The Origin of a Species—A Snake in the Grass

EVOLUTION

Lesson Set 1 of 5

NCSE
National Center for Science Education

Teacher Prep

Age Levels: 9th-12th grade

Time Commitment: 7 days
(if all activities completed)

Key Vocabulary/Concepts:
characteristics, traits, evolution, inherit, genetics, species, speciation, fossils, variation, extinct, ancestor, selective pressure

Materials:

- Sticky notes, small sheets of paper, individual whiteboards
- Pens, pencils, markers, dry erase markers
- Rulers
- 3D-printed or computer images of snake vertebrae
- Digital calipers
- 2 empty cylindrical containers (such as Pringles cans, rinsed and dried)
- Uncooked dry rice or beans
- 2 small prey items such as toy mice
- 2 bins or trays to capture rice or beans
- 1 wooden craft stick
- Duct tape
- Scissors
- Eye finger puppets (optional)
- 12 plastic eggs (2 pink, 2 orange, 2 yellow, 2 green, 2 blue, 2 purple)

Continued on next page.

Introduction

This lesson set explores the speciation of squamates—otherwise known as scaled reptiles—like lizards and snakes by examining the genetic and environmental factors that led to limb reduction and the human impact on snake morphology.

Teacher Goals

1) Provide structured opportunities for students to ask questions that drive the learning process.
2) Develop students' ability to synthesize multiple sources of data regarding the evolution of lineages (such as squamates) from a common ancestor.
3) Provide tools necessary for evaluating how environmental conditions and genetic variation result in the emergence of species over time.

Student Learning Goals

1) Generate questions in order to clarify: a) the relationship between genetics and evolution; b) speciation; and c) the human impact on the evolution, expansion, and extinction of species.
2) Compare and contrast characteristics of modern and ancient lineages (such as squamates) in order to create a phylogenetic model and justify the claim of common ancestry.
3) Explain how the environment in which a species lives creates pressures that lead to the adaptation of a population over time.

Evolution Lesson Set Series

https://ncse.ngo/supporting-teachers/classroom-resources

EVOLUTION

Teacher Prep (continued)

- Pop beads or pony beads and Chenille stems (bead colors: 21 red, 19 orange, 41 yellow, 24 green, 36 blue, 16 purple)
- Permanent markers

Apps and Software:
- Google Jamboard or Google Drawings
- Graphing software (Excel, Google Sheets, Vernier LoggerPro, or Vernier Graphical Analysis)
- MorphoSource
- OneZoom

Student Learning Goals (continued)

4) Justify the cause-and-effect relationship between an environmental change and its impact on a population. Examples of impact include: increasing the number of individuals, causing the emergence of a new species over time, or causing extinction.

Background

Teacher Knowledge

Nature of Science

It's recommended that students work through the NCSE Nature of Science lesson sets at some point during the year. However, if this is not possible, be sure to introduce students to FLICC, a framework for understanding science denial, prior to presenting this lesson set. *Part E: The Characteristics of Science Denial* in Nature of Science Lesson Set 1: Science is a Way of Knowing is especially valuable. It takes students through several examples of FLICC in action while dismantling common misconceptions about the COVID-19 pandemic. Learn more about FLICC.

Evolution

Evolution explains many aspects of biology and is an indispensable part of a life science curriculum. The scientific community sees evolution as the unifying principle of *all* biology. The biological unity of life on our planet can be understood by examining anatomical features, genetics, or embryological development; this evidence can be used to identify a common ancestry of different species. Likewise, the diversity among life on our planet can be understood through the lens of evolution. Understanding how natural selection leads to speciation is a part of that story.

This lesson set is meant to help students understand the role of evolution in the emergence of new species and the role that genes have in this process. If a refresher on evolution is necessary, consider checking out the University of California Museum of Paleontology "Understanding Evolution" resource or Nature Education's primer "Speciation: The Origin of New Species" before introducing this curriculum to your students.

