

Title: *“That Vertebrate Ate What Exactly? A lesson using bycatch discovery from CT scans”*

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Abstract:

Analyzing data from various sources is one of the invaluable skills any scientist must utilize to make new discoveries. During the course of this lesson, students will analyze CT scan data and observe bycatch (or an unknown discovery) captured during the scanning process of vertebrates. Using the images created from CT scans, the students will formulate ideas about what bycatch data can reveal about their lifestyle of that animal. Following the initial analysis the students will compare two separate CT scans of bycatch data and for the students to develop connections about known information of the organisms shown in the CT scans. Further extension of these first two phases will have the students will then compare the 3D pictures of the skulls, developed from CT scans of extant species of burrowing lizards, burrowing snakes and non-burrowing snake skulls. They will be tasked with relating the skull characteristics to the evolutionary history of snakes.

Subject, Grade, Level:

This activity is targeted for high school classrooms, grade 9th and 10th for Environmental Science and Biology. The activity is created for both regular and honors classrooms. Extension questions are designed to help teachers utilize the lesson and alter the rigor level to their specific classroom.

Learning objectives:

At the conclusion of this activity, participants will be able to:

1. Identify the general structure of a vertebrate skeleton.
2. Compare the known information about a vertebrate with the bycatch data in a CT scan.
3. Relate the anatomical structures and physiology of snakes to bycatch data.
4. Assess the skull changes of extant snakes with related species to their last common ancestor

Learning Standards:

- AP Biology Standard(s): Science Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.
- L.O. 1.2 -The student is able to evaluate evidence provided by data to qualitatively and quantitatively investigate the role of natural selection in evolution.
- L.O 1.11 - The student is able to design a plan to answer scientific questions regarding how organisms have changed over time using information from morphology, biochemistry and geology.

- L.O. 1.16- The student is able to justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.
- L.O. 4.11- The student is able to justify the selection of the kind of data needed to answer scientific questions about the interaction of populations within communities.

NGSS Standards

- HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
- HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

Florida Sunshine State Standards

- SC.912.L.15.1 Explain how the scientific theory of evolution is supported by the fossil record, comparative anatomy, comparative embryology, biogeography, molecular biology, and observed evolutionary change.
- SC.912.L.15.5 Explain the reasons for changes in how organisms are classified.
- SC.912.L.15.7 Discuss distinguishing characteristics of vertebrate and representative invertebrate phyla, and chordate classes using typical examples.
- SC.912.N.3.5 Describe the function of models in science, and identify the wide range of models used in science.
- SC.912.N.2.4 Explain that scientific knowledge is both durable and robust and open to change. Scientific knowledge can change because it is often examined and re-examined by new investigations and scientific argumentation. Because of these frequent examinations, scientific knowledge becomes stronger, leading to its durability.

Timeframe:

Instructor preparation- 60 minutes total- 30 minutes to create powerpoint(s), 30 minutes to prepare other materials worksheets

Three separate lessons: lasting five 60-minute periods; for 90 minute block schedules, 3 full periods and a 30 minute part of a 4th period

- For 60 minute periods: Part 1- 60 minutes, Part 2- 120 minutes, Part 3- 120 minutes
- For 90 minute block periods: Part 1 and 2 180 minutes and Part 3- 120 minutes

List of materials:

- Computer with Powerpoint and projector
- Student access to the internet to view images
- Student handouts

Procedure and general instructions (for instructor):

