STUDENT GUIDE

Observing your shark's braincase and brain

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Description

In this module, you will become more familiar with the structure of the braincase and brain of the spiny dogfish shark (*Squalus acanthias*) through observation and gain a better understanding of why they have the shape that they do.

Introduction

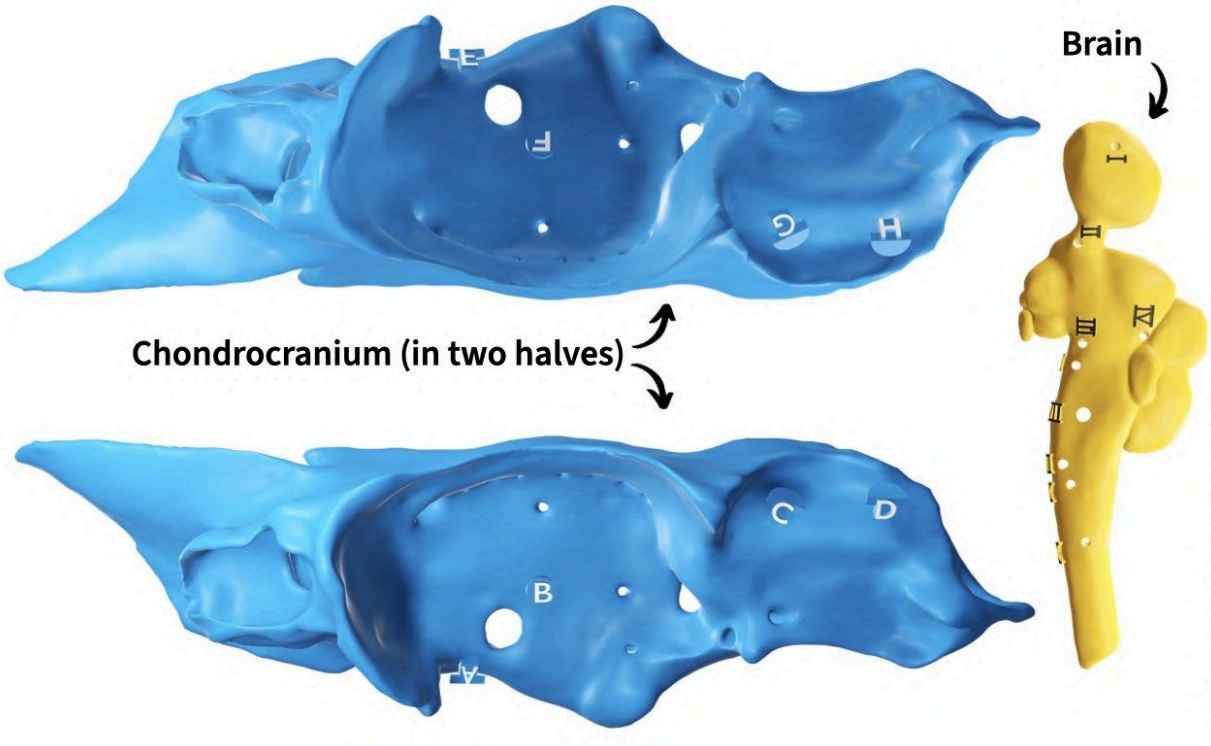
The chondrocranium of a shark will probably look like nothing you have ever seen before—like alien anatomy. However, the more you observe something, the more familiar it will become. And the more you will see, and the more you will understand. For one thing, what are all those holes for?

In this module, you will become more familiar with the structure of the braincase and brain of the spiny dogfish shark through observation and gain a better understanding of why they have the shape that they do. In particular, you'll reason through the orientation of the chondrocranium and the functions of some of its features.

Materials needed

For this module, you'll need:

- The **Student Notebook** for this module (SA02).
- The **chondrocranium** and **brain** from your shark kit (see image below). The chondrocranium comes in two parts and these are the largest parts in the kit. If your kit is color coded, the chondrocranium pieces are blue and the brain is yellow.



