Teachers' Guide: Introduction to MorphoSource and 3D Anatomy

The activities are largely adapted from: https://www.sciencenews.org/learning/guide/component/a-peek-inside (can view in incognito mode or by removing cookies) and expanded and modified by the NoCTURN Education & Outreach Community.

Grade Level: Grade 6–12 (additional activities are provided for higher grade levels)

Lesson Plan Length: 50-80 minutes

Science Education Standards:

Grades 6-8

- Waves and their Applications in Technologies for Information Transfer
    - MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials: https://www.nextgenscience.org/pe/ms-ps4-2-waves-and-their-applications-technologies-information-transfer
    - MS-PS4-3: Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals: https://www.nextgenscience.org/pe/ms-ps4-3-waves-and-their-applications-technologies-information-transfer
- From Molecules to Organisms: Structures and Processes
    - MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively: https://www.nextgenscience.org/pe/ms-ls1-4-molecules-organisms-structures-and-processes
- Biological Evolution: Unity and Diversity

Grades 9–12

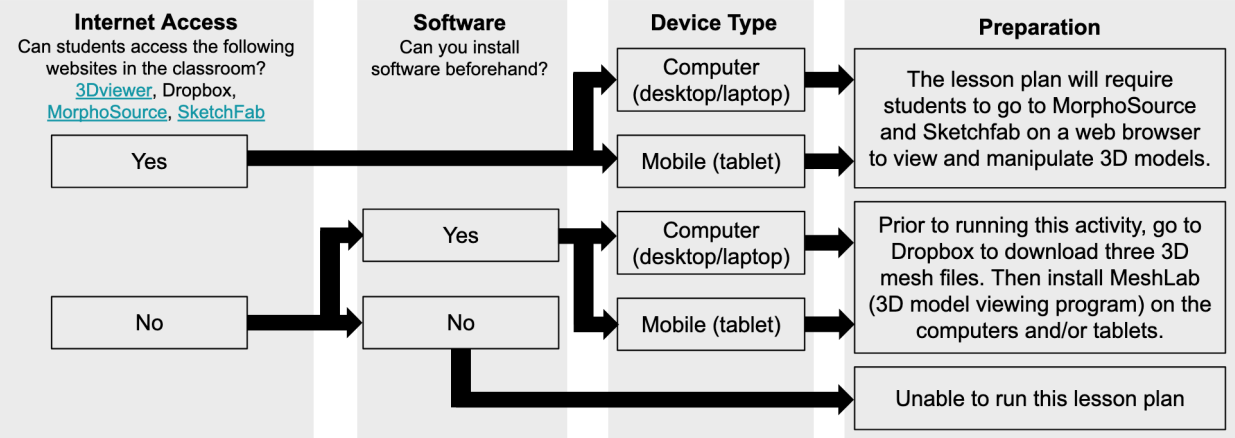
- Waves and their Applications in Technologies for Information Transfer
    - HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter: https://www.nextgenscience.org/pe/hs-ps4-4-waves-and-their-applications-technologies-information-transfer
    - HS-PS4-5: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy:

https://www.nextgenscience.org/pe/hs-ps4-5-waves-and-their-applications-technologies-information-transfer

- Biological Evolution: Unity and Diversity

Required Materials:

- ☐ Computing devices (for each student or for a group of 2–4 students). The diagram below indicates the preparation needed depending on the computer resource available.
- ☐ Printout of worksheets (1 per student or group)
- ☐ **If there is no reliable classroom Internet access:** Print out the "See 3-D models of animal anatomy from openVertebrate's public collection" article featured in *Science News*.
- ☐ **If there is no reliable classroom Internet access:** Print out the *Science News Explores* article "Scientists Say: CT scan."
- ☐ **If there is no reliable classroom Internet access:** 3D models of specimens downloaded from Dropbox [insert link]
- ☐ **If there is no reliable classroom Internet access:** MeshLab program (install on computer devices prior to running this lesson plan)



Learning Objectives:

After going through these exercises, the students should be able to:

- Understand the value of scanning animals for scientific research by providing examples and explaining their potential benefits.
- Briefly describe how computed tomography (CT) data is collected (as stack of images) and what it allows us to see in the animal
- If students have Internet access, apply an understanding of data repositories to navigate MorphoSource, request and download a 3D anatomical dataset of an animal using the MorphoSource web tools.

