Teaching Guide. Threads from the Web of Life: Stories in Natural History.

"The trouble with ecology is that you never know where to start because everything affects everything else." - Robert A. Heinlein (*Farmer in the Sky;* 1950)

What is this book? ***Threads from the Web of Life*** is a collection of lessons in biological science each folded into its own short story. The book contains sixteen plot-driven tales, or theme-driven essays that introduce topics from **reef ecology** to **animal migration**. The material is easily grasped, since it is presented from the perspective of the organisms involved in each particular narrative. The stories illustrate a range of concepts from **ecological relationships, reproductive strategies**, and **evolutionary adaptation**, to **mass extinction.** The concepts are integrated into the narrative.

Grade levels. Students grades 9 through college should be able to read these stories by themselves, as supplementary material for a range of biological science classes. The book can be used by middle school teachers who can read portions of the text to reinforce concepts in the natural science curriculum. The material (and the vocabulary) can be discussed with middle school students as/after it is read to them.

What topics are contained in the book, and covered in this teaching guide? The content of this book has significant overlap with the **California Department of Education content standards** for biology/life sciences, and earth sciences; for grades nine through twelve. The points of overlap with those state standards in the areas of Ecology, Evolution, and Earth Science are listed in **Part 3 of this guide**, starting on **page 19.**

The concepts in Natural History presented in this text are reviewed in a set of **study questions**, given in **Part 2 of this guide**, starting on **page 4**. The questions are suitable for student discussion or for written responses. The basic questions are answered merely through comprehension of the content of the chapters in the book, from which they taken. These questions cover the topics listed below. The first group of questions deals with an organism's biological environment (1-11); then comes the physical environment (12-15). The study questions end with two topics from the history and philosophy of science (16-17). Some of the more thoughtful questions will require higher order thinking, and/or further information, e.g. from further reading, or from a teacher's synopsis.

Study question number	topic area
1.	Ecological niches
2.	Food webs
3.	Symbiosis
4.	Mutualism
5.	Parasitism
6.	Predatory strategies
7.	Speciation
8.	Adaptive radiation
9.	Extinction
10.	Reproductive strategies
11.	Migration
12.	Tectonics
13.	Volcanology
14.	Elemental cycles
15.	Weather/cloud physics
16.	Scientific theories
17.	Well known scientists in Natural History

What is the purpose of this book? ***Threads from the Web of Life*** aims to instill in students a sense of wonder and respect for the workings of the natural world. Such a framework is intended to motivate understanding. Contained within this framework is an introduction to the complexity of the world of which we humans are just one part.

How does this book propose to achieve that purpose? The book is written to hold a student's attention through the use of a linear narrative -- a plot line or a theme that organizes a specific story. Stories are short – averaging five pages (not counting the notes and bibliography); each one is limited in the number of concepts it imparts.

What is the book's title premise? Let us define a few terms here. The study of **Natural History** is the description of natural phenomena – their origins, evolution, and interactions. Organisms, from the smallest virus, to the largest whales, and everything in between, exist only through a series of interactions with their environments. The biological component of those environments is made up of the other organisms with which each organism interacts. The physical component of the environment consists of the geological and atmospheric context in which the interactions play out. The study of the interactions of any given organism with the components of its environment is called **Ecology**. These interactions are alluded to in the title of this book – they are the "Threads" that relate every living thing to everything else. As they interconnect all organisms, these threads weave the web of life.

What is the book structure? Different examples from the animal or plant worlds illustrate the concepts covered in each chapter.

Chapter	topic area	title	starting Page
1.	Reef ecology	*Stories in the Sand*	3
2.	Open ocean ecology	*the Neon Flying Squid Vanish*	11
3.	Shoreline ecology	*the Calm beyond the Surf*	21
4.	Forest ecology	*the Living Wood*	37
5.	Forest ecology/defensive chemistry	*Forbidden Fruit*	43
6.	Extinction/geology	*Secret of the Cenotés*	49
7.	Mutualism	*Housekeeping*	59
8.	Predation/parasitism	*Wolves in sheep's clothing*	65
9.	Earthquake/paleontology	*the Opening of Sister Falls Lake*	75
10.	Seafloor spreading/biogeography	*the Broadening of Sister Falls Lake*	81
11.	Avian migration/weather	*Set in Motion*	91
12.	Avian migration /seasonality/speciation	*Living on the Edge of Springtime*	100
13.	Avian migration/introduced epidemic	*Chestnut Warbler*	111
14.	Avian migration/desert environment	*Sighting in the Desert*	119
15.	Adaptive radiation	*Silversword: Flowers of the Sun*	129
16.	Volcanism/elemental cycles	*Mountain Time*	141