Discussion Points

- What is the relationship between genetics and evolution?
- How do natural selection and other evolutionary processes lead to the emergence of a new species?
- How do scientists model the evolutionary relationship between species?
- How do scientists use individual fossils to understand extinct species as a whole? To understand the climate in which these species lived?

Prerequisite Student Knowledge

Before starting the activities below, students should have some experience with extinct species and be able to identify some modern species and how they resemble species from Earth's past. They should also be able to express what the fossil record is and how the fossil record gives us information about the existence, diversity, and extinction of past organisms. Students should also be able to express that populations have genetic variability, and some of these genetic variations provide advantages to some individuals and disadvantages to others, leading (when the variations are inheritable) to natural selection. When the environment changes and individuals with beneficial traits survive, the genetic makeup of the population changes. Individuals in the resulting population tend to be better adapted to the new environment. The process of adaptation is ongoing and can lead to speciation.

Students should also have a working knowledge of the role played by DNA and chromosomes as the instructions for traits that are passed from parents to offspring.

Core Misconceptions

✘ **MISCONCEPTION:** *Every species arose uniquely.*

✔ **FACT:** The concept of species helps humans provide discrete names to the diversity of our world, but all species share a common ancestry and are a part of a continuous spectrum of life.

✘ **MISCONCEPTION:** *Evolutionary processes cannot result in significant changes—including the emergence of new species—in populations over time*

✔ **FACT:** Such significant changes—including, but not limited to, the emergence of new species—can indeed result from the processes of natural selection, mutation, migration, genetic drift, and reproductive isolation (in numerous variations and combinations).

✘ **MISCONCEPTION:** *No one has observed speciation.*

✔ **FACT:** Scientists have numerous examples of speciation that have occurred, including speciation events that are currently happening at the present time. Additionally, the fossil record supports the current findings of speciation.

✘ **MISCONCEPTION:** *Differences in phenotype are due exclusively to differences in DNA sequences.*

✔ **FACT:** Because all organisms share many of the same genes, differences in DNA alone cannot account for the different phenotypic traits of each species. Phenotypic traits are influenced by both genetic and environmental factors.

Teacher Instructions

Anchoring Phenomenon

Anchor: A Titan of a Snake

- Ask students to think about the following questions:
  - *What are the largest species of snakes?*
  - *How long do you think snakes can grow?*
- Provide students with rulers or meter sticks. This will help them to better visualize the lengths in both their predictions and the description of *Titanoboa*.
- Introduce students to Titanoboa. Play the Smithsonian Channel video Titanoboa: Monster Snake—What Does it Take to Make a Monster Snake? (1:10).
- After the video, ask students to recount what they remember from the video. Ask students what the approximate diameter and length of *Titanoboa* was. Inform the class that its diameter was roughly three feet.
- Ask students to stretch out string, yarn, ribbon, or other visualization tool precut to 48 feet to show the length of Titanoboa.
- Pair students up and have each pair of students discuss the following questions:
  - *What do you know about snakes?*
  - *How and why did snakes evolve their characteristics?*

Driving Question Board: A Snake in the Grass

- If you're working in-person or without access to digital media, then create a physical version of the Driving Question Board that can be displayed prominently in the classroom. Provide students with sticky notes so they can add their questions to the board.
  Note: *The sample Driving Question Board (DQB) can be found in the Teacher Resource Folder linked above. Please make a copy of the template provided before beginning the activity.*
- Organize students into pairs. This will allow them to have someone to help develop their questions. On the class DQB, have each student pair type or write one or more open-ended snake evolution questions on separate sticky notes, along with their initials. Open-ended questions require answers beyond yes or no or a single word. If students are struggling to think of open-ended questions, have them consider questions related to snake genetics, snake traits, or snake behavior. Sample open-ended questions include:
  - *What environmental conditions contributed to Titanoboa growing so large?*
  - *How is length inherited in snakes?*
  - *What tactics do snakes use to catch their prey?*
- Read a few of the student-generated questions aloud to the class. Inform the class that you will view all sticky notes later and organize them into groupings. After class ends, arrange similar questions into categories and add subtitles above the sticky notes.

