

Darwin on the Bluff

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Additional information and copies are available online at www.calpoly.edu/~rfield/Darwin.htm.

Click on the link to the Darwin on the Bluff document and open it with the password: LOMS

Seventh Grade Science Standards:

Evolution 3.1 and 3.5 and Earth and Life History 4.1 (plus 6th grade Earth and life science standards):

“Genetic variation and environmental factors are causes of evolution and diversity of organisms.”

“Extinction of species occurs when the environment changes and the adaptive characteristics of a species are insufficient for its survival.”

“Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.”

Location: Montana de Oro bluff trail about one mile round trip in 2 hours + 20 minute break

15 minutes trail walk: what do you see?

15 minutes: co-evolution of the land, sea, and sky

15 minutes: co-evolution of the Earth and its biosphere

15 minute activity: relationships of the solid Earth, hydrosphere, atmosphere, and biosphere

20 minute snack break

15 minutes: co-evolution of plants and animals

15 minutes: co-evolution with algae, fungi, and bacteria

15 minute activity: relationships of the six kingdoms of life

15 minutes return trip to trailhead

Theme: Darwin traveled the world before he understood the origin of species, but all we have to do is explore the MdO bluff to illustrate how the Earth and its biosphere have been co-evolving for billions of years. It's all about relationships: The diversity of life depends on interactions of energy and matter in the ocean, atmosphere, solid Earth, and Sun.

Sub-themes:

1. The transfer of energy by radiation and convection currents drives many processes on the Earth's surface.
2. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.
3. Plants inherited photosynthesis from green algae ancestors whose chloroplasts evolved by endosymbiosis from captured cyanobacteria.
4. As plants transitioned from an aquatic environment to land, they developed roots, stems, leaves, seeds, flowers, and fruits and they co-evolved with terrestrial animals and organisms from other kingdoms.

Activities: Students talk about what they see and how everything we see depends on things that we don't see. We discuss direct and indirect influences of the OASES (ocean, atmosphere, solid Earth, and Sun). We discuss the building blocks of life: cells (molecules and metabolic processes), organisms, ecosystems, and the whole biosphere. We discuss relationships involving the six kingdoms. Complexity grows when energy flows.

Eight guiding questions are common to our efforts to observe and explain the natural environment:

1. What do you see (observations and descriptions)?
2. What are natural systems made out of (composition and structure)?
3. How do natural systems work (material properties and interactions with energy)?
4. How do natural systems change over time (evolutionary processes)?
5. Where do natural systems come from (origin and/or formation from building blocks)?
6. What are the relationships between the parts of a system (interactions and/or common origins)?
7. What are the relationships between natural systems (interactions and/or common origins)?
8. How do natural systems become more complex over time (entropy decreases)?

Darwin on the Bluff activity sheet

Everything you see depends on things you don't see

Select the best word for each blank. Circle each word as you use it.

Physical processes of land, sea, and sky

uplift volcanic nuclear erode fold

1. Heat from radioactive decay fueled the _____ flow that formed Morro Rock.
2. Sunlight provides the energy that drives the wind and water cycles that _____ rocks.
3. Heat from radioactive decay also helps _____ and _____ layers of sedimentary rocks.
4. The Sun and Earth evolve because _____ reactions change the composition of materials.

Co-evolution of the Earth and biosphere

diatoms phosphorus carbon nitrogen oxygen Pangaea cyanobacteria

5. Marine terraces include the fossil remains of _____ deposited on the seafloor.
6. _____ reduced the _____ and increased the _____ in the atmosphere.
7. Decaying organisms help erode rocks and enrich soil with nutrients like _____ and _____.
8. The formation of new islands and the break-up of _____ influence plant and animal evolution.

Biological processes

symbiosis selection evolution fungus algae mutations

9. _____ are tiny alterations in genes that produce variations in traits among offspring.
10. The variation in the traits of an entire population over many generations is called _____.
11. Natural _____ determines which traits survive in a given environment.
12. The mutually beneficial relationship of _____ and _____ in lichen is an example of _____.

