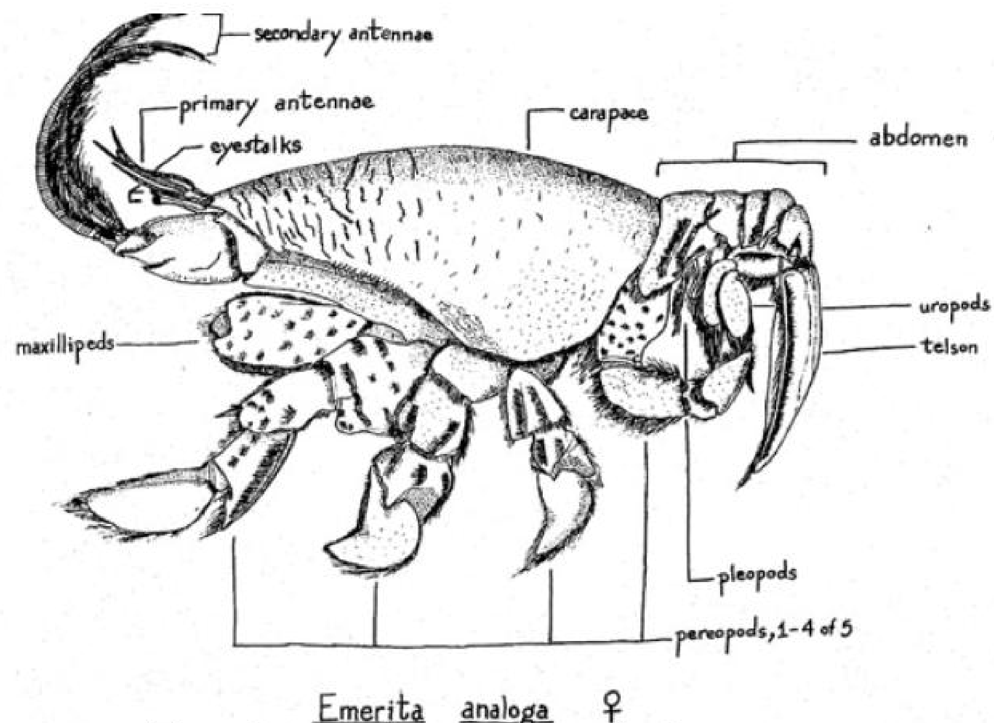
Today's dissection explores the intricate design of a decapod crustacean. The example we are using is the mole or sand crab *Emerita analoga* . *Emerita* is an anomuran decapod along with other crabs such as hermit crabs and porcelain crabs and can be found buried in the sand in the surf zone of beaches on the West Coast of the United States.

You should at minimum get the following from your experience today in lab:

1. observe and sketch the external anatomy of your crab
2. observe (no sketch necessary) the antennas
3. observe and sketch the structure of maxillipeds 1,2 & 3
4. dissect and sketch the circulatory system (including gills)
5. dissect and sketch the digestive and reproductive system (after removing the heart).



