Horseshoe crab molt lab: exploring horseshoe crab anatomy through observation of molted shells

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Class Time: 1-2 class periods (depending on depth of study and assessments used)

Subjects: Biology

Grade Level: Middle School/High School

Materials: 8-10 horseshoe crab molts (4" wide or larger), 1 ruler (with mm markings), 6 hand lenses, laminated copies of 8 molt lab station cards, copies of molt lab answer sheet (1 per team of students), tray of water (or a 50% glycerin/water mixture) for rehydrating molts (to make flexible for observing and determining sex); optional: scissors and microscope (for cutting out section of shell around compound eye for close-up view of facets), LCD projector and *Limulus* Parts Smarts PowerPoint.

Overview:

Students, working in teams, rotate through 8 stations to explore and learn about horseshoe crab (HSC) external anatomy through observation of molted shell specimens. Descriptive, photo-illustrated station cards provide the focus for students to observe, learn about, and answer questions pertaining to the structure and function of key HSC body parts, on an accompanying two-page answer sheet. Follow-up assessment tools, in the form of an interactive PowerPoint-based slide show and/or a suggested lab practical set-up plan, are also offered.

Concepts:

- Horseshoe crabs (HSCs) shed their shells several times as they grow, each time leaving behind a cast shell that reflects key parts of their external anatomy.
- The size of molts can be used to approximate the age of the HSC at molting.
- The anatomy of the HSC shell consists of three basic parts, with key appendages tucked beneath and a distinctive hinge between front and mid-piece for flexibility.
- The HSC visual system includes two pairs of eyes on the top of its shell: a lateral pair of compound eyes and a pair of simple eyes at the front of the shell.
- The HSC underside features numerous paired appendages that are structured and suited to perform multiple functions critical to the HSC's way of life.
- The sex of HSC molts can be determined by rehydrating the molts and observing the underside of the operculum (gill cover) with a hand lens.

Learning Objectives: Through this activity, the students will be able to:

- understand the process and outcomes of the way HSCs grow by molting
- identify key structures of the HSC's external anatomy
- recognize and associate particular structures with their respective functions
- appreciate the simple, yet highly effective, functionality of the HSC body plan

Background and Teaching Tips: The molted shells of HSCs offer an excellent tool for exploration of basic anatomical features. Molts can be easily collected in large numbers and varying sizes from Atlantic coast and associated bay beaches, especially after some autumn storms. They can be stored in boxes or tubs and brought out for examination at any time. Although delicate and easily broken (especially in early stages), molts can be rehydrated (by immersion for 5-10 minutes in water) to make them more pliable for observation. There is a limit, however, to how many times this can be done (they tend to fall apart after 4-6 cycles of rehydrating/drying). We've also had great success pre-soaking molts in a half-half glycerine and water mixture, as this provides optimal flexibility to the shells for months after drying.

Teacher Preparation: This activity is designed for optimal use as a rotation lab. Teacher prep is mainly in the form of preparing the station materials (which once organized, can be packaged in kits and used again and again) and making sufficient copies of the student answer sheets for the class size. Stations set-up is as follows:

station card & topic	molt specimen features	other materials needed
1. molting process	large enough to show fine fold lines on side of shell	hand lens (to observe network of fine zig-zag lines that unfolded in molting)
2. aging your molt	any size molt works here	ruler (with mm markings)
3. dorsal body parts	any molt at least 3" wide	tray of water (to make molt pliable for observing telson range of motion)
4. observing the eyes	Dorsal prosoma shell piece wide enough (6" or more) so median eyes are visible	hand lens and/or stereo microscope, penlight for backlighting eyes for viewing ommatidia with hand lens
5. ventral anatomy	one w/all appendages intact	hand lens (to view pusher leg tips)
6. the HSC mouth	specimen w/flabellum visible	hand lens (for viewing fine structures)
7. sexing your molt	one male and one female (the larger the better)	dishpan of water (to immerse molts for flexible viewing), and hand lens
8. internal structures	molt carefully dissected so that ventral & dorsal parts of shell are separate	hand lens (for viewing crop-gizzard on ventral shell piece & chitin ridges for muscle attachment to gills in dorsal)

Evaluation/Assessment: If time permits at the close of the lab period, a simple 10-slide PowerPoint show is offered as a tool for quick review and assessment of student learning. More ambitious teachers may opt to assess student learning individually via a lab practicum approach (see sample question sheet below).

