Amazing Arthropods
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email: ggraeber@disl.org
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- Though debated, about 1 million of the 1.5 million described extant (living) species of animals are arthropods. 2 million of the 3 million total (extinct and extant) described species are arthropods.

- Arthropods range in size from microscopic adults to …

- the largest of all arthropods is the 12 foot wide (from claw to claw) 41 pound **Japanese giant spider crab** (*Macrocheira kaempferi*) and it lives at depths of 1000 feet!

- largest terrestrial arthropod is the 3 feet long 37 pound **robber or coconut crab** (*Birgus latro*) a relative of the hermit crab though lacking a shell. It feeds on the “white meat” of the coconut by breaking and chipping it with it’s claws!

- **Copepods** are the most abundant multi-celled animals.

- **The Sydney Funnel-web Spider** (*Atrax robustus*) possess the most venomous bite of all spiders. The neurotoxin can kill an adult human in 15 minutes!

- **The Death Stalker Scorpion** (*Leiurus quinquestriatus*) is the most venomous scorpion and occurs in North Africa and the Middle East.

- **The Horseshoe Crab** (*Limulus polyphemus*) is the most researched invertebrate in the world.

- **Sea Spiders** or **Pycnogonids** are not true spiders because it possess from 4 to 6 pairs of legs. They are carnivores that use a proboscis to feed rather than fangs, and due to it’s small abdomen their stomach extends into their very skinny legs!

- **Halobates** and **Hermatobates** are two genera of insects known as **Sea Skaters**. These two genera have the very rare distinction of being marine insects, and living on the surface of the open ocean worldwide. They do not dive or live in the ocean, and must place their eggs on floating debris. It is still not known why insects, as successful as they, do not live in the ocean.
the Shape of Life

Activity Guide

A Co-production of

National Geographic Television and

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# Phylum Comparison Chart

## Key

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Characteristics</th>
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</thead>
<tbody>
<tr>
<td><strong>SPONGES</strong></td>
<td><strong>CNIDARIANS</strong></td>
</tr>
<tr>
<td>Phylum Porifera</td>
<td>Phylum Cnidaria</td>
</tr>
<tr>
<td>No symmetry or consistent body shape</td>
<td>First muscles and nerves</td>
</tr>
<tr>
<td>Water flows through its body, full of canals</td>
<td>Some have stinging structures (nematocysts)</td>
</tr>
<tr>
<td>Spicules act as a skeleton to give it structure</td>
<td>Some free-drifting medusae</td>
</tr>
<tr>
<td>No locomotion; stationary animal</td>
<td>Some non-swimming polyps</td>
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<tr>
<td>Specialized cells, but not organized into organs or tissues</td>
<td>Hollow body cavity for food</td>
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## ARTHROPODS

| Phylum Arthropoda | Feeding device like a toothed, rasping tongue (radula) | Five-part radial symmetry | All have notochord; most have backbone |
| Champions of variations in appendages | Most have a calcium-carbonate shell | Tube feet used for locomotion | Increased complexity made possible by much more DNA |
| Exoskeleton (outside skeleton) made of chitin and protein | Muscular “foot” used to slide, dig, or jump | Some spines are little pincers (pedicellaria) | Most have inside skeleton of bones |
| First phylum to venture into the air | Some propel, using their siphon as a water jet | Hard but flexible bodies with interlocking plates under thin skin | Phylum to which humans belong |
| Pioneered jointed legs | Mantle of tissue covering the body | All members live in the ocean | Jaws and skulls important in their evolution |
| More species than any other phylum | Complete digestive tract with two ends | Complete digestive tract with two ends | Complete digestive tract with two ends |
| Complete digestive tract with two ends | Bilateral phylum that added segmentation | Bilateral phylum that added segmentation | |
Activity Six

Animal Investigations

Episode Titles: “The Conquerors” (Arthropods), “Survival Game” (Molluscs)

Activity Subjects: Body plans and parts, animal behaviors, locomotion, feeding, habitats, diversity, science process

Grade Level: 3-12 (Students in elementary grades may not be able to do all of the exercises or understand all of the abstract concepts.)

National Science Education Standards:
Standards are noted as (standard:benchmarks).

Grades 3-5
- Life Sciences (5:2,3), (6:3,4), (7:2)
- Physical Science (10:4,5,6)
- Nature of Science (11:1,2,3,4), (12:1,2,5), (13:1,2,3)

Grades 6-8
- Life Sciences (5:5,7), (6:2), (7:1,4,5)
- Physical Science (1:0,4)
- Nature of Science (11:1), (12:1,2,4,7,8), (13:1,2)

Grades 9-12
- Life Sciences (5:8), (7:1,2)
- Nature of Science (11:1,2), (12:1,3,6), (13:6)

Video Segment References: Shape of Life video references are noted as (episode number/minutes:second) in all Animal Investigation exercises. Set your VCR counter to “0” at the first frame of the video on each tape. Remember that counter accuracy will vary.

Learning Objectives:
- Students investigate the body plan and structure of a variety of animals.
- Students use the inquiry process and design investigations to study the behavior and environmental preferences of a variety of animals.
- Students work on research teams and share their findings with others.
- Students use a science notebook to record their observations, data, and conclusions.

Assessment: Students participate in discussions, write descriptions and observations, and draw illustrations.

Time: One class period per investigation (viewing only video segments recommended in each investigation)

Group Size: Entire class or pairs or small teams of students conduct investigations.

Materials and Preparation
Each student needs a science notebook before beginning investigations. Additional information is provided with each activity.

Procedure
1) Review Arthropod Investigations and Mollusc Investigations that follow, paying particular attention to the materials required and the time needed to obtain them.

2) Based on the activity or activities selected, all students should go through Exercise 1 in Arthropod Investigations and/or in Mollusc Investigations. This will give them the opportunity to get comfortable with their animal they are investigating, observe its physical structure and body plan, and get a general sense of how it will behave. After completing these general observations, proceed with one of the following steps with your students.

- Give students the opportunity to design an investigation of their own to explore some aspect of their critters. Have students prepare a simple proposal that they present to you for approval. The proposal need not be too elaborate, but should include a) the question being asked and b) the procedures the student will use. This gives you the opportunity to discuss how investigable the student’s question is and the feasibility of the procedures. For older students, the proposal could also include specific data-taking techniques and a sample data table to be filled in.

- If you prefer more specific activities, offer your students the choice of one or several of the exercises described after the initial body plan observations (Exercise 1 referenced above).
3) In the spirit of inquiry, allow students the opportunity to develop questions of their own about the animals they are observing and their behavior. Talk with students about setting up investigations that test only one variable. For example, if they are investigating dry versus moist, they need to make sure that factors like light and temperature are kept constant. It is rather easy to overlook these other factors, setting up the experimental system with one end pointing toward a window or a radiator. Give students the freedom to repeat an investigation and determine for themselves what needs to be controlled. Remember that the students are asking questions and making observations. Since they will be reporting on those observations, they cannot be wrong. What they see is what they see. However, they may see what they want to see rather than what they actually see. That can be a great source of individual or classroom discussion.

4) The observation techniques described in all of the following activities are general in nature and will have to be modified according to the particular animals being studied. Flexibility and creativity are important attributes for all keen observers. In general, don’t let the animals get too hot or too cold, too wet or too dry. Handle them gently and for short periods of time. Give them a “rest,” and then handle them some more.

See www.shapeoflife.org for links to additional animal investigations.

Arthropod Investigations

Science Background
The segmentation and flow-through gut of the annelids opened the evolutionary door for an incredibly diverse group of organisms called arthropods. The term arthropod comes from the Greek arthron meaning “joint” (as in arthritis) and pedos meaning “foot” (as in tripod). These organisms (crustaceans, like crabs and lobsters, spiders, insects, and a host of others) all have a hard outer covering called an exoskeleton made of chitin (5/11:50) with protein and sometimes minerals or wax. This exoskeleton provides protection from predators and the rigors of the physical environment (heat, cold, dryness, exposure to ultraviolet light, etc.) and a support structure for the attachment of the muscle system. But in order for this exoskeleton to move, it must have lots of flexible joints. And so it does. In the investigations outlined below, students will look at many examples of this jointedness.

During the evolution of arthropods, jointed appendages that sprouted from segments all along their bodies were modified for many new uses. There are good old legs for walking, but there are also: mouth parts for manipulating food, antennae for sensing the environment, claws for grasping, and perhaps most wonderful of all, wings for flying (5/14:00 and 5/20:30). Arthropods evolved a set of adaptations that made it possible for them to leave the marine environment and invade dry land and ultimately even get up into the air. As a result, there are more different kinds of arthropods on Earth than all other organisms put together!

Materials and Preparation
In the investigations below, students make close observations of a particular arthropod. A list of some good classroom candidates include:

Insects
• Milkweed bugs, Oncopeltus fasciatus, can be purchased from most reputable biological supply houses. They can be purchased in various life cycle stages or as a culture kit. They are harmless, rather nice-looking, and they won’t fly away.
• Mealworms (the larvae of Tenebrio beetles) are another possibility. Their segments are clearly seen and could be compared to the segments of annelids. Of course, they can also be used as food for other organisms. They can be purchased from pet stores and bait shops as well as biological supply houses.

Crustaceans
• Hermit crabs, fiddler crabs, crayfish, or pill bugs (sow bugs, roly-poly, 5/26:30) can be purchased or can be rather easily collected, depending upon where you live.
• Dead crabs, shrimp, and lobsters can be purchased in grocery stores.

Arachnids
• Spiders, scorpions, ticks, and mites are not so good for classroom investigations because they tend to bite or sting.
• A display tarantula is a possibility.

Millipedes and centipedes
• Millipedes are harmless vegetarians (detritus feeders), but a bit expensive. In some habitats, they occur in very large numbers at certain times of year. If you have an outbreak of millipedes, take advantage and bring some into class.
The Shape of Life Activity Guide

- Centipedes, like most arachnids, are not so good for classroom use. They are fast-moving carnivores (insectivores), and they may bite.

You will need various containers, tools, and other implements to house these critters and to manipulate them a bit. Exactly which containers and tools will depend on which critters you chose. Following is a general list that might be helpful. If you buy organisms from a biological supply company, the company may also suggest and sell appropriate equipment.

- aquarium/terrarium with cover to prevent escape
- water
- shoebox or shoebox lid or clear plastic box and lid
- vinegar
- hand lenses
- pencil
- straws (for gusts of "wind")
- paper towels
- cotton swabs
- science notebook
- ruler

Procedures
The following exercises are designed to be read aloud to your students. Answer guidelines are provided in brackets. The Shape of Life video references are noted as (episode number/minute: second).

Exercise 1

What is the body plan and structure of your organism?

1) Put your critter in a convenient container so that it is easy to watch but so that it cannot escape. A shoebox lid may be just the thing. Carefully look at its body plan and structure. Draw and label the organism in your science notebook. The following questions may help you decide what to put in your notebook:

- a) Dogs and cats have heads and tails and legs attached to their central bodies. Does your organism have similar structures?
  [Insect bodies have three major divisions, tagmata, which are groups of segments: head, thorax, and abdomen. Crustaceans are similar, though in some cases the head and thorax are fused together into a cephalothorax. Arachnids have a cephalothorax and an abdomen.]