Study Questions. Concepts from the study of Natural History and Ecology can be taught by example from the scenes depicted in the pages of ***Threads from the Web of Life.*** Student understanding of those concepts can be fostered through the study questions below. Answers to the basic questions given in this guide are derived from a comprehensive command of the chapters of the book. The questions from particular chapter(s) may be discussed in class; or they may be assigned as written essay / homework. For written work, advanced students could be asked to do some of their own research and consult/include information from one or more of the citations to the primary literature found behind each particular chapter. Students may be assigned to search on-line, to find images of the creatures depicted in various chapters. For a written assignment in the form of a term paper, students could be asked to consult one of the books listed in the "Suggested Readings in Natural History" section, p153 in the book, or other sources. The suggested reading books cover topics from the following categories:

1. Natural History
2. Evolution
3. Geology and Paleontology
4. Chemical Ecology
5. Ornithology
6. Herpetology
7. Physiology
8. Symbiosis

We expect instructors will further generate their own individual questions about other concepts that can also be illustrated by examples in this book.

<u>Teaching Guide: Part 2.</u> Study Questions section

Answers to the questions below will illustrate for students the concepts that are covered in **Threads from the Web of Life**. Specific questions begin with **Q**., answers begin with **A.;** chapters in the book pertinent to the answers are indicated. These are basic knowledge questions that measure a student's comprehension of what has been read. More stimulating questions, which may require higher order thinking, or branch out beyond the specific text into the broader discipline, follow the basic questions, and are marked with an *asterisk*.

1. Q. What is an **ecological niche** of an organism?

A. An ecological niche describes a position an organism occupies in the physical world, and in the associated ecosystem. The biological constraints of an ecological niche will have optimized the organism's survival under the pressures imposed by the organisms above it (its predators) and below (its prey; or the plants it feeds upon) in the food web. Different uses of similar circumstances will constitute different ecological niches.

Q. Describe some of the different niches found in the same forest habitat that support the various different species of micromoths (Chapter 4).
A. Use of the same host plant 1) at different times of the year, 2) under different geographic exposure conditions, 3) at different stages of the plant's annual development.

***Q.** Why do we never have two species that occupy the same ecological niche?
***A.** The one species that is best suited to thrive in a particular niche prevails over all others, filling the niche by displacing less well suited competitors. More closely matched competitors take longer spans of time to sort out the winner. New niches are occupied by generalists species until the generalists are displaced by new specialist species.

***Q**. What is the current niche of *Homo sapiens*?
***A**. We make our own niche, by altering our surroundings to suit our needs. Thus, we do not migrate into new niche space, but displace other species from established niches by usurping their physical space.

2. Q. What is a **food web**? Organisms interact through many sorts of relationships. These relationships may cross-link different **food chains**, leading to the second order concept of a <u>food web</u>.
A. A food web is a complex network of many interconnected food chains and feeding interactions. Food chains are ultimately based on a primary plant source, such as terrestrial flora, or aquatic/marine photosynthetic free-swimming algae.

Q. **Food chains**. List the members of a) the pelagic food chain that includes the neon flying squid (Chapter 2), b) the terrestrial food chain that includes the Cane Toad (Chapter 8), c) the branching forest floor food chain that starts with the fungi (Chapter 5). D) List some organisms that occupy positions on the food chain below the owl in Chapter 7. E) Describe the food chains based on a large but transient primary source, such as the body of beached dead whale (Chapter 3).
A. a) Dinoflagellate algae, copepods, shrimp, pilchards, lantern fish, squid, swordfish.
b) Larval stage Blue butterfly, ichneumon wasp, toad.

c) Mushrooms, mice, owls or snakes or martens.
d) Crickets, shrews.
e) Condors, turkey vultures, gulls, ravens, bear, wolves; eel, surf perch, pompano, mackerel, sand sharks, skates, rays, brittle stars, sand urchins, snails, shrimp, crabs, amphipods, tube worms, sponges, corals; plovers, godwits, yellow legs, sanderlings, loons, terns, diving ducks, cormorants, pelicans.

Q. Describe some organisms that exist on top of food chains.
A. Grouper (Chapter 1), hawk (Chapter 11), swordfish (Chapter 2), man.

Defensive strategies. Creatures lower on the food chain have developed defenses that help them avoid the predators above them.
Q. Describe the defenses used by the following creatures. A) Luminescent dinoflagelate algae (Chapter 2); b) psylocybin mushrooms (Chapter 5); c) squid, octopus (Chapter 2); d) sea turtle (Chapter 10); e) sand pipers (against hawks; Chapter 11); f) ichneumon wasps (against ants; Chapter 8); g) moths (against spiders; Chapter 4-notes).
A.
a) Luminescence attracts predators higher on the food chain to a site of an attack on an algal cell.
b) Toxin incapacitates fungivors that browse mushrooms.
c) Cryptic coloration (pigments: octopi, luminescence: squid) conceals cephalopods.
d) Shells provides an armor to deter turtles' predators.
e) Formation flying prevents aerial attackers from identifying individual targets in flocking birds.
f) Ichneumon wasps uses chemical signals that mimic those of the ants, confusing them.
g) Moths are covered with loosely-attached scales that allow them to bounce off of spider web.