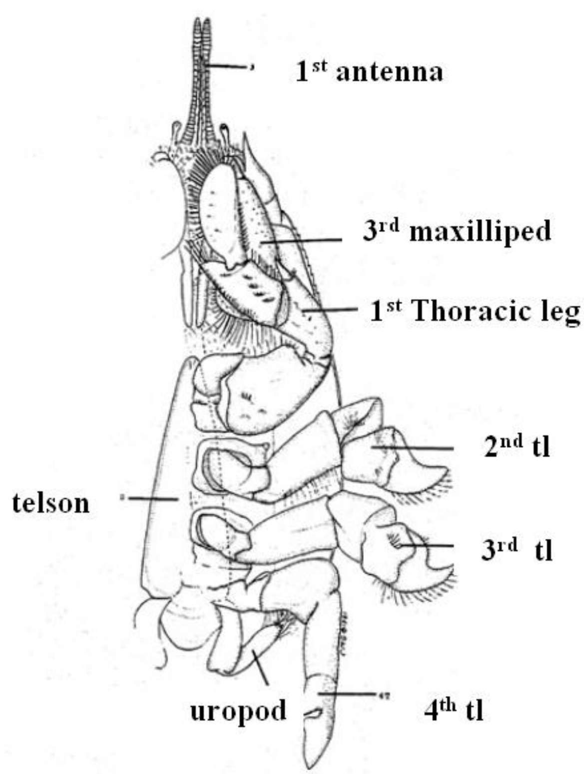
Emerita analoga external view

The Antennas

Emerita has an intricate system of antennae to gather both food and oxygen. The animal has two sets of big antennae, a primary and a secondary pair. The former is located on either side of the central rostral spine. The animal buries in the sand facing seaward and points its primary antennae up and forward together, forming a V-shaped trough. Could this be a means of funneling water down to the gills? How does the water get down to the those gills even if it indeed is given this channel to go through? -- after all, the crab's exoskeleton lacks cilia that might beat water along. As you dissect this animal, keep trying to think of what its structures actually do, and how they work. That's part of their beauty: that they work.

The second antennae are used for filter-feeding. The crab is capable of straining particles down to 4-5 microns in size from receding waves. These particles are trapped in the criss-crossing bristles (setae) on either side of each antennae, and the antennae are alternately swung in and scraped clean by the maxillipeds. When the crab is not feeding, its long second antennae are folded down under the thoracic appendages along the mid-ventral body wall. Why does Emerita feed only on receding waves? What might it do, instead, during incoming waves?

Using fine forceps, remove one of the second antennae and look at it under the dissecting scope's highest magnification. Fiddle with the light to reveal extra details. Then, look at the attachment of the second antenna you have left on the crab. Notice the exquisite joint system that allows the animal not only to rotate the antenna to an upright position but also to form a locking mechanism for holding the antenna erect against the force of the retreating waves. NASA engineers with their big bucks ought to see what this little crab engineers for free?



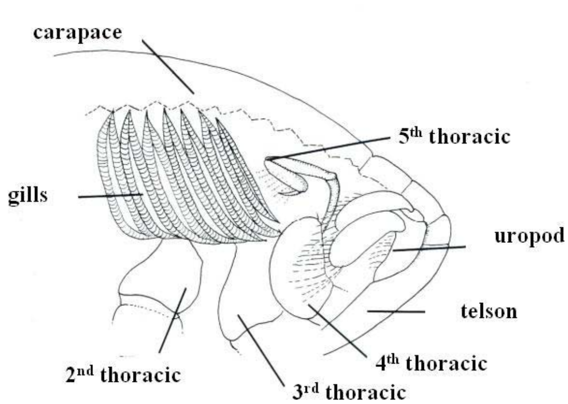
Emerita analoga appendages

The Thoracic Limbs

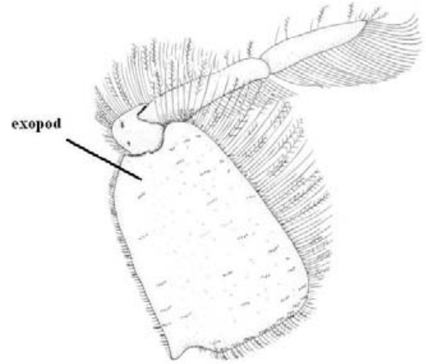
Well, is it a boy of a girl? Females of this species are larger (15-30 mm) than males (10-20 mm). There may be sequential hermaphroditism, too; that is, juveniles may go through a male phase and only eventually become a female -- in some populations or under some conditions. (Odd sex-ratios suggest this -- they also suggest sex-dependent predation patterns -- or maybe differential recruitment by sex -- or, well, you name it, because most facts suggest all sorts of plausible interpretations: the hard part is devising rigorous tests to choose among the alternatives.) You can sex your animal more reliably by closely examining its legs. The dactyls (the endmost segment) of the fourth thoracic legs (pereopods) of the male each have a suction pad, composed of an oval bare spot surrounded by short stiff hairs. He uses these pads to cling to the female during copulation. The embrace occurs at about the level of the third pair of pereopods in the female, where her genital pores open just proximally to the base of the fifth pair of pereopods. Additionally -- and here's the quickest way to sex these crabs -- the female has three pairs of abdominal pleopods, modifies for brooding the fertilized eggs, while the male lacks pleopods. But check the gonoporal sites anyway, in order to learn about the crab's body, not just about its sex.