- b) What do you see at the front end? Is there a head? Are there eyes? A nose? A mouth? Ears? Are there other sensory organs? Are there other appendages on the head?

- c) If you looked at earthworms, you may remember seeing lots of body segments. Does your critter have body segments? If so, do all the segments look the same?
  [The segments in centipedes and millipedes look a lot like those in earthworms. The segmentation in other arthropods is not always so obvious, though the segments can often be seen on their abdomens.]

- d) How about legs? Count them. Watch them. Listen to them as your critter walks about. Feel them as your critter walks on your hand (if it is safe to do this). What do the legs look like? Can you describe how the legs move with respect to one another? How many legs do mammals have? Is this true for all mammals?
  [The word arthropod means "jointed foot," or more loosely translated, "jointed leg." All of these critters have appendages with lots of joints. Insects have three pairs of legs (six all together). Arachnids have four pairs (eight all together). Crustaceans are variable, and it depends on what you call a leg. For example, there are walking legs and there are claws. Centipedes do not have 100 legs, and millipedes do not have a thousand. But the former do have one pair of legs per body segment, while the latter have two pairs of legs per body segment. The overall effect is that they sure do have lots of legs! Mammals all have four legs, though we sometimes refer to the front ones as arms. In the case of bats, the front ones are called wings!]

e) Crab legs (or even whole crabs) may be available at your local grocery store. Since arthropods have hard exoskeletons, their joint movements are constrained in ways that are different from those of mammals like humans. Examine a whole leg, noting in particular the amount and angles of bending of the various joints. Now examine your own leg. Here are some questions that might guide you in writing descriptions in your science notebook:
  - i) How many joints are there in a crab leg?
  - ii) How many joints are there in a human leg?
  - iii) How are the joints in your leg different from the joints in your fingers?
v) What sort of freedom of movement do you have with your leg? (Think of the agility of a soccer player.)

i) Can the crab get its legs into the same positions?

ii) Consider the “arthropod robots” you saw in “The Conquerors” about arthropods (5/43:00).

h) How about claws, pincers, or stingers? Where are they? Are they the same size? Think about what they might be used for.

i) From your observations, you can see that arthropods have many more appendages than mammals. (See Swiss Army knife analogy, 5/20:30.) In fact, all those antennae, mouth parts, claws, and wings are really just modified legs! Do you think that’s true for your nose, eyes, ears, jaws, and so forth?

Walking legs.
[Aquatic larvae of dragonflies also breathe with gills located in their rectums.]

What characteristics do animals share?
All animals must eat to survive. They are comprised of multiple cells differentiated in shape and function and possessing nuclei. (Hence, all single-celled organisms like ameba or paramecium are not animals.) All animals can reproduce sexually with sperm and eggs; some can also reproduce asexually. After the egg is fertilized, it divides into cells and tissues, undergoing a process known as embryogenesis. Lastly, most animals are capable of movement during some stage of their lives, using muscles and nerves to accomplish this feat.

Exercise 2

Does your arthropod move toward dry or moist conditions?

1) Set up a shoebox lid with moist paper towels on one side and dry paper towels on the other side. Place several organisms in the middle of the box. At five-minute intervals, draw a map showing where each one is. Repeat these observations for one half-hour.

2) In your notebook, write a few sentences describing what you saw and what you think it means.

3) Are you sure that differences in moisture account for the organisms’ behavior? Write a few sentences to show how you could repeat the investigation to validate your conclusion.

[Students may inadvertently be exposing their organisms to factors other than moisture—e.g., bright light or heat or even the students themselves, moving around and making noise. They could repeat this experiment by reversing the wet and dry paper towels and seeing if the organisms go the other way.]
Exercise 3

How long is your arthropod?

1) Measure the length of your organism in millimeters.

2) If you worked with earthworms previously, you may remember that measuring their lengths was not easy. Why is it easier to measure the length of an arthropod? [Arthropods have rigid exoskeletons while worms are flexible bags whose body fluid forms the skeleton—a hydroskeloton as opposed to an exoskeleton.]

3) When you are done, compare your results with those of another student group. Did they use the same techniques? If not, whose techniques seem to work better?

Wrap-up

The investigations above should help students explore the basic arthropod body plan and some of the behavior patterns these organisms exhibit. The possibilities for further explorations of the enormous diversity of arthropods are endless. Their segmentation, jointed appendages, and exoskeletons have allowed for an incredible evolutionary radiation. Though we, as humans, tend to think of ourselves as holding some exalted place in the hierarchy of animals, the arthropods have evolved into species that can inhabit the hottest, the coldest, the wettest, the driest, the highest and the lowest places on the surface of the Earth. Though no one species may dominate, as a whole, arthropods surely do win the numbers and diversity game.

Mollusc Investigations

Science Background
Molluscs have evolved with a remarkable diversity of different body plans. At first glance, it is difficult to see how clams and octopuses can be classified into the same phylum. However, they do share certain physical characteristics (6/630). All molluscs have a muscular foot generally used for locomotion. They all have a radula, a mouth-part generally used in feeding. And all molluscs have a layer of tissue called the mantle that usually secretes the shell. The wonderful thing about molluscs, however, is that these structures vary so widely throughout the phylum. The foot, for example, is used for gliding locomotion in snails and digging in clams, but has evolved into a jet-propulsion organ in squids and octopuses. The mantle produces the spiral shells of snails, the double shells of clams, the chambered shells of nautiloids, and the internal 'pens' of squids.

Most molluscs show characteristics similar to the other phyla explored in earlier episodes of The Shape of Life. For example, they have a front end with a head (except in bivalves, such as clams). They have a flow-through gut with a mouth and an anus. The exercises outlined below start with an exploration of the mollusc body plan, using snails as a convenient organism. This exploration is followed by several investigations looking at various aspects of molluscan structure and behavior.

Materials and Preparation
Probably the most interesting, affordable molluscs are snails and slugs. Bivalves (clams, oysters, mussels) simply will not do anything exciting in a classroom situation. Squids and octopuses are truly fascinating creatures, but are expensive and difficult to maintain. For most classrooms, snails and slugs are the easiest to get and maintain. Both snails and slugs are readily available from biological supply companies. They can also often be found in gardens and yards or under logs in most any woodland in warm weather. We suggest using terrestrial (land) snails since they are relatively active and easy to maintain in a terrarium. You can set up a simple terrarium using an empty aquarium with a lid, a water source, and lots of lettuce. Rotting sticks and leaves add a nice touch. Pond snails can be kept in an aquarium with water, and as everyone who keeps aquarium fish knows, the snails can reproduce rapidly.
Arthropods

Seventy-five percent of all animals belong to the phylum Arthropoda. Arthropods include the chelicerates (horseshoe crabs, spiders, and mites), the insects, and the crustaceans (crabs, shrimps, and lobsters). Nearly all marine arthropods are crustaceans.

All arthropods have an exoskeleton made of chitin, a protein. This external hard shell, in addition to being protective, gives rigid support for the attachment of the arthropod’s muscles. The exoskeleton is made of separate plates connected by thin membranes. The segmented exoskeleton creates joints, allowing the arthropod to move its body and appendages. Due to this segmented nature of arthropods, they are believed to have evolved from an ancestral annelid (the phylum Annelida comprises the segmented worms). Although an arthropod grows, its exoskeleton does not, so the exoskeleton must be molted from time to time.

Arthropods have jointed appendages (“arthro” means joint, “pod” means leg) that perform a variety of functions, including swimming, walking, handling food, and gathering sensory information. Most arthropods have eyes, and most are dioecious (separate male and female individuals).

The largest group of marine arthropods is the subphylum Crustacea. Typically, the body of crustaceans is divided into two sections: the head and the trunk. The head has five pairs of appendages: two sets of antennae and three pairs of feeding appendages. The trunk is usually divided into the thorax and abdomen. Most often the gills are located where the legs are attached to the thorax. The exoskeleton of crustaceans is made of chitin and calcium.

Crustaceans usually brood their eggs. Upon hatching, the larvae look very different from the adults. With each successive molt, the immature crustacean develops a more adult-like appearance.

Lobsters, crabs, and shrimp, the most edible crustaceans, belong to the class Malacostraca. A typical malacostracan is illustrated below.
Barnacles

Louis Agassiz, an American naturalist, once described the barnacle as a “shrimp-like animal standing on its head in a limestone house kicking food into its mouth.” The most familiar types, the Acorn, Balanus, and Goose, Lepas, barnacles live on rocks, pilings, floating logs, and even on whales, shellfish, and penguin toes. Barnacles congregate quickly on almost any submerged surface in salty water, but cannot settle easily on fast-moving objects.

Barnacles are the only sessile (attached) crustaceans. Most are hermaphrodites—one barnacle has both male and female sex organs. But to propagate, most barnacle species must be fertilized by a neighbor. A retractable tube containing sperm reaches outside the shell as far as several inches to another barnacle.

Newborn barnacles emerge from their parents’ shells as bristly, one-eyed larvae. After voraciously consuming plankton, they grow and molt into non-feeding, weak-swimming cyprid larvae, which soon settle to the bottom, creep around on their antennae, and search for a home. Within a few hours, a brown glue, now being studied by dentists for dental applications, anchors the larvae to the substrate. The larvae soon begin to metamorphose into adults.

Acorn barnacles secrete a volcano of overlapping calcareous plates, which totally encases them. Goose barnacles secrete a two-part shell and attach themselves to the substrate by a fleshy stalk. To feed, both barnacles use muscles to open their shell plates and extend their six feathery feet into the water, trapping plankton. The legs also have gills for gas exchange. The thin, soft cuticle covering the barnacle inside the plates is molted, but the hard plates themselves never are; they grow larger with the barnacle.
Crabs

Crabs in the family Portunidae, such as the Blue crab, have paddles on the end of their last legs, enabling them to swim. *Callinectes sapidus*, the commercially important Blue crab, is found from Cape Cod to Florida, and is very common in estuaries. Blue crabs are fast swimmers and voracious carnivores, two traits that have led to the demise of countless small fish and helpless snails. Picking up a Blue crab involves more temerity than dexterity. These crabs can pinch!

A few crabs lead an amphibious existence. The fiddler crab, *Uca*, burrows intertidally in protected sand and mud beaches from Cape Cod to Texas. Male fiddler crabs have one claw greatly enlarged. The crab brings the excavated sand to the surface in small balls attached to its legs. At low tide, Fiddler crabs come out to eat detritus. As the tide comes in, they retreat to their burrows.

Fiddler crabs are gregarious and burrow very close to one another. This makes it easy for males and females to get together. Through an elaborate courtship ritual of claw-waving and rapping, males attract females to their burrows.

Another amphibious crab is the Ghost crab, *Ocypode quadrata*, found above the high tide line on sandy beaches from Delaware to Florida. Both the Fiddler crab and Ghost crab have reduced gills capable of extracting oxygen from the air as long as they are kept wet.

Ghost crabs move with celerity, racing sideways, constantly changing directions. Their burrows are J-shaped and spaced far apart from each other. At night, Ghost crabs are very active, scavenging at the surf line for detritus or bivalves and wetting their gills at the same time.
CRAB PATTERN

Male

Female

Juvenile

Adult
Blue Crab Dissection

Objectives: Students will be able to:

- Identify the crab’s major external structures
- Identify the crab’s major internal organs
- Describe how crabs respire, feed, reproduce
- Describe the classification of the blue crab

Materials:
Blue crabs are available from local seafood retailers or Carolina Biological Supply. If fresh crabs are purchased, you can steam them, dissect them and then EAT them!