Directions for Teachers:

1. Confirm the computing devices and Internet access you will have in your classroom. Because hardware and software capabilities vary and changing constantly, we strongly advise that the teacher first ensures that the activities can be done on their classroom devices prior to running the lesson plan. For questions and troubleshooting, the Education & Outreach members of NoCTURN are happy to assist!

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2. You can become acquainted with the tools by following these step-by-step instructions here: https://www.floridamuseum.ufl.edu/digital-lab/resources/access-ct-scans-online/
3. Visit the NoCTURN homepage and contact a member of the Education & Outreach community of NoCTURN (https://nocturnetwork.org/organization-structure-of-nocturn/communities/education-and-outreach-community/). See if there is a member who is located nearby who can potentially visit the school in person. If not, connecting through phone or video conference is always a good option.
4. Ask students to read the *Science News* article "See 3-D models of animal anatomy from openVertebrate's (oVert's) public collection" and answer the set of questions below. Students can work alone or in a group of 2–4 students for the second section of the activity, "Making observations." For background information on CT scans, point students to the *Science News Explores* article "Scientists Say: CT scan."
5. Printout questions related to the *Science News* article, pre-set animal species (Mexican Bearded Lizard, Aquatic Caecilian, Lined Seahorse), and additional optional questions
6. If you'd like, students can be given an opportunity to present their animal and their findings to class.

Directions for Students

Read the *Science News* article "See 3-D models of animal anatomy from openVertebrate's public collection" and answer the questions below.

https://www.floridamuseum.ufl.edu/science/scientists-ct-scanned-thousands-of-natural-history-specimens-which-you-can-access-for-free/ - instead of science paywall

I. Scanning Animal Diversity (with answer key)

1. What is the purpose of the openVertebrate project? Why is it called "openVertebrate"?

Aims to make vertebrate specimens freely available online. It is called "open Vertebrate" because putting the scans up online and making it "open" for people to share and download the data.

2. How will having a freely available repository of 3-D models or CT scans of specimens increase scientific understanding? How is it different from studying just model organisms like mice?

It will increase the accessibility of data on specimens and allow for more scientists to do research on individual organisms and compile information on different species. It also allows citizen scientists to access the repository and potentially contribute to scientific studies.

3. What are the benefits of using CT scan-generated 3-D models of specimens to learn more about animal anatomy? How does this compare with traditional investigations by dissection?

A 3-D model allows scientists to visualize the internal anatomy of an organism. As compared with a traditional dissection, a 3-D model allows researchers to see more of an organism's internal anatomy and its arrangement in a non-destructive way. Using CT scans to study a specimen causes less damage than traditional dissection would.

4. Describe how the 3-D models of each organism were created.

To take CT scans, scientists placed specimens in tubes and took X-rays of each specimen as its tube was rotated, producing a 3-D image. Prior to scanning, some specimens were soaked in iodine to make the muscles and organs visible.

5. What was one of the challenges scientists faced while developing a method to scan each specimen?

Each specimen needed to be mounted inside of the tube. But vertebrates come in various shapes, so scientists needed to find a material that would hold the specimens in place without damaging the samples or showing up on the CT scan.

Some specimens are large and don't fit in the field of view of the CT scanner. Sometimes scientists will scan half a specimen before repositioning it to scan the other half, and then stitch the two scans together.

Museum specimens came in a broad range of different sizes. Researchers have to adjust the "power" of the X rays to penetrate the specimen (higher power for larger specimens, lower power for smaller specimens.

Additional Questions for Grade 9–12 (with classroom Internet connection):

6. How many known species of vertebrates are in the world today? Calculate the percentage of species that have been scanned so far through the oVert program.

There are about 70,000 known vertebrate species alive today: ~6,400 mammal species, >10,000 bird species, 11,000 reptile species, 8,000 amphibian species, and >34,000 fish species. 13,000 museum specimens were scanned through the oVert project, so 13,000/70,000 = 18.6%.