***Q.** Why are top predators, like the swordfish or the grouper, only represented by single individuals? Why are they uncommon relative to creatures that exist farther down the food chain?
***A.** Top predators limit the populations of the species below them (which are also predators – of the species below them). If predators become over abundant, they cause the decline toward extinction of their prey. That comes back around to drive those predators with a predilection to over-abundance to extinction.

3. Q. What is **Symbiosis?**

A. The intimate association of two organisms in a mutually beneficial relationship. Symbiosis differs from mutualism in that symbiosis is often obligate, e.g., where one or both of the partner organisms cannot survive and reproduce in the absence of its symbiotic relationship. An example of a symbiosis is hard corals that provide shelter for endosymbiotic algae whose photosynthetic output they consume.

Q. Describe the symbiotic relationship between the cleaner wrasses and their client fish in Chapter 1**.**

A. The wrasses receive food while in the process of providing cleaning services.

***Q.** Why don't the larger fish eat the cleaning fish?

***A.** Because the food value they would gain is less than the energy sapped from them by the parasites removed by the cleaner fish while the cleaner fish are present.

***Q.** Cleaner fish mimics (Chapter 1 notes) are fish that look like cleaner wrasses, and feed by gaining close access to other fish at the cleaning station, then taking a bite out of them. Why are they rare, compared to the actual cleaner fish?

***A.** Their survival requires that their prey not be wary of them. If they become common, larger fish will not risk visiting the cleaning station.

4. Mutualism: Mutualistic relationships involve two free-living species living together in an association from which both benefit. Examples include clown fish that derive protection from their predators by hiding in an anemone, and pay for that protection by chasing off smaller predators that would attack their guardian host; other examples are ants that protect acacia trees which grow modified thorns that provide shelter (and food) for the ants; and the algal and fungal components of lichens (each of which can live (less successfully) alone). In comparison, **commensalism** relates pairs of organisms in a relationship in which only one benefits; the beneficiary is a "commensal." An example of commensalism is orchids living on tree branches in cloud forests and benefiting from the elevation into the light -- an association from which the trees themselves derive no benefit.

Q. Describe the mutualistic relationship between a) the larval stages of the butterfly in the Blue family and the ants in Chapter 8; b) the screech owl and the blind snake in Chapter 7; c) the Rufous (or Allen's) Hummingbird and the penstemon in Chapter 12**.**

A.

a) The ants accept honeydew solution secreted by the caterpillar, in exchange for offering protection services.

b) The blind snake lightens the arthropod parasite burden upon the nestling owlets, and derives food in the form of the arthropods that the nest supports.

c) The birds derive sustenance in the form of flower nectar, and the flowers, in turn, receive pollination services from the birds.

***Q.** Penstemon flowers are brightly colored. Why are they not sweetly scented? Why is it that highly scented flowers are often pale -- not brightly colored?

***A**. Visual hunters for nectar (diurnal animals) find their flowers primarily by looking for the bright petals. Olfactory hunters (nocturnal animals – moths, bats) find flowers not by their color, but their scent; the color is not important (in the dark) so those plants can save the energy required to generate petal color and incur no reproductive penalty.

5. Q. What is **Parasitism?**

A. A relationship in which one species benefits at the expense of another. It differs from predation, in that parasites debilitate their host more gradually than do predators; parasites do not always kill the host, and can be so innocuous as to act as commensals as opposed to parasites. Obligate parasitism is the most common type, in which the dependent organism cannot survive in the absence of its relationship.

Q. Describe the parasitic relationship between the ichneumon wasp and the caterpillar (Chapter 8).

A. The wasp larva lives internally within the caterpillar, feeding from its host's tissues, growing within the host and eventually killing it.

***Q.** What sorts of parasitism is exemplified by a) the remora, b) mistletoe, c) the malaria plasmodium in mosquitoes?

***A** a) transportational parasitism, b) positional parasitism (though mistletoe also commandeers sap nutrients from its tree hosts); c) hyperparasitism (a parasite of a parasite).

***Q**. How is a cowbird like an ichneumon wasp in its parasitism?
***A.** Both brood their young at the expense of their hosts.