Procedure: Identify the following:

External Anatomy:
- Abdomen
- Carapace
- Telson
- 3rd maxillipeds (big flaps)
- 2nd maxillipeds
- 1st maxillipeds
- 2nd maxillae
- 1st maxillae
- mandibles
- mouth
- 2nd antennae
- 1st antennae
- chelipeds
- walking legs (3 pairs)
- swimming legs (1 pair)
- penes
- 1st pleopods
- 2nd pleopods
- Stalked eyes

Internal Anatomy:
- Gills
- Gill cleaner
- Heart
- Stomach
- Hepatopancreas
- Intestine
- Testis/Ovaries
Figure 1. Dorsal view of the male of *Callinectes sapidus* Rathbun.

Figure 2. The sensory appendages. Antenna left, Antennule right.

Figure 3. The first and second abdominal appendages. Lower left figure is female, others male.

Figure 4. The mouth parts of *Callinectes sapidus* Rathbun: A. Mandible; B. First Maxilla; C. Second Maxilla; D. First Maxilliped; E. Second Maxilliped; F. Third Maxilliped.
Get Crabby!

I. Classification
Kingdom Animalia
Phylum Arthropoda
Class Crustacea
Order Decapoda (ten legs)
Infraorder Brachyura (true crabs; “shortened”; i.e. abdomen folded under – compare to shrimp)
Family Portunidae – swimming crabs
Genus Callinectes – “beautiful swimmer”
Species sapidus – “savory”

II. Crab Biology
Appendages:
1st antennae – sensory
2nd antennae – sensory
mandibles – chop food
1st maxillae – hold food
2nd maxillae – hold food
1st maxillipeds
2nd maxillipeds
3rd maxillipeds – big flaps – count back from these
pleopods
perioepods – chelipeds, walking legs, swimming legs

Feeding:
Crabs will eat almost anything and are constantly scavenging the ocean floor for a meal. They have several mouth parts used to hold food and chop food, but they can put big hunks of food in their mouths because they chew food with their teeth in the stomach. When the food is put into the mouth, it next goes to the cardiac stomach where there are hard teeth to grind the food. The food leaves the cardiac stomach and goes into the pyloric stomach and then the hepatopancreas where digestion is completed. Other particles go to the intestine and out the anus as waste material.

Excretion:
There are glands near the antennae called ‘antennal glands’ or ‘green glands,’ which function like kidneys. This is where the urine comes out.

Ecdysis:
Molting, the shedding of the exoskeleton, occurs in all arthropods. This process is triggered by hormones. This exoskeleton provides important protection for the animal, but must be shed periodically for growth. This process is quite an involved one for crabs and can be very stressful for the animal. Not only does the animal risk being preyed upon until its new exoskeleton hardens, but lots of energy is expended during the process. One of the reasons for this is because the teeth in the stomach must also molt! When crabs are young, they molt about once a week. As they get older, they only molt about once a month and then once a year as adults. When females molt from the sally (immature) stage to the sook (mature) stage, this is typically their final molt since females die after reproducing.
Reproduction:

When female crabs are ready to mate, they send out a chemical in their urine that they are getting ready to molt. Males try to look big to attract a female. A male carries the female beneath him until she’s ready to molt. He releases her, helps her to molt and then inseminates her and carries her until her exoskeleton hardens. She stores the sperm and fertilizes the eggs. Ovaries release the eggs and seminal receptacle releases the sperm. The female crabs leave the estuary and go to the open ocean because the crab larvae cannot tolerate brackish water. She holds the fertilized eggs in her telson where they appear as an orange spongy mass. This orange color is the eggs’ yolks. As the yolk is consumed by the larvae, the spongy mass turns a grayish brown – these are the millions of eyes of the tiny crab larvae. When the larvae are ready to be released, they send a chemical signal to the female. She flaps her abdomen, breaking the egg membrane and zoea larvae are released. Upon this, the female dies.

III. Other Crabs

Hermit crabs are one of the most common seashore dwellers that entertain and fascinate beachcombers everywhere. Their soft, muscular tail requires them to inhabit the shells of gastropods to protect them from predators. As a larva, the hermit crab selects a shell and moves from small shells to larger ones as it grows. Like other crabs, hermit crabs are important scavengers, cleaning the ocean floor free of dead remains. Hermit crabs found for sale in pet stores are usually not the same type as the ones found on Gulf of Mexico beaches. These pet store versions are actually land crabs native to South America, whereas the ones native to the Gulf live in salt water.

Fiddler crabs are small and very abundant crabs commonly seen in salt marshes. Unlike blue crabs, they are not swimming crabs and only have legs adapted for walking on the land. Male fiddlers have one large claw and one small one. The large one is used mainly for waving around to attract a female.

A crab commonly found on beaches, is the nocturnal ghost crab. During the day, the large burrows of these crabs can be seen, but the crabs themselves are usually only out at night. If a burrow is occupied and another crab starts to enter, the crab will rub parts of its body together to cause vibrations, which tell the incoming guest that the burrow is occupied.

Horseshoe crabs, Limulus polyphemus, are arthropods with jointed appendages, but are not Crustaceans – they are in the subphylum Chelicerata and Class Merostomata. Recently horseshoe crabs have been discovered to be useful in the medical field. A compound called lysate is present in horseshoe crab blood. Lysate clots in the presence of endotoxins produced by bacteria. The blood is used to test for the presence of these endotoxins in medicines.

Did you know?? The world’s largest arthropod is the Japanese spider crab, which has a leg span of 12 feet!
Crabs are decapod (ten–legged) crustaceans, along with shrimp and lobsters. Unlike shrimp and lobster, however, which have a well–developed and delicious, muscular tail, the crab’s abdomen is just a tail flap. It is turned forward and hidden under the crab’s body.

Crabs are well–adapted for a benthic, or bottom dwelling, existence. They crawl actively on their many–jointed thoracic legs. These same legs have an upper branch, the gill, which is hidden under the carapace and provides the oxygen for their active life style. The first pair of thoracic legs is usually modified to form strong claws for feeding and defense. They have well–developed compound eyes, mounted on the upper front of the body, for seeing above them. The appendages of the head form a square or triangular mouth into which a crab will stuff almost anything. Crabs make up the oceans biggest garbage detail, they are constantly scavenging. They are important in transforming the dead material into living and frequently tasty protein.

There are many different types of crabs, the Atlantic and Gulf have twenty–one families of common crabs and half–crabs (see “Half–crabs” in Marinating Your Vocabulary). Some of their diversity can be realized by noting that there are: land–dwelling crabs, amphipod crabs, swimming crabs, crabs that are prisoners in coral caverns, crabs that live on or with other animals, and crabs from very deep water. Crabs can also be an important fisheries resource; blue crabs, and stone crabs support many fishermen throughout the Gulf of Mexico.

Pictured above is the swimming crab Callinectes sapidus, commonly known as the blue crab. It is one of the most abundant and the most important commercial species in the Gulf of Mexico. Blue crabs brought a total of 10 million dollars to Gulf fishermen in 1988. From the diagram you can see most of the important features of crab anatomy.

**PORTUNIDAE—THE SWIMMING CRABS**

There are many swimming crabs, the familiar blue crab pictured is one of these. The portunids have modified the last pair of walking legs into paddles for swimming. The carapace is usually broad and has spines along the anterior/lateral margin (front/side edge). Large spines are also usually present on both sides, frequently giving these crabs an almost diamond–shaped carapace. The claws are long and strong — and in a defensive posture, the crab may hold them up, aggressively, in front of itself, in a crab–like impersonation of Richard Nixon.
The Crab Fishery

Crabs can be a delicious food item and thus are an important fishery resource. As much as 40 million pounds of blue crab are taken from the Gulf annually worth almost $10,000,000. Frozen kings crab can be found in most grocery stores and dungeness crabs are eaten by Californians. In the Caribbean they eat a large spider crab and in south Florida stone crab claws are served at most restaurants. Along the southeast coast of the United States a deepwater fishery is developing for the large red crab, Geryon squamipes. Researchers are presently studying the feasibility of a similar fishery in the Gulf for both red crabs and its close relative, the even larger, Geryon fenneri, the golden crab.

Commercial fishermen usually use crab “pots” to harvest the animals. These pots are porous boxes which are dropped in the water at sites where crabs are usually found. The pot is designed with large exterior openings which funnel into small openings on the interior. Inside is a wire “bait box” which is stuffed with the preferred bait, usually dead fish. Crabs attracted by the scent of the bait, easily make their way into the trap but rarely find the means of escape.

The crab pot line is placed overboard and each trap is marked with a buoy. This allows the fisherman to find and check his traps easily. As each trap is pulled aboard the fisherman opens a hinged lid and shakes his catch into slatted boxes or baskets. The trap is then rebaited and thrown back overboard. Several types of crab traps are pictured below.

Many coast residents “crab” off piers and bridges using a simple string basket. Bait is tied to the middle of the basket and dropped in the water. By checking the basket periodically crabs attracted to the bait are lifted to the surface. This simple gear is also illustrated below.

THE HORSESHOE CRAB
A Crab Impostor

Horseshoe crabs (Limulus polyphemus) are actually crab impostors. Although, they are arthropods with jointed legs and a crunchy outer skeleton, they are only superficially crab-like.

Horseshoe crabs are a very ancient form and have existed, much as they are today, for about 300 million years. Their closest relatives are the extinct trilobites and sea scorpions of Paleozoic seas. They are common in Gulf waters and their molts (shed shells) are frequently found on beaches. The animals themselves may appear on beaches in large numbers during the molting season, when the larger females come into the intertidal areas to lay their eggs, sometimes with several males in tow.

SOFT-SHELL CRABBING

Because soft-shell blue crabs are so valuable, special fisheries have evolved to meet the demand for these animals. Recently-molted, soft-shell crabs are easy prey for their hard-shell peers which have no qualms about cannibalism. They seek shelter in grass beds or submerged brush or almost any other area in which they can find cover and shelter. The delicate and fragile crabs are especially vulnerable at this time.

Generally, crabbers fish for the hard-shelled animals but may separate and hold animals which are about to molt. By inspecting the rear legs, paddles, for color signs the “peelers” can be separated from the others. Special gear for harvesting these potential soft-shells has been designed. For instance, bottom scrapes with mesh bags are pulled through grass beds. In Louisiana a brush trot-line is used; this a long rope with bushy limbs tied at regular intervals along it. Marked with buoys this can be pulled and any crabs gently shaken from the brush. These pre-molt crabs are then housed in special shedding boxes and watched carefully until they have undergone ecdysis (see Marinating Your Vocabulary). The soft-shell is then prepared for market and frozen, or sold fresh to dealers.

In shallow water, recreational crabbers capture the soft-shells using dip nets.
COMMON FAMILIES OF CRABS FOUND IN THE GULF OF MEXICO

DROMIDAE—THE SPONGE CRABS
These crabs are known for their habit of carrying a living sponge on top of themselves as camouflage. While so attired, they can virtually disappear into the surroundings. The last pair of walking legs is reduced and curves upward to hold and support the bulky sponge. The carapace is usually about as long as it is wide and the body may be covered with setae (hair-like bristles).