- **OPTIONAL** One pipe cleaner (any color) for tracing paths of cranial foramina

Section 1. What is the anatomical orientation of the braincase and brain?

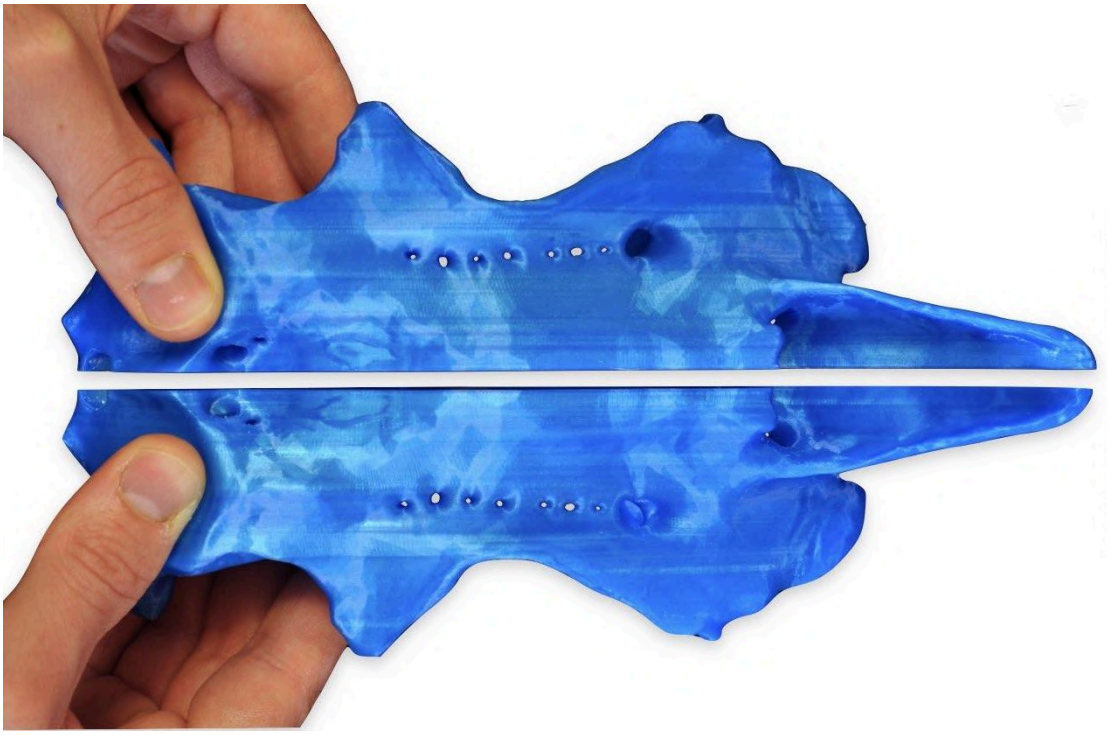
In sharks, the **chondrocranium** (meaning, "cartilaginous skull") is also known as the **braincase** because it *encases* the brain. If the two halves are not already snapped together as a whole piece, can you solve how they fit together? If you get stuck, use the hint at the bottom of this page. When you think you have it correct, check against the solution on the next page.

HINT: Find the flat surfaces

Find the completely flat surface of each half; this is where the two halves fit together.

ASSESS: Braincase made whole

The two halves of the chondrocranium join together as shown in the image below.