7. Watch the video linked in the *Science News* article "Here's why pumpkin toadlets are such clumsy jumpers." https://youtu.be/IDpuqX738I4?si=_QymDMBwIqXeSJgW What aspects of the toad's behavior in the video may confuse scientists? How could images such as those shared through the oVert project help scientists understand the toad's behavior?

https://www.floridamuseum.ufl.edu/science/miniature-frogs-set-record-as-first-vertebrates-to-lose-the-ability-to-balance/

https://www.youtube.com/watch?v=w-ngnnhcT-s

While most toads can land on their feet, these toads cannot control their landings. Scientists may have been confused as to why the toads were unable to orient or stabilize themselves midair. The images generated from CT scans allowed scientists to see the structure of the toad's inner ears. Physically, the

frogs inner ear structures are so tiny that they are difficult to examine with the human eye. With CT scans we can look at tiny things in great detail. That revealed that these toads have tiny inner ears that don't work well for sensing body positioning and rotation, which likely contributes to their clumsy, uncontrolled landings.

II. Navigating through 3D Data

1. Pick the animal species you'd like to look at. Your choices are: the lizard Mexican Beaded Lizard (*Heloderma horridum*), a worm-like caecilian amphibian (*Typhlonectes natans*), and Lined Seahorse (*Hippocampus erectus)*.

Mexican Bearded Lizard

Aquatic Caecilian

Lined Seahorse

If you have online connection in the classroom:

1. You can view the scan data of each species by clicking on the link below:

   Heloderma: https://skfb.ly/6RIqw

   Caecilian: https://skfb.ly/oNEBE

   Seahorse: https://skfb.ly/o6LTU

2. Spend some time getting used to navigating the 3D models by trying the following motions:
   a. Rotate (**Computer:** dragging left click; **Mobile:** dragging)
   b. Zoom in/out (**Computer:** scrolling up and down; **Mobile:** pinch in/out)
   c. Pan (**Computer:** dragging right click; **Mobile**: drag with two fingers)

If you do NOT have online connection in the classroom:

1. Open the program MeshLab that should be pre-installed on your device
2. Open *Heloderma*, Caecilian, or seahorse models in MeshLab.
3. Spend some time getting used to navigating the 3D models by trying the following motions:

a. Rotate (**Computer:** dragging left click; **Mobile:** dragging)
b. Zoom in/out (**Computer:** scrolling up and down; **Mobile:** pinch in/out)
c. Pan (**Computer:** dragging right click; **Mobile**: drag with two fingers)

III. Making observations

Questions for Students:

1. What collection and specimen did you choose?

Student answers will vary but should identify their selected specimen and the collection it is from.

2. Take a moment to explore your specimen. The 3-D model is fully navigable. Use the mouse wheel to zoom in and out, the left mouse button to rotate, and the right mouse button to pan or move the image. What do you observe about the specimen you chose?

Student answers will vary but should highlight key aspects of the images.

3. Which part of the animal's anatomy is visible in the scan?

The skeleton (bones).

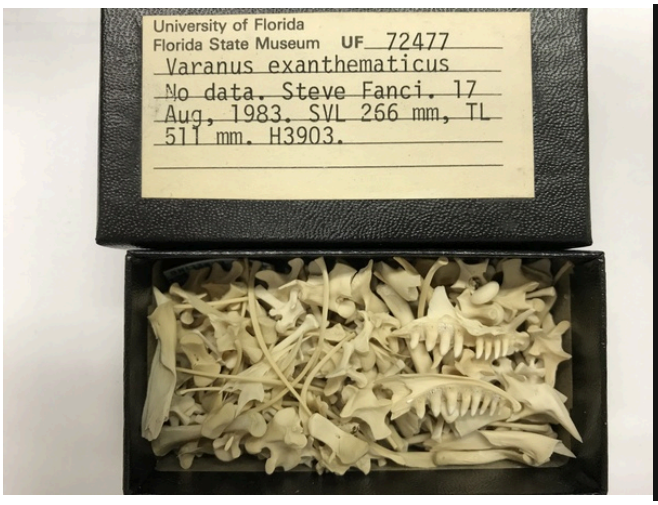
4. Do you see teeth in these animals?