GECARCINIDAE—THE LAND CRABS
These large, terrestrial burrowers are familiar to residents of south Florida and Louisiana. The carapace is round or oval, and the eyes are large, placed well apart, and on long stalks. Land crabs are largely vegetarian and can be a pest in rice or tomato fields. In order to breath, these crabs have special gills which are held erect and separated by stiff lamellae. The gill chamber also contains spongy highly vascularized tissue which functions as a lung.

XANTHIDAE—THE MUD CRABS
These are oval, to square, to hexagonal crabs with massive claws tipped in black (or less frequently in white) and thick heavy bodies. They are shy retiring types, hiding in holes or burrows or under rocks and debris. The stone crab is the largest one in the Gulf, and the only one of commercial value, but many small varieties are present locally. Normally dark, xanthid crabs are usually some shade of brown or grey, the coral crab, however, is an exception and is a vibrant red hue.

LEUCOSIDAE—THE PURSE CRABS
These animals get their common name from their resemblance to the full-roundness of a well-stuffed drawstring handbag. Please picture the bag with legs. It is the round or oval carapace that gives this purse-like appearance and there are frequently one to three spines along it’s back edge. The claws are long and slender and its last pair of walking legs is somewhat reduced. These animals have a triangular mouth frame.

OCYPODIDAE—THE AMPHIBIOUS CRABS
These abundant crabs are almost always intertidal to semiterrestrial burrowers. It includes the ghost and fiddler crabs which are familiar to all visitors of the seashore. They have square to rectangular bodies and big eyes on long stalks. The claws are usually unequal in males (in the fiddler crabs this difference is greatly exaggerated) and are used in sexual displays.

PARTHENIDAE—THE ELBOW CRABS
These small crabs can be recognized by their long, sharp, bent claws. These claws are usually markedly disproportionate when compared to the other walking legs. Their carapace is usually roughly triangular in shape and may look as though it’s divided in three parts. These animals seem to prefer sand or broken shell bottoms.

RANINIDAE—THE FROG CRABS
These are burrowing crabs, they may appear strange, largely because of the adaptations for living beneath the substrate. The last pair of walking legs is reduced and is placed close to the top of the body. The abdomen is slightly flexed beneath the body. The legs themselves are broad and flat and the carapace is usually longer than wide. The antennae and antennules are large and do not fold up against the front of the body. Frog crabs are usually found offshore in the northern Gulf.

GRASPIDAE—THE GRAPSID CRABS
This a very diverse family of crabs, it includes marine forms, amphipodous, and freshwater forms. Generally, these crabs are depressed (form/vestrally flattened) and squarish. Their eyes are located at the front corners of the carapace. The claws are almost always equal and similar. They are many semi-terrestrial or amphipodous forms, like the colorful Sally-light-foot crab of the tropical Atlantic.

GONOPLACIDAE—THE GONOPLACID CRABS
The family Gonoplacidae are very like the xanthid (mud crabs) and can only be distinguished by comparing the male genitalia of gonoplacid to that of xanthid. Some animals are so similar in appearance that only very close examination can determine their familial affiliation. Gonoplacids are small quadrable crabs of mud bottoms. Usually their claws are not quite as massive and heavy as the xanthid and they may or may not be tipped with color. Many of them have setose (hairy) areas on the inside, elbow-like region of the claw.

MAJIDAE—THE SPIDER CRABS
This is a large and diverse family of crabs. The carapace is roughly triangular as it is narrowed toward the front into a rostrum. The shell itself is frequently covered with hooked and barbed setae (bristles) and spines which allow the firm attachment of bits and pieces of the surrounding environment. The claws are usually long and slender and differ only slightly from the walking legs.

CALLAPIDAE—THE BOX CRABS
These animals are also known as chameleon-faced crabs because they hold the massive, flat, claws close against the front of their body. Their body is thick, usually triangular to oval in shape and protected by a heavy exoskeleton or shell. The mouth is triangular and the last pair of abdominal legs (tropopods) are absent. These crabs have one claw modified into a can-opener-like devise for breaking into mail shells— for the small shells or the hermit crabs that later occupy them.

PINNOITHERIDAE—THE PEA CRABS
These are tiny crabs almost always living in close association with another animal. The carapace is round to oval, and is frequently membranous and soft (especially in the females). One of the most famous is the pinnotherid in the oyster crab which steals oyster meat off of the digest of a feeding oyster while protected within the shell of it’s host. While this association is parasitic, many other pinnotherid/host relationships are not. A number of small pinnotherids of the genus Pinnixa are found with worms, ghost shrimps, and burrowing sea cucumbers in the Gulf of Mexico.
DID YOU KNOW?

* King crabs, the large species which is harvested from the north Pacific, is closely related to hermit crabs. Although it has abandoned the habit of using a small shell (luckily, for it would need a very large shell), if examined carefully the bottom of the abdomen still exhibits the twisting characteristic of hermit crabs and the last pair of legs are so small they are virtually invisible.

**King crab**

* Members of the tropical crab family Potamidae are all found in fresh water. Some of the members of the family Grapsidae are also freshwater animals.

* In land dwelling crabs, like the family Gecarcinidae, and the hermit crab family Coenobitidae, the gill becomes a spongy, highly-vascularized tissue, much like the lung tissue of terrestrial animals.

* Female crabs glue their eggs to feathery structures on the underside of their abdomen. Here they are aerated and protected until hatching. This egg mass is frequently yellow (from the egg yolks) to dark black (from the young crabs developing eyes) and forms a thick spongelike growth beneath the crabs tail fan. In fact, these expectant crabs, are commonly known as sponge crabs.

* The crabs excretory organ, the green gland, is necessary to rid the body of nitrogenous wastes (ammonia, uric acid) and is located just beneath the antennae.

* Most crabs copulate only when the female is soft. The rigid exoskeleton may hamper the penetration of the male sexual organs, the gonopods. These specially adapted legs transfer a packet of sperm to the female. The male will frequently cradle the female, for sometime prior to mating, he may help her accomplish her molt and protect her during this vulnerable period. This guarantees that his offspring will have a chance at survival.

* Hermit crabs may also have to wait until the female molts. However, precopulatory activity does not involve the gentle cradling of the receptive female, instead the male pulls his prospective mate around with him by one of her exposed legs. In some crabs mating may take place for weeks while in some hermit crabs copulation lasts less than five seconds.

* Spider crabs (family Majidae) have hooked spines on their bodies. The crabs affix algae, bryozoans, corals, or any other handy bit of the surrounding environment onto their shells with a glue-like salivary secretion. This decoration helps to camouflage them.

* The world's largest arthropod is a crab, the Japanese spider crab, *Macrocheira kaempferi*, and has a leg span of 12 ft. (4m). However, one of the world's smallest crabs is found in the Gulf of Mexico. This crab, *Dissodactylus*, is symbiotic on (living with) the common sand dollar and may be only 2 mm across.

* Stone crabs may produce sounds, by rubbing a column of ridges, found on the inside of their claw, against their carapace. A closely related mud crab produces a sound similar to that of a grasshopper.

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**Hermit Crabs**

These ubiquitous (common and abundant) seashore inhabitants fascinate and intrigue most beachcombers. They busy themselves along most of the world's shores scavenging for edibles, investigating shells, and generally scurrying about in a busy manner. These animals are such efficient scavengers that aquarium keepers frequently keep them to clean the bottom of their tanks. Not too picky about the food they consume, the hermit crab is also important in keeping our beaches and ocean bottoms free from dead and decaying remains.

Hermit crabs are "anomuranus" a group that is intermediate between the lobsters and the true crabs. In these animals, the muscular tail has a soft membranous covering and makes the animal vulnerable to predation. The hermit crab has solved this problem by tucking its hind-end into the shell of a deceased snail. This mobile home is such a part of its existence that it is rarely seen without one.

The shell is such a constant feature that many persons are unaware that a small snail inhabited the shell, thinking instead that the crab fashioned this bulgy, burdensome, necessary shell. In fact, shells are such an important part of the crabs life that it selects one as a larave, moves from small shells to larger ones as it grows, will be quickly eaten if there are not enough available, carefully investigates any shell it comes upon, and will fight for an adequate one. Hermit crabs give up their shells only under the greatest of stress.

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**GENERALIZED CRAB LIFE-CYCLE**

Female crabs glue their eggs to feather-like legs beneath the abdomen (tail flap). When the eggs hatch the young crabs, which have long spaces on their carapace, are known as zoea. The zoea may drift for some time as a part of the plankton, and there may be several zoeal stages. After a while the young crab will shed its last zoeal shell, and the new, larger larave will possess well-developed claws, it is then known as a megalopae. The megalopae still has a very lobster-like tail, however, with the next molt, it's tail turns under and the familiar crab-like form is apparent. This first-crab will grow and molt several times before it becomes sexually mature and starts the cycle over again.

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Drawings adapted from: Identification of Marine Crabs and Crayfish by Bruce L. Eastman, Texas A&M University, College Station, Texas, 1962, and published by Texas A&M University Press.
Marinating Your Vocabulary

EXOSKELETON: An external skeleton, which provides protection, supports the body tissue, and serves as a surface for the attachment of muscles. A crusty, shell of chitin (a protein) solidified by the addition of calcium salts forms the exoskeleton of crabs.

ECYDISIS: Molding, the shedding of the exoskeleton in arthropods (crustaceans, insects, and arachnids). Once dry and enriched with calcium salts the arthropod exoskeleton is a rigid structure. This shell must be periodically discarded to allow for body growth.

SOFT-SHELL CRAB: A term which can refer to any recently molted crab, in which the new shell is still membranous and without any hardening calcium salts. It is, however, almost always used to refer to newly molted blue crabs, Callinectes sapidus, which are considered a gourmet delicacy.

GLAUCOCHTHOE: The megalop stage of a hermit crab. It is in this megalop stage that the crab begins to hunt its first shell home.

BRACHYURA: The taxonomic group which includes the true crabs. This group first developed about 135 million years ago. It exhibits a surprising diversity and about 4,500 different species are known. These animals have a broad, usually flattened, carapace, the first thoracic legs form strong claws, and they have a symmetrical abdomen which is reduced and lightly flexed beneath the cephalothorax (fused head and thorax).

HALF-CRABS: These are animals which are placed in the taxonomic infraclass Anomura, which means odd-limbed. They all have a depressed carapace, the fifth pair of thoracic legs is reduced or turned upward, and the abdomen is usually soft or partially folded beneath the cephalothorax and is frequently asymmetrical. This group includes the ghost or mud shrimp (sometimes called yabya), the hermit crabs, the squat lobsters, the porcelain crabs, and the mole crabs.

Hermit Crab Cha Cha Rhythm

1. This is a rhythm in which the whole class may participate.
2. As they sing, the children pretend to be the Hermit Crab by sliding along in a forward manner on their feet as follows:

**Hermit Crab Cha Cha**

- **The Hermit Crab**
  - Cha (slide L. foot)
  - Cha (slide R. foot)
  - Cha (slide L. foot)

- **It has no home**
  - Cha (slide R. foot)
  - Cha (slide L. foot)
  - Cha (slide R. foot)

- **It has no shell**
  - Cha (slide L. foot)
  - Cha (slide R. foot)
  - Cha (slide L. foot)

- **To call its own**
  - Cha (slide R. foot)
  - Cha (slide L. foot)
  - Cha (slide R. foot)

As it scurries along in the ocean near the shore.