Evolution of plants

spores roots stems wind leaves vascular algae

13. Plants evolved from green _____.
14. The evolution of _____ structures enabled plants to thrive on land.
15. These multicellular structures evolved into _____, _____ and _____.
16. Plants that produce _____ use the _____ to transport their offspring.

Relationships of plants and animals

co-evolution flowers toxins fruit seeds spines

17. Over many generations, competition and cooperation lead to the _____ of plants and animals.
18. _____ attract pollinators with colorful modified leaves and fragrances and reward them with nectar.
19. Animals disperse _____ that are enclosed in _____.
20. Some plants defend themselves against animals with _____ and _____.

Relationships among the six kingdoms

bacteria carbohydrates phosphates chloroplasts oxygen nitrogen

21. Photosynthesis combines sunlight, water, and carbon dioxide to form _____.
22. Photosynthesis in algae and plant cell structures called _____ evolved from _____.
23. Photosynthesis by cyanobacteria releases a powerful gas _____.
24. Plants use bacteria to fix inorganic _____ and fungi to access insoluble _____.

Interpreting our observations on the Darwin on the Bluff walk:

1. The structure, composition, origin, and evolution of the sedimentary rocks you can see from the bluff reveal the forces of nature that have deposited and then altered them, the ocean being one of the key influences. The rocks came from the erosion of continental igneous rock that came from the depths of the Earth. Much of the sediment came from the remains of plankton that extracted silica from seawater.
2. The Sun influences the ocean, the atmosphere, and the land in many ways; it is the energy source for winds, waves, tides, air and water temperature, and the web of life. Over billions of years, changes in the Sun's output can be extremely important.
3. The atmosphere influences the ocean and the land and yet life itself has altered the atmosphere and has affected climate and living conditions and the course of evolution. Over billions of years, changes in the composition of the atmosphere have proven disastrous for some forms of life and beneficial to others.
4. The flowering plants on the bluff evolved from algae with help from bacteria (fixing nitrogen), fungi (phosphorus), and animals (insect, bird, or bat pollinators). Co-evolution, cooperation, competition, and reproductive strategies are all factors in the ecosystem that includes all five living kingdoms. Chance mutations of DNA imbued the descendants of green algae to evolve into multicellular, differentiated, vascular plants with the ability to form leaves and to form and disperse seeds through the production of flowers and fruits. Changing conditions favored the descendants with certain traits by means of natural selection.
5. The appearance and behavior of plants and animals vary with daily and seasonal changes in the environment including tides and weather as a result of natural selection. For more information, see my website.

Conclusions:

Everything evolves; everything changes over time - the sea, sky, land, and life itself.

Everything you see is highly interactive and literally closely related.

It is the role of science to provide plausible natural explanations for natural phenomena.

Science is just getting started, so be patient: it may take a century or more to explain everything.

How do things change? When energy flows, complexity grows.

Or to be more precise: When energy flows, (local) complexity (often) grows.

Some key words to Google: coevolution, adaptive radiation, convergent evolution, symbiosis, competition, cooperation, ecosystems, kingdoms, cell complexity. Wikipedia is a great online encyclopedia for science.

At the Trailhead –

The MdO Bluff is a special place because of its intrinsic beauty, the result of the meeting of sea, sky, and land. As we walk along the bluff trail, we will stop to examine graceful peaks, marine terraces, rugged bluffs, speckled and layered sedimentary rocks, powerful crashing waves, the light and color of the sky, and examples of the five kingdoms of life – plant, animal, algae, fungus, and bacteria. Everything you see from the bluff has a natural history; that is, everything changes over time.

The trail is 1.5 miles but we will only walk a half mile. Because our theme is evolutionary processes, we will not be identifying every plant, bird, rock that we pass on the way out. We may stop at Corallina Cove to look at tide pools. As we walk, be on the lookout for special things like coyotes or marine mammals, etc., but also look closely at the ordinary things you see.