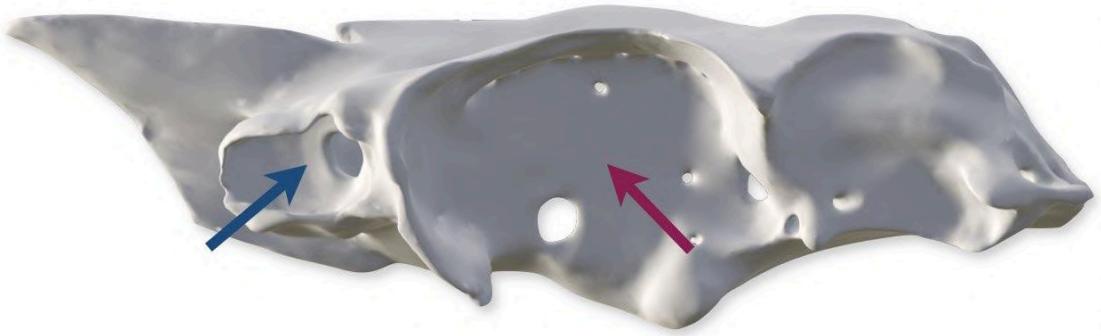


Now that you've solved how the two halves of the chondrocranium fit together, which is the left half and which is the right? Which end is **rostral** (toward the shark's snout or front end) and which end is **caudal** (toward the tail or back end)? Which side is **dorsal** (the shark's back) and which side is **ventral** (the shark's belly)?

Fill in the blanks on page 1 of your **Notebook** with these directional terms. When you think you've got it right, use the following hints to check your work.

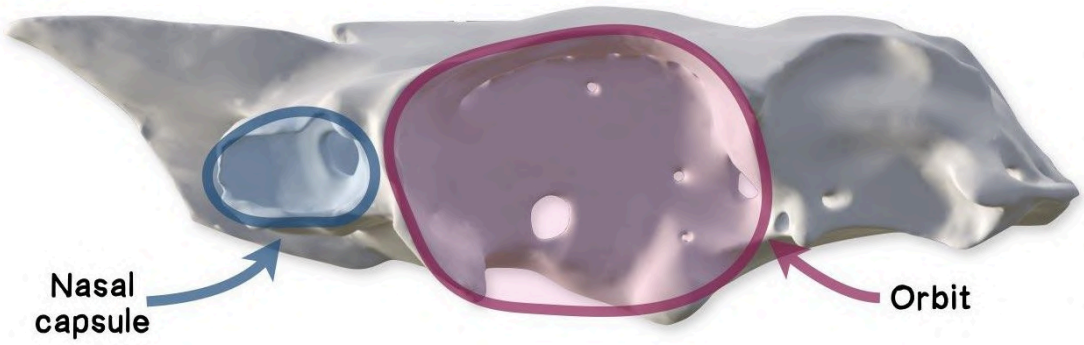
HINT: Where are the nose and eye?

The arrows below show the positions of the **nasal capsule** (which houses the olfactory organ) and **orbit** (which houses the eye). Which do you think is which? Do you need to change any of your answers in your **Notebook**? Check your answer in the next hint.



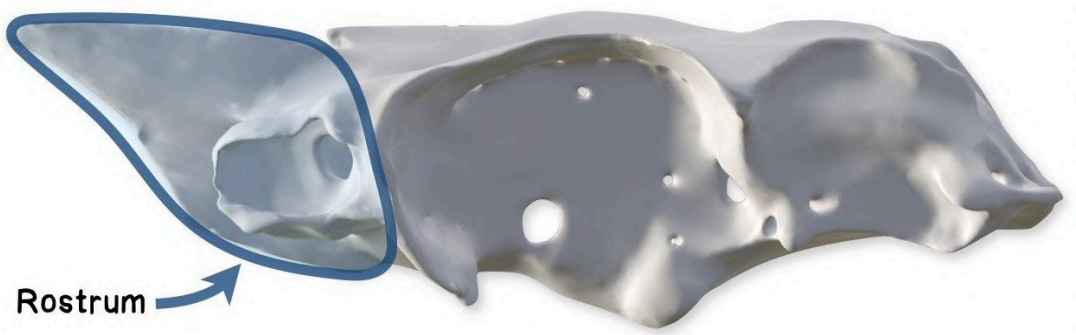
HINT: The nose is in front

The labeled arrows in the image below indicate the nasal capsule (more rostral) and the orbit (more posterior). Do you need to change any of your answers?