- Cha (slide L. foot)
- Cha (slide R. foot)
- Cha (slide L. foot)
- Cha (slide R. foot)
HERMIT CRABS

Living Marsh

The

Chamene Dindo

by

stinging tentacles.

A hermit crab will pick up an anemone and place it on top of its shell. The anemone helps protect the hermit crab because it has a tough shell.
A hermit crab is a small animal with a soft stomach, lots of crusty legs and two claws.

It looks like this.

Who likes to eat hermit crabs? Big fish, sea stars and octopus.
Hermit crabs live in empty sea shells like an oyster drill or moon snail. Sometimes they will fight other hermit crabs and try to steal their shell. A young hermit crab will outgrow its shell.

to protect the soft part of its stomach.
Hermit crabs nibble at dead fish, snails and clams along the shore.

Their favorite food is a bright green seaweed called sea lettuce.
HERMIT CRABS

Hermit crabs — the name implies a leggy loner, shunning the company of others. Instead, they are gregarious and conspicuous members of most seashore communities. Indeed, these fascinating creatures have entertained and amused most seaside visitors. Abundant in these intertidal zones—where they taste both the oceanic and terrestrial worlds—hermit crabs also inhabit many oceanic environments. In addition, members of one tropical family are land-dwellers as adults.

Hobbling about in the adopted shells of dead snails, hermit crabs, hide the soft twisted back-side that makes them so unique. These beautiful mobile-homes are frequently the envy of shell-collectors. The shell is of such importance that one almost never finds a crab without it. Furthermore, if you deliberately take the crab from its shell, the nude animal will change from an aggressive claw-waving crustacean to a cringing and timid animal desperately looking for cover.

The crab's very form has changed to accept these shelters. The soft abdomen has become a grotesque twisted feature. Its terminal pair of legs forms a hooked fastener which closes over the central column of the snail shell. The crab's last two pairs of walking legs are reduced. The second of these turns up and over the crab's back to help secure the animal inside its shell.

This diagram shows a hermit crab as it fits in its adopted shell. The uropods, the final pair of legs, sold onto the rod that supports the middle of the hell.

When a hermit crab outgrows its adopted snail shell, it merely finds a new one. But, when it outgrows its exoskeleton it must shed the old one in order to grow.
THE LIFE OF HERMIT CRABS

Hermit crabs are a diverse and adaptive group. They are found in most marine habitats from shallow, warm waters to cold, abyssal depths. One finds them in tidal pools, along sand beaches, amongst coral reefs, mangrove swamps, grass flats, salt marshes, mud flats, on rocky bottoms and over oceanic ooze.

Hermit crabs are opportunistic feeders. They prey on live animals, scavenge dead ones, feast on particles of detritus, graze amongst algae, and even filter feed. They consume both animal and vegetable matter. They find these tasty morsels with taste receptors on the antennules and on the tips of their walking legs.

Hermit crabs have separate sexes, but close inspection of abdominal appendages is necessary to tell males from females. Reproduction has not been extensively studied. Males of some species may pull females around by one of their walking legs, others just follow her, trying to stay close. In some species, molting of the female is necessary for successful transfer of the sperm packet, but, in others molting is 10% necessary. Pre-mating behaviors include a male who may rotate, rock, shake or jerk his prospective mate. Receptive females may signal their willingness to mate by stroking the top of the male's mouth or his antennal region with her claws. Mating is quickly completed, usually taking less than five seconds.

SOME HERMIT CRABS FROM THE GULF OF MEXICO

The Odd Tails: A Strange Group of Crabs

Hermit crabs belong to that strange group of decapod crustaceans sometimes known as half-crabs. Scientists know these, half-crabs, as anomurans. The root term also gave rise to the word “anomalous” which means odd or apart from normal. They are an odd, though not necessarily, abnormal assemblage: ghost shrimp, mole crabs, king crabs, squat lobsters and porcelain crabs all belong in this same category. Anomurans in spite of their ten legs are noticeably different from the more familiar shrimp, crabs, and lobsters to which they are related. Their common name comes from having an abdomen that is intermediate between the large muscular and extended abdomen of lobsters, and the small nonmuscular and folded abdominal apron of true crabs.

Hermit crabs are probably most like the secretive ghost shrimp who also have a soft abdomen or tail. In fact, they may have evolved from an ancestor much like present day ghost shrimp. Somewhere along that evolutionary line, however, the hermit crab ancestor gave up burrowing in the bottom. It traded this burrow-confined life for the more mobile existence a protected abdomen allowed, even if you had to find that protection yourself.

Hermit crabs are characterized by having an abdomen that is soft and twisted to the right. The twisting, of course, allows them to occupy the shells of dead snails. The abdominal appendages on the right hand side are small or missing altogether. The last pair of appendages, the uropods, form a hook for grasping the columnella (central support) of a snail shell. Finally, the last two pair of walking legs are smaller than the others and quite useless for walking. The last of these two pair of legs is also turned up and over the crabs back and helps to hold the animal into its assumed home.

There are three families of hermit crabs: The Paguridae, Diogenidae, and the Coenobitidae. Pagurid crabs are usually found in temperate oceans. They are most often right handed, with their right claw being larger than the left. The last pair of mouthparts is usually widely separated in this group. The Gulf of Mexico contains several members of this family, the most common are: the flat-clawed hermit crab, Pagurus pollicaris; the long-clawed hermit crab, Pagurus longicarpus; and the small inconspicuous Pagurus annulipes.

Diogenid crabs are most often tropical in distribution, although several temperate exceptions are found in the Gulf of Mexico. If one claw is larger than the other, it is usually the left claw, but, many have claws equal size. The last pair of mouthparts are touching each other. The striped hermit crab, Clibanarius vittatus, is a diogenid crab. It is probably the Gulf’s most frequently encountered hermit crab. Petrochirus diogenes, the giant red hermit crab is also well known.

Coenobitids include all the land hermit crabs. Tropical in distribution, these animals have lung-like tissue which has replaced the gill. The left claw is usually larger than the right, in some species, remarkably so. The coenobitid hermit crab found in the Florida Keys and throughout the Caribbean, Coenistiylus clypeatus, is also known to many children, because it is commonly sold in pet stores.

A SHELL FULL OF HOUSEGUESTS

Hermit crabs are not the loners their name would imply, in fact, they are found in close association with many other animals. I have found as many as 21 other animals living with the striped hermit crab, *Clibanarius vittatus*, a common resident of Gulf shores. A crab's shell may be encrusted with so many animals that the totality has been described as a community. The name, hermit crab, comes from their reclusive habit of retreating to the depths of their shell when picked up by beachcombers.

One of the most frequent associations is that of hermit crabs with sea anemones. Here in the Gulf of Mexico, the tricolor anemone, *Calliactis tricolor*, is frequently found on hermit crab shells. The anemones stinging cells may keep octopuses and other potential predators from attacking the crab. In some crabs the anemone grows along with the crab. This ever-increasing anemone cloak does away with the need to find a new shell. The relationship is so well-developed that signals have evolved which allow a crab to encourage anemones to inhabit its shell. A gentle tapping at the base of the anemone, or tapping combined with a gentle stroking of the column will cause the anemone to loosen its pedal disc. This allows the crab to place the anemone on its shell. Some species of anemone are found only on hermit crab shells.

Hermit crab fur is another animal, or colony of animals, whose stinging cells help keep predators away from the crab (See Marinating Your Vocabulary). In return the crabs messy eating habits provide scraps of food for the hitchhikers.

A fascinating and colorful symbiont (closely associated organism), found with hermit crabs in the Gulf, is the small red and white porcelain crab, *Porcellana sayi*. These flat filter feeding crabs probably benefit by feeding in currents set up to pass water over the crab's gills. On some giant red hermit crabs as many as 10 porcelain crabs have been found. Just how this association works and whether the hermit crab derives any benefit is yet to be studied.

Worms may also take refuge inside or within the crab's shell. In Europe, the ragworm frequently inhabits hermit crab shells. It gains protection by living inside the shell, but also, steals an occasional meal, eating right from the mouthparts of the feeding crab. In the Gulf of Mexico, relatives of the ragworm, also inhabit hermit crab shells or burrows within those shells. However, here, the relationship has not progressed to thieving food from their host's mouth, as far as we know. Scale worms another common marine worm in the Gulf, shelter in the umbilicus (central exterior cavity) of moon snail shells inhabited by hermit crabs.

The shell itself may serve as a refuge of hard substrate. In the soft-bottom areas of the Gulf these shells frequently sport barnacles, encrusting bryozoans (sea lace), tube worms, slipper snails and even oysters. Shell burrowing worms, like blister worms, and boring sponges also live within the very substance of the shell.

This aspect of hermit crab life, that is, the creatures it shares its shell with, is not well studied and deserves further investigation. A number of advantages and disadvantages have been surmised, but few are proven or even tested experimentally. Frequently, there appear to be both advantages and disadvantages. For instance, associate organisms may benefit by getting a free ride, or access to additional food, or better feeding currents. They may be helped by not being buried in the sand or just having something hard to live on. The crab may get protection, or an advantage in shell fights. Heavily encrusted shells appear larger and bigger shells are an advantage in shell fights. However, it may have a heavier, more cramped, and sometimes weaker shell (from boring worms and sponges).
THE IMPORTANCE OF A SHELL

The hermit crab's habit of securing its vulnerable abdomen inside the abandoned snail shell is its most distinctive feature. The shell affords protection and prevents intertidal and terrestrial forms from drying out. It also protects the developing brood which is secured to the abdominal appendages of the female. Unprotected crabs quickly fall prey to predators. Indeed, populations of crabs are thus limited by the very presence of shells. Experimenters have both increased and decreased populations of crabs by increasing or decreasing the number of available shells.

As the animal must change shells as it grows, considerable energy is spent investigating empty shells. These shells are turned until the opening faces the crab and carefully inspected. Both internal and exterior surfaces of the shell examined. Interior dimensions are measured by extending its antenna and claws inside the shell.

Hermit crabs have proven to be picky shell-buyers. Crabs will consistently pick one species of shell over another, even if they are apparently comparable shells. Different species of crab have different preferences. However, any shell will do in a pinch. Occasionally crabs have been found in clam shells or even in bottle caps and light bulb sockets. When a transfer to a new home is decided upon, the change of shells happens so quickly that it is easily missed. Frequently, the crab will drag its old home around with it until assured it is completely satisfied with its new shell.

Several other behaviors underscore the shell's importance. Perhaps, the most telling behavior is the ritualized "shell fight." Hermit crabs have evolved a method for exchanging shells so each crab can maximize shell fit. In these encounters, one crab, crab "A," will approach another hermit-crab-occupied shell. Crab "A" will present itself aggressively to the other crab, crab "B," and face the opponent. Crab "A" will then grasp his opponent and tap on the outside of "B"s shell or in some species rock crab "B"s shell back and forth.