Part 1- Introduction to CT Scan Data

- Introduction 15 minutes: The lesson should begin with the instructor introducing their students to the oVert project and CT scanning.
- Suggested activity is a Powerpoint Presentation with the following information:
 1. Discussion about the oVert project and its goal of creating CT scans of 20,000 vertebrates with representation from most genera.
 - a. Sources of information:
 - <https://www.sciencemag.org/news/2017/08/new-3d-scanning-campaign-will-reveal-20000-animals-stunning-detail>
 - <https://www.floridamuseum.ufl.edu/science/overt/>
 2. The short video created by Science Magazine: <https://youtu.be/zGZJeNKTMQY> is a quick introduction about the project and basics of CT scanning. (Video running time 2:30)
 3. An additional video about CT scans creating many 2D images and then how the 2D images are used to create a 3D image can be shown to contrast CT scan with a standard x ray: <https://www.youtube.com/watch?v=l9swbAtRRbg> is recommended to be shown. (Video running time 1:30)
 4. Show several 3D images created from oVert CT scans from morphosource.com or sketchfab.com, including Frog eat frog.gif.
 5. Images to include access for the students to use are *Heterodon*, *Xenopus eyesoli*, *Paedophyrne*, *B. curupria* stomach in blue, *Bitis caudalis* and *Barborulua busagensis*

Student Activity Part 1 45 minutes:

1. Have the students work in groups of two to four students, with each group having access to one of the bycatch pictures on their computer.
2. Distribute the student worksheet for each student or group of students

3. Students will view the CT scan of a vertebrate answer the questions about the image on their worksheet.
4. After completing initial observations about the CT scan data, the students will then fill out information about the vertebrate in the scan.
5. The group will then formulate a short verbal (2-4 minutes) report to share with the class concentrating on what they learned about their respective vertebrate and whether the bycatch data is supports the known information or whether the bycatch data is not found in the known data.
6. Have the students share their verbal reports with the entire class and project their CT scan as they share their report.

Notes about the activity:

- Students are encouraged to ask one another questions about their conclusions and contradict other groups.
- Instructor should establish rules of decorum for the students to follow during their presentation and questioning

Part 2- Comparison of two CT Scans of Snakes

- **Introduction 10 minutes:** Review the CT scans used in Part 1 and the discussion about the bycatch data. Introduce the students to the 2D and 3D scans of the *Bitis caudalis* and the *Heterodon*, either on a projector or via their computer.

Student Activity Part 2 110 minutes:

1. Have the students work in groups of two to four students (a larger group would be easier to help with the research), with each group having access to both of the bycatch pictures of the *Bitis caudalis* and the *Heterodon*.
2. Distribute the student worksheet for each student or group of students
3. Students will view the 2D and 3D CT scans *Bitis caudalis* and the *Heterodon* and answer the questions about the images on their worksheet, including watching videos about each snake species.
4. After completing initial observations about the CT scan data, the students will then research and record lifestyle information about each of the snakes species.
5. The group will then formulate a short, creative verbal report (3-5 minutes) to share with the class about how each of the snakes ended up with the food in their bodies and what the bycatch data shows about that respective snake.
6. Have the students share their verbal reports with the entire class and project the CT scans as they share their report.

Notes about the activity:

- The story created by the students should be factual based, but creativity is highly encouraged.
- Students are encouraged to ask one another questions about their conclusions and contradict other groups.
- Instructor should establish rules of decorum for the students to follow during their presentation and questioning.

Part 3: Comparison of Extant Snake Skulls with Extant Burrowing Lizard Skulls

- **Introduction- 15 minutes** The lesson should begin with the instructor introducing their students to basic evolutionary history of snakes.
- Suggested activity a PowerPoint Presentation with the following information:
 1. Discussion about basic anatomy of snakes.
 2. Video of snakes evolution created by PBS, 'The Great Snake Debate' <https://www.youtube.com/watch?v=gIvrGtgVtr8> presents a quick background on snake evolution. (Running time 7:20)
 3. Introduction of three 3D models, one of a non-burrowing snake skulls, one of a burrowing skulls and one of a burrowing lizard.

