Evidence of Evolution

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Field(s) of Interest: Biology, Paleontology, Embryology

Brief Overview (1-3 sentences):
In this lesson, mentees will learn the basics of the evolutionary process and the types of evidence (embryological and paleontological) we use to make conclusions about evolution.

Agenda:
- Introduction (5 min)
- Module 1: Built Different (00-00 min)
- Module 2: I'm Just A Baby!!! (00-00 min)
- Module 3: Yo Mama So Old... (00-00 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:

Evolution: the theory that all living things are related and developed from earlier organisms
Adaptation: the process of change by which an organism becomes more suited to its environment
Embryology: the study of embryos
Vestigial Structures: features that exist in current species but have lost all function
Fossils: the remains or impression of a prehistoric organism in rock
Strata: layers of rock in the ground

Background for Mentors

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Module 1

- **Evolution**
- **Adaptation**

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Evolution is the theory that all organisms came from a single ancestor, and the process by which organisms developed and differentiated from previously existing organisms. The theory of evolution was first popularized by naturalist Charles Darwin in 1859 with the release of his book *On the Origin of Species*. The book documented Darwin's observations of finches on the Galapagos Islands.

Evolution works through the mechanism of *natural selection*, which is defined by the differential reproductive success of individuals based on their heritable traits. Natural selection changes the distribution of traits in a population. *Microevolution* refers to evolution at a scale below the species level, meanwhile, *macroevolution* refers to evolution at the scale above species.

Because natural selection is a *non-random process*, it positively selects for advantageous traits and negatively selects for disadvantageous ones through altering the survival and reproductive success of individuals with those traits. Over time, this leads to a population generally well-suited to the current conditions of its environment. This is what is called the process of **adaptation**. An important point to note is that adaptation and natural selection occur at the population level. One example of adaptation is bacterial populations developing antibiotic resistance.

We can observe evolution through several means, including embryology, fossils, molecular biology, biogeography, and direct observation of microevolution. Learning about evolution is key to understanding our ancestries and can be applied to help us solve biological problems (especially in infectious disease). For example, we can trace disease-causing genes to help control diseases in people. In addition, learning about the evolutionary patterns of bacteria can help us stay ahead of pathogenic diseases.

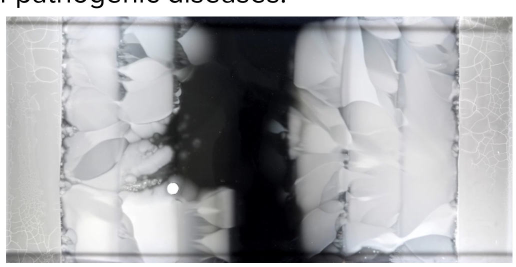

Figure 1: This bacterial strain was exposed to different concentrations of an antibiotic (increasing going inwards), and developed resistance, eventually colonizing the whole space.

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Module 2 ● Embryology ● Vestigial structures	See right column content below

Embryology is the study of embryos and their development, formation, and growth. Oftentimes, structures present in embryos may not appear in adult form. For instance, all vertebrate embryos develop gill slits and tails in early development. However, these traits are lost by birth for species in terrestrial groups like great apes. Hence, embryology provides additional insight to evolution. The process of embryo development is unique to each species, but evolutionary similarities can be compared. Not to mention, organisms with similar embryos are proof of a common ancestor. If they look similar for a longer period of time, the ancestor is likely a more recent one.

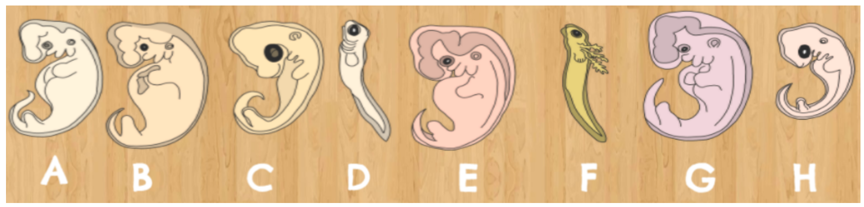
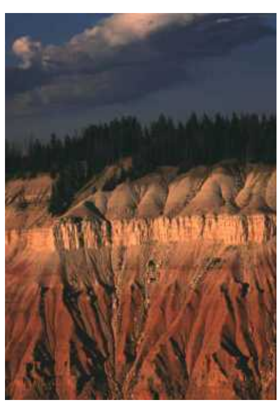


Figure 1. Comparative embryology gives insight into adaptive changes and evolution

Vestigial structures are features that exist in current species but have lost all function. They are evidence of evolution and are caused by changes in environment or behavior. Although futile, vestigial structures will persist until eliminated through genetic drifts or other events (eg. natural selection). For example, human vestigial structures include the following: wisdom teeth, the appendix, tonsils, and the coccyx. Wings of flightless birds and the pelvic bone of snakes are also considered residual features of a past ancestor.

Figure 2. A whale's pelvis has no necessary use but is evidence of a past ancestor. The feature has remained to aid in reproduction.