After being confronted, crab "B" can do one of three things. It can emerge from its shell holding its claws up and out in a clear message of aggression. It might however, choose to retreat deep into its shell and hope that its tormentor leaves, or finally, it might abandon its shell and wait patiently on the top of its home while the potential trader checks out the inner dimensions.

The third option is chosen if crab "B" is in a poor fitting shell. If crab "A" finds the shell suitable, it will take up immediate residence leaving its abandoned shell for crab "B." If the second option is chosen and crab "B" retreats into the safety of its shell, crab "A" may still continue to tap and rock an invitation to change shells. A crab, thus harassed for some time, may eventually come forward and abandon its shell.

DID YOU KNOW?

* King crabs, those giant gourmet delicacies from the north Pacific, are closely related to hermit crabs. They probably evolved from them. Their abdomen is skewed to the right and has appendages only on one side. Additionally, their lst pair of walking legs is reduced and held up and over their back in the manner of true hermit crabs.

* A deep-water hermit crab may find its way over the ocean floor by using the light of its associate anemone. The anemone glows in the dark. This crab has very large eyes even though there is no natural light, at that depth, by which to see.

* "Birgus," the coconut or robber crab of the south Pacific is actually a hermit crab. As a young crab these animals find a shell and behave much as any other hermit crab. However, as they grow, the forward part of their abdominal shell hardens. Given this extra measure of protection they soon give up their shell for a burrow. Still, they carefully tuck their still vulnerable lower abdomen tightly between their legs. These peculiar crabs are the largest land dwelling crustaceans. The natives consider them a staple food item.

* Although, the hermit crab's most distinctive feature is its borrowed snail shell, some crabs have forsaken the typical snail shell for something more exotic. One deep water hermit houses his abdomen in hollow pieces of wood. A Pacific species uses bamboo pieces. Some prefer the elongate tube-shaped tusk shells. One uses the elongate tubes of dead worms. Another variety backs his abdomen into burrows in coral reefs. Yet another, uses the soft body of a sponge as its mobile home. Desperate crabs have been found carrying clam shells, light bulb sockets, bottle tops, coconut shells, and other odd items over their "Achilles heel".

* Coenobia diogenes, of Bermuda are found only in fossil shells. The snail shell preferred by these crabs, Livona pica, is now extinct in Bermuda.

* Snails, when being preyed upon by others of their kind, release a hormone-like substance into the water. Studies have shown that hermit crabs can detect minute amounts of this substance and that they will assemble at predation sites. Like greedy ambulance chasers they wait for possession of a newly-liberated shell. As soon as the carcass of the unfortunate victim is consumed a crab takes up residence.

* Planktonic larval crabs (baby crabs drifting in the water) will drop to the bottom and practice shell investigation, as they approach their final molt. It may be that finding a suitable shell will trigger that last larval molt.
MARINATING YOUR VOCABULARY

CHELA: A claw or pincher-like structure on the terminal end of an arthropod appendage. A true chela exists when two opposing digits can be used to grasp and manipulate objects. Animals possessing chela are said to be chelate.

CHITIN: A protein which is the principal component of the arthropod exoskeleton. This protein takes on a hard brittle texture when impregnated with calcium salts. It is this calcified chitin that forms the classic shellfish "shell". The chitin of a hermit crab's carapace and walking legs is calcified and brittle. This hard shell must be molted in order for the animal to grow (See illustration on page 1). However, the chitin of the abdominal region is not calcified and remains soft and elastic. As the animal grows, it is this poorly protected "rear" that the crab must protect. It does so by finding larger and larger snail shells to inhabit.

GLAUCOTHOE: The megalopa stage (last larval stage, chela first evident) of a hermit crab. It is in this glaucothoe stage that the crab begins to hunt its first shell home. (See "Marinating Your Vocabulary", Crabs, Volume 2 (8):4).

ZOEA: The first larval stage of decapod crustaceans (shrimp, crabs, lobsters and anomurans). These larvae are recognized by the elongate spines of the head and carapace. They also have well-developed, muscular tails and well-developed eyes.

ANTENNULES: The first, and usually the smaller, of two pair of antennae found in crustaceans. They are moveable, elongate, segmented, and most importantly, sensory structures. In hermit crabs they are frequently flicked back and forth rapidly in assessing the water around them.

AESTHETASCS: Hair-like chemoreceptors found on the antennules of many crustaceans, including hermit crabs. These are used to detect various dissolved substances present in the water.

HERMIT CRAB FUR: The colonial hydroid, Hydractinia echinata. Colonies of these animals frequently cover the shells occupied by hermit crabs. Certain species of crabs prefer shells with the hydroids. These crabs are more tolerant of the hydroids potent stinging cells. The presence of a living colony of Hydractinia appears to deter predation by some animals, notably octopus. Thus, the crab within the hermit-crab-fur-covered shells is protected.
Introduction:

Along with crabs, lobsters and shrimp, hermit crabs are members of the Class Crustacea in phylum Anthropoda. Hermit crabs are in the order decapoda which means that they have 5 pairs or 10 legs or appendages on the cephalothorax body (head and thorax) region. The ordinary hermit crabs are very common on every coast. Two of the very common hermit crabs found along the Gulf Coast are Pagurus pollicaris and Clibanarius vittatus. The Pagurus is off-white in color with one claw larger than the other one. The Clibanarius is brown and white striped and both claws are almost the same size. These organisms have well-developed, soft, and somewhat coiled abdomens that are inserted in empty mollusk shells. They carry these shells around on their backs so that they can retreat into them for protection when attacked. In our area most hermit crabs live in moon shells or oyster drill shells. As the crab increases in size, it most often will find a larger mollusk shell. Appendages found on the left side of the sixth abdominal segment of the hermit crab are adapted for holding onto the columella or central support of the shell.

Since hermit crabs are very active organisms, most people take an interest in them. These organisms can be found in the area between the high and low tide lines (intertidal zone) along the beach. You may capture these marine inhabitants with a dip net or simply by picking them up with your hand. Hermit crabs are scavengers: consequently, they will eat a wide variety of materials.

Part I: Behavior of the Hermit Crab

Materials (per group of four students)
One (1) hermit crab in a large bowl of sea water  paper towels

Procedure
In your group of four students observe the hermit crab which will provide answers to the following questions.

1. How do hermit crabs move?  

2. How do they use their legs in walking?

3. Do you think hermit crabs move fast or slow?

4. What happens when you pick up the crab?

Take the hermit crab out of the water and put it on the table, observe.

5. Does the crab walk differently on this surface?

What happens to the hermit crab on the edge of your desk?

(be careful and do not let it fall.)
6. What is the most interesting behavior that you have observed about the hermit crab? ________________

7. Describe the hermit crab. __________________________________________
Give the scientific name (refer to introduction) ________________________________
________________________ Look at the other hermit crabs in the room. Are they all alike? ______
if not describe other crabs. ________________________________________________

8. Describe the shell the hermit crab is carrying around. __________________________
are all of the shells alike? ______ if not, describe. ____________________________

**Part II: House Hunting**

**Materials** (per team of four students)
2 hermit crabs in a large bowl cigarette lighter wet paper towels

**Objective**
To observe the hermit crab without the shell and observe as it selects a new shell and establishes a new home.

**Procedure**
Select one of the hermit crabs that has established itself inside a shell and place it on a wet towel. Allow the crab to become accustomed to the new condition. Hold the shell so that the crab can crawl out of the shell. Be careful not to burn yourself. The heat will cause the crab to leave the shell. The wet surface of the towel will also lure the organism out of the old shell. Do not move the shell or the crab will not come out, even if you burn him. You should not move or it will scare the crab. This is hard to get the crab out of the shell. You must be still and have patience. Once the hermit crab is out of its shell, put it in the water. When another group get their hermit crab out, put the hermit crabs together in the water but put only one shell in the water and observe.

9. Observe the behavior of the crabs as they both compete for the same shell. Note their behavior as they measure the shell for a possible home.
Write observations. __________________________________________________________

10. Can you predict which crab will secure this particular shell for a home? ______
Does the loser seem to exhibit submission behavior? ____________________________
Explain. ________________________________________________________________

11. Now provide another shell of adequate size. Does the other crab seem interested? ______
Discuss the observed behavior. ____________________________________________
Part III: Anatomy of the Hermit Crab

Objective
To identify the major parts of the hermit crab.

While you are waiting for the hermit crabs to select a new home, make appropriate anatomical observations to respond to the following questions.

1. What are the major body parts of the hermit crab?

2. What parts of the crab are visible when the crab is walking around in the shell?

3. What parts are always covered when the crab is walking around in the shell?

4. On the following drawing label these parts: walking legs, abdomen carapace, pleopods, telson, eyestalk, antenna, and modified walking legs.

5. How are the pleopods used by hermit crabs?

6. How does the hermit crab use the modified walking legs?
Hermit Crab Craft!

Supplies:
Snail Sea Shell (big enough to fit your finger inside)
Modeling Clay or Play Doh
Red Fuzzy Pipe Cleaners
Brown and Black Regular Pipe Cleaners
Large Pearly Seed Beads
Scissors

Directions
1. Cut 1 red fuzzy pipe cleaner in half for claws, leaving 2 fuzzy ends together
2. Cut 3 short pieces of brown pipe cleaners about 3 in. for legs and body
3. Cut a piece of black pipe cleaners about 1-2 in. for eye stalks
4. Fold black pipe cleaner in half to form eye stalks and place white beads on the tips
5. Fold brown pipe cleaners in half to form 2 pairs of legs
6. Put fuzzy red pipe cleaner “claws” in front of legs
7. Put black “eye” pipe cleaner in front of claws
8. Connect all body parts by twisting a brown pipe cleaner around the middle
9. Place a piece of clay for the back end of the body on the twisted body pipe cleaner, shape clay to resemble hermit crab abdomen
Hermit Craft Supplies

Regular Pipe
Cleaners "Legs"

Fuzzy Pipe "Claws"
Cleaners

"Eye"
Regular Pipe
Cleaner (Approx. Size)

Clay Abdomen

"Eye" Beads
DOCENT FACT SHEET
HORSESHOE CRAB
*Limulus polyphemus*

NOT A CRAB AT ALL! Crabs have two pair of antennae and a pair of mandibles (jaws), the horseshoe crab lacks all three. Crabs have five pairs of legs; horseshoe crabs have seven. The closest relatives of the horseshoe crab are spiders and scorpions.

DIFFERENCE BETWEEN BOYS AND GIRLS--The female is 30% larger than the male. The male's second pair of claws (called pedipalps) are shaped like hooks, which he uses to "hold-on" to the female's shell so he can follow her and fertilize the eggs she lays (external fertilization).

REPRODUCTION--The female lays between a few thousand and 20,000 eggs at a time. Eggs are about the size of a BB. Eggs mature in two weeks. Juvenile are about an eighth of an inch across and look like miniature adults, except they lack a telson (tail). Mating can occur between April and December, but the peak activity is May to August.

FOOD--Horseshoe crabs are bottom feeders. they push along the bottom picking up tiny worms, clams, sand dollars, or other benthic creatures, and use their-mouth-like-structure to grind up this food. The tiny claws in front of the mouth (called chelicerae) help push the food into the mouth.

GROWTH--These animals grow by molting; a new shell is produced between the old shell and the body. A split occurs in the front of the shell, the crabs crawls out and fills the tissue with water; in 24 hours the new shell hardens; and the crab is 25-30% larger.