6. Predatory strategies.
Q. What is the difference in survival strategies between a) a predator, such as the sand pipers in Chapter 11 hunting for invertebrates in the sand, b) a scavenger, such as the condors in Chapter 3 hunting for beached whales, and c) a parasite, such as the wasp hunting for caterpillars in Chapter 8?
A: the predator kills live prey; the scavenger eats prey that has already died, or is dying due to prior causes; the parasite does not immediately kill its prey (often (but not in this case in Chapter 8) only debilitating, but never killing its host).

***Q.** A creature that eats both live animal and plant matter is called an omnivore. A) Name a creature that is both an omnivore and a scavenger. B) Name a creature that is both an omnivore and a parasite.
***A.** a) coyote; b) cowbird.

7. Q. What is **Speciation**?
A. The evolutionary formation of new biological species, usually by the division of a single species into two or more genetically distinct species.

Q. Describe the "Aztec Hummingbirds" (Chapter 12) as one species, as it may have existed during the past ice age. Then describe the process of division of that species into two new species: 1) the Allen's Hummingbird, and 2) the Rufous Hummingbird. What drives this speciation? Note: "Aztec Hummingbird" is a group name conferred upon two named species that appear to be closely related but diverging.
A. Speciation is driven by the subdivision of a species' ecological niche, producing subspecialties in varieties of that species – which varieties may co-evolve with their evolving niches to the point that they no longer interbreed with each other. (Here, separate species are defined as non-inter-fertile, or non-inter-interbreeding relatives.) Speciation often involves geographic isolation.

Q. Describe how different species of micromoths (Chapter 4) could arise a) from ancestral moth species that develop sub-specialties in different parts of the same host plant (e.g., young leaves vs. old leaves vs. fallen leaves), or b) from an ancestral moth species that co-evolves with different, divergent varieties of the ancestral host plant as those plants evolve into separate species.

***Q**. At what time in the world's history were there the greatest number of species? Why then?
***A.** Now. New species arise from prior species, and in so doing, increase the number of species. So, species numbers will always be increasing, in proportion to the number of species from which new ones can arise. (There have been dips in this rising curve, at the times of mass extinctions.)

8. Q. What is **adaptive radiation**?
A. The diversification of a species as it adapts to different ecological niches, becoming specialized for the new environments, eventually evolving into different species. An example is Darwin's finches in the Galapagoes; or the Honey Creepers of Hawaii (Chapter 15).

Q. Illustrate "adaptive radiation" using the Hawaiian Silversword (Chapter 15) or the "Aztec" Hummingbirds (Chapter 12) as an example of the colonization of a novel environment, and adaptation to it during subsequent periods of geographical isolation.

***Q.** What would be unique to Muir's Tarweed, the progenitor of the Hawaiian Silverswords, that allowed it to evolve into so many different species?
***A**. Nothing. Any species has the potential to radiate into new niches and produce a group of new species, if it is presented with novel, open niche spaces.

9. Q. What is **Extinction?**
A. The loss of species from the Earth.

Q. Describe the Cretaceous/Terniary (K/T) extinction (Chapter 6). Give some of the ways the catastrophe of the Cretaceous-Terniary impact could have changed the environment (Chapter 6) leading to the extinction of species.
A. Injection of CO_2 into the air, causing global warming; injection of SO_2 / SO_3 into the air, causing acid rain; changing the chemistry of the air and water, interrupting food chains upon which top predators depend by destruction of their bases; injection of particulate matter into the air, altering the local climate by blocking the sunlight.

Q. What is **mass extinction?**
A. A period of especially high rates of extinction of species. Several such events are seen in the fossil record. Some paleobiologists suggest that we are on the brink of another mass extinction today, caused by human activities**.**

Q. Which of those environmental factors listed as in-play during the K/T extinction are again changing, this time as a result of the activities of our own species.
A. All of the above.

Q. What other activities of man may lead to extinction of species.
A. Habitat destruction, e.g., in Australia (Chapter 8); importation of exotic species incompatible with the native species (such as argentine ants to the Hawaiian Silversword habitat (Chapter 15), or chestnut blight fungus into American Chestnut habitat (Chapter 13)); whaling, over fishing (Chapter 3); over hunting (Chapter 3); contamination of the environment (plastic bags in the ocean (Chapter 10)); over grazing (feral Hawaiian goats and pigs; Chapter 15).

***Q.** What percentage of all the species that have ever existed on the Earth are now extinct?
***A**. 99+%

***Q.** Explain how any one of the actions of man detrimental to other species could also be detrimental to the future of our own species.

10. Reproductive strategies Some animals use most of their resources on producing very large numbers of young, but then spend no further energy caring for those progeny. These are **r-strategists.** Other animals produce only a few young but spend a lot of resources on caring for and protecting them. These other animals are **K-strategists**. r-strategists often live under conditions where resources for growth of progeny are readily available, but where there is also considerable predation. K-strategy creatures often live under conditions where the population is limited by scarce resources rather than by predation. K-strategy populations would be slow to increase in response to a sudden excess of food, whereas r-strategists would increase rapidly in response to a sudden improvement in conditions.