Module 3 ● Fossils ● Strata	**Fossils** are the remains or impression of an organism from a previous geological time period that has been preserved in the Earth's crust. Many things can be fossils, such as plants, animals, and bugs, and they can take the form of bones, shells, impressions, and much more. The study of these prehistoric organisms is called *paleontology*. Paleontologists use fossils to better understand evolution, the environments, extinctions, and other prehistoric characteristics and events.  Figure 1: Dinosaur fossil. **Strata** are layers of rock in the ground in which fossils can be found. These layers are formed when sediments are deposited and pressed on top of each other, creating a type of rock called sedimentary rock. The fossils found in different strata of sedimentary rock can be used by paleontologists to understand the progression of different fossils. In sedimentary rock, the oldest strata are on the bottom, and the youngest are on the top. Fossils in the bottom layers look very different from any organisms alive today, while fossils in the top layers look much more familiar, like organisms around today. The fossils in top layers also tend to be more complex than older fossils in the bottom layers, as they have evolved through time. Paleontologists can look at fossils to discover when certain life forms evolved; they are able to date the rocks to figure out when each layer was deposited and piece together the history of evolution and when certain events occurred.  Figure 2: Layers of sedimentary rock.

Introduction

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Concepts to Introduce

- Evolution
  - The theory that all living things are related and developed from earlier organisms
  - Evolution continues to play a role today even if we cannot see it
- Embryos
  - The early developmental stage of an animal while it is in an egg or the uterus
  - For humans, an embryo is referred to as a fetus after eight weeks
- Fossils
  - Preserved remains or impressions of plants and animals buried in sediment

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Questions to Pique Interest

- How do we know that dinosaurs existed?
- How did humans come to be?
- How are we related to chimpanzees?
- What do babies look like before they are born?

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Scientists, Current and Past Events

- The naturalist Charles Darwin popularized the theory of evolution after observing finches and turtles on the Galapagos Islands.
- The Cambrian Explosion approximately 530 million years ago, is a relatively short period of time in which around 30 phyla rapidly appeared in the fossil record

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Careers and Applications

- Paleontologist - scientist who studies the history of life on Earth through fossil record
- Archeologist - scientist who studies human history and prehistory through excavation sites
- Evolutionary Biologist - scientists who studies theories of evolution, biodiversity, animal or plant behavior
- Fetal Medicine - branch of medicine that provides care for the fetus and mother, includes fetal growth, fetal disorders, and support for parents

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Module 1: Built Different

Mentees will learn the basics of the theory of evolution and how it leads to organisms being more adapted to their environment.

Teaching Goals:	Materials:
1. **Evolution:** the theory that all living things are related and developed from earlier organisms 2. **Adaptation:** the process of change by which an organism becomes more suited to its environment	● 1 printout per mentee BEAM final Lesson Module 1.pdf

Procedure

1. Ask the mentees if they have heard of evolution, and what they think it is. Explain the teaching goals and how the outcome of evolution is an organism (you can just say animal) that is more suited to its environment.
2. Each mentee will have a piece of paper with an outline of an animal, representative of a whole animal species.
3. The mentors will give different scenarios that that species might encounter, such as changes in the environment. The mentees will then draw additional features onto the animal that represent the species adapting new beneficial traits to survive in their new environments.
    a. **Scenario 1:** The area where the animal lives is a forest full of brown tree trunks and green grass and leaves.
        i. For this, the mentees could experiment giving their creatures types of camouflage, either through adding physical features or shapes to them or coloring them a certain way.
    b. **Scenario 2:** There are lots of trees where the creature lives, and it might want to go up and down the trees every once in a while, to get food or to rest in the branches.
        i. For this the mentees could draw claws or other features on the organism.
    c. **Scenario 3:** There is an even bigger creature that could eat this animal (therefore, it needs a way to protect itself or shoo off the other creature).
        i. For this scenario, the mentees could draw horns, spikes, polka dots, big teeth, or other things that could deter predators.
4. At the end of the simulation, each mentee should have a cool unique species that demonstrates evolution and adaptation.

Module 2: I'm Just a Baby!!!

Mentees will learn that because some animals existed so long ago, we can't see them any more. Embryology can be used as one evidence of evolution. In this module, mentees will learn more about evolution and what embryology is.

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Teaching Goals

1. **Embryology**: the study of embryos and their development
2. **Vestigial structures**: features that exist in current species but have lost all function due to evolution

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Materials

- 5 printout pages per site
  Cut 5 of the printouts into two card decks
  The other 5 are answer keys
  One set of animal labels (fish, salamander, turtle, chicken, sheep, and human) per group

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Procedure

1. Mentees will be split up into 5 small groups.
2. Each group will be supervised by a mentor and will receive printed cut-outs with early stage and late stage embryos of 6 different animals.
3. Have mentees sort the late-stage embryos into what animal they think they belong to (Fish, salamander, turtle, chicken, sheep, or human).
4. Mentors will determine if the sorting is correct and can point out/discuss the physical traits that characterize each embryo.
5. Mentees will observe the early-stage embryos and their features. Through similarity in features (ex. tail), discuss vestigial structures. For instance, one of the embryos must be human, but all of them have tails.
6. Mentees will then sort early-stage embryos according to what animal they think they each are (Fish, salamander, turtle, chicken, sheep, or human).
7. Mentors will correct the sorting and explain similarity in embryos. All early stage embryos look alike but changes become more noticeable in the late stages (ex. Chicken and sheep).

