Education (MARE) program, Co-Director of COSEE California, and Director of the Communicating Ocean Sciences to Informal Audiences (COSIA) program at the Lawrence Hall of Science. She has led the implementation of the Communicating Ocean Sciences courses throughout the National COSEE Network.

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ON YOU AND YOUR INFLUENCE ON THE OCEAN

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