Lab practicum station & setup*		Question(s)
1	dead/dried HSC shell (if available), alternatively, use molt & reverse question	Is this a molted HSC shell? Explain why or why not. *NO! A molted shell would show a distinct split around the front rim of the shell, and this one does not*
2	molt specimen (dorsal view) with label at compound eye	What is this structure and what do you know about it? ***Compound (lateral) eye*** *– made up of hundreds of lenses providing multiple image view of environment*
3	molt specimen (ventral view) with label affixed to the tip of the hind (pusher) legs	What is this structure called and what is it used for? ***Pusher legs*** *– allow HSC to dig and push into sand, push off in scuttling, and mold eggs into clusters*
4	molt, ruler & copy of chart correlating HSC size to age	About how old was the HSC when this shell formed? *Answers will vary depending on size of specimen used*
5	molt specimen w/label placed in the hinge area between prosoma and opisthosoma	What is the significance of the labeled structure? *Answer could relate to flexibility it provides and/or as place of needle insertion in biomedical bleeding*
6	molt specimen (ventral view) with label affixed to area of the book gills	Identify these structures and describe their function. ***Book gills*** *- used by HSC in breathing (respiration) as well as in swimming (by flapping motion)*
7	molt specimen (dorsal view) w/label attached to HSC tail	Name this part and tell something you know about it. ***Telson*** *- it is not a stinger or weapon, but aids the HSC in righting itself when it gets flipped over*
8	molt specimen (ventral view) with label on chelicerae	What is this structure called and what is it used for? ***Chelicerae*** *– used to manipulate food into the mouth*
9	molt specimen (ventral view) with label on operculum	Name this structures and describe its importance. ***Operculum*** *– covers and protects the book gills; also flaps to aid HSC in swimming, and holds gonopores*
10	larger molt specimen (dorsal view) with label affixed to area of the simple eyes	What structures are found here and what do they do? ***Simple (median) eyes*** *- detect ultraviolet light from the moon and stars, enabling HSC to see well at night*
Bonus	rehydrated molt(s) of either (or both) sex(es), with hand lens to tell which is which	Is this a male or female HSC? Explain your answer. *Male crabs show pimple-like, raised, hard gonopores; female pores appear flat, soft and horizontally split*

* As an alternative to sticking pins in HSC structures (which can cause the shell to split or break), we suggest using sticky tape labels with arrows to indicate the particular structures you wish students to identify or answer questions about.

Adaptations & Extensions: If time and equipment allows, we also suggest setting up a stereoscope station for close-up examination of the lateral eye. To make this work, have one of the students cut-out (with scissors) a section of the molt shell around the compound eye. Place this under the microscope with a backlighting source (so that light is shining up through the eye as you view it). This enables students to better appreciate the compound nature of the HSC eye, as well as to see how the individual facets are structured and organized. This lesson connects well to the "Eyes on the Prize" lesson featured in module 3 of the GE&S curriculum.

Horseshoe Crab Molt Lab: Station #1 (the molting process)

1. Like other arthropods, horseshoe crabs (HSCs) must shed their exoskeleton several times to grow from larval to adult form. This process is called 'molting'. HSCs molt 16-18 times from the time they hatch out of the egg to adulthood, each time increasing in size by about 25-30%.

The "how" of molting: Using its old shell as a mold, the HSC grows a larger shell underneath. This new shell is wrinkled and soft. As it prepares to molt, the HSC burrows in sand and takes in water. The new shell swells, causing the old shell to split along its front edge. The crab slowly crawls out in its new shell, leaving the old behind. What's left is the molted shell, dried out and delicate.

Split in shell

The easiest way to know you have an HSC molt (and not a dead HSC) is to turn the shell over and observe. Molted shells will not smell bad! Molts also show a distinct split along the front rim of the shell. This is where the old shell separated as the new shell underneath it expanded. *Look for that split on your molt and answer question #1 on your sheet.*

Bonus question: *Using a hand lens, look closely along the sides of the front part of the HSC shell of the specimen provided. Notice the network of fine zig-zag lines. On your answer sheet, describe what you think caused these lines to form* (hint: think about what happens in the process of molting).

Horseshoe Crab Molt Lab: Station #2 (aging your molt)

2. The size of a molted shell can be used to estimate the age of the HSC at the time it molted. This is best measured by turning the crab over on its back and using a ruler or measuring tape to measure the distance (in cm) across the widest part of the shell. This measurement is called *Prosomal Width* (PW). The chart at left shows the average PW of HSC molts taken from a population on Cape Cod.* *Using the chart at right and ruler provided, determine the prosomal width, molt number and estimated age of your molt. Record this information in the spaces at #2 of your answer sheet.*

Molt number	Year since hatching	Average Prosomal Width (cm)
6	1	1.7
7	1.5	2.2
8	2	3.0
9	2.5	4.1
10	3	4.9
11	4	6.3
12	5	7.7
13	6	9.1
14	7	10.3
15	8	11.5
16	9	13.4
17	10	16.0

* Size with age of HSCs varies with geographic location. The data in the chart is taken from: RH Carmichael, D Rutecki and J Valiela. 2003. Abundance and population structure of the Atlantic horseshoe crab *Limulus polyphemus* in Pleasant Bay, Cape Cod. Marine Ecology Progress Series 246: 225-239.

Horseshoe Crab Molt Lab: Station #3 (dorsal view body parts)

3. *Observing the molt specimen with its dorsal (top) side facing up, locate the horseshoe crab's three main body parts:* ***__prosoma__*** *(front),* ***__opisthosoma__*** *(midpiece) and* ***__telson__*** *(tail) and label them in the photo provided on your answer sheet.*

Find the horizontal hinge between the prosoma and opisthosoma. In a live crab, pairs of strong muscles connect the opisthosoma and prosoma across the hinge. This enables the HSC to flex its opisthosoma as much as 90° upwards when overturned. *How might this flexibility help the HSC?* Now observe the slightly raised area that runs vertically along the molt midline. In bleeding HSCs for biomedical use, a needle is inserted through the hinge and into the center of that area (comprising the HSC's heart) to draw a portion of its blood. *Draw a large* ***H*** *in the area of the photograph on your answer sheet where you think the needle would be inserted.*

Observe the structure of the HSC molt ***__telson__***. If your specimen has been made wet and pliable, move the telson around gently with your hand, and think about how that flexibility could relate to its function. Though the HSC telson looks menacing, it is not a 'stinger', nor is it used as a weapon of any kind. *Answer the question on your answer sheet about the HSC's telson.*

Horseshoe Crab Molt Lab: Station #7 (sexing your HSC)