Emerita has four big pairs of pereopods, which it uses to move sand. The most anterior pair are spade-like and push sand far forward and out, while the pairs behind it bring sand forward for the first pair to handle. (Remember, the crab burrows backward.) A fifth pair of tiny pereopods is to be found tucked up under the carapace. These little limbs usually get called "vestigial", but what can that mean to the crab itself? What function do you think they might serve? What might be the function of the uropods, which you can find (and do: find them) attached laterally just anterior to the telson. Try dropping a lively animal into seawater-filled finger bowl with some sand at the bottom. How do the crab's limbs (especially its thoracic ones) work? Too fast, you say? Add some MgCl2, wait a few minutes, and try again.

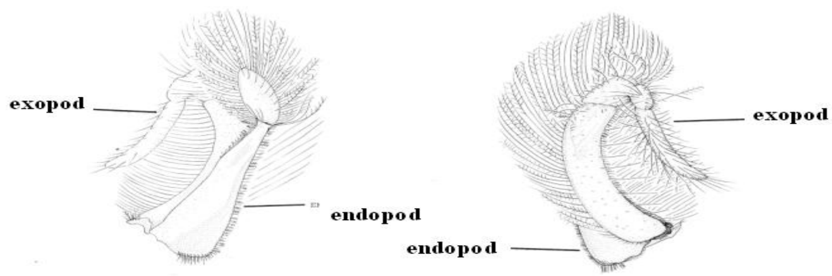
If Emerita is a "crab", where are its big "claws"? On other crabs, the crushers and pincers are on an especially sturdy pair of first thoracic appendages, but in Emerita these specialized appendages are not so outlandish. Or are they? Now consider Emerita's whole body. To swim, it paddles about with its thoracic limbs and telson. But amidst that surf, shouldn't it be as helpless as a stone? Given its design, how can/does Emerita accommodate and use the surf that must dominate its world? As you take the design of Emerita apart, keep trying to put the world of Emerita together.



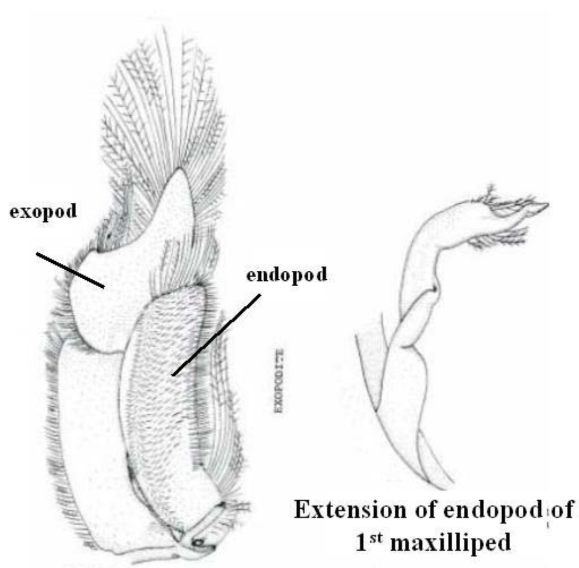
Emerita analoga branchial chamber



Emerita analoga 3rd maxilliped



Emerita analoga 2nd maxilliped



Emerita analoga 1st maxilliped

The Mouth Parts: Especially The Maxillipeds

Crustacean mouth parts are tough to figure out, and Emerita's are particularly difficult. The mandibles are not the heavy crushing ones that scavenging crabs have (why aren't they?). And the maxillae (two pairs), as in most decapods, are tiny and odd. Feel satisfied merely to locate these mouth parts, and to exercise examples of them that interest you, for close examination under epi-illumination and high magnification with the dissecting scope. Someday, you should extensively compare these mouth parts with other Emerita appendages, but that is too long-haul a commitment for this jammed lab.

Instead, for now, concentrate on the maxillipeds. There are three pairs of maxillipeds. The outermost (third) pair is broad and flat and has a long narrow blade attached proximally to it. Both the limb and the accessory blade close over the mouth parts, like parts of a double-door. Can you describe the actions of the other two pairs of maxillipeds are densely coated with (often branched) hairs (setae). When articles or entire maxillipeds are so set, these setal fringes cross over each other to form a net. The plankton and detritus trapped to the mouth. What about the mandibles? Which are they; what do they do in all this? And those little maxillae: what goes on there? -- or is the crab just stuck with them "by design"? By fiddling with all these elaborate appendages, what more can you figure out about Emerita's world?