Pause - Why do we cross a bridge here? Point out poison oak and reference toxins that plants can produce.

Pause – Look out over Smuggler's Cove and discuss the forces that created and shaped it. The creek that occasionally flows under the bridge we crossed opened this area up and deposited some of the material in this area. Wave action played a major role in widening the cove. If you look across at the vertical striations, you see evidence that water flowed down the steep face of the rocks following rains.

Stop 1 – The power of the sea is revealed in the crashing waves that erode the bluffs today. Below the bluff, you can see the top layers of sedimentary rocks that are actually 2000 feet deep.

The rocks came from a mixture of the silica skeletal remains of organisms that settled to the sea floor and other fine sediments that washed to sea from the land. The organisms lived in the surface waters of shallow seas that covered this area seven million years ago. These rocks have finer grains of silica than sandstone and include the remains of the hard tests of plankton, mostly diatoms. The golden algae build tests from silica dissolved in seawater.

Notice that there are regular layers in the rock, typically a few inches. Each of these layers may have taken decades or centuries to form. Within a layer, there may be a finer structure that represents seasonal variations in sedimentation rates. The space between the layers may represent a brief rapid deposition that erodes more easily because it had less time to form and compact. Notice that the rocks form fingers. Some areas are missing because they wear faster because the original rocks were softer. We will see more examples of this later.

Horizontal depositions formed at a depth of perhaps 1000 feet below sea level and covered an area of 1000 miles or more. Older sedimentary rocks may form layers up to ten miles thick under these rocks.

Hundreds of square miles of these rocks were uplifted, folded, and then carved by wind and water as they emerged from the sea. Notice that the rocks are tilted so as to face toward the south, the direction we are walking. Which rocks are older, the ones on the left or on the right as we look down from the bluff?

Valencia Peak was also uplifted from the sea floor by seismic forces between the North American and Pacific tectonic plates. The lighter sedimentary rocks were driven over the continental shelf as the heavier iron-rich ocean crust sank below the continental margin. Waves also carved the marine terraces of Valencia Peak during lulls in the uplift.

The energy for the uplift is geothermal: heat escapes from the Earth's interior by convection of molten rock, the same force that lifts continents above the sea floor. Even the silica in the ocean that formed the plankton came from less dense molten rocks deep in the Earth that slowly "floated" to the Earth's surface. Morro Rock is a volcanic plug that formed about 26 million years ago hundreds of miles south of here.

The conglomerate of rocks that buried the wave-cut folded rock layers is an alluvial fan that washed down from the hills after being eroded by wind and water from the uplifted sediments. Later creeks channeled the water and carved the creek beds and the coves and deposited onto the beaches and into the sea.

Stop 2 – We check the rocks to see if they are still tilted to the south. Absorption of sunlight by the oceans keeps the oceans from freezing solid because the Earth's surface is constantly cooling as it radiates energy back into space. Sunlight is absorbed near the ocean's surface where evaporation initiates the water cycle: evaporation, condensation, precipitation, and surface transport. The web of life is based on sunlight.

Stop 3 – Where does the sea get its power? Waves are generated by winds which are produced when the atmosphere absorbs sunlight. Temperature differences cause variations in air density which leads to air flow or wind.

Clouds and fog cool the Earth during the day by scattering sunlight into space. Clouds and fog warm the Earth at night by scattering infrared back to the Earth. Ozone absorbs ultraviolet, shielding us from its harmful rays. Greenhouse gases trap heat on the Earth's surface. We should also look for optical phenomena in the sky and the surf.

The atmosphere used to be mostly carbon dioxide. Photosynthesis by cyanobacteria ("blue green algae") removed carbon dioxide and released oxygen. This led to the oxygen holocaust which killed off most of the things living at the time. With the big drop in greenhouse gases, wouldn't you expect global cooling to freeze the oceans solid? Not if the Sun has been getting brighter and hotter over time.