7. The underside of the HSC operculum (broad plate that sits above book gills) holds the **__gonopores__** through which eggs (in adult females) and sperm (in adult males) are released during spawning. The shape and feel of these gonopores can be used to sex HSCs. This can be done by lifting the operculum (as shown in photo at left below) and gently running your fingers along the underside. In males, the pores will protrude, feel hard, and appear raised and conical. In females, you may not even be able to feel or see the pores, as they are much softer and flatter. Under good viewing conditions with a hand lens, you may notice the horizontal slits (see photo below right). This is where eggs will come out in spawning (see photos at right). *Gently pull back the operculum on each of the specimens and feel/observe as described above. Label the sex of each on your sheet.*

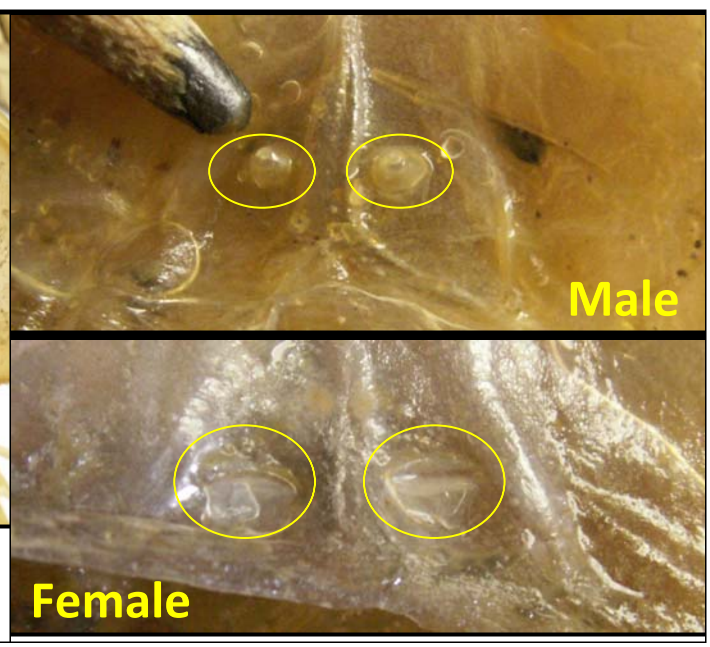
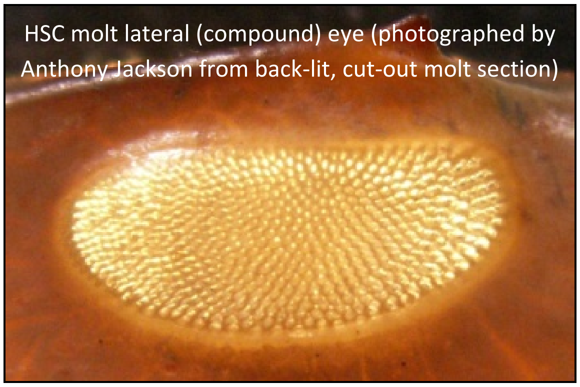


__Photo above__: underside of HSC molt operculum showing gonopore location (circled in yellow). __Right photos__: view of male & female gonopores

Horseshoe Crab Molt Lab: Station #4 (observing the HSC's eyes)

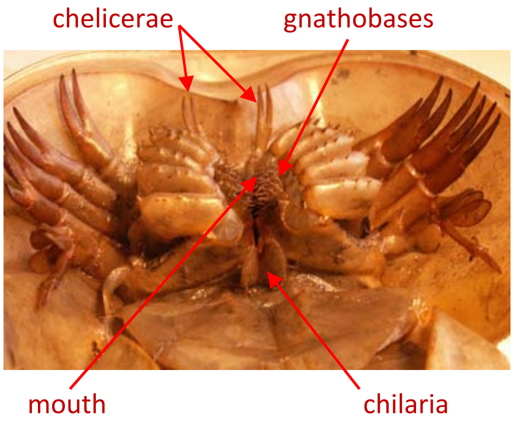
4. *Locate the pair of* **lateral eyes** *on your molt and label them in the photograph on your answer sheet*. These eyes are compound (like those of a fly), and are made up of hundreds of facets. Use the penlight to shine light up through the eyes and *view with the hand lens provided. Use what you observe about the lateral eye structure to answer the question on your sheet.*



Look for a small pair of ***median eyes*** *near the front-most central spine on top of the HSC shell* (see photograph at left). *Label the location of these eyes on your answer sheet photo. Use the penlight to shine light up through these simple eyes.* These eyes detect ultraviolet light reflected from the moon and stars.   *Think about how this sensing could help the HSC.*

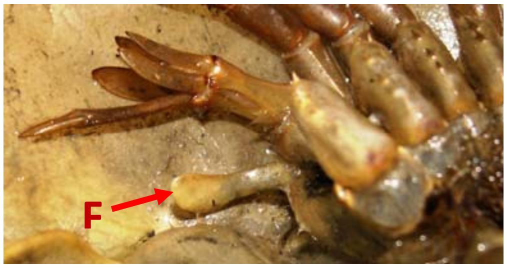
Horseshoe Crab Molt Lab: Station #6 (the HSC mouth)

6. HSCs have a highly unusual **mouth**, in that it is located on its underside and centered between its legs. Notice the spines at the base of the legs that frame the mouth. These are called **gnathobases**.   They serve to condition food for entering the HSC's esophagus.   *Draw a circle around the HSC's mouth and gnathobases in the photo on your answer sheet.   Read the descriptions below of some of the finer appendages surrounding the mouth, then label them on your answer sheet photo and answer the accompanying questions about each.*