Sources of information:

- A. Burrowing snake *Leptotyphlops scutifrons* <https://sketchfab.com/3d-models/leptotyphlops-scutifrons-mcz-r-36512-skull-99e3cb9e9e4741f1af88a860ae941dcb>
- B. Non-burrowing snake *Corallus caninus* <https://sketchfab.com/3d-models/tree-boa-snake-skull-7f48cbcbf2c94a7ea49b04b21ae83390>
- C. Burrowing lizard to be added

Student Activity Part 3- 45 minutes

1. Have the students work in groups of two to four students, with each group having access to the three 3D pictures on sketchfab.com
2. Distribute the student worksheet for each student or group of students
3. Students will view the 3D skulls on sketchfab.com and make observations about each, after completing initial observations on each 3D skull, the students will then answer questions about differences between the skulls and the evolutionary changes of snakes.
4. Discuss as a class what differences and similarities the students noticed about the skulls of the three animals. Continue the discussion about how the skull changes allow non-burrowing snakes to swallow large prey.

Notes: Teacher directed discussion should be focused on evolutionary changes to the non-burrowing snake skull as compared to the other two skulls.

Procedure and general instructions (for students).

- Part 1: View the CT scan image given to you and answer the questions on the worksheet about your image. Use resources on the internet to research about the organism in the picture. You will share your ideas at the end of the class.
- Part 2: View the two CT scan images given to you and answer the questions on the worksheet about your image. Use resources on the internet to research about the organism in the picture. You will share your ideas at the end of the class.
- Part 3: View the three 3D images given to you and answer the questions on the worksheet about your images. Discuss with the class your findings.

Student assignments related to the activity

- See worksheet attached for student activities related to Parts 1, 2, and 3.

Extension Ideas for High Level students

Part 1:

- Have the students research the limitations of using CT scans on organisms
- Students can describe the process of CT scanning and how different machines and lenses are used to create images of different type objects (i.e. lion versus frog)

Part 2:

- Use the biological data about either to both snakes and have the students create various ecological charts (food chain, food web, energy pyramid, etc.) about one or both snakes used in the activity and have the student include the prey items in their charts

Part 3:

- Use a phylogenetic tree to trace the evolution of snakes and lizards, focusing on the loss of limbs and changes to skull shape in snakes

Standards for Activity

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Reference list

Videos:

- <https://youtu.be/zGZJeNKTMQY>
- <https://www.youtube.com/watch?v=l9swbAtRRbg>
- <https://www.youtube.com/watch?v=gIvrGtgVtr8>

Articles:

- <https://www.sciencemag.org/news/2017/08/new-3d-scanning-campaign-will-reveal-20000-animals-stunning-detail>
- <https://www.floridamuseum.ufl.edu/science/overt/>
- <https://ssarherps.org/2019/03/herpetological-review-501-available-online/>
- <https://ssarherps.org/2017/06/herpetological-review-482-released/>
- <https://www.biotaxa.org/hn/article/view/32970/30569>

Websites:

- Sketchfab.com
- Morphosource.com

What Did the Vertebrate Eat?

Part 1: Introduction to CT Scan Data

Directions- You will be given a 2D CT scan of a vertebrate with bycatch data found during the scanning process. Make observations about the scanned organism and the bycatch data, while answering the following questions about your organism.

1. What is the scientific name and common name of your vertebrate?
2. Give the following information about your vertebrate:

Kingdom	
Phylum	
Class	
Order	
Family	
Genus	

Description of organism (body type and size, limbs, coloring, etc.)	
Location and description of their habitat	
Food commonly eaten by vertebrate	
Other interesting facts about organism	

3. What is bycatch data? How is it captured on a CT scan?

4. Describe the bycatch data seen in your image of the vertebrate (type of organism, location of organism and other relevant details)

5. Explain how the vertebrate likely encountered and then ingested the organism inside

6. How does this bycatch data support or change the known data about your vertebrate? (i.e. is the organism a normal food source or something not described as a normal food)

7. Imagine that you are conducting research about your vertebrate and their diet, how would you use the bycatch data on the CT scan as part of your research?