Check the rocks to see if they are still tilted to the south.

Stop 4 – The theme of our walk is that everything evolves.

Where did all these plants and animals come from? How did plants and algae “learn” to convert sunlight into food? How did plants and animals adapt to the land from the sea? How do bacteria influence plants? What do plants do? What are they made out of?

How do they interact with each other? How do they interact with the other four kingdoms and with the physical environment?

The natural history of the flowering plants you can see on the bluff involves the other four kingdoms: they evolved from algae with the help of bacteria for fixing nitrogen, fungi to provide phosphorus, and animals (insects or birds or bats) to pollinate. Co-evolution, cooperation, competition, and reproductive strategies are all factors in the ecosystem that you see here. Furthermore, some cyanobacteria evolved into algae and plant chloroplasts, produced atmospheric oxygen, and removed carbon dioxide, preventing another Venus.

Chance mutations of DNA imbued the descendants of green algae to evolve into multicellular, differentiated, vascular plants with the ability to form leaves and to form and disperse seeds through the production of flowers and fruits. Changing conditions favored the descendants with certain traits by means of natural selection.

So everything you see on land has ancestors that lived in the sea.

Pause - We will keep going but I point out the trail to Corallina Cove for future reference if you want to go tide pooling or examine the beach.

Stop 5 – From the bridge, you can see that the creek that flows into Corallina Cove is unusually straight. You might suspect that this feature did not occur naturally, but one plausible natural explanation is that an earthquake fault line created a straight channel for the creek’s water that helped carve the cove.

We already discussed geothermal energy and seismic movements. Where does the heat come from? Originally the Earth was molten because of the gravitational and kinetic energy of dust and rock condensing to form our planet. Radioactive decay of atoms in the mantle has released enough energy to keep the Earth’s interior from cooling enough to halt the convection process in the mantle that builds continents. Otherwise the land would erode and vanish. Without convection, volcanism would not recycle buried carbon from the sea floor to the atmosphere. Without atmospheric carbon dioxide to trap heat, the climate would change and the oceans would cool and freeze.

The Earth collects organic matter on its surface, unlike the deep blue sea, where material sinks far beyond the reach of sunlight. The solid Earth provides a sea floor, particularly valuable on the shallow continental shelf where sunlight reaches things that live on the bottom. Can plants use the nitrogen from the air? How do you think nutrient nitrogen becomes available to plants?

Stop 6 – Check the rocks to see if they are still tilted to the south. Corallina Cove is at a syncline where the rock folds changed direction – this is the bottom of the fold. These rocks are the youngest rocks we have seen so far. So which rocks are older those to the north or south? That may have been related to a fault line and why the water ran down along a fault and formed the cove. It’s time to talk about what is in the tide pools briefly. There are creatures related to things living on the bluff. If it’s green in the tide pool, what does that tell you? The sea anemone looks like a plant and is green but it is an animal with photosynthetic microbes living in its tissues. The cove is named after the pink Corallina alga which is reminiscent of its namesake, corals, which are inanimate animals, but it is a photosynthetic alga that does not have green chlorophyll and has a stony skeleton made from calcium. The tide pools have many other creatures like the sea star, urchin, sculpin, and many creatures with shells.

Pause – The tilt of the rocks has changed again - they are facing south again – so we have found the top of the fold in the rocks - an anticline. We talked earlier about the diatoms whose hard mineral body contributed to the sedimentary rocks. Where did the organic parts go? Some was consumed or decomposed, but some may have been trapped in the sediments - so an anticline may be a good place to look for oil.

The appearance and behavior of plants and animals vary with daily and seasonal changes in the environment including tides and weather as a result of natural selection.