Identify (and label on your answer sheet) the small clawed structures located just to the front of the mouth. These are called the **chelicerae**. They are used to direct food into the HSC's mouth. *Then look for a pair of small paddle-like structures just below the mouth and in front of the gills.* These are the **chilaria**. They help move food forward to the mouth. *Label them as well.*

Note the structure labeled 'F' in the photo at right. This special organ (located at the base of each of the pusher legs) is called the **flabellum**. It features hundreds of thousands of sensory receptors, including ones that monitor the composition of the water that passes over the HSC's gills. *Look for these structures on your molt and label them on your answer sheet photo.*



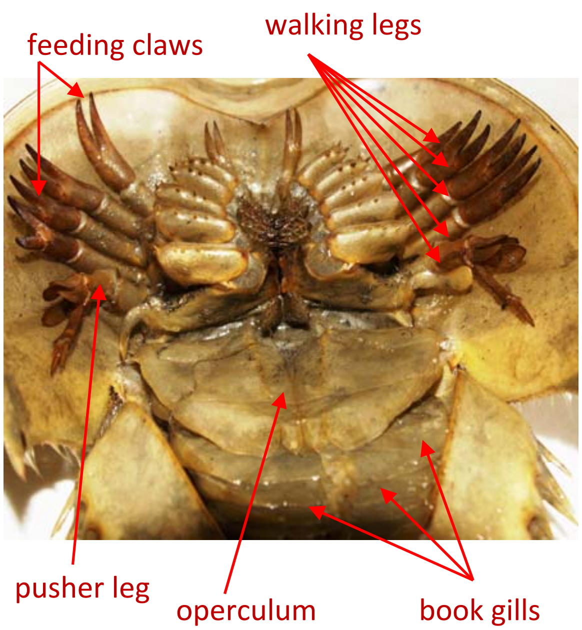
Horseshoe Crab Molt Lab: Station #5 (observing ventral anatomy)

5. *Gently flip the molt specimen at this station on its back so that its underside is showing. Using the photo and descriptions of the structures that follow, identify those parts on your molt, label them in the photo on your answer sheet, and answer the questions that relate to each.*

HSCs have five pair of **walking legs**. These are used for locomotion and feeding. Each of the first 4 pair of legs ends in a small claw, which is used to manipulate food.

In adult male *Limuli,* the claws of the front-most walking legs (called **pedipalps**), are modified into a special structure (photo left) that plays a key role during spawning. *What do you suppose its function is?*

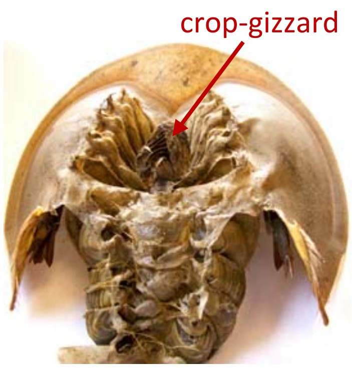
Notice the modified tips of the hind pair of walking legs. These are the **pusher legs**. They are adapted for digging, and for pushing off as the HSC scuttles along the bay or ocean bottom. Female HSCs also use the pusher legs to mold the eggs they lay into clusters during spawning.



Behind the pusher legs is a broad, plate-like structure called the **operculum**. It protects the more delicate **book gills** below. In addition to their role in respiration, pulsations of the book gills and operculum aid in swimming, as well as in creating currents to move sperm over eggs during spawning.

Horseshoe Crab Molt Lab: Station #8 (molted internal structures)

8. At this station the upper side of a HSC molt shell has been separated from its underside so that you can see what's inside each. The photo at right shows the inside of the underside, including (in the top half) parts of the shell located beneath its mouth. Along with external shell parts, when HSCs molt, they also re-form chitinous parts of their digestive system, including the lining of the esophagus, crop-gizzard and rectum. *Use the drawing to help you locate the **crop-gizzard** on your specimen. It has thick ridges of chitin that serve to grind and mash food materials.*



The photo at left shows the inside of the top side of a HSC molt. Notice the deeply vaulted space on the bottom part of the shelf. If you look carefully inside that space you'll see two lines (one on each side, running from the hinge area down) each containing 6 structures that stick up (see arrows at right). These structures have an important function for the parts of the HSC that lie above them. *Using the underside of the intact molt shell provided as a reference, figure out what those key body parts are and how these structures might relate to the function of those parts. Write your answers on the space provided on your sheet.*

Horseshoe Crab Molt Lab Answer Sheet

Name(s):

Use this sheet to answer the questions related to the horseshoe crab (HSC) molt specimen(s) you'll be observing at each of the lab study stations. Since students will be starting at different stations, be sure that your numbered answers correspond to the numbers at the respective stations you are visiting.

1. Is this specimen a molt or a dead crab? ______________________ How can you tell the difference?

   Bonus: Using a hand lens, look closely at the sides of the top shell of the molt specimen. Notice the zig-zag network of fine lines. What do you think caused these lines to form?