Going In

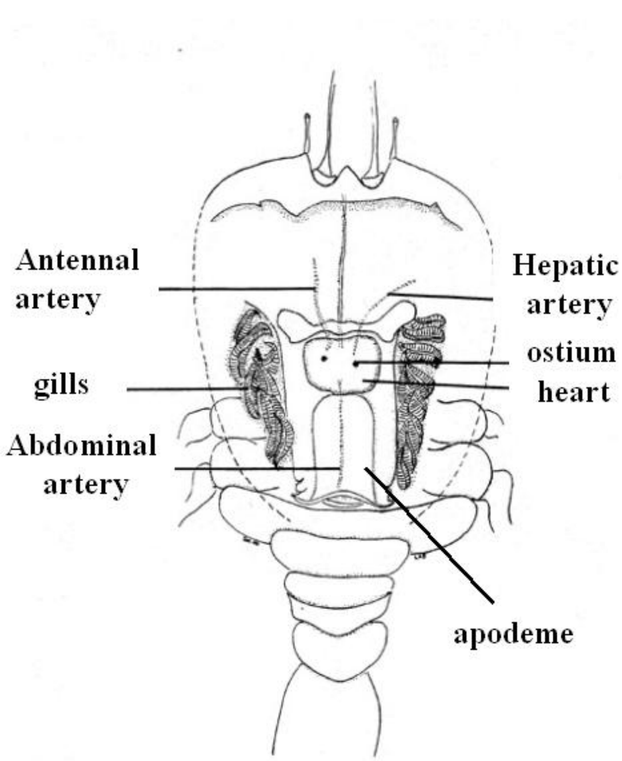
Dissections work best in finger bowls or small dishes or pans. Standard dissecting pans are much too big for little animals -- or, for that matter, for most invertebrates. ALWAYS dissect with the specimens UNDERWATER; otherwise, tissues collapse on one another and stick together and dry out and in other ways make tough what would be far easier to do and far easier to see underwater.

Once the crab is asleep or dead, as you choose, use a small pair of scissors (small body: small pan, small tools) to make a transverse (left -right) cut just anterior to the abdominal flexure. Cut all the way across the dorsal surface of the carapace. Be careful to keep the inner point of the scissors close against the carapace's internal surface. Next, make two lateral cuts, one at each edge of the carapace where the dorsal and ventral surfaces are joined, again being careful to keep the penetrating-scissor point at a shallow angle. This whole entry will give you a sort of lid through the carapace, with a hinge far anteriorly. Complete the incision with another transverse cut, this one far anteriorly, just behind the rostrum -- in effect, making that lid into a square plug of carapace, which you know have to remove. Gently lift the carapace away, starting at one side and working across to the opposite side, delicately separating the underlying epidermis from the carapace. If you find this too hard, make an EXTREMELY carefully, shallow longitudinal (fore-aft) incision along the mid-dorsal line of the body and then try to remove the carapace on the left and on the right of this line.

We acknowledge that the animal can be exasperating to enter surgically. After all, the animal's body looks almost designed to not let this happen -- and you have never tried it before. So your first little victory of this dissection is going to be just getting in neatly at all. That's what surgery is about, too.

The Respiratory And Circulatory Systems

To observe the circulatory system, use a fresh specimen of *Emerita*, dead or alive, and remove the carapace. A living prep reveals the heart in action -- an extraordinary sight that you should not miss. In any event, be the animal alive or dead, enter dorsally and with great care. Key structures lie very close to the epidermal surface there and can be unrecognizably mangled by a messy entry.



Emerita analoga circulatory system

Crab's insides are unexpectedly small and cramped, with lots of structure jammed in. Most of the "inside" is actually outside -- the carapace-enclosed gill-chamber, for example. Be sure to get straight what is inside the body in your dissection and what is revealed by "going in " but actually lies outside.