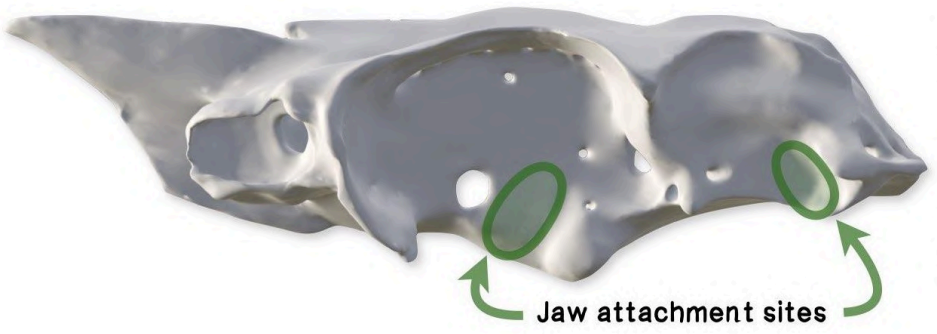
HINT: The snout of the shark

This image shows the **rostrum** (snout) of the shark. Do you need to change any of your answers?



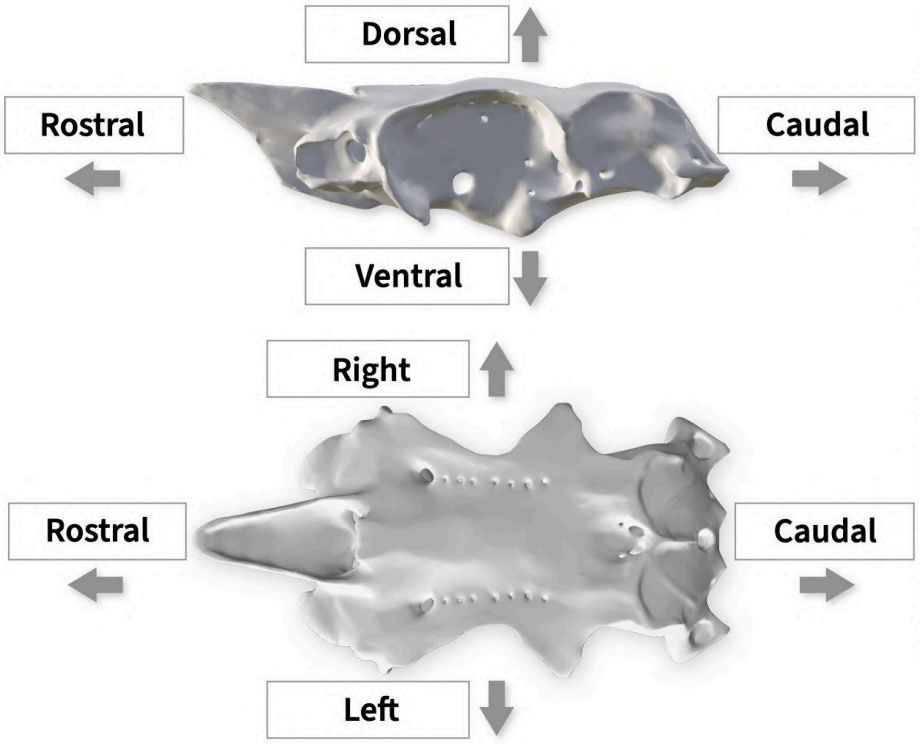
HINT: Where the jaws attach

And the circled areas in this image indicate where the jaws attach. Do you need to change any of your answers?



ASSESS: Braincase oriented

Compare page 1 of your **Notebook** with the image below to check your work.



Now that you have the orientation of the chondrocranium figured out, how is the brain oriented? Figure out how the brain fits inside the **endocranial cavity** (the space inside the chondrocranium that holds the brain). If you get stuck, check out the hint below.

HINT: The braincase encases the brain

If you have the brain properly oriented within the chondrocranium, you should be able to bring the left and right halves together completely with the brain inside.

