

Anatomy of the Mud Puppy *Necturus*

KINGDOM Animalia

PHYLUM Chordata

CLASS Amphibia



EXTERNAL MORPHOLOGY

Necturus is studied as an example of a primitive amphibian closely related to the forms from which more advanced land vertebrates develop. Its intermediate phylogenetic position as a primitive terrestrial tetrapod is reflected in the fact that it retains some features found in fish and exhibits structural elements corresponding to those in higher vertebrates.

Because the mudpuppy has limbs and lungs it is placed within the superclass Tetrapod. Because it has a tail, it belongs to the amphibian order Urodela (Caudata). The genus *Necturus* is represented by two species one of which has in turn subspeciated. The most common form *N. maculosus maculosus* ranges from the Great Lakes to Louisiana and east to the Atlantic. The other species, *N. punctatus*, is found chiefly in the lower segments of the rivers of North and South Carolina. It is a small uniformly colored form and is probably a dwarf derivative of *N. maculosus*. Another form found in the Carolina states closely resembles *N. maculosus* but fails to attain its size. It is therefore considered a distinct subspecies *N. maculosus lewisi*.

Necturus is frequently caught by fishermen but is of little commercial value. It searches for food at night and lives on crayfish, aquatic insects, and worms. Like other amphibians, *Necturus* cannot withstand elevated temperatures for prolonged periods. The optimal temperature for its survival is about 18°C. The fact that the mud puppy lives in a wide variety of habitats suggests that temperature does not significantly control distribution. Rather, the distribution of amphibians like that of fishes and birds, often depends upon their breeding site preferences. Thus, *Necturus* is most commonly found in streams having a stony bed, since such sites are preferred to any other habitat for nesting. Although *Necturus* spends its entire life in water, it does not undergo metamorphosis as do most other amphibians, but rather retains its external gills. The persistence of a larval characteristic in an adult animal that has not undergone metamorphosis is known as neoteny.

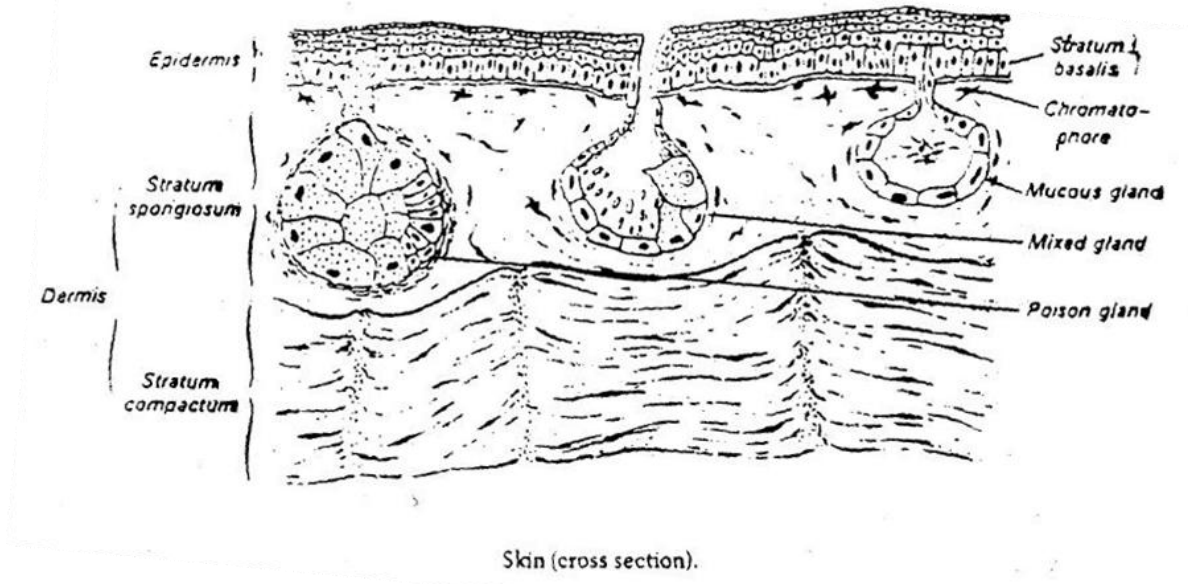
Integument

The skin of *Necturus* is specialized as a highly protective coat. This protective quality is due to a slimy nature and the fact that the body color changes according to variations in environmental light. These properties are the result of the activities of distinct histologic structures in the skin.

With a compound microscope, study a prepared section of skin from Necturus or from another amphibian if a mud puppy is not available.

Like other amphibians, *Necturus* lacks scales. Its skin is smooth and moist because of the presence of numerous glands capable of secreting copious amounts of mucus.

