EDUCATOR GUIDE

Simulating the motions of your shark's jaws

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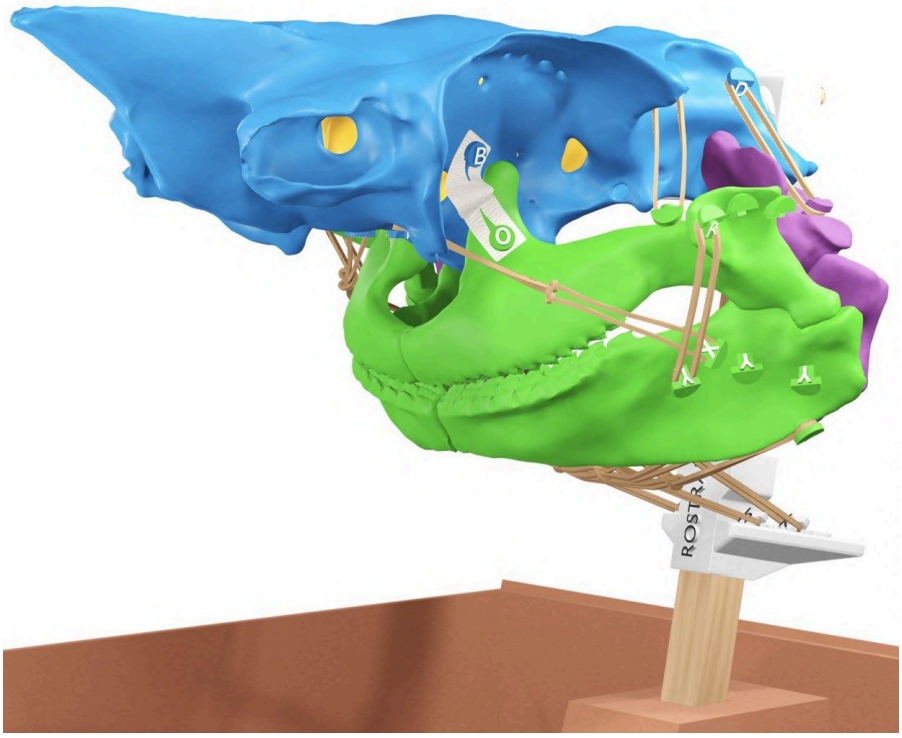

Time to complete: 60-80 min
Age level: Grades 11-12 or College
Bloom's levels: 1, 2, 3, 4 & 5
Description: In this module, your students will identify the jaw muscles of the spiny dogfish shark (*Squalus acanthias*), infer their actions by simulating motions, and explain how sharks can manipulate food without a tongue.
Materials needed:

- SA05 Student Guide & Notebook v1.0
- Dogfish Shark Skull Kit v1.0
- **OPTIONAL** Dressing forceps

Systems:

- Muscular
- Skeletal

Core concepts:

- Structure & Function

Competencies:

- Observation
- Scientific reasoning

Module ID: SA05
Module version: 1.1
Module sequence (suggested):
SA02 → SA03 → SA01 → **SA05** → SA04

How to use and edit this module

This is an open-source active learning module created by 3D Anatomy Studios and licensed under CC NC-BY-SA for use with the Dogfish Shark Skull Kit.

Module Structure

This module has an **Educator Guide**, a **Student Guide**, and a **Student Notebook** and is divided into one or more sections, each with a number, a motivating question as its heading, and a learning objective.

Educator Guide

The **Educator Guide** is intended for educators and contains a pedagogical schema for the module to help implement the module in a course (e.g., learning objectives, target Bloom's level and competencies, core concepts), an answer key for certain prompts/questions in the the **Student Notebook**, and module updates.

Student Guide

The **Student Guide** is intended for students to read as they complete the module's activities and can be read on a device or printed out.

Student Notebook

The **Student Notebook** contains worksheets or diagrams on which students can write or draw as a part of the module's activities. The **Student Notebook** can be printed out or filled in using a digital tablet.

Sharing and Editing

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Purchasing Kits

To purchase kits, please visit 3danatomystudios.com/shop/dogfish-skull-kit.

Pedagogical schema

Section 1. What are the shark jaw muscles?

Learning objective	**Identify (Bloom's Level 1 - Remember)** the shark jaw muscles, **interpret (Bloom's Level 2 - Understand)** their orientations, and **demonstrate (Bloom's Level 3 - Apply)** their origins and insertions by **building (Bloom's Level 3 - Apply)** a 3D model.
Activity	Attach rubber bands to muscle attachment sites on a 3D model of a shark skull and fill in the blanks of a table.
Self-assessment	Compare the constructed 3D model and filled table responses with answers in the student guide.
Systems	**Muscular** **Skeletal**
Core concepts	**Structure & function**
Competencies	

Section 2. How can your shark's jaws move and which muscles drive those motions?