ECONOMIC IMPORTANCE--An extract (lysate) from the crab's blue blood (copper-based) is used as an indicator for gram negative bacteria. Medical researchers are using this blood for exploration into human spinal meningitis and kidney disfunctions. Extensive eye research has also been done using the horseshoe crab. The shell is made of chitin, a protein, and is used for medical sutures and contact lens. Chitin is also used to make "artificial skin" for burn victims because of its ability to retard the growth of bacteria and promote healing.
COAST
Written by Willie Heard

On the cutting edge...
There are only four species of horseshoe crabs in existence in the world today. These are Limulus polyphemus, Tachypleus gigas, Tachypleus tridentatus, and Carcinoscorpius rotundi-cauda. These creatures are sometimes called "living fossils" because they have changed little from their fossilized relatives; the earliest species identified is approximately 450 million years old. Horseshoe crabs are a valuable resource, commercially as a fertilizer and as a source of calcium for enriching fowl grains and medicinally in identifying endotoxins. The most persistent study on these animals has focused on the properties of their blue blood. In 1977, The Food and Drug Administration of the United States approved a new test for identifying endotoxins using Limulus Amoebocyte Lysate (LAL) purified from horseshoe crab blood. In spite of their commercial and medical importance, horseshoe crabs are threatened by the loss of living and breeding habitats. This habitat degradation has resulted in a rapid population decline over the last few decades.

Horseshoe Crabs

Lesson Objectives: Students will be able to do the following:
• Describe the difference between a true crab and a horseshoe crab
• Briefly discuss the life history of the horseshoe crab
• Give some medical and commercial uses of the horseshoe crab

Key Concepts: chitin, Limulus Amoebocyte Lysate (LAL), chitosan, exoskeleton, pedipalps, molt, arthropod, decapod, chemoreceptors, pheromone

What is a Horseshoe Crab?

Even though the horseshoe crab has a hard shell and numerous appendages with claws, it is not really a crab. Horseshoe crabs belong to the phylum, Arthropoda, along with crabs, insects, and other invertebrates with jointed legs, but their closest living relatives are spiders and scorpions.

True crabs have two pairs of antennae and a pair of mandibles, or jaws; horseshoe crabs lack these structures. Further, comparing the legs of a true crab with the legs of a horseshoe crab reveals another significant difference. True crabs classified as decapod crustaceans, have five pairs of legs, which include a pair of claws. Horseshoe crabs have seven pairs of legs under their helmet-like shells; five of these seven pairs of legs are equipped...
with claws. In adult males, the second pair of claws (pedipalps) has a "boxing-glove" appearance and is used to grasp females during spawning. Horseshoe crabs also have four simple eyes on the top of their carapace instead of two as with the true crab. Our North American species has been named *Limulus polyphemus* – *Limulus* meaning "a little askew or odd" and *polyphemus* after the giant cyclops in Greek mythology.

Horseshoe Crab Anatomy

Biology/Life History of the Horseshoe Crab

Horseshoe crabs are among the world's oldest and most fascinating creatures. The earliest horseshoe crab species had already inhabited Earth at least 200 million years before the dinosaurs arrived or about 400 million years ago.

Today, there are four species of horseshoe crabs in the world, but only one is found on North American shores. Our native horseshoe crabs live along the Atlantic coast from Maine south to Florida and the Yucatan Peninsula. They are also found in several places along the eastern shores of the Gulf of Mexico.

The largest concentration of horseshoe crabs is found in Delaware Bay, located between Delaware and New Jersey. Horseshoe crabs are animals of the temperate seas. During the cold months, they lie half-buried in the ocean sediments. Horseshoe crabs have been observed mating from April through December, although the peak reproduction period occurs during the highest tides in late May and early June, at the time of the full or new moon. Most spawning is at night because of the protection afforded by darkness.
In spring, males arrive at the shorelines first, followed by the females a week or two later. Females average being 30% larger than males and attract the males by releasing a pheromone, or natural chemical stimulant, into the water. Horseshoe crabs also use their relatively good vision to help locate potential mates. Males patrol the nearshore waters and use their pedipalps to attach to the abdomen of a female as she moves toward the beach. She drags him to the water’s edge and scoops out a series of five to seven crude nests, where she deposits tens of thousands of eggs. The attached males and other males that gather around the female fertilize the eggs as she lays them. The new eggs are about 1.5 mm, or 1/16 inch, in diameter, and are an opaque, pastel green color. In a few days, they double in size and the outer layer peels away, leaving the eggs transparent. Moisture from the tides, and the warmth of the sun, allows the eggs to hatch in the two-week period between spring tides (the higher-than-normal tides that occur at the new and full moons.) After hatching, the juvenile horseshoe crabs dig their way “out of” the sand. When born, the tiny horseshoe crabs look very much like their adult counterparts. They begin life as miniature adults, about three mm (1/8 inch) across, but lack a fully functional digestive system and a movable tail. For about a week, they “swim about,” eating their yolk sac as their digestive systems mature. They swim upside down, moving their legs and gills in a progressive wave-like oscillation from front to back.

Horseshoe crabs push their way along the bottom, digging small furrows in search of food. They use their first pair of legs as feelers to determine the presence of prey. When the crab feels or smells a worm, clam, or dead fish, one of the claws picks it up and pushes it toward the heavy, spiny projections that surround the mouth; the horseshoe crab has no nose; but the tiny hairs on the spiny projections around its mouth are chemoreceptors, allowing the crab to smell prey. Since the horseshoe crab has no jaws to chew its food, it must bring all of its legs together and use the spiny projections around its mouth then the first set of legs to crush the worm or clam. Horseshoe crabs also have gizzards containing sand and small bits of gravel to help grind their food.

Horseshoe crabs continue to grow for nine to ten years until they reach maturity. The young horseshoe crabs molt, or shed, their outer skeleton (exoskeleton) often until they reach sexual maturity, then molting slows, occurring only about once annually. The animals increase in size by 25-30% with each molt by pumping in water to expand their new shells, which will harden in
approximately 24 hours. Males are sexually mature at their sixteenth molt or ninth year. Females need at least 17 molts and mature in their tenth year. Unlike the blue crab, which “backs out” of its old shell, the horseshoe crab crawls forward out of its shell through a split that develops along the junction of the dorsal (top) and ventral (bottom) surfaces. No one really knows how long horseshoe crabs live, but some scientists believe that 30 years is possible. Generally, an animal which does not begin reproduction until age nine or older would have a life span enabling reproduction for a number of years.

Commercial Importance of Horseshoe Crabs

Though the eggs and flesh of Limulus polyphemus are not toxic, they are not eaten by people today. Years ago, indigenous American people did eat the lump of meat in the abdomen which moves the tail. They also used the shell to bail water from their canoes and the tails as spear tips. More recently, horseshoe crabs were used as fertilizer and as feed for chickens and hogs.

Chicken and hogs fed on horseshoe crab developed a bad taste, so using horseshoe crabs as a food source was discontinued.

Today horseshoe crabs are important to people for their use in medicine. For over fifty years scientists have used horseshoe crabs in eye research. Scientists can easily study the large eyes and optic nerve (the nerve that sends signals from the eye to the brain) of the horseshoe crabs. Scientists have learned a great deal about how human eyes function from research on horseshoe crab eyes.

Chitin is a substance found in the shells, or exoskeleton, of horseshoe crabs, as well as other arthropods, such as lobsters, crabs, shrimp, spiders, beetles, and mosquitoes. Chitin has received a lot of attention from scientists because it is non-toxic and biodegradable. When chitin is processed, another substance, chitosan, is produced and can be used as a raw material to manufacture a variety of important products.

Contact lenses, skin creams, and hair sprays can also be manufactured from chitin. Chitin can be used to remove lead and other harmful chemicals from wastewater. Chitin joins the fight against fat when added to foods. It has the ability to bind with fats and then pass them through the body without being absorbed. Besides absorbing fat to promote weight loss, chitosan also inhibits “bad” cholesterol uptake and boosts “good”
Activity: Horseshoe Crab “Hands On”

The horseshoe crab is compared to the giant cyclops (*polyphemus*) in Greek mythology. Yet, despite this frightening comparison, the horseshoe crab with its large spiny body and spiked tail is not poisonous, but completely harmless.

**Objectives:** Students—in groups of two or four—will be able to do the following:
- Touch and hold the horseshoe crab.
- Identify the external anatomy of the horseshoe crab.
- Identify the gender of the horseshoe crab.

**Materials:**
- Live horseshoe crabs, male and female
  (There are a number of vendors for living horseshoe crabs, however, one vendor is: Dynasty Marine Associates, 10602 7th Avenue, Gulf Marathon, FL 33050. Phone: 305-745-7666. Horseshoe crabs are approximately $12 each depending on size and seasonal price variations.)
- Molts from various sizes of horseshoe crabs
- Paper towels
- Hand soap

**Procedures:**
1. The instructor should review the history of the horseshoe crab and research uses, as well as discuss the safe handling techniques for these animals.
2. Removing the live animal from its tank, the instructor should present the animals to the class, identifying the major external, anatomical structures.
3. Students should be given time to carefully feel the tail, legs and pinchers of both the live animals and the molts.
4. The instructor should review, using male and female animals, the distinguishing characteristics of the claws between the two sexes.
5. Students should wash hands thoroughly at the conclusion of the class.

**Extensions:**
1. Compare the horseshoe crab with a true crab such as the blue crab (*Callinectes sapidus*).
2. Locate recent and historical research reports utilizing horseshoe crabs by accessing via internet the web sites of Delaware Sea Grant College Program.
3. Construct a paper model of the horseshoe crab using Dr. Bill Hall’s published model available through Delaware Sea Grant College Program.
cholesterol. Other chitosan uses include: promoting the healing of ulcers and lesions; serving in antibacterial action; acting as an antacid; helping to control high blood pressure; and treating and preventing irritable bowel syndrome. Lastly, chitosan can be made into string used to suture surgical wounds and in wound dressings. People are less likely to experience an allergic reaction to the chitosan-based stitches, which dissolve slowly, and the dressings actually promote healing.

In 1950, Frederick Bang discovered the blue-colored blood of the horseshoe crab contained special cells that react to certain kinds of disease causing bacteria. *Limulus*

**Amoebocyte Lysate (LAL)** was found in Factor C, the first enzyme to be activated by the endotoxin from gram negative bacteria. LAL is now used as a fast and effective way of testing drugs to make sure they are free of these harmful bacteria before they are administered to people. Pharmaceutical companies used the LAL to test sterility of antibiotics and kidney dialyzers, to detect some cancers, and to detect spinal meningitis.

Sometimes during the peak summer months, more than 1,000 crabs per week are harvested for their blood. Up to one-third of the animal’s blood is painlessly removed by medical researchers. The cost of horseshoe crab blood has reached $15,000 dollars per quart. A horseshoe crab collector can make up to $1,000 dollars a night.
Horseshoe Crab Biotech Applications

Clotting properties of HC blood first documented by W. H. Howell, of Johns Hopkins University in 1885.

Revisited in 1956, by Frederick Bang, who was studying bacterial infection and response in benthic invertebrates. Because bacteria are especially abundant in the shore waters, where bacterial counts of predominantly gram negative bacilli (most disease-causing bacteria are gram negative) may reach several million per gram of sediment, Bang wanted to study the immune responses of benthic invertebrates.