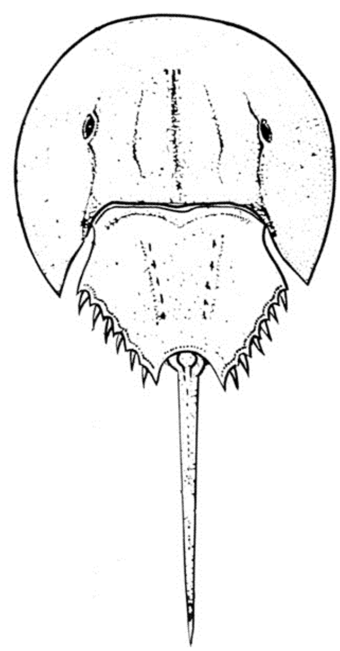
2. Using the chart, ruler and instructions, determine the size, molt number and age of this specimen.

   _____ prosomal width (cm) _____ molt # _____ age (years)

3. Locate the **prosoma**, **opisthosoma** and **telson** on your molt and label them in the illustration to the right.

   Read the paragraph about the HSC's hinge and heart. Label the **hinge** area on the photo to the right. How might the flexibility provided by the hinge be useful to the HSC?

   Observe the structure of the **telson**. Scientists have found that HSCs with a short or damaged telson run a greater risk of stranding when spawning on the beach. What does this suggest about a function of the telson?



4. Locate the **lateral eyes** and **median eyes** on this molt and label them in the photo next to #3 above. Describe what you are able to observe about the structure of the HSC's lateral eyes.

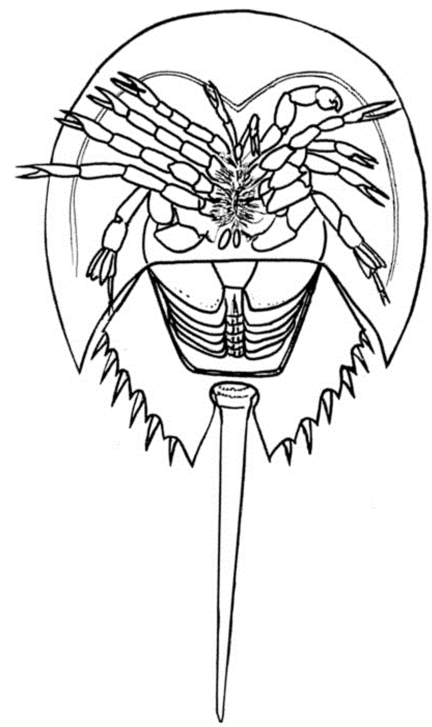
   How might the sensitivity of the median eyes to moon light and star light be helpful to the HSC?

5. Locate the underlined parts below on your molt and label each in the drawing to the right.

   Draw a triangle around the structure in the drawing that is modified in an adult male. Describe the modification.

   Describe two key functions of the **operculum** and **book gills**.

   Tell how the structure of the **pusher leg** suits its functions.



6. After reading the descriptions of the structures provided, answer the questions about each that follow.

   Draw a circle around the HSC's **mouth** in the drawing to the right and describe what is unusual about it.

   Label the **chelicerae** and **chilaria** and describe their purpose.

   Draw in the **flabellum** to show where it's located and what it looks like in the illustration at right. Describe its' function.

7. After reading the description of how HSC molts can be sexed, use the hand lens to locate the **gonopores** and identify the sex of each of specimen provided. Give your answers and reasons for each below.

   sex of specimen A: __________ Why you think so: ____

   sex of specimen B: __________ Why you think so: ____

8. These specimens reveal the inside top and bottom layers of the HSC shell. Compare the drawings and information provided on the station card to the specimens, and answer the questions that follow.

   What part(s) of the HSC's digestive system can you see and how does the structure suit the function?

   Find the muscle attachment points on the specimen as are illustrated in the lower drawing on the station 8 card. What parts of the HSC do you think they support and why?

Use this sheet to answer the questions related to the horseshoe crab (HSC) molt specimen(s) you'll be observing at each of the lab study stations. Since students will be starting at different stations, be sure that your numbered answers correspond to the numbers at the respective stations you are visiting.

Depends on teacher set-up:

1. Is this specimen a molt or a dead crab? could use molt or dead HSC How can you tell the difference?

   Molt will show distinctive split along front rim of shell; a dead HSC will not have its shell split that way.

   Bonus: Using a hand lens, look closely at the sides of the top shell of the molt specimen. Notice the zig-zag network of fine lines. What do you think caused these lines to form?

   These are fold lines from molting. As the new shell forms under the old, it is at first soft and wrinkled. As the new shell expands, those wrinkles unfold, leaving behind a network of fine stretch lines. You can also see these lines well on new adult HSCs that come into spawn along the beach.

2. Using the chart, ruler and instructions, determine the size, molt number and age of this specimen.

   _____ prosomal width (cm)   _____ molt #   _____ age (years)

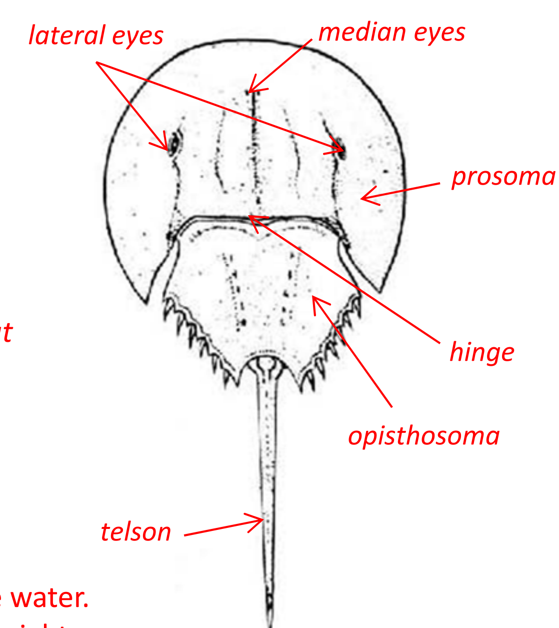
   Answers will vary depending on molt size used (see chart on station card #2 to assess answer accuracy).