Section 2. What do you notice about the brain relative to the endocranial cavity?

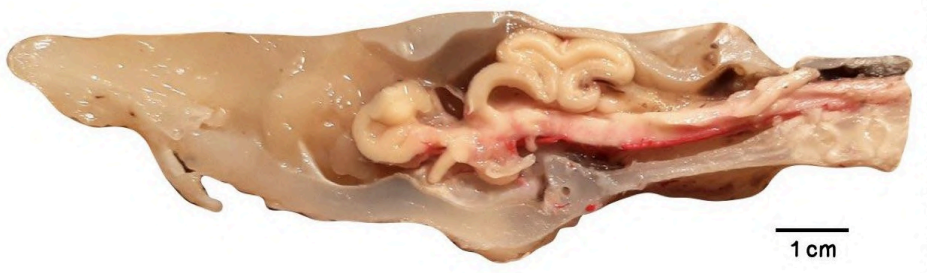
Because the chondrocranium encases the brain, it has a close relationship with the brain. Take some time to observe the brain in relation to the endocranial cavity. What do you notice? List your observations on page 2 of your **Notebook**. If you get stuck, check out the hints below.

HINT: Is the brain a tight fit?

Are the brain and the endocranial cavity the same size? If you put the brain inside the endocranial cavity, "close" the braincase by bringing together the left and right sides, and shake the braincase, what do you notice?

HINT: A dissected brain

Here's another perspective that may help. This image is of a shark specimen, with the chondrocranium and brain cut down the middle (a midsagittal cut).



Once you've finished your observations, proceed to the next page.

One observation that you may have made is that the brain does not completely fill the endocranial cavity. *Why* do you think this is? Write one or more potential explanations on page 2 of your **Notebook**.

Other scientists have also noticed that the brain doesn't completely fill the endocranial cavity in some sharks. This 2019 research article by Yopak and colleagues, for example, discusses a potential explanation. Search that paper for their explanation and compare it with your own. Your goal is *not* to read the paper. Your goal is to find the relevant section of the paper as quickly as possible. If you get stuck, check out the following hint.

HINT: Use the search tool

Try using the "Find" feature in the browser or PDF viewer to locate relevant terms (e.g., "endocranial"). Remember that the Discussion section of research articles typically contains the authors' explanations of results or other observations.

Once you've understood their explanation, summarize it in your own words on page 2 of your **Notebook** and compare it to your own explanation.

In humans, does the brain completely fill the endocranial cavity? (If you're unsure, a Google image search can help you find an answer quickly). Does your revised explanation explain the size of the brain relative to the braincase in *both* sharks and humans? If not, come up with a revised explanation on page 3 of your **Notebook**.

Section 3. Which chondrocranium foramina could be for cranial nerves?

As you have been observing the chondrocranium, you've probably noticed that it is full of holes! These are not defects; they represent actual **foramina** (holes) of the chondrocranium.

The brain and spinal cord together form a **central nervous system** (abbreviated **CNS**), which receives, sends, and integrates information from all over the body. Think of the CNS as a continuous system: within the braincase it's called the brain, within the spine it's called the **spinal cord**. To reach the CNS, nerves need to travel in and out of the braincase and spine. The nerves that enter and exit the CNS within the chondro*cranium* are called ***cranial* nerves** whereas those that enter and exit the CNS along the *spine* are called ***spinal* nerves**.

Using observation and reasoning, can you figure out which foramina of your chondrocranium could potentially **convey** (allow passage of) cranial nerves *directly* from the brain? Circle these foramina on page 4 of your **Notebook**. Also, mark with an arrow the **foramen** (singular of foramina) you think conveys the CNS as it leaves the chondrocranium (i.e., the spinal cord).

If you need help, use the hint below. Then check your work on the next page.