He discovered that HC blood clotted on contact, not just with live bacteria, but with heat stable/heat treated (meaning “dead”) bacteria. This indicated a sensitivity to toxins, termed endotoxins, produced by the bacteria. They are a structural component of the cell walls of certain gram-negative bacteria.

At that time, rabbits were used to test for endotoxins. Rabbits, like us, are sensitive to endotoxin. If something was suspected of contamination, it would be injected into the rabbit. If it caused fever, it was contaminated. The test was time-consuming (it could take up to 48 hours) and expensive (to keep thousands of disposable rabbits).

Horseshoe crabs and other arthropods have semi-closed circulatory systems (for excellent drawings of the HC circulatory system, see Milne Edwards illustrations, found at the first link below – marine bio. lab, Woods Hole). Large sinuses exist that allow blood direct contact with tissues (as opposed to our closed circulatory systems, which transport blood in vessels). HC do not develop antibodies. Their blood, which is blue due to the copper-pigmented hemocyanin molecule, contains a single type of cell, the amoebocyte (it has motility). The source of this cell has been shown to be the gill flaps. The amoebocytes are often obloid in the blood stream, and perform most of the normal functions associated with blood cells: engulfing foreign or dead cells, transport and storage of digested materials, repair of wound sites. The amoebocytes are packed with small granules. These granules contain clotting factors that are released outside the cell when they detect nanogram quantities of bacterial endotoxin. The shape of the amoebocyte changes to an irregular amoeboid shape with numerous cytoplasmic processes streaming in all directions. The cell discharges the granules of coagulogen, which empty the cell. Bang also discovered that under some circumstances, all of
the blood in the HC’s body clotted, causing the animal to die. This response is analogous to a mammal dying due to the body producing fever to kill bacteria.

LAL – Limulus Amoebocyte Lysate is produced from the blood of horseshoe crabs. The blood is centrifuged, resulting in the separation of blood cells (amoebocytes) from the serum. A small, whitish pellet forms at the bottom of the tube. The serum is poured off, and the pellet is rinsed with saline. Eventually, pyrogen-free, distilled water is mixed with the suspension of blood cells. This causes the cells to absorb fresh water and lyse (hence “lysate”). This releases the coagulogen into solution. This solution is filtered to remove cellular debris and then freeze-dried to form a white powder of the lysate. This lysate is then packaged and sold to be reconstituted to perform the LAL assay, wherein a suspect sample is mixed with reconstituted LAL. Allowed to sit in a small tube for 45 minutes, the sample is then inverted; if a clot has formed, it will stick to the top of the inverted tube.

HC blood is worth $15,000 per quart.

LAL is a multi-million dollar business. It received FDA approval in the 1970’s for use in the testing of drugs, blood products, intravenous fluids, and disposable pharmaceutical devices.

LAL is now used to test IV fluids, invasive medical equipment, cosmetics, foods, water, spinal meningitis, among many other things.

LAL is being used by NASA to verify cleanliness of spacecraft, and it is now part of the effort to discover life on Mars and other planets.

Removal of blood is achieved by cardiac puncture and is usually not fatal (10% - 15% fatality), but there are concerns about this finite supply of something people have become so heavily reliant on.

Horseshoe crab blood is being cultured in the lab using cut sections of the gill flaps, which last 45-60 d(ays?). The resultant amoebocytes are much smaller than normal (4-4.5 micrometers compared to 13-14 micrometers). It has been hypothesized that this is due to immaturity. As of May, 2002, there was no determination of the effect that immaturity had on the performance of LAL produced with the in-vitro amoebocytes.

Scientists at the National University of Singapore have successfully cloned the enzyme that clots the blood of the horseshoe crab. A patent for the discovery of the compound, called Factor C, has been issued in the U. S. The technology for its production was licensed to the American biotech company, BioWhittaker.
Horseshoe crabs are colored to match the muddy or sandy bottoms on which they live. They may range from dark olive brown to light tan.

Diagram A
Adult horseshoe crabs rarely swim, but when they do, they swim upside down, moving their book gills in a successive wave.
The horseshoe crab's telson isn't poisonous as some people believe. It does have an important use, however—it helps overturned crabs to right themselves. First, the animal bends its hind part forward. Then it thrusts the telson's point down against the sand. By kicking its legs, it rocks back and forth until it rolls over. A horseshoe crab should never be picked up by its telson because doing so would injure the muscles that operate the telson.

In addition to its two large compound eyes, the horseshoe crab has numerous photoreceptors on its top shell and down the length of the telson. These photoreceptors are sensitive to light and help synchronize the animal's internal clock with daily cycles of light and darkness.
CHELICERATES

subphylum Chelicerata, one of the three evolutionary lines of living arthropods. The body of a chelicerate is divided into a cephalothorax (or prosoma) and an abdomen (or opisthosoma). Chelicerates lack antennae and are the only subphylum of arthropods in which they are absent. This is the most distinguishing characteristic of the subphylum. The first pair of appendages are feeding structures called chelicerae. The second pair are called pedipalps and are modified to perform various functions in the different classes. The pedipalps are usually followed by four pairs of legs.

There are three classes of chelicerates. Two small classes, the Merostomata and the Pycnogonida, contain marine species, but most chelicerates are terrestrial and belong to the class Arachnida.

(a)

(b)

FIGURE 11.1
Chelicerata, Merostomata. External anatomy of Limulus. (a) Dorsolateral view. (b) Ventral view.
Climbing Critters

Spider in a Web

1. Color the spider body pattern. Glue the body and web patterns onto thin cardboard and cut them out. (You may want to glue pieces of yarn onto the web pattern to make it look three-dimensional.)

2. Cut two 1/2-inch pieces from a drinking straw. Glue the pieces onto the underside of the spider body as shown. If you're using a plastic straw, tape the straw pieces to the cardboard spider's body to make sure they stick.
Activity: Biodiversity Quiz

Objectives: Students will be able to do the following:
- Identify which niche horseshoe crabs fill.
- Define "niche".
- State the importance of horseshoe crabs in research.

Materials:
- Live horseshoe crabs
- Paper
- Pencil

Procedure:
Two camps of animal rights activists argue concerning the use of marine invertebrates for biomedical purposes. Some individuals believe passionately that research involving living subjects of any kind is cruel and unnecessary. Other individuals believe invertebrates can be substituted for warm-blooded research animals, i.e., mammals. A list of uses for horseshoe crabs has been provided below. Explore your value system by ranking the uses from most to least acceptable. Tell which uses should be continued and discontinued, and why. Be prepared to explain your answers.

1. Horseshoe crab nerve cells are large, accessible, and good for modeling human nervous system mechanisms. Horseshoe crabs' relatively large and simply constructed compound eyes have an easily accessed optic nerve; and because they are easy to keep in the laboratory, horseshoe crabs have contributed greatly to human eye research.

2. American Indians began using horseshoe crabs thousands of years ago. They ate the abdominal meat, the tail muscles, and possibly other parts. Shells were not discarded, but used to "bail out" dugout canoes. Spear tips were constructed from horseshoe crab tails, and Indians buried the crabs as a time released, high-nitrogen fertilizer.

3. American settlers also used horseshoe crabs for fertilizer, leading to an industry that lasted until the 1950s. A few farmers continue the practice today. Horseshoe crabs have also been used as stock feed, but imparted a fishy flavor to hogs and chickens. Horseshoe crabs' eggs are still used as eel bait in a small fishery supporting U.S. and European markets.

4. The chitin of horseshoe crab shells is extremely pure, and chitin-coated sutures reduce healing time in humans by 35-50%. A Japanese company spins pure chitin dressings for burns, surface wounds, and skin-graft donor sites.

5. Limulus Amoebocyte Lycate (LAL) is a clotting agent extracted from horseshoe crab blood. LAL is the standard test for injectable and intravenous drugs, during which it clots in the presence of toxins and impurities. LAL is also used to diagnose diseases such as spinal meningitis. Large horseshoe
Even though the horseshoe crab has a hard shell and numerous appendages with claws, it is not really a crab. Horseshoe crabs belong to the arthropod phylum along with crabs, insects, and other invertebrates with jointed legs, but their closest living relatives are spiders and scorpions.

True crabs have two pairs of antennae and a pair of mandibles, or jaws; horseshoe crabs lack these structures. Further, comparing the legs of a true crab with the legs of a horseshoe crab reveals another significant difference. True crabs classified, as decapod crustaceans, have five pairs of legs, which include a pair of claws. Horseshoe crabs have seven pairs of legs under their helmet-like shells, with five pairs of legs equipped with claws. In adult males, the second pair of claws (pedipalps) has a “boxing-glove” appearance and is used to grasp females during spawning. Horseshoe crabs also have four simple eyes on the top of their carapace instead of two as with the true crab. Our North American species has been named Limulus polyphemus — Limulus meaning “a little askew or odd” and polyphemus after the giant cyclops of Greek mythology.

Chitin is a substance found in the shells, or exoskeletons, of horseshoe crabs, as well as other arthropods, such as lobsters, crabs, shrimp, spiders, beetles, and mosquitoes. Chitin is non-toxic, biodegradable, and is processed to produce another substance called chitosan (aminopolysaccharide) that can be used to produce a variety of important products. Horseshoe crabs grow larger by molting, or shedding their outer shell, which is actually their skeleton (exoskeleton).

Too often, we learn the value of something only after it is gone. In the case of the horseshoe crab, we now know its value and as a result, many people are concerned about the horseshoe crab’s future. We should learn from the experience of the Japanese, whose horseshoe crab species is considered endangered. The medical value of the horseshoe crab is easily measured economically, yet environmentally, the picture is much more complex when we consider the millions of shorebirds and other animals — fish, turtles, and the entire estuarine food chain — that depend on horseshoe crab eggs as a food source.
Horseshoe Crab Vocabulary

Carapace-the front top portion of the shell of the horseshoe crab

Chelicerae-the first pair of pincers located in front of the horseshoe crab's mouth

Chemoreceptors-tiny hairs located on the spiny projections that surround the horseshoe crabs' mouths that allow them to "smell" prey

Chilaria-appendages located in the rear of the horseshoe crab's mouths

Chitin-a cellulose-like substance found in the shells, or exoskeleton of horseshoe crabs, as well as other arthropods

Chitosan-processed chitin; used in a variety of manufactured products

Decapod-creatures that have five pairs of jointed legs

Dorsal-top portion of the carapace where the shell splits during molting

Exoskeleton-the outer structure (skeleton) of the horseshoe crab's body

Gnathobases-the heavy, spiny projections that surround the horseshoe crab's mouth

*Limulus Amoebocyte Lysate*-a clotting agent extracted from horseshoe crab blood

Molting-the process by which crabs grow by shedding their exoskeleton

Pedipalps-the second pair of claws of the male which has a "boxing glove" shape and which are used during spawning to grasp the female's abdomen

Pheromone-a natural chemical produced by female horseshoe crabs that acts as a sexual stimulant to attract males

Prey-an animal that is hunted for food

Telson-the long, spike-like tail of the horseshoe crab

Ventral-the bottom portion of the carapace where the horseshoe crab's shell splits during molting
Horseshoe Crab References