Advanced Discussion Questions for the Darwin on the Bluff walk

- How do plants interact:
 - What do plants do for each other?
 - What do plants do to each other?
 - How do plants defend themselves from each other?
 - How do plants deal with each other's defenses?
 - How are plants related to each other phylogenetically?
- How do animals interact:
 - What do animals do for each other?
 - What do animals do to each other?
 - How do animals defend themselves from each other?
 - How do animals deal with each other's defenses?
 - How are animals related to each other phylogenetically?
- How do plants and animals interact:
 - What do plants do for animals?
 - What do animals do for plants?
 - What do animals do to plants?
 - How do plants defend themselves from animals?
 - How do animals deal with plant defenses?
- How do algae, fungi, and bacteria interact with plants:
 - What do algae, fungi, and bacteria do for plants?
 - What do plants do for algae, fungi, and bacteria?
 - What do algae, fungi, and bacteria do to plants?
 - How do plants defend themselves from algae, fungi, and bacteria?
 - How do algae, fungi, and bacteria deal with plant defenses?
 - How are algae, fungi, and bacteria related to plants phylogenetically?
- How do algae, fungi, and bacteria interact with animals:
 - What do algae, fungi, and bacteria do for animals?
 - What do animals do for algae, fungi, and bacteria?
 - What do algae, fungi, and bacteria do to animals?
 - How do animals defend themselves from algae, fungi, and bacteria?
 - How do algae, fungi, and bacteria deal with animal defenses?
- How do algae, fungi, and bacteria interact:
 - What do algae, fungi, and bacteria do for each other?
 - What do algae, fungi, and bacteria do to each other?
 - How do algae, fungi, and bacteria defend themselves from each other?
 - How do algae, fungi, and bacteria deal with each other's defenses?
 - How are algae, fungi, and bacteria related phylogenetically?
- How do energy, material, and information flow among the five or six kingdoms?
- What are the relationships between the solid Earth, hydrosphere, atmosphere, and biosphere as well as external influences of the solar system including the Sun, moon, asteroids, and interplanetary dust?
- What are the relationships between invertebrates, fish, amphibians, reptiles, birds, and mammals?
- Why do we have seasons? What causes tides? Would we have tides without the Moon? Why does the Earth rotate daily? Do tides vary seasonally? Why does the Moon rotate and revolve monthly?
- How do tides affect tide pool life? Who lives in tide pools?
- Where did Morro Rock come from? Why do continents move? Where did the continents come from? Where did the Earth, oceans, air, and Sun come from? Where did atoms like oxygen, carbon, nitrogen, silicon come from?
- How do plants "know" when it is time to grow and bloom? How do birds know when to migrate or produce breeding plumage? How do other animals know when to be active or dormant? How do seasonal changes in sunlight and moisture influence plants and animals? The summer thaw in the frigid zones keeps the oceans from freezing solid.

Darwin on the Bluff
1809 – 1831 - 1859
uniformitarian
geologist & naturalist
plausible natural explanations
for natural phenomena

sea sky land life
composition
structure
interactions
evolution

water cycle
rock cycle
energy flows:
nuclear fusion
radioactive decay

thermal convection
absorption
scattering
emission
chemical energy

Relationships
everything you see
depends on things
you don't see

biosphere cycles
carbon
nutrients: N, P, S
minerals: Si, Ca
energy flows

oxygenic
photosynthesis
cyanobacteria,
algae, & plants

evolution by
natural selection =
genetic variations
+ competition for
finite resources

relationships
family
working

six kingdoms
of biosphere
plants & algae
animals & fungus
bacteria & archaea

autotrophs
heterotrophs
producers
consumers
decomposers

What is lichen?
fungus plus
algae &/or
cyanobacteria

it's all about
relationships
everything evolves
complexity grows
when energy flows

cyanobacteria
endosymbiosis
chloroplast
chromoplast

co-evolution of
plants with
animals,
fungus & bacteria
& Earth's surface

multicellularity +
gene expression =
roots stems leaves
seeds flowers fruits
toxins colors smells