Learning objective	**Demonstrate (Bloom's Level 3 - Apply)** the motions of the jaws by **simulating (Bloom's level 5 - Evaluate)** the motions with a 3D model and **infer (Bloom's level 4 - Analyze)** the actions of the jaw muscles by **experimenting (Bloom's level 4 - Analyze)** with and **interpreting (Bloom's level 5 - Evaluate)** how rubber band muscles on the model change length during the motions.
Activity	Simulate muscle actions using a 3D model with rubber bands and fill in the blanks of a table.
Self-assessment	Compare the filled table responses with possible responses in the student guide.
Systems	**Muscular** **Skeletal**
Core concepts	**Structure & function**
Competencies	**Scientific reasoning**

Section 3. How do sharks use body muscles to open their mouth?

Learning objective	**Explain (Bloom's Level 4/5 - Analyze/Evaluate)** how sharks use their epaxial and hypaxial muscles to open their mouth by **experimenting (Bloom's level 4 - Analyze)** with a 3D model.
Activity	Simulate cranial and jaw motions using a 3D model and write short answers
Self-assessment	Compare written responses with possible responses in the student guide
Systems	**Muscular** **Skeletal**
Core concepts	**Structure & function**
Competencies	**Scientific reasoning**

Section 4. How do sharks manipulate their food without a tongue?

Learning objective	**Explain (Bloom's Level 4/5 - Analyze/Evaluate)** how sharks are able to manipulate their food without a tongue by observing an articulated and mobile model of a shark skull.
Activity	Observe model of shark cranial skeleton and write short answers
Self-assessment	Compare written responses with possible responses in the student guide
Systems	**Muscular** **Skeletal**
Core concepts	**Structure & function**
Competencies	**Observation** **Scientific reasoning**

Answer key

Section 1. What are the shark jaw muscles?

	Attachments		Potential actions (concentric only)							
			Lower jaw		Upper+Lower				Hyoid arch	
Muscle name	**Which elements does this muscle connect?** (Use abbreviations below table)		**Elevation**	**Depression**	**Elevation**	**Depression**	**Protrusion**	**Retrusion**	**Elevation**	**Depression**
Levator palatoquadrati	CC	PQ								
Levator hyoideus	CC	HM								
Preorbitalis	CC	MC								
Quadratomandibularis	PQ	MC								
Coracomandibularis	PG	MC								
Coracohyoideus + Coracoarcualis	PG	BH								
Interhyoideus	LCH	RCH								
Intermandibularis	LMC	RMC								

Section 2. How can your shark's jaws move and which muscles drive those motions?

	Attachments		Potential actions (concentric only)							
			Lower jaw		Upper+Lower				Hyoid arch	
Muscle name	Which elements does this muscle connect? (Use abbreviations below table)		Elevation	Depression	Elevation	Depression	Protrusion	Retrusion	Elevation	Depression
Levator palatoquadrati	CC	PQ			X			X		
Levator hyoideus	CC	HM						X		
Preorbitalis	CC	MC	X		X		X			
Quadratomandibularis	PQ	MC	X							
Coracomandibularis	PG	MC		X		X		X		
Coracohyoideus + Coracoarcualis	PG	BH		(X)		X		X		X
Interhyoideus	LCH	RCH					X		X	
Intermandibularis	LMC	RMC					X		(X)	

Lower jaw elevation and depression

The adductor mandibulae complex (preorbitalis and quadratomandibularis) can elevate the lower jaw (these rubber bands shorten during elevation) whereas the coraco muscles can depress the lower jaw (these rubber bands shorten during depression). Because the hyoid and lower jaw are variably coupled, the coracohyoideus may also be able to depress the lower jaw to some degree; since this is variable and not well understood, this "X" has parentheses.

Upper+Lower jaw elevation and depression

Levator palatoquadrati and preorbitalis can elevate the upper+lower jaw whereas the coraco muscles can depress the upper+lower jaw.

Upper+Lower jaw protrusion and retrusion

Preorbitalis can protrude the upper+lower jaw but so can the ventral sheet muscles (interhyoideus and intermandibularis). As the jaws protrude, they also compress mediolaterally. This is a common feature of linkage mechanisms: the connections among links cause certain motions to be correlated with other motions. As a consequence, the ventral sheet muscles could also help protrude the jaws by compressing the jaws

mediolaterally. You can also observe this correlated motion of the jaw linkage in the rotation of the hyomandibula during protrusion-retrusion. As the jaws protrude, the hyomandibula rotates ventrally, stretching the levator hyoideus. Thus, by contracting, the levator hyoideus can help to retrude the protruded jaws, along with the levator palatoquadrati and the coraco muscles.