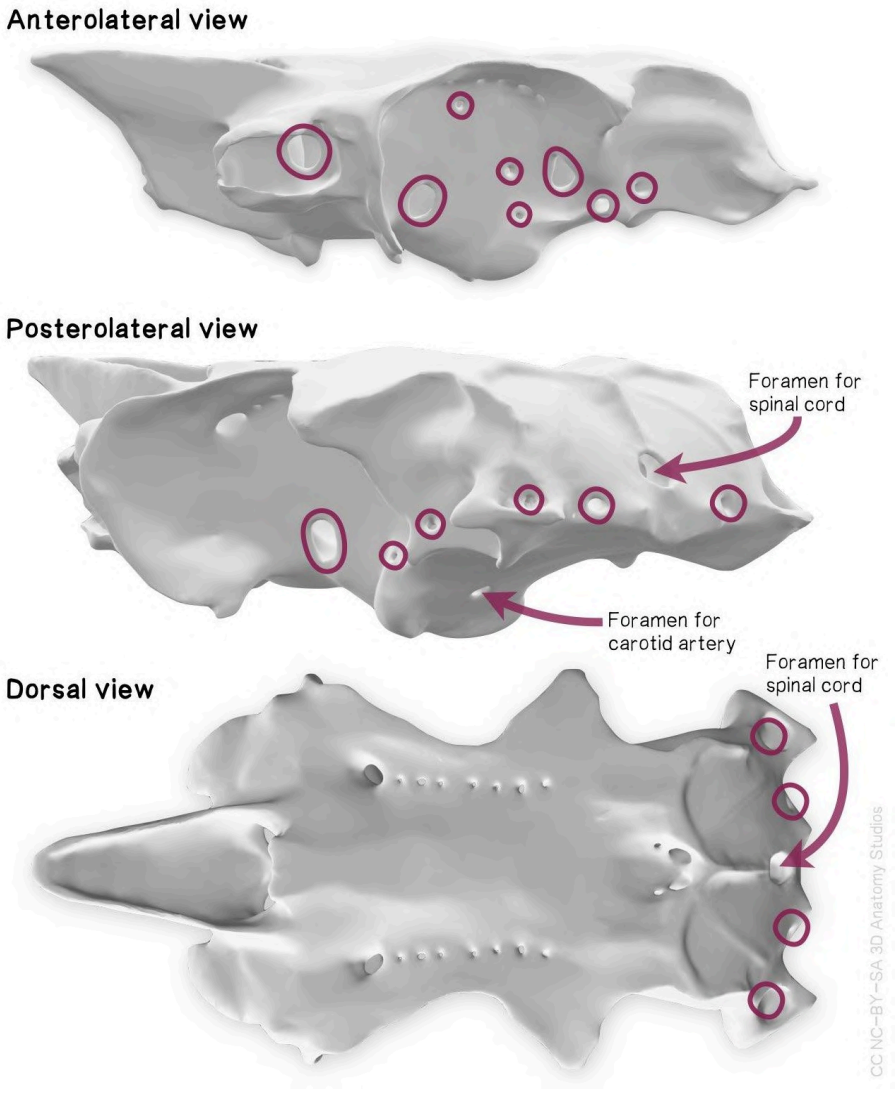
HINT: Connect the spaces

You might find it easier to make these observations with the whole chondrocranium (the two halves together). Try shining a light into the endocranial cavity through one of the foramina. Or try inserting a pipe cleaner into the foramina to see where they lead.

If a foramen could potentially convey a cranial nerve directly from the brain and out of the chondrocranium, what two spaces must it connect?

ASSESS: Cranial nerve foramina

Nearly all of the foramina that connect the endocranial cavity with the area outside of the chondrocranium carry cranial nerves directly from the brain, indicated by circles below.



A few exceptions are: the carotid artery foramen and the foramen for the spinal cord (the **foramen magnum** or "big hole"). Take a moment to appreciate the power of observation in anatomy: without any specialized knowledge and by just observing the connectivities, you were able to identify nearly all of the cranial nerve foramina!

Section 4. Which of these foramina isn't like the others?