Verbal Report- *Create a short, 2 to 4 minute, report that will be shared with the class.*

Topic: What you learned about the vertebrate in the CT scan, the bycatch data and discuss whether the bycatch data supports the known information about your vertebrate or whether the bycatch data is not found in the known data.

What Did the Vertebrate Eat?

Part 2: Comparison of two CT Scans of Snakes

Directions- You will be given a 2D and 3D CT scan of two separate snakes, each with bycatch data found during the scanning process. Make observations about the scanned organisms and the bycatch data, while answering the following questions the scans.

Scan 1: *Bitis caudalis* (Horned Addler)

Fill out the background information on *Bitis caudalis*

Size	
Method of killing prey	
Habitat	
Food sources	

Search online and watch two videos that show and/or describe the lifestyle of *Bitis caudalis*, then share information you learned about the snake after watching the video. Record the URL of the video.

Video 1: URL _____

Information learned:

Video 1: URL _____

Information learned:

Scan 2: *Heterodon* (Hog-nosed snakes)

Fill out the background information on *Heterodon*

Size	
Method of killing prey	
Habitat	
Food sources	

Search online and watch two videos that show and/or describe the lifestyle of *Heterodon*, then share information you learned about the snake after watching the video. Record the URL of the video.

Video 1: URL _____

Information learned:

Video 1: URL _____

Information learned:

Directions- After conducting your research and watching the videos for each of the two snake species answer the following questions about the CT scan bycatch data, using both the 2D and 3D Scans

Scan 1: *Bitis caudalis* (Horned Addler)

1. Briefly describe the bycatch data shown in the CT scans (organism, location inside the snake, etc.)
2. How does the bycatch data of the lizard help to explain information about the lifestyle of the snake?
3. Contrast the digestive process of the lizard within the snake with your digestive process after eating a meal
4. Explain the size of lizard relative to the body size of the snake and describe the size of the meal that you would need to eat to be equivalent the lizard

5. Why must a snake swallow their prey whole, whereas a human can chew and swallow small bites of food?

Scan 1: *Heterodon* (Hog-nosed snakes)

1. Briefly describe the bycatch data shown in the CT scans (organisms, location inside the snake, etc.)
2. How does the bycatch data of the newt and the frog help to explain information about the lifestyle of the snake?
3. Contrast the digestive process seen in the horned adder with one shown in the hog-nosed snake
4. Explain how a hog-nosed snake could open their mouth wide enough to swallow a frog larger than its' skull
5. Based on the scans of the *Heterodon*, develop an explanation of how the frog created the damage to the hog-nosed snake

Verbal Report- Create a short (3 to 5 minute) report that will be shared with the class.

Topic: Explain, in a creative way, how each of the snakes ended up with the food in their bodies and what the bycatch data shows about that respective snake.

What Did the Vertebrate Eat?

Part 3: Comparison of Extant Snake Skulls with Extant Burrowing Lizard Skulls

Directions- You will access 3D images of a non-burrowing snake skull, a burrowing snake skull and a burrowing lizard skull. Make observations about each of the skulls and answer the questions on your worksheet.