Q. Would you say the sea bass in Chapter 3 is an r- or a K-strategist?
A. r.

Q. How about the Screech Owl in Chapter 7?
A. K.

***Q.** Why might sea bass change genders as they grow older, to become male? Why might it be that other orders of marine animals (isopods, cnidarians) change genders when they grow older, to become female?
***A.** Where age (size) disproportionately increases the probability of reproductive success of one or the other gender, such creatures have evolved the capacity to change genders and maximize that reproductive advantage.

11. Migration is the movement of organisms from one locality to another. This enables them to take advantage of different habitats at different times in their lives.

Q. Describe the migration of the Arctic Tern (Chapter 11); the Rufous and Allan's Hummingbirds (Chapter 12); the Chestnut-sided Warbler (Chapter 13); the American White Pelican (Chapter 14); the nesting migration of the Green Turtle (Chapter 10); diel migration of nocturnal marine invertebrates (Chapter 2). What is the advantage of each of these migrations, compared to staying in one place?
A. Migration of the birds is biannual (twice/year; back and forth). Migration of the turtles is biennial (alternate years) or triennial, starting at sexual maturity (age ~ 25 yr). Diel migration of nocturnal midwater marine animals is diurnal (day/night cycle) movement between deeper water by day and surface waters by night. All these migrations afford traveling species access to distant resources.

***Q.** How many daylight fishing hours are available per year to the Arctic Tern? How does that compare to the hours available to a non-migratory Belted Kingfisher in California? Or to the invertebrates involved in diel migration (Chapter 2)?
***A**. The Arctic Tern never sees complete darkness for 8 months of the year. The nocturnal pelagic invertebrates never see full daylight ever.

12. Q. What is **Tectonics?**
A. A branch of geology describing the major structural or deformational features of the Earth, and their origins. These features include the troughs at

seafloor spreading centers and continental margin subduction zones, the mountain ranges where continental plates collide against each other, and the earthquake faults where the plates slide past or under one-another.

Q. How is the action of plate tectonics manifest in the spatial arrangement of the islands of the Hawaiian Archipelago (Chapter 15)?
A. The Hawaiian hot-spot is fixed in place, producing a series of islands in a northwest-tending chain as the Pacific Plate moves across it to the southeast.

Q. How is the action of plate tectonics manifest in the shapes of the coastlines of Western Africa and Eastern South America (Chapter 10)?
A. Continental coastlines surrounding the South Atlantic are shaped compatibly, as if they were created by a single rift across a larger ancestral continent.

***Q.** New acreage of tectonic plates is continually created, such as at the sea floor spreading center that is currently widening the Atlantic Ocean. Since the surface area of our spherical world is not getting any bigger, the same acreage of plate area must simultaneously be being destroyed somewhere. How would that be?
***A.** By subduction at plate boundaries. Surface area is also diminished by compression, where colliding, non-subducting plates build mountains (such as the Himalayas).

***Q**. How has plate tectonics effected the geology of the western U.S. a) in the Cascade Mountains, b) central-coastal California?
***A**. A) The volcanoes of Cascadia result from subduction of the Pacific Plate under the North American Plate to their west. B) Central-coastal California used to be South-coastal California, before slippage of the Pacific Plate against the North American Plate there moved the southern landforms north.

13. Volcanology Volcanoes can be divided into two classes: stratovolcanoes and shield volcanoes. *Stratovolcanoes* are steep-sided, symmetrical cones built of alternating layers (strata) of lava, ash, and larger rocks (Chapter 16). Their explosive eruptions involve the release of pressurized gasses.

Q. What types of sudden, catastrophic eruptions build the layers of stratovolcanoes?

A. Pyroclastic flows, lahars, ash clouds.

Q. What sorts of gasses might be released by stratovolcanoes?
A. H_2O (steam), CO_2.

Shield volcanoes are gently sloping domes, built almost entirely of lava flows. Eruptions are not explosive – less gas is released: the lava flowing from shield volcanoes is less viscous than that flowing from stratovolcanoes. Viscosity is the "thickness" or resistance to flow of a liquid – e.g., water is less viscous than maple syrup. Non-viscous lava flows long distances before it solidifies, building flat domes. Viscous lava that solidifies into rocks soon after eruption builds steeper cones**.**

Q. What type of eruption builds shield volcanoes (Chapter 15)?
A. Continuous, non-viscous flows.

***Q.** What are the plate-tectonic settings for shield *vs*. stratovolcanoes?
***A.** Over mantle hot-spots, *vs* over plate boundary subduction zones.