3. Locate the **prosoma**, **opisthosoma** and **telson** on your molt and label them in the photo to the right.

   Read the paragraph about the HSC's hinge and heart. Label the **hinge** area on the photo to the right. How might the flexibility provided by the hinge be useful to the HSC?

   Allows the HSC to flex its body in different situations (which is better than being rigid). This could aid in movement as well as defense, and also appears to help keep the gills from drying out when stranded on the beach during spawning.

   Observe the structure of the **telson**. Scientists have found that HSCs with a short or damaged telson run a greater risk of stranding when spawning on the beach. What does this suggest about a function of the telson?



That it provides a way of helping the HSC turn back towards the water. Actually, the HSC uses its telson like a lever to help turn itself upright when flipped over on its back on the beach by waves during spawning.

4. Locate the **lateral eyes** and **median eyes** on this molt and label them in the photo next to #3 above. Describe what you are able to observe about the structure of the HSC's lateral eyes.
   Students should observe the compound nature of the HSC eye, and note the hundreds of facets in each. More detailed descriptions of individual facet structure may be offered, pending magnification available.

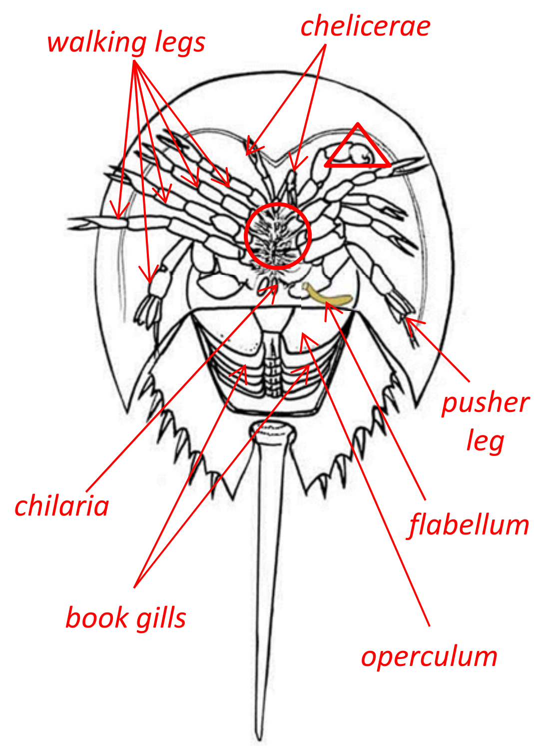
   How might the sensitivity of the median eyes to moon light and star light be helpful to the HSC?
   Anything that suggests helping its night vision is acceptable. The sensitivity of the median eyes to UV light (from the moon & stars) light sends a message to the brain telling the lateral eye how much to crank up its light sensitivity, allowing it to see as well on a dark new moon spawning night as in bright daylight.

5. Locate the underlined parts below on your molt and label each in the drawing to the right.

   Draw a triangle around the structure in the drawing that is modified in an adult male. Describe the modification.
   the front claw is modified for grasping or clasping, allows the male to lock onto the female for spawning purposes.

   Describe two key functions of the **operculum** and **book gills**.
   creating currents that aid in swimming and spawning, and providing q large amount of surface area for respiration

   Tell how the structure of the **pusher leg** suits its functions.
   the leaf-like tips can spread out, allowing them to push in to the sand or push off the bottom, and also to ball up the eggs (all things the scissor-like claws on the other legs can't do).



6. After reading the descriptions of the structures provided, answer the questions about each that follow.

   Draw a circle around the HSC's **mouth** in the drawing to the right and describe what is unusual about it.
   The mouth is tucked underneath between the legs, and the spines of the leg bases actually help soften the food.

   Label the **chelicerae** and **chilaria** and describe their purpose.
   Both structures serve to manipulate food towards the mouth.

   Draw in the **flabellum** to show where it's located and what it looks like in the illustration at right. Describe its' function.
   It comes off the base of the pusher leg. It provides sensory information about what's in the water washing over the gills.

7. After reading the description of how HSC molts can be sexed, use the hand lens to locate the **gonopores** and identify the sex of each of specimen provided. Give your answers and reasons for each below.

   sex of specimen A: *female* Why you think so: *gonopores are flat, soft and have a horizontal slit*

   sex of specimen B: *male* Why you think so: *gonopores are hard, pointy and cone-shaped*

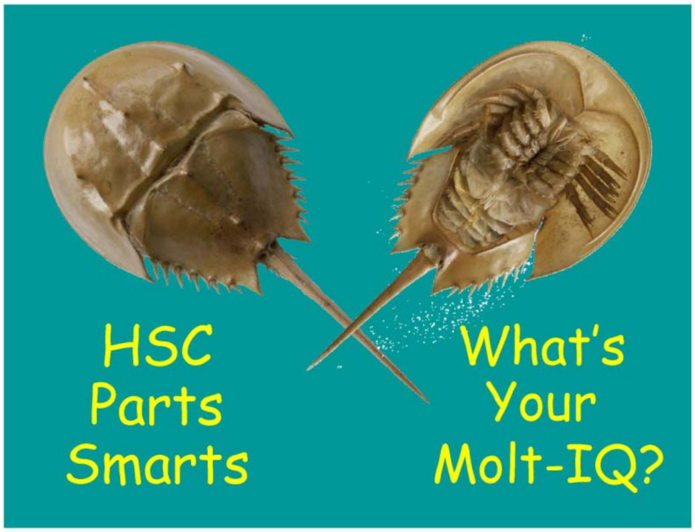
8. These specimens reveal the inside top and bottom layers of the HSC shell. Compare the drawings and information provided on the station card to the specimens, and answer the questions that follow.