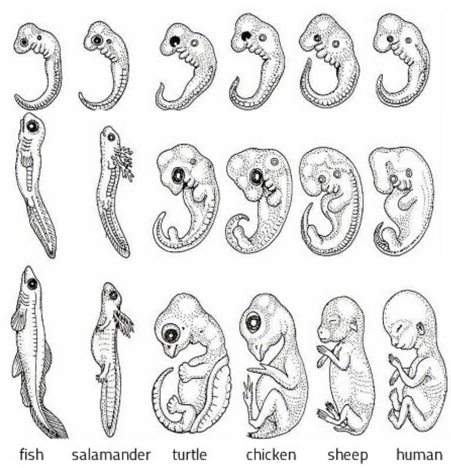

Figure 1: Embryo stages used for sorting

Classroom Notes

Sorting the early-stage embryos may be difficult, but allow for a mix of guesses

Module 3: Yo Mama So Old…

Mentees will learn about fossils and how they are formed. They will learn about how we can use strata of the fossil record to show the timeline of a species' existence.

Teaching Goals:	Materials:
1. **Fossils:** The remains or impression of a prehistoric being preserved in rock 2. **Strata:** Layers of rock in the ground in which fossils can be found	Per group of 6 mentees: ● 1 sandbox/container of sand ● 2 pieces of cardboard interspersed through the sand to represent Strata ● 8-12 paper fossils spread throughout the sand and strata ● **Lowest Layer**: Mollusk, Fern, Trilobite ● **Middle**: Dinosaurs, Dragonfly, Fish, Spider ● **Top**: Chicken, Dodo, Crab, Bird, Lizard ● Beam Final Lesson Module 3.pdf ● Digging materials (hands, plastic utensils, etc) ● Something to scoop the sand with

Procedure

1. Prior to the lesson, mentors should construct the boxes so the fossils are relatively evenly distributed and **the more complex fossils are in higher strata.**
2. To construct each dig site, put these things in the sandbox in this order:
   - A layer of sand
   - 3 fossils
   - A sheet of cardboard

   When finished, there should be 3 layers. The box holding the sand should sit inside a pie tin to minimize spill over.
3. Split the mentees into 4 groups, and give each group a dig site.
4. Taking turns, each mentee will scoop sand out of the way until they find a fossil. **Tell the mentees not to throw sand out of the box.**
5. Remove the fossil, and pass the tools off to the next mentee.
6. When the mentees encounter the cardboard, the mentor will remove it.
7. When all the fossils have been discovered, ask mentees what differences they see between fossils found in different strata. (The more simple ones are lower down).
8. **Make sure to mention that we can view strata in rock as a timeline for earth's history. The youngest layer is on top, and the oldest layer is on bottom.**
9. As best as possible, collect all the loose sand in a bin.
10. See pictures below for what the activity looks like

Classroom Notes: Control the sand (to the best of your ability) for the love of everything you consider good and/or holy in this world. To take the dig sites apart, remove all the fossils and cardboard, then scoop the sand into the bag. Once the amount still in the bin is small enough, pour it into the bag. Please please do this outside.

Do the same process for the last layer

Conclusion

In this lesson, mentees learned three different pieces of evidence for the theory of evolution, which are the existence of well-adapted organisms, similar embryology, and fossils. First, they modeled the evolution of a creature by creating adaptations to help it survive in its environment over time. They also learned how human embryos are similar to those of other animals, and how vestigial structures show this similarity. Lastly, the mentees searched for fossils to learn how organisms became more complex over time. Ask mentees what activities in the lesson they liked best, and what was their favorite thing they learned about!

References

- Understanding evolution is important, UC Berkeley. Understanding evolution
- Vestigial Structures, Biology LibreTexts. Vestigial Structures
- Evolutionary Embryology, Yashaswi Sharma, Microbe Notes. Evolutionary Embryology
- Evidence of Evolution, Biology LibreTests. Evidence of Evolution
- Fossils 101: The Basics of Paleontology, wttw. Fossils 101: The Basics of Paleontology
- Fossil Layers, New England Complex Systems Institute. Fossil Layers

- Add references in case your mentors want additional information!
- Title of Source, Author, Organization. http://www.example.com/

Summary Materials Table

Material	**Amount per Site Expected $$ Vendor (or online link)**
Printout for Module 1	25 per site
Printout for Module 2	5 per site
Printout for Module 3	25 per site