***Q.** A) What does rock derived from rising magma that cooled after eruption look like? B) What does it look like if it cools before erupting?
***A.** A) Extrusive (volcanic) rocks that have cooled relatively quickly are fine grained (andesite, basalt). B) The same material that cooled relatively slowly (intrusive rock) is coarse grained (granite).

14. **Mineral cycles**. The elements on the surface of the Earth interconvert in a cyclic fashion between their various chemical and physical states. Compounds important to life are driven through these changes through a series of inter-linked abiotic and biotic cycles. **Water** is a compound, an oxygen atom carrying two hydrogen atoms -- H_2O. It cycles between its gas, liquid, and solid states, and in so doing, it drives the weather (see next question, below). **Carbon** atoms exist as compounds with oxygen -- CO_2, CO (carbon monoxide); and as carbohydrates (in living matter). Gas phase CO_2 is removed from the atmosphere by dissolution into the ocean, beginning the **abiotic carbon cycle.** In the ocean the CO_2 combines with calcium to form a solid precipitate that accumulates on the seafloor as limestone – calcium carbonate.

Q. How is the carbon returned to the atmosphere to complete this cycle? (Chapter 16)

A. Calcium carbonate dissimilates back to CO_2 (and calcium oxide) when limestone rocks are subducted as sea floor is destroyed beneath continental margins; the CO_2 generated in this process is returned to the atmosphere by volcanic eruption. CO_2 is also slowly released from up-lifted carbonate rocks by weathering.

Q. What effect does volcanic eruption have on Earth's atmosphere? (Chapter 16 – notes)
A. Should the volcanoes cease erupting, continuing sequestration of CO_2 by its dissolution into the oceans would eventually remove all of it from the air, leading to cooling of the atmosphere (reverse greenhouse effect) and eventual freezing of the entire surface.

The **biological carbon cycle** sees gas phase CO_2 removed from the atmosphere and incorporated into organic matter by the action of photosynthesis. The reverse biological reaction that consumes organic matter and releases CO_2 back to the atmosphere is respiration (which includes biological decay).

***Q.** What *abiotic* reaction releases CO_2 from organic matter back into the atmosphere?
***A.** Fire.

Nitrogen atoms exist as compounds with oxygen – NO_2 (nitrite), NO_3 (nitrate).

Q. Describe the two nitrogen cycles (Chapter 16 - notes).
A. The **abiotic nitrogen cycle** sees atmospheric nitrogen N_2 gas converted to oxides of nitrogen by lightening. These nitrogen oxides then dissolve from the atmosphere into the ocean and precipitate as solid nitrates, becoming incorporated into the rocks. This process does not reverse by itself, but is reversed through the biological nitrogen cycle. The **biological nitrogen cycle** sees atmospheric N_2 converted to ammonia (NH_3) by microbes. Other microbes oxidize NH_3 to nitrate, then reduce nitrates back to gaseous N_2. Nitrates and ammonia are incorporated by living organisms into organic matter.

15. **Weather**. Solar energy is stored in the atmosphere in the form of water vapor (humidity) that evaporates from the ocean as the water is warmed by the sun. Storms are driven by the energy liberated when water vapor is

transformed from gas (vapor) to its liquid or solid forms, in which it is deposited back on the ground (**the hydrology cycle**). These are “phase” changes of water. When you blow across liquid water (or rubbing alcohol) placed on the back of your hand, you feel the cold. Energy (warmth) is being taken from your skin during the process of the evaporation of the liquid into its vapor form. The reverse reaction – condensation of a gas back into its liquid form – gives away that heat again. The appearance of rain drops or fog (droplets) warms the air around the drops with the heat that is given away by air molecules when they condense into liquid.

Q. Water converts among its different forms, or “phases” when heated or cooled. What does water vapor change into as it gives away its heat (chapter 11)?
A. Cloud droplets or rain (liquid phase); snow (ice crystals; solid phase).

Q. What form does that heat energy take as it is given back to the air (Chapter 13)?
A. Wind (increased air motion).

***Q.** A) What percentage of the atmosphere does water vapor constitute? B) Phase changes of water release the heat that drives storm formation, produces the clouds and the rain. Do any of the other molecular constituents of the atmosphere (which make up the bulk of the atmosphere) effect the weather?
***A**. a) As opposed to the other constituents of the atmosphere, the percentage made up by water vapor is not fixed, but varies from place to place and time to time. b) The bulk atmosphere absorbs heat from the surface and transports that heat; that heat plays a determinative role in the phase inter-conversions of water.

The weather is one of the challenges presented by the physical world, for which the creatures living here must be prepared in order to survive. Creatures of the air are particularly at risk.