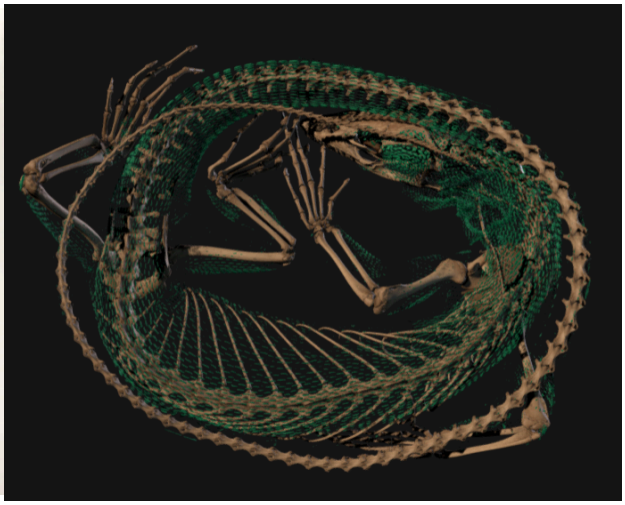
Yes for Heloderma and caecilian. Seahorses lack teeth.

5. Why do you see these structures in the scan and not the organs like the heart or lungs?

CT scanners use x-rays to create 3D data of specimens, so only the hardest/densest substances in the body will be visible, such as bone and teeth [unless special staining is used].

3. Would you have been able to make all the same observations exploring a physical skeleton of your specimen? Why or why not?





Student answers will vary but should identify if the 3-D model contained additional information that could not be observed in the skeletal remains of the same organism. This additional information may include labeling, scales, organs, muscles, or the inside structure of skeletal cavities, including the skull. Students with knowledge of fish species may also mention that some of these species are cartilaginous and do produce a calcified skeleton.

4. Based on your observations, form a scientific question about your organism or specimen.

Student answers will vary. Two example scientific questions: "What material are the sungazer lizard's scales made of?" or "How does the Brazilian electric ray's skull shape contribute to the survival of this species?"

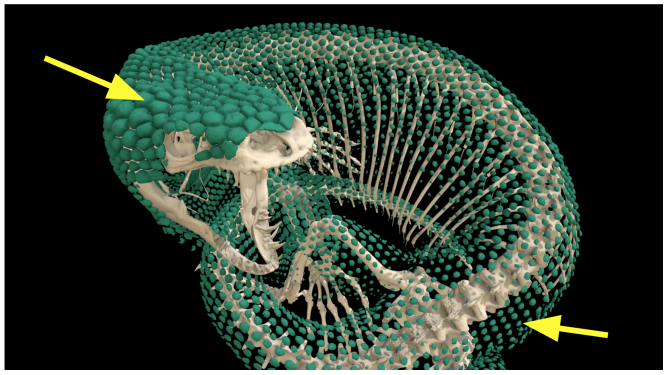
5. What would you need to investigate or answer your scientific question?

Student answers will vary. Example responses: "I would have to take samples of the sungazer lizard's scales and perform a chemical analysis to identify the molecules present" or "To figure out how the skull shape of the Brazilian electric ray contributes to its survival I would have to observe the ray in its natural habitat and take note of its behavior."

Questions Specific to Each Species

Heloderma:

1. What are the small structures surrounding the skeleton?



Scales.

2. Identify forelimb and hindlimb, and count the number of fingers/toes.

Has 5 fingers and 5 toes–like humans!

3. Based on the shape of its teeth, what do you think these animals eat?

They eat other animals, including small reptiles and insects.

Caecillian:

1. How many bones make up the skull?

   11 types; 21 total (there are paired left and right bones for all except one bone: sphenethmoid).

2. Which bones have teeth on them? What are the names of the bones?

   Nasomaxilla, maxillopalatine, vomer, pseudodentary

3. How many rows of teeth does this animal have? How many do you have?

   4 in upper jaw and 2 in lower jaw. Humans only have 2 rows of teeth.