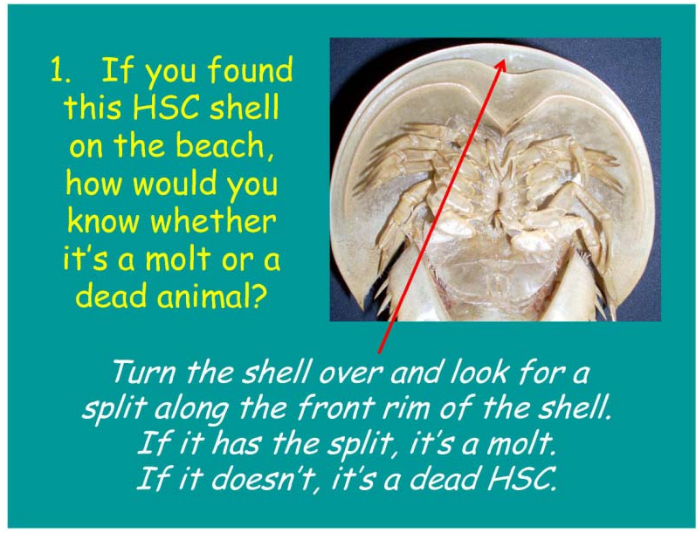
   What part(s) of the HSC's digestive system can you see and how does the structure suit the function?
   lining of crop-gizzard & esophagus; the crop-gizzard features spines of chitin to help grind & mash food

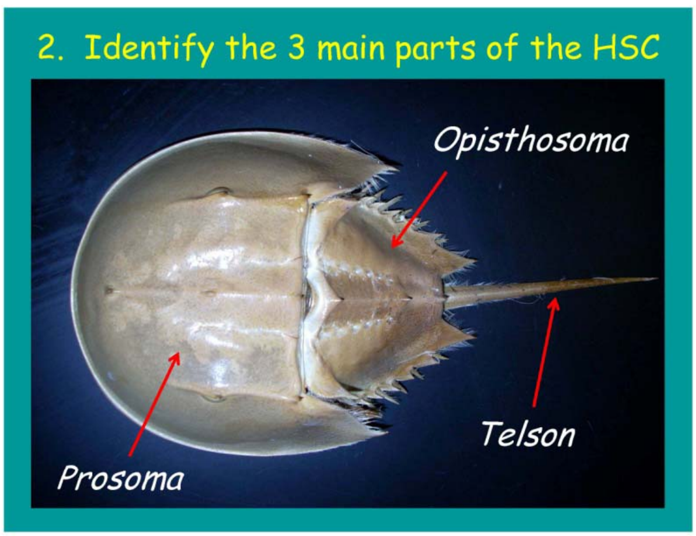
   Find the muscle attachment points on the specimen as are illustrated in the lower drawing on the station 8 card. What parts of the HSC do you think they support and why?
   Students should be able to associate these chitinous structures as lying beneath the gill plates – i.e. these structures provide points of attachment for muscles, enabling the HSC to flap its gills for rapid movement.

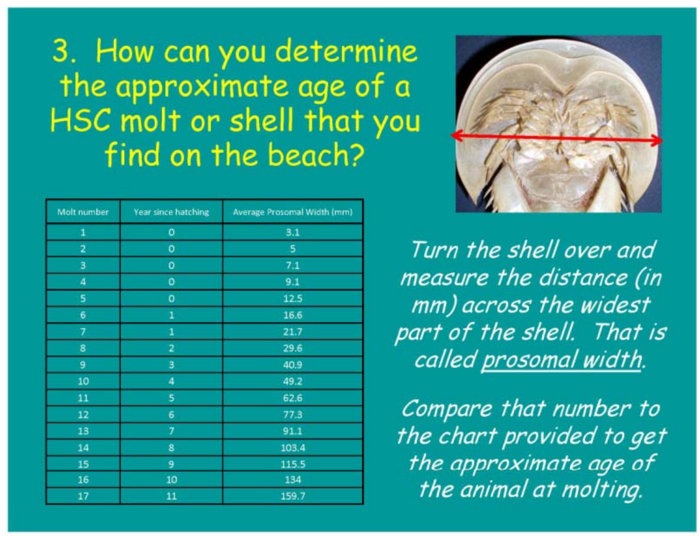
Limulus Parts Smarts Molt Study Guide Assessment Slides

(available in interactive Powerpoint format as part of this lesson)