Q. Describe the challenges to the lives and habitats of the birds posed by severe weather (chapters 11, 13).
A. Birds are blown from the sky; blown off the beach by storm surge; blown off track during migration, thrown from roosts when trees fall.

16. **Scientific Theories**. Scientific prediction of events, based on observations of similar events, leads to the formulation of hypotheses. Hypotheses, the predictive values of which have proven generally reliable, are accepted as theories. Over-arching theories have arisen in each branch of science. These theories serve to unite different aspects of a discipline, and to predict the answers to questions that arise from observations anywhere within their disciplines. Examples of theories (and their proponents) that unified their respective disciplines include the heliocentric theory of the solar system (Copernicus), the "big bang" theory of cosmology (no single primary proponent), the "genes" theory of genetics (Mendel), the "theory of relativity" in particle physics (Einstein), the "plate tectonics" theory of geology (Wegener), and the "evolution" theory of biology (Darwin). These theories cannot be proven directly, usually because the effects they describe transpire over reaches of time and space beyond the human scale – no one has directly observed a continent move, the behavior of particles traveling near the speed of light, nor the evolution of one species into another. Nonetheless, these theories serve to organize the observations -- upon which their branches of science are based -- behind generally accepted principles.

Q. Give examples that illustrate the theory of plate tectonics.
A. The string of Hawaiian volcanoes (Chapter 15); the compatible shoreline shapes that bound the South Atlantic (Chapter 10); see question 12, above.

Q. What forces are thought to drive plate tectonics?
A. Convective flow of the Earth's molten mantle, upon which the plates float

Q. Give examples that illustrate the theory of evolution.
A. Speciation (Chapter 12); adaptive radiations (Chapter 15).

Q. What forces are though to drive evolution?
A. The variation of the genome over time (mutation; reorganization), coupled with natural selection among the novel phenotypes that arise by genetic variation from their predecessors.

***Q.** What is the difference between a theory and a fact.
***A.** Facts are real (verifiable by all observers), such as head counts, species types, dates and times. Theories, on the other hand, are abstractions -- used to reflect the current thinking in a discipline, and to predict the nature of its advancement. Theories are based in the current knowledge, but they are

nonetheless subject to different interpretations by different observers. They can be disproved by newly discovered information (at which time they are modified and refined), but – even though they are consistent with all the presently known facts -- they are ideas – lines of thought that can never achieve verified (proven) status.

17. **Well known scientists in Natural History**. Using general sources of information (e.g., the encyclopedia, the internet)…
Q. who were: John Muir, Charles Darwin, and Asa Gray (Chapter 15), John James Audubon (Chapter 13), Alfred Wegener and Archie Car (Chapter 10)? Give dates of birth – death; make a time-line showing how they were related as contemporaries.

These naturalists worked to refine theories based on scientific observation – theories that now serve to predict the behaviors of the inter-connected workings of the world.

Q. Did the works of some of these scientists influence the work of others? Give an example of the contributions of one of them, and its influence.
A. Darwin's evolutionary theory and its impact upon Muir's creationism (Chapter 15). Wegener's theory of tectonics as an explanation of the migration of Carr's turtles (Chapter 10).

Using a plant taxonomy text:
Q identify a few plants native to the U.S. that were formally identified by Asa Gray and so carry his name.
A. E.g., look among the lupines or the manzanitas; their scientific names will often be found to carry his name as a suffix: e.g., *Eschscholzia californica* v *Douglasii* Gray -- California poppy. Gray's name has been associated with thousands of species and subspecies of plants in the taxonomic literature.

Using a bird field guide:
Q identify a few birds that were named after John James Aububon**.**
A. Their common names will carry his name as the species designation: e.g., Audubon's Warbler, Audubon's Shearwater, Audubon's Crested Caracara.

Comments on the teaching guide are welcome, at this site.

Teaching Guide: Part 3. Board of Education Content Standards

California Content Standards: Science Classroom concepts. This book covers topics from the California Board of Education science concepts lists. That coverage is given below, point by point. Topics from the areas of Ecology (six of seven points), as well as non-molecular points in Evolution, and some points in Earth Science can be taught from examples/references contained in **Threads from the Web of Life.**

Biology/Life Science; Ecology -- section 6; six points.

a. Students know *biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.* Alteration of habitats gives rise to new species, which have adapted to the novel conditions. Biodiversity is generated by such speciation. Chapter 15 describes the radiation of a founder species upon its transposition into a novel habitat. The Silversword plants of Hawaii are described as one species that radiates into many, in response to the presentation of an expanded suite of habitats into which the plant diverges. Habitat alteration as a driver of new species formation is also described in Chapter 12 with the divergence of one hummingbird species into two in response to the broadening of its habitat to the north, following the current retreat of the glaciers.