Hyoid arch elevation and depression

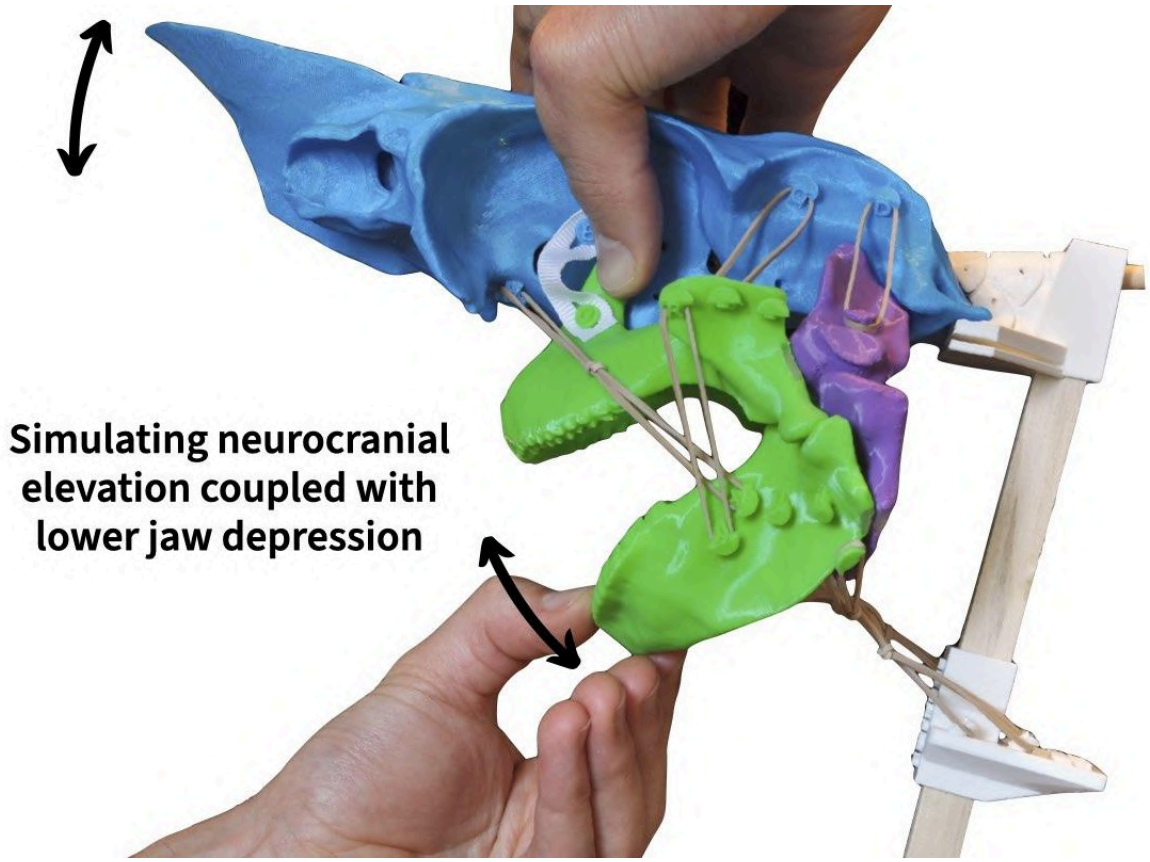
The coracohyoideus and coracoarcualis can depress the hyoid arch by pulling it back toward the pectoral girdle; in other species of sharks, the coracohyoideus can even store energy as a part of a spring-loaded system to rapidly depress the hyoid (Ramsay & Wilga 2017). As the hyoid arch is depressed two things can happen. At moderate levels of depression, the ceratohyals rotate such that the attachments of the interhyoideus are pulled further apart. This means that by shortening, the interhyoideus can elevate the hyoid arch. If the hyoid arch is depressed further, it pushes up against and stretches the intermandibularis. Thus, at greater levels of depression, the intermandibularis can also elevate the hyoid arch. Since the intermandibularis may not always be able to elevate the hyoid arch, parentheses are added around the "X" in the table.

Section 3. How do sharks use body muscles to open their mouth?

Using your shark skull to perform simulations, can you explain how fish can use their body muscles to open their mouth and generate suction? Your explanation should include which muscles are involved and their role. Feel free to write in bullet points.

- If the epaxials and levator palatoquadrati shorten at the same time, the epaxials will elevate the chondrocranium and upper jaw together.
- If the coraco muscles and hypaxials shorten at the same time, the lower jaw and hyoid will be depressed.
- Thus, if the epaxials, levator palatoquadrati, coraco muscles, and hypaxials all shorten at the same time, the mouth will open and the throat will be expanded.
- Expansion of the throat (i.e., expansion of a volume) will generate suction.

To simulate this in your shark, your students could do something similar to the following image.



Section 4. How do sharks manipulate their food without a tongue?

How can sharks manipulate their food without a tongue? Feel free to write in bullet points.

- Sharks don't just bite up and down, they're capable of moving their jaws in many different ways.
- The jaws and skull of sharks are capable of at least five different actions (including neurocranial elevation) and even more when asymmetrical motions are included.
- Sharks compensate for their lack of a kinetic tongue by having a kinetic cranial skeleton.
- Sharks have at least 9 muscles on each side of the skull for moving the chondrocranium and jaws. This is similar to the number of muscles that humans have for moving their jaws and tongue.
- Sharks have a similar number of muscles associated with jaw motions as we do, they just attach to rigid skeletal elements rather than to a muscular tongue.

Updates

Version 1.1

- Moved most of the self-assessment from the Student to Educator Guide.