Non-burrowing snake skull Species name _____

Burrowing snake skull Species name _____

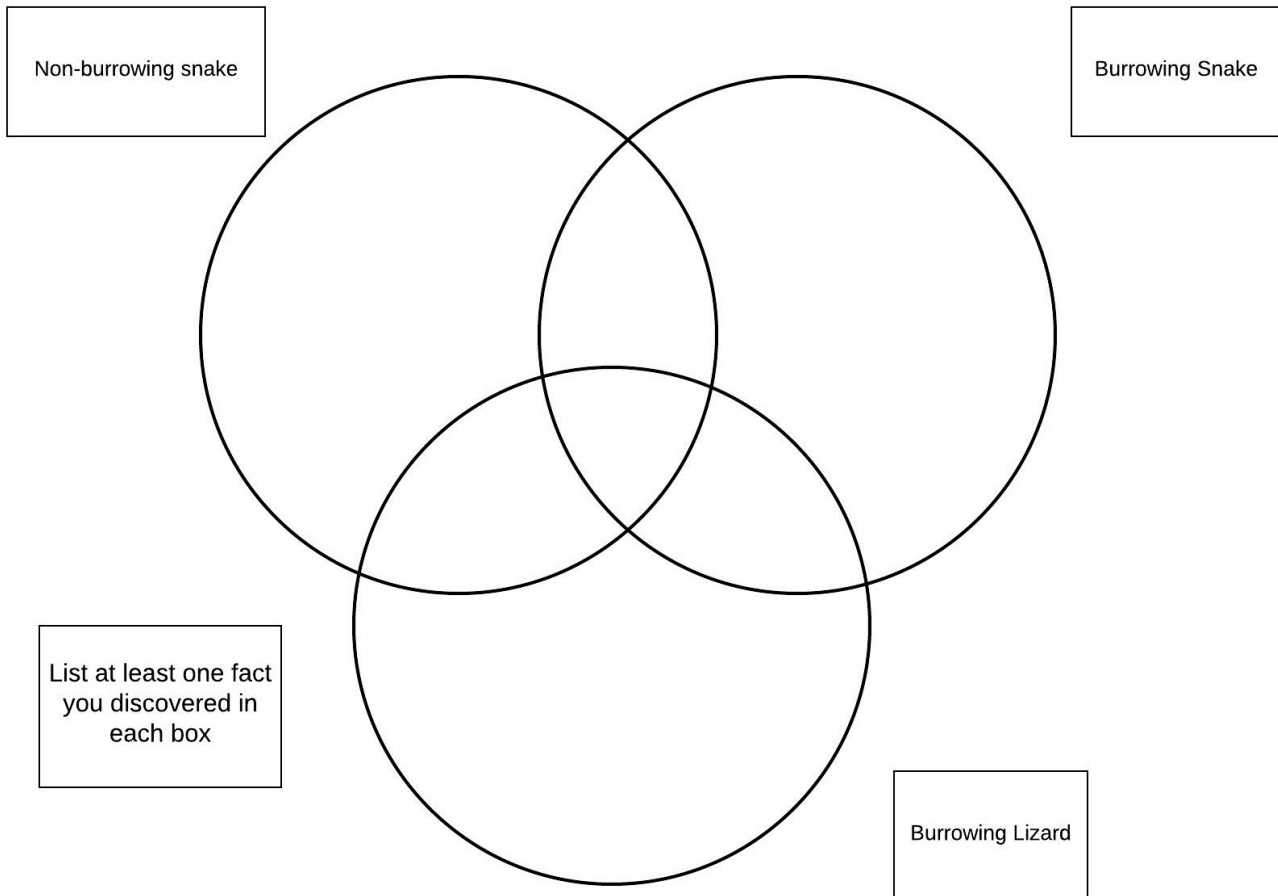
Burrowing lizard skull Species name _____

Fill out the chart below about each of the skulls:

	Non-burrowing snake	Burrowing snake	Burrowing lizard
Skull shape			
Top of skull			
Orbital (eye socket) shape			
Dentary (lower jawbone) shape			
Maxilla (upper jawbone) shape			
Teeth structure and size			
Number of teeth (note any fangs)			
Nasal openings			

Any additional notes about the skulls:

Complete the Venn Diagram the characteristics of the skulls



Answer the following conclusion questions about snake evolution:

1. The current theory about the evolution of snakes is that their last common ancestor was with a burrowing lizard before losing their legs completely. What advantages for survival did finally losing their limbs give snakes over their ancestor?
2. Snake that live on land and do not burrow are more common throughout the world, why would snakes stop burrowing and live aboveground full time?
3. Discuss the advantages and disadvantages of swallowing your prey whole versus chewing and swallowing your prey like mammals.