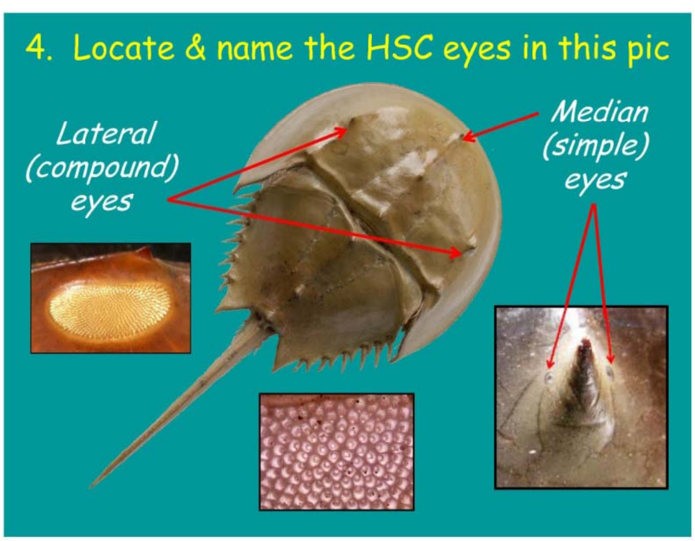


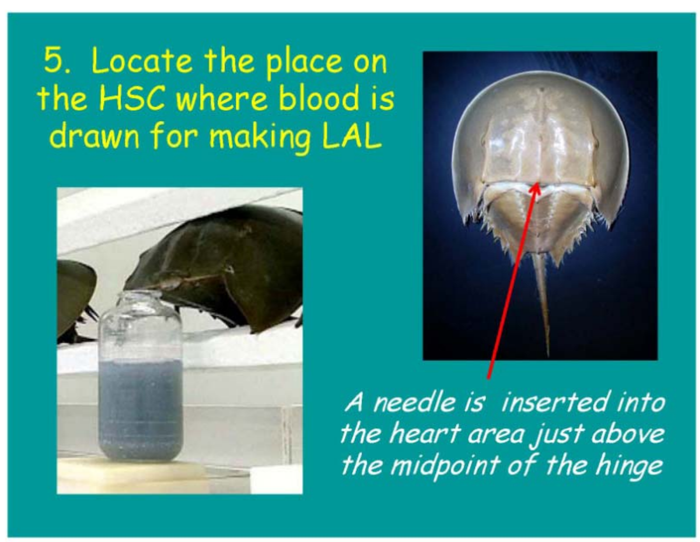






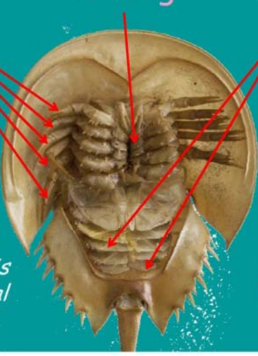
Molt number	Year since hatching	Average Prosomal Width (mm)
1	0	3.1
2	0	5
3	0	7.1
4	0	9.1
5	0	12.5
6	1	16.6
7	1	21.7
8	2	29.6
9	3	40.9
10	4	49.2
11	5	62.6
12	6	77.3
13	7	91.1
14	8	103.4
15	9	115.5
16	10	134
17	11	159.7





6. Locate and name the parts of the HSC in the molt photograph below that are responsible for each of these activities:

Walking Eating Breathing



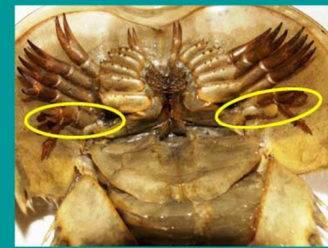
*The HSC has 5 pair of **walking legs** that it uses for crawling on land or along the ocean bottom.*

*In addition to their role in respiration, the HSC's **Book Gills** also beat in unison to aid it in swimming.*

*The HSC's **Mouth** is located in an unusual place for an animal.*

*The HSC's **Mouth** is actually located between its legs!*

7. Circle the pusher legs in the photo at right and tell what is special about them.



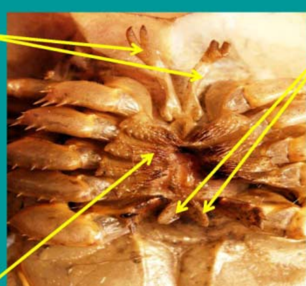
Name the structure pointed to in the photograph below.

The tips of the pusher legs are adapted for digging. They also assist the HSC in moving, and are used by the female to mold the eggs into snowball-like clusters.

*The structure pointed to in the photograph is the **flabellum**.*

8. This is a close-up picture of a HSC mouth. Identify the structures that are pointed to and describe the function of each.

__Chelicerae__ are the two small claws near the front of the HSC that move and manipulate food into its mouth.



__Chilaria__ are the small paddle-like appendages at the base of the pusher legs; they help move food forward to the mouth.

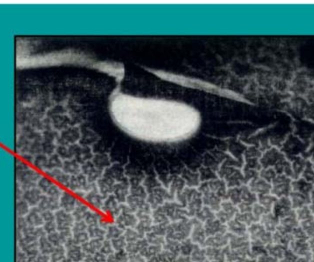
__Gnathobases__ are the strong spines on the bases of the walking legs that help to condition food as it enters the mouth

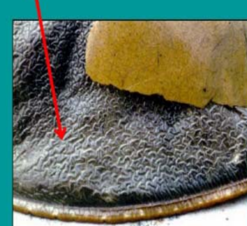
9. Locate the part of a HSC where eggs and sperm will be released from adult crabs

*The **operculum** of the HSC (along with protecting the gills) holds (on its underside) the openings where the eggs (in females) and sperm (in males) are released during spawning.*

10. This is a section of an HSC operculum that was cut out from a molt and photographed with a zoom lens. Is it a male or a female?

<u>Bonus</u>: What do you think caused the pattern of 'crinkly' lines that you see in these molts?





When the new shell forms under the old before molting, it is all folded and wrinkled at first. As it fills with water and swells the wrinkles unfold, but leave these fold-line marks behind.