Anchoring Phenomenon (continued)

Driving Question Board: A Snake in the Grass (continued)

- The DQB is meant to guide instruction and therefore should be referenced periodically, such as at the start of a class or when transitioning between activities, to highlight what questions have been answered and where the storyline is headed next. Not all student-generated questions will be answered. At the end of the storyline, teachers may elect to have students do research to address the unanswered questions.

Storyline Activities

Part A: Back-to-Back

- Using the *Back-to-Back Student Handout*, read the prompt and task aloud to the class. Have students work in groups to measure and calculate estimated sizes for each snake type using either the *Back-to-Back: Squamate Vertebrae Samples*, 3D-printed vertebrae, or the MorphoSource website.
- Students will then apply the knowledge gained from estimating sizes to explain how average long-term temperature can affect squamate body sizes as they complete the *Back-to-Back Student Handout*. Go over the correct answers with the class.
- Say to the class, "*Let's go back about 59 million years to the rainforest of South America and then watch the events of Titanoboa's discovery!*" **Play only the first 2:36 seconds of the PBS video** "How a Hot Planet Created the World's Biggest Snake" (8:04). ***Note:*** *it is important to watch only the first 2:36 because otherwise it will give information about the next lesson.*
- Following the video, answer the following questions as a whole group to check for understanding:
  - *Where in South America was Titanoboa discovered?*
    Colombia, in a coal mine.
  - *How was the climate different when Titanoboa lived?*
    Warmer, more tropical.
  - *What family of snakes did Titanoboa belong to?*
    Boas, which is why "boa" is the suffix of the name Titanoboa.

Part B: Go Out on a Limb

- Using the *Go Out on a Limb Jamboard or Go Out on a Limb Student Handout*, read the prompt and ask students to individually write answers to the two questions at the bottom of the page:
  - *What do you notice?*
  - *What do you wonder?*
- Next, have students share their ideas with a peer seated nearby, then select students to share their ideas with the entire class. The teacher should remain neutral to all ideas presented.

Storyline Activities (continued)

Part B: Go Out on a Limb (continued)

- Organize students into small groups and say to the class, "*Let's investigate the evolution of squamates or squamata. Squamates are scaled reptiles, like lizards and snakes. Turtles, alligators, and crocodiles are not members of the order Squamata. Your group will be examining a set of 10 cards. The blue cards are extinct reptiles, and the orange cards are extant or living reptiles. Your task is to use the cards to model how you think the organisms evolved and to draw lines indicating divergence of new species over time.*"
- Shuffle the *Go Out on a Limb: Squamate Speciation Cards* and pass out a set to each group. Actively monitor student groups and discuss their ideas and work. Ask probing questions and provide guidance to move thinking forward without providing answers. For example, if students are not sure where to begin, suggest they compare and contrast the squamates to determine which are more closely related. Or suggest they organize the blue cards first, then add the orange cards. If a group is creating a linear model, ask them to consider whether evolution proceeds in a straight line or in a branched, tree-like manner.
  Note: *The card activity may be done digitally using the Go Out on a Limb: Squamate Speciation Jamboard.*
- After sufficient time, do a gallery walk. Hand out sticky notes to each student and prompt students to write a comment (I notice…) and a question (I wonder…) on the sticky note and leave it at each model they visit. Alternatively, you can ask students to vote on which models they think best reflect squamate speciation and provide reasoning for their vote.
- Discuss with the class what made some models better representations than others. Exemplary student models will begin with the base ancestral organism having four robust legs (*Megachirella*); show limb reduction occurring over time; and be branched or tree-like in representation with lines drawn between organisms and the extinct blue cards positioned as short dead end branches lower on the tree, with longer extant orange branches extending towards the top of the evolutionary tree.
- **Teacher Tip:** Be aware that evolutionary trees are hypotheses based on current evidence and that experts do not always agree on the branching points. In addition, there is not a consensus among evolutionary biologists on which squamate was the first four-limbed reptilian ancestor, but most experts accept *Megachirella* as the strongest contender.
- Provide students with time to revise their models based on the exemplary components identified by the class after the gallery walk and the class discussion. Students should also use this time to complete the *Go Out on a Limb: Squamate Speciation Student Handout*.
- Say to the class, "*Let's analyze an expert-derived evolutionary tree.*" Direct students to explore the OneZoom website or demo the website to the class. Search for "squamata" in the "Search all life …" search box at the top of the webpage, then select the first entry "Lizards and Snakes." Use the following discussion questions to guide student learning:
  - *When did the first ancestor of squamates evolve?*
  - *What evidence is there that four-limbed reptiles evolved before more of the limbless reptiles?*
  - *Where on this evolutionary tree should Titanoboa be placed?*