The most obvious structure under the carapace (and, of course, outside the body) are the rows of gills, which lie laterally along the posterior half of the thorax. These rows comprise eight plumes on either side all directed anteriorly. Why are they so oriented? What is the direction of water-flow over these gills? The gills are attached at their base to the bases of the pereopods, as in other decapods. Try to designate exactly which article of the thoracic appendage is the one carrying the gill -- that is a good way to learn those articles themselves, which are confusing around the limb-base.

If you were very carefully removing the carapace, you should be able to see the transparent gill-coverings in place. These are called branchiostegites. By holding one of the plumes aside you can see the fine blood channels leading from the heart to the gill cavity. If you are dissecting a living Emerita and are having signal success, you will see blood circulating: which direction in what channels?

The heart lies mid-dorsally in the posterior half of the thorax, It is an off-white square-shape organ just under the epidermis. Carefully peel back the epidermis to expose it. In living preps you can see the heart's larger movements with the unaided eye, but we recommend you watch the action more closely under the dissecting scope. The sight is worth the effort.

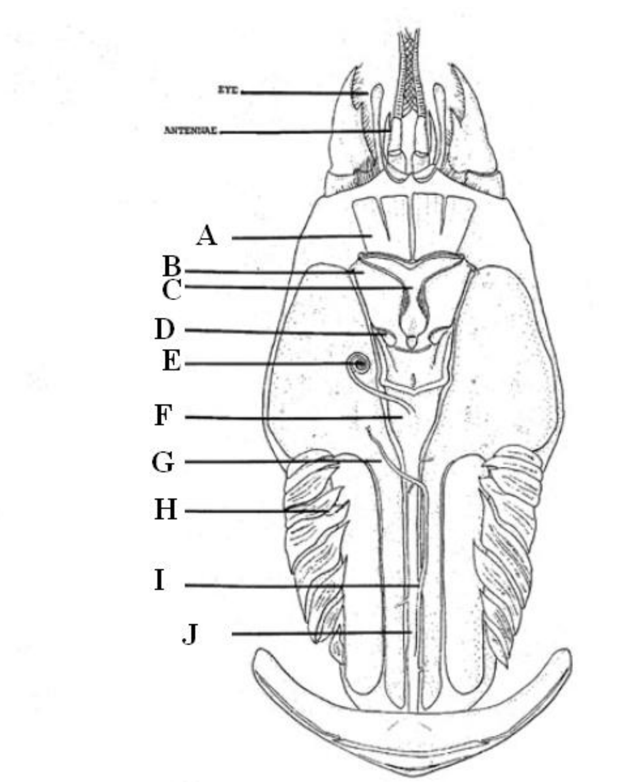
Crustaceans, of course, have an open circulation system. Blood moves outward from the heart via open-ended aortas and returns through various blood-sinuses to re-enter the heart through its ostia. Valves in the right places keep blood flow in order directionally and prevent chaotic back-ups. There are 3 pairs of ostia -- dorsal, lateral, and ventral -- in the wall visible in your prep as small silvery bubbles. Find them if at all possible, to watch them in action. They work!

Four sets of aortas or big arteries emanate from the heart. These are the ophthalmic, dorsal abdominal, paired hepatic, and paired antennal arteries. The ophthalmic artery is visible with little or no magnification as a mid-dorsal line running from the heart directly anterior to the base of the rostrum. The dorsal abdominal artery runs posteriorly into the abdomen, where it branches into a set of sternal arteries that accompany the hindgut to the end of the telson. The hepatic and antennal arteries take a bit of looking, as they are always there if sought with patience. All these arteries peter out eventually. The crab's tissue are bathed with by sinuses from which body movements and the pressure of more blood entering from the arteries are enough to nudge blood back toward the heart again.

The Digestive System

Start tracing the digestive system at the mouth. With the crab on its back, move apart the large, flap-like third maxillipeds. Fold out the antennae from inside the buccal cavity and move the 1st and 2nd maxillipeds aside to expose the slit-like mouth lying at the bottom of the cavity. The tissue that surrounds the mouth is bright red. (Hmm!) Observe this area under a dissecting scope. Tease back the margin of the mouth, noting the structures within. Remove the maxillipeds for easier access, if necessary.