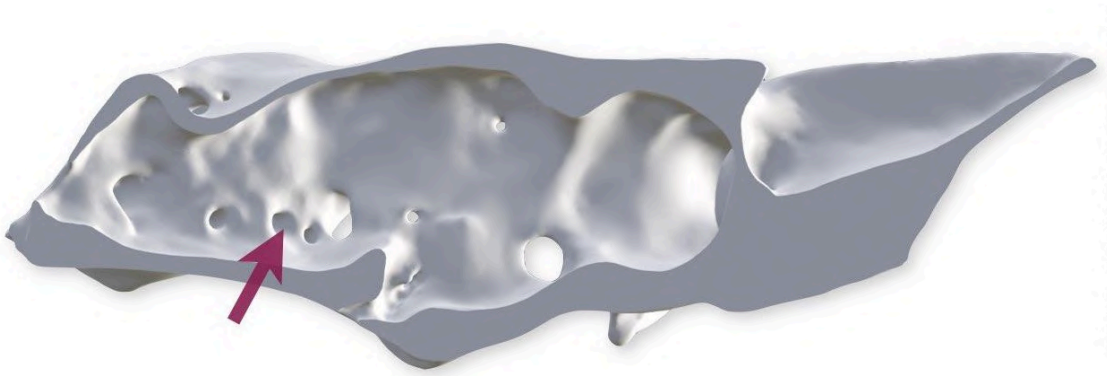
Now take some time to observe the foramina of the chondrocranium from the inside by looking at the half chondrocranium. In the previous activity, you observed the connectivities of the foramina (i.e., what spaces they connect). Observing the foramina from the inside, which foramen *inside* the endocranial cavity isn't like the others? Check out the hint below if you get stuck and check your answer on the next page.

HINT: Where does each hole lead?

Use a light or a pipe cleaner to test where each foramen leads from the endocranial cavity.

ASSESS: The dead-end foramen

Did you find the one foramen that *doesn't* connect to a space outside of the braincase? It's indicated below.



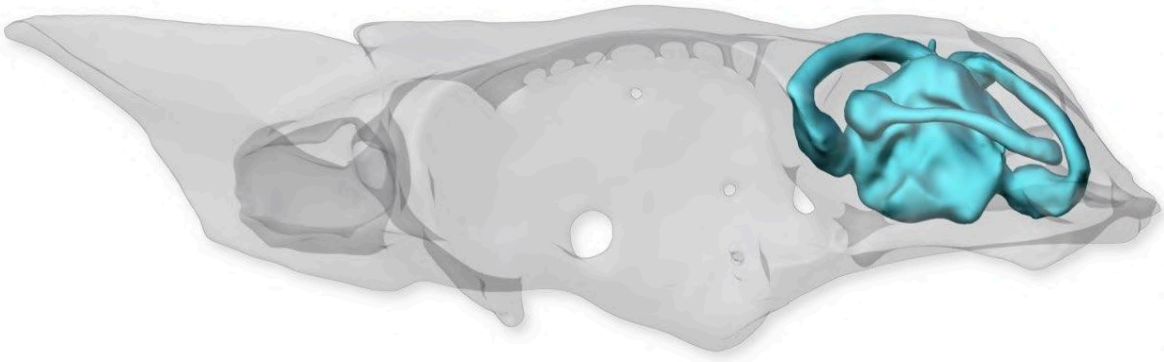
The foramen indicated by the arrow in the image above carries a cranial nerve. What structure do you think you would find at the end of this foramen/canal? That is, what structure do you think this cranial nerve is carrying information to/from? If you get stuck, check the hint below.

HINT: An internal sensory system?

What sensory structure is contained within your skull? It's not really "exposed" to the outside like the eyes or nose. It can get all the sensory information it needs within the skull. And if this structure is damaged, one of the symptoms you would likely feel is dizziness.

ASSESS: The vestibular system

This foramen that is not like the others leads to the **vestibular system**, highlighted in the image below.