Storyline Activities (continued)

Part B: Go Out on a Limb (continued)

- Say to the class, "*Let's revisit the video from yesterday*." Play the remainder of "How a Hot Planet Created the World's Biggest Snake" (8:04). Use the following questions in order to guide students' thinking:
  - *How does the second half of this video connect to what we have learned so far?*
  - *How has the second half of this video extended your understanding?*
  - *What new questions have arisen for you?*

Part C: Do You Dig It?

- Ask the class the following questions and allow for responses. Remain neutral to all ideas presented.
  - *Why did snakes lose their limbs?*
  - *What is the evolutionary advantage for snakes to be limbless?*
- Say to the class, "*We will model the environmental selective pressure that may have contributed to limb loss in snakes*." Ask for two student volunteers. These students should have narrow hands that are able to fit comfortably into a Pringles container. If you are using the eye finger puppets, please be aware that these have a small ring size; students may need to pull the two eyes apart slightly to wrap the puppets around the base of their fingers. Say to the class, "*The dominant hands of the volunteers will represent snakes for this demo*."
- Show the class the two Pringles containers that are filled with the dry rice or beans and have a small mouse toy at the bottom. Say to the class, "*These cans represent a burrow and there is prey inside. The task of our two volunteers is to hold the burrows upright with their nondominant hand and use their 'snake hand' to retrieve the prey as quickly as possible when I give the signal*." Have the volunteers complete the activity over an empty tray if possible to allow for easier cleanup.
- Countdown from three and prompt the two volunteers to retrieve the prey as quickly as possible with their "snake hands."
- Afterwards, say to the class, "*Recall the ancestor of snakes had limbs. We will now model a limbed ancestor.*" On the winning volunteer's "snake hand" place a wooden craft stick perpendicular to the palm. Secure the stick in place with duct tape. The wooden craft stick should only be added to the volunteer who won the first burrowing competition.
- As before, place the prey at the bottom of the burrow and fill the containers with dry rice or beans. Count down from three and prompt the two volunteers to retrieve the prey as quickly as possible for a second time. Students will witness that the limbed ancestor is unable to burrow very far and will likely not retrieve the prey or will retrieve it more slowly, while the limbless snake successfully completes the task.
- ***Note:*** *While this demonstration is simplistic, it is meant to model the actual environmental pressure of burrows that likely contributed to limb loss in snakes. In addition, the value of watching the volunteer with limbs struggle to reach the prey will have a positive effect on student understanding and retention.*

Storyline Activities (continued)

Part C: Do You Dig It? (continued)