b. Students know *how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.* Changes in ecosystems are detailed in the book. Changes in the environment as a consequence of a natural disaster are described Chapter 6, which lists the sequence of environmental changes that would have occurred as a result of asteroid impact on the earth (K/T extinction). Change as consequences of human introduction of nonnative species is described in Chapter 13 (introduction of a fungal plant pathogen into the forest), Chapter 15 (introduction of non-native goats, pigs, mongoose, argentine ants), Chapter 8 (introduction of a non-native predator – the cane toad). Changes in ecosystems resulting from human activity are described in Chapter 3 (hunting pressure, over-fishing), and at the end of Chapter 10 (consequence for a sea-going species of contamination of the environment with plastic refuse). Changes in an ecosystem resulting from climate change (end of an ice age) are described in Chapter 12 regarding species range expansion.

c. Students know *how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.* Fluctuation in population sizes is treated in Chapter 3 where the removal of a food source (whale fall) from the bottom of the food chain has consequences that ripple through the ocean food chain. Chapter 13 describes the population increase of the migratory Chestnut-sided Warbler (a forager in disturbed habitats) as a consequence of an increase in its habitat area – an indirect consequence of man's activities.

d. Students know *how water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem and how oxygen cycles through photosynthesis and respiration*. Abiotic carbon and nitrogen cycles are treated in Chapter 16, and in the notes section behind that chapter. They hydrological cycle that converts water through its phases and transports it from the ocean back to the land is treated in Chapter 11. The biochemistry of photosynthetic carbon fixation is not treated in the text.

e. Students know *a vital part of an ecosystem is the stability of its producers and decomposers.* The anchor of the food chain by the photosynthesis of the plants is treated in Chapter 2, which describes the algae that form the base of a pelagic food chain. Decomposers are treated in chapter 3 wherein a whale fall to the bottom of the ocean is reduced, and the cache of nutrients there recycled, by a cohort of creatures.

f. Students know *at each link in a food web some energy is stored in newly made structures but much energy is dissipated into the environment as heat. This dissipation may be represented in an energy pyramid*. biochemistry of anabolic energetics is not covered in the text.

g.* Students know *how to distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.* Accommodation to conditions is exemplified in the book by the Chestnut-sided Warbler, Chapter 13; the population of the bird increases in response to modification (expansion) of its preferred habitat. Gradual adaptation to changing conditions is exemplified in the book by the Rufous Hummingbird, Chapter 12; the divergence of this bird's lineage is shown as response to gradual range extension into an alternative habitat. Gradual adaptation to a new environment also changes the lineages of the Hawaiian Silverswords (Chapter 15).

Biology/Life Sciences: evolution – section 8; three points.

a. Students know *how natural selection determines the differential survival of groups of organisms.* Examples of specific advantage refined by selection are contained in the text. These include the refinement over evolutionary time of a mushroom toxin, which is advantageous to the survival of the species (Chapter 5). Examples of the radiation of moth species during the subdivision of the available niches are given in Chapter 4. Co-evolutionary symbioses advantageous to both participating species are described among ants and butterfly larvae (Chapter 8), and cleaner wrasses and their clients (Chapter 1).

d. Students know *reproductive or geographic isolation affects speciation*. Speciation as a consequence of geographic isolation is exemplified in the evolutionary radiation of Silversword plants (Chapter 15), and in the speciation which is currently dividing Rufous and Allan's Hummingbirds as the geography of their available ranges diversifies through expansion (Chapter 12)

e. Students know *how to analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction*. Mass extinction as a consequence of global environmental upheaval is exemplified by the Cretaceous/Terniary extinction event, described in Chapter 6.

Earth Sciences; plate tectonics, section 3; two points.

a. Students know *features of the ocean floor (magnetic patterns, age, and sea-floor topography) provide evidence of plate tectonics.* Rifting and sea floor spreading are illustrated in Chapters 9 and 10 in the description of the splitting of Gondwanaland and the opening of the South Atlantic.

e. **Students** know *there are two kinds of volcanoes: one kind with violent eruptions producing steep slopes and the other kind with voluminous lava flows producing gentle slopes.* Both stratovolcanoes and shield volcanoes are described in the text. Shield volcanoes rising over a geologic hot spot are exemplified by Chapter 15's descriptions of the Hawaiian archipelago.

Stratovolcanoes and their typical types of eruptions are described in Chapter 16.

Earth Sciences: climate, section 4; one point.

a. *Students* know *weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere*. The absorption of heat by water evaporating from the sea surface, and the release of that heat back into the atmosphere driving cloud-building by condensation are described in Chapter 11.

Earth Sciences: elemental cycles, section 7; one point.

b. *Students know the global carbon cycle: the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, fossil fuels, and the movement of carbon among these reservoirs.* The abiotic carbon cycle is described in chapter 16.

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