The vestibular system is like a gyroscope and accelerometer all in one. It helps an organism sense orientation and acceleration to maintain balance. Since the vestibular system is contained entirely within the braincase, the cranial nerve that enters this foramen does not need to leave the braincase.

Section 5. What differences do you notice among the cranial nerve foramina?

Besides differences in connectivity, what other differences do you notice among the chondrocranium foramina that convey cranial nerves? Write your observations on page 5 of your **Notebook**. If you get stuck, check the hint below.

HINT: Group by describing

If you were to group the cranial nerves, what characteristics would you use to group them? If you were to describe them to another person, what words would you use to describe them?

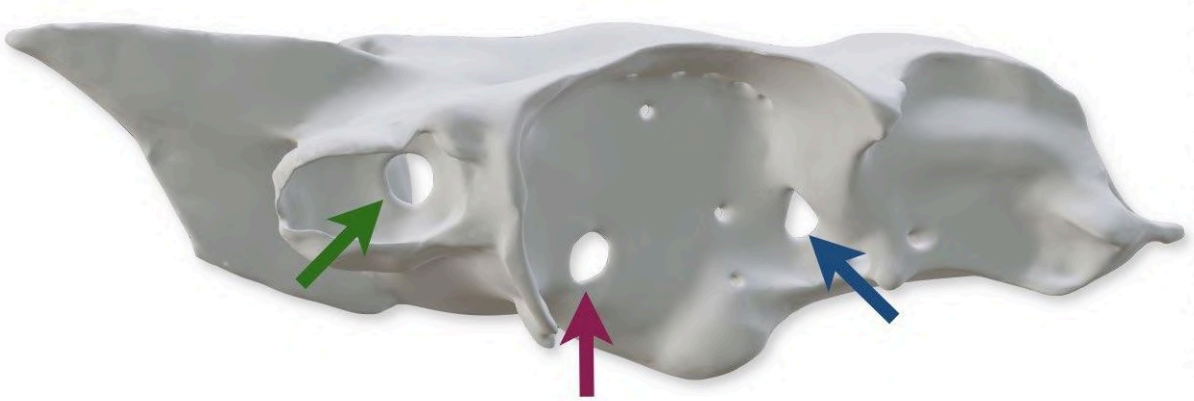
Once you've finished your list of observations, compare your list to some potential observations on the next page.

One observation you may have made is that the foramina are of different sizes. This is something you would see in all vertebrates. *Why* do you think this is? Write one or more potential explanations on page 5 of your **Notebook**. If you get stuck, check the hint below.

HINT: Diametrical analogies

A **nerve** is a bundle of many **neurons** and each neuron can carry a certain amount of information. In this way, a nerve is analogous to a bundle of fiber optic cables, electric wires, a water pipe, etc. Just as a larger diameter cable/wire/tube can carry more signals/current/water and carry them faster, a larger diameter nerve can carry more information and carry this information faster.

Based on your explanation, what information do you think is carried by the cranial nerves that pass through the three largest cranial nerve foramina (indicated in the image below) and *why*? Write your best guesses on page 5 of your **Notebook**. After you have some guesses, check the following hint to see if you're on the right track.



HINT: The information transmitted

Here's a list of the information carried by cranial nerves, grouped by the chondrocranium foramina that they pass through (in no particular order):

- Orientation and acceleration (from vestibular system)
- Motor control of a muscle that moves the eyeball
- Olfaction and chemosensation (from the olfactory organ)
- Sensation and motor control around the rostral gills
- Motor control of four muscles that move the eyeball
- Electroreception, sensation of fluid flow on the skin, jaw motor control
- Visual information (from the retina of the eye)
- Sensation and motor control around the posterior gills and gut

Your three guesses should be somewhere in this list. Use this hint to update your answer in your **Notebook**, if needed.

References cited

- Yopak, Kara E., et al. "Comparative brain morphology of the Greenland and Pacific sleeper sharks and its functional implications." *Scientific reports* 9.1 (2019): 1-15. DOI: 10.1038/s41598-019-46225-5.