4. Based on the shape of its teeth, what do you think these animals eat?

   Other animals, including insects and small fish

Seahorse:

1. Can you see fins?

   Seahorses are fish, but lack large, visible fins. There are still very small bones that make the dorsal fin on its back.

2. The tail of seahorses can curl around. What is this ability good for?

   Seahorses use their tail to grasp and hold onto their environment to help them stay in their place, especially with strong currents. They use it similar to how we use our hands.

3. Does the seahorse have teeth?

   No.

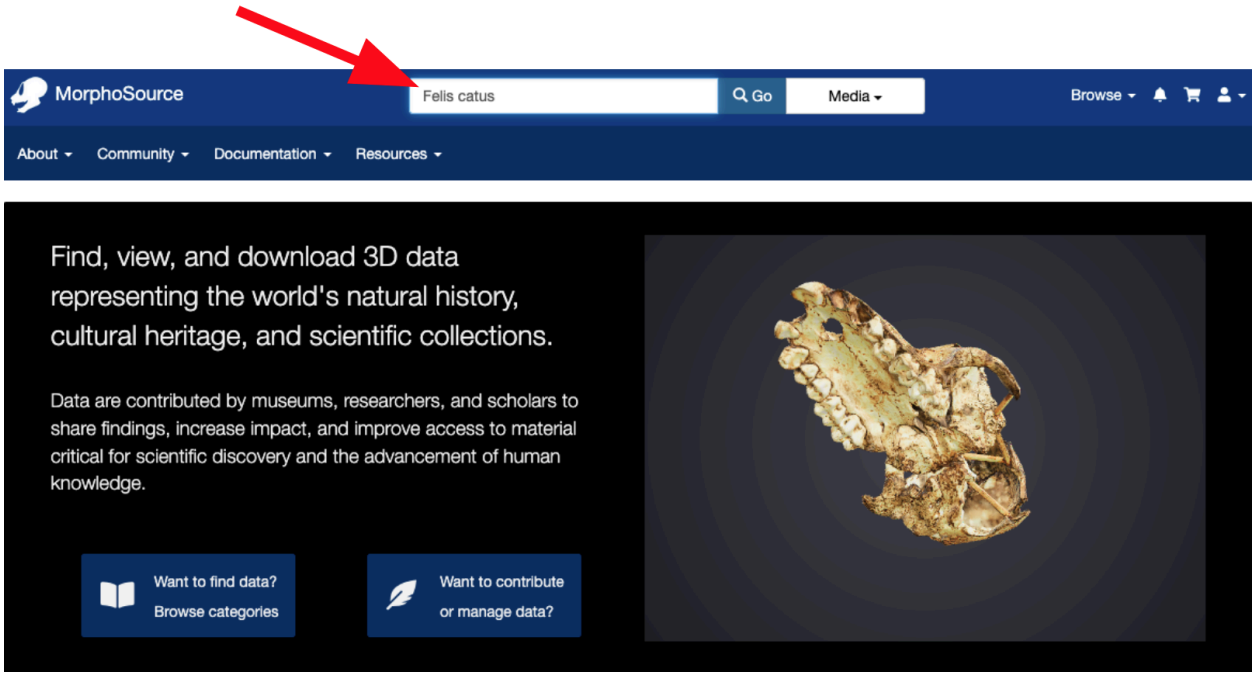
4. Without teeth, how do you think seahorses capture their food?

   They use suction kind of like a straw.

Additional Activities for Grades 9–12 (Internet Access Required)

1. Have students select an animal that they'd like to search for in the CT database. With a computer with Internet access, have the students look up the scientific name of that animal. For example, for the domestic cat: *Felis catus*.

2. Go to MorphoSource (morphosource.org) and have students type in the scientific name in the search bar:



If results do not populate after search, then try another animal.

1. Click on the page with CT scan data [show this with a screenshot]

If none of the pages of the selected species do not have CT scan data, then try another animal.

2. In 3D view, adjust the threshold to view the internal anatomy of the animal (either bone or organs).

3. Look at the teeth (if they have them) and limbs or fins. Try to answer what the animals eat and how they move around (quadrupedal, bipedal, swimming, slither).