Now turn the animal over and pin the animal belly-down, submerged in a dissecting dish, in the following manner: extend its 1st and 3rd thoracic limbs (pereopods) outward on either side, and, using insect pins (long, fine ones) pierce through the 1st limbs at the level of the third pereopods, angling the pins slightly posterior and away from the body. All this should anchor the crab and give you tool-handling room under the scope.



Emerita analoga digestive system
A = abdominal muscles, B = crop, C = cardiac ossicle, D = apodeme
E = spiral diverticulum, F = midgut, G = hepatopancreas, H = gills
I = accessory intestinal tube, J = intestine

When the animal is secure, carefully tease away the delicate orangish layer of cells. What might be the function of this layer? What might be the source of its color? Posterior to the base of the antennae are two pairs of white anterior stomach muscles that attach the stomach to the body wall ahead of it. The stomach is shaped rather like a tetrahedral pyramid of triangles, with a larger anterior (cardiac) end and a smaller posterior (pyloric) end. (Of course, "cardiac" is somewhat of a misnomer, when you think where the heart is.) Exercise the two posterior stomach muscles, at the junction of the cardiac and pyloric regions, to expose the chitinous ossicle, pearly in appearance, which provides a framework for the surprisingly thin-walled stomach..

On both sides of the stomach, locate the large, yellowish lobulated digestive glands. In a female, these glands are partly obscured by the ovaries, with which they interweave protrusions. The digestive glands are extensive in Emerita and continue posteriorly on both sides of the digestive tract all the way to the hindgut.

To trace the gut, you must remove the heart. Cut all the vessels that extend from the heart and gently lift it out. This should expose the midgut. Just past the junction of the stomach and the midgut, a spiral diverticulum branches from the dorsal surface of the midgut. Trace this white, coiled structure by moving the digestive gland away from the lateral surface of the stomach. This diverticulum varies in its position relative to the stomach; it may lie against the right or left side. But it characteristically has its remarkable, spiral shape.

If you are adventurous in nature, you may opt to open the stomach, to gain a better sense of the path traveled by food particles going through it. First, cut and remove the spiral diverticulum; then cut through the midgut at this point. Cut any tissues connecting the sides of the stomach to the digestive gland; detach the stomach from the anterior stomach muscles, which is best done by gently but steadily tugging on the muscles while holding the stomach in place. (Yes, deft!) Finally, lift the stomach up, on its way out of the body, and carefully pull it away from its last point of attachment, the esophagus, which is easily identified by the red tissue (Hmm!) surrounding it. If the stomach does not come free easily now with GENTLE tugging, cut directly through the esophagus, too. That ought to do it.

Put the stomach underwater to open it. This surgery involves micro-dissection of the finest technique. But you are gaining that skill all the time! If you get frustrated by it, don't let it get you down; for sure, don't give up even before you try. Dissection of this caliber takes a lot of practice and sometimes even -- well, can we call it luck? With the stomach ventral side up, use fine forceps to hold both sides of it. A very delicate cut now will weaken the stomach along its ventral midline. (This, of course, takes three hands, since you already holding two forceps, technique!) Gently pull until the tissue on the ventral side of the stomach splits fore-aft-fore, end-to-end. Pin back the flaps of torn stomach-wall. If all goes well, one median tooth and two lateral teeth will be visible in the cardiac region of the stomach's interior. The median tooth lies at the tip of the ossicle-skeleton. Notice the abundance of setae in both regions of the stomach. Why might Emerita need teeth and setae inside its stomach when it eats only minute particles of food? Are the particles really that minute? Try to get into the scale of Emerita's world; don't force it into the scale of your own. Now try to map the path of food from that esophageal cut to that midgut cut, now that you have found what the food encounters along the way.

The Female's Reproductive System

Emerita 's sex is best determined by checking for pleopods -- the females have them, the males don't.

Ease away the tissues of the digestive glad, gills, etc., to expose the stomach and its ossicle-skeleton. Use a probe to follow the midgut back to where it disappears (as the hindgut) posteriorly into the abdomen. Lying directly on top of the midgut, and often extending beneath it, are the ovaries, which are often complexly tangled with the digestive gland.

The oviduct is just posterior to the stomach's site. it is often filled with eggs. You can try to trace it to the crab's ovipores, which are at the bases of the third pair of thoracic legs.