- Ask the class the following question and allow for responses.
  - *Aside from capturing small prey, what are some other reasons snakes go into burrows?*
    Possible answers include that snakes use burrows to hide from predators, sneak up on prey above ground, lay eggs, or seek shelter for thermoregulation.
- Say to the class, "*Now that we understand why snakes evolved to not have limbs, we will watch a short video to understand how this happened at a genetic level.*" Play the University of Florida video "UF Health researchers uncover how snakes lost their legs" (2:55).
- After the video, engage the class in a discussion using these guiding questions:
  - *What gene is required for limb development?*
  - *How is gene expression different in a python (or boa) compared to limbed organisms?*
  - *Do major changes to the body plans of organisms such as limb loss occur due to many genetic changes or due to a few genetic changes?*
  - *Did the three genetic changes responsible for limb loss occur in the SHH gene or elsewhere in the snake's DNA?*
- **Activity Variation:** Older students may find that their hands do not quite fit into the Pringles can. If this is the case, teachers may want to obtain cylindrical 22-oz raisin containers or oatmeal containers.
- **Teacher Tip:** To complete this activity in small groups, obtain enough containers for each group of four to have two containers. Assign the following roles to the students: squamate 1, squamate 2, recorder, material manager. Squamate 1 and 2 should complete the race as the recorder keeps the time. The recorder is also in charge of sharing out the group's findings. Materials manager is responsible for collecting and passing out the supplies and supervision of their safe use. Remind students that everyone is responsible for cleaning up.

Part D: A Twisted Tale

- Prior to class, prep the snake offspring, snake eggs, and amino acid bead chains using the instructions found in the *A Twisted Tale_Teacher Instructions*.
- Ask the students the following questions and allow for responses, while remaining neutral to all student ideas presented:
  - *How could humans influence the traits of snakes?*
  - *What impact could humans have on wild populations of snakes?*
- Say to the class, "T*o answer these questions, we will 'breed' and examine the genetics of ball python offspring, then investigate their status in the wild.*" Prompt students to read the Background section on the *A Twisted Tale Student Handout*. Model an example of transcription and translation for students if necessary.
- Divide students into small groups and actively monitor students as they complete the *A Twisted Tale Student Handout*.

Storyline Activities (continued)

Part D: A Twisted Tale (continued)

- Once students have completed the activity, bring the class back together in order to discuss the impact of artificial selection on color variation. Discuss how humans may influence the evolution of ball python coloration in the future.
- **Anchor to Activity—Tying it All Together:** Provide students with the opportunity to go back to the original questions they asked. Give time for students to reflect on what their question was, what they learned related to their question, and what new questions they have. Prompt students to think about how scientists might learn the answers to these questions or how they might go about researching it themselves. Students should share their reflections either in small groups or with the whole class.

Time After Deep Time Check-in: The Origin of a Species Timeline Cards

- If you would like students to create a timeline of biological and geological events connected to evolution throughout the NCSE evolution curriculum, review the teacher guide and materials for Evolution Lesson Set 5, Part D: Time After Deep Time, Variation 2: Integrated Activity.
- Have students set up the timeline. You may choose what event cards you would like to have students add to the timeline and when. Event cards are provided at the end of each lesson set.
- For this lesson set, students will sequence the major events that occurred in squamate evolution by putting the timeline cards in the order of occurrence they think best reflects squamate evolutionary changes. These cards are one component of a bigger timeline that ties all the National Center for Science Education evolution lesson sets together. *The Origin of a Species Cards* are a part of a bigger card set that connects each of the Evolution lesson sets together.

Extension Activities

Deeper Dive

- Snake Digestion Activity
- Snake Discovery: An Intro to Snake Genetics! (8:30)

Online Resources

- » Teacher Resource Folder
- » Smithsonian Channel Video: Titanoboa: Monster Snake—What Does it Take to Make a Monster Snake? (1:10)
- » PBS Eons Video: How a Hot Planet Created the World's Biggest Snake (8:04)
- » OneZoom interactive phylogenetic tree website
- » University of Florida Health Video: UF Health researchers uncover how snakes lost their legs (2:55)

Primary Literature/Works Cited

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