As in other vertebrates, the integument of *Necturus* consists of an epidermis and a dermis. The epidermis is made of a stratum basalis, a layer of low columnar cells, upon which rest several layers of increasing numbers of polyhedral cells that grade into flattened cells near the free surface. The outermost squamous layer is only slightly cornified as well as with all water-living amphibians. A stratum corneum, or true cornified layer, is present in the land-living amphibians, such as frogs.



The epidermis of *Necturus* is characterized by the presence of numerous club, or flask-shaped cells which appear to be of a glandular nature and together with the mucous glands, are responsible for the slimcoat covering the body surface.

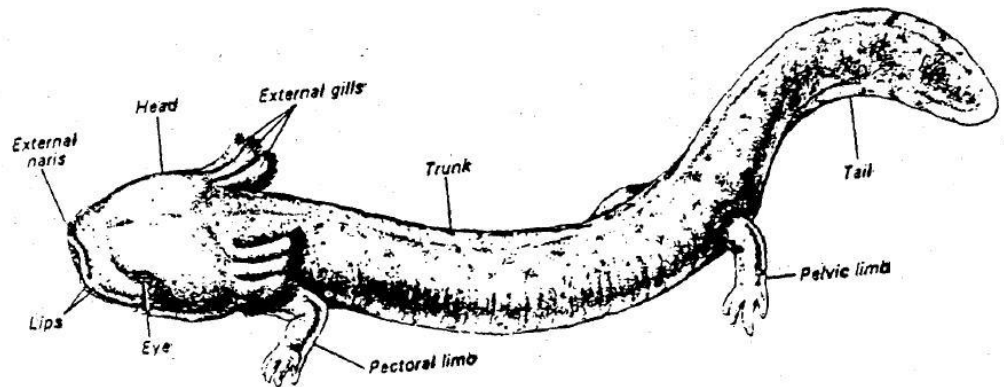
The epidermis is separated from the dermis by a basement membrane and a fibrous layer containing pigment cells which are known as chromatophores. They are classified on the basis of the kind of pigment they contain. The general color tone of amphibians is green, owing to the arrangement of the chromatophores in three layers. The melanophores, which contain dark pigment are the deepest and are covered by a middle layer of iridocytes. The iridocytes are pseudochromatophores, since they lack pigment but contain crystals of guanine that diffract the light. This light has a blue-green color. The most superficial of the three pigment layers is made up of lipophores, which contain a yellowish pigment that filters out the blue so that the overall color effect is green. Changes in body coloration are determined by pigment cell activity. Pigment cells may respond directly or indirectly to incident light. In an indirect response, impulses resulting from stimulation of the eyes are relayed first to the brain and then to the adrenal and pituitary glands, causing hormonal secretions that bring about pigment cell alterations.

The dermis is relatively thin and is composed of an outer looser stratum spongiosum and an inner more compact stratum compactum. The dermis contains an abundant number of blood vessels, lymph spaces, nerves, and glands. The glands consist of secular mucous glands and poison glands, both of epidermal origin. The mucous glands, lying just subjacent to the epidermis, have a low cuboidal or almost squamous cell lining. The poison glands, containing granular, irregularly spaced secretory cells, are larger and more deeply located and are sheathed in a heavy connective tissue layer. The poison glands occur on

the dorsal surface of the body and function as a deterrent to predators. Mixed mucous and poison glands can occasionally be observed.

External Features

- *Head*: flattened dorsoventrally, it contains a terminal mouth.
- *Lips*: These are fairly well developed and bound the mouth, which sucks in water through the front.
- *External nares*: Widely separated at the anterior end of the snout, they communicate with the mouth and the internal nares.
- *Eyes*: Small, located above the corners of the mouth. They have no lid.
- *External gills*: Three in number, they are functional and are located just in front of the forelimbs. Being derivatives of the integument, these gills are homologous with the internal gills of fishes.
- *Gill slits*: Two pairs are present bilaterally between the external gills. They communicate with the pharynx.
- *Gular fold*: Transverse fold of skin located at the ventral surface anterior to the level of the gills. It is the dividing line between head and trunk.
- *Trunk*: compressed dorsoventrally and covered by a smooth skin.
- *Pectoral limbs*: The forelimbs are small and weak and each is divided into an arm, a forearm, and hand that bears four digits.
- *Cloacal aperture*: This opening is located ventrally in the midline, posterior to the hind limbs. Thus situated, it marks the posterior limit of the trunk. Digestive product is excretory products, and gametes pass through the cloacal aperture.
- *Tail*: Compressed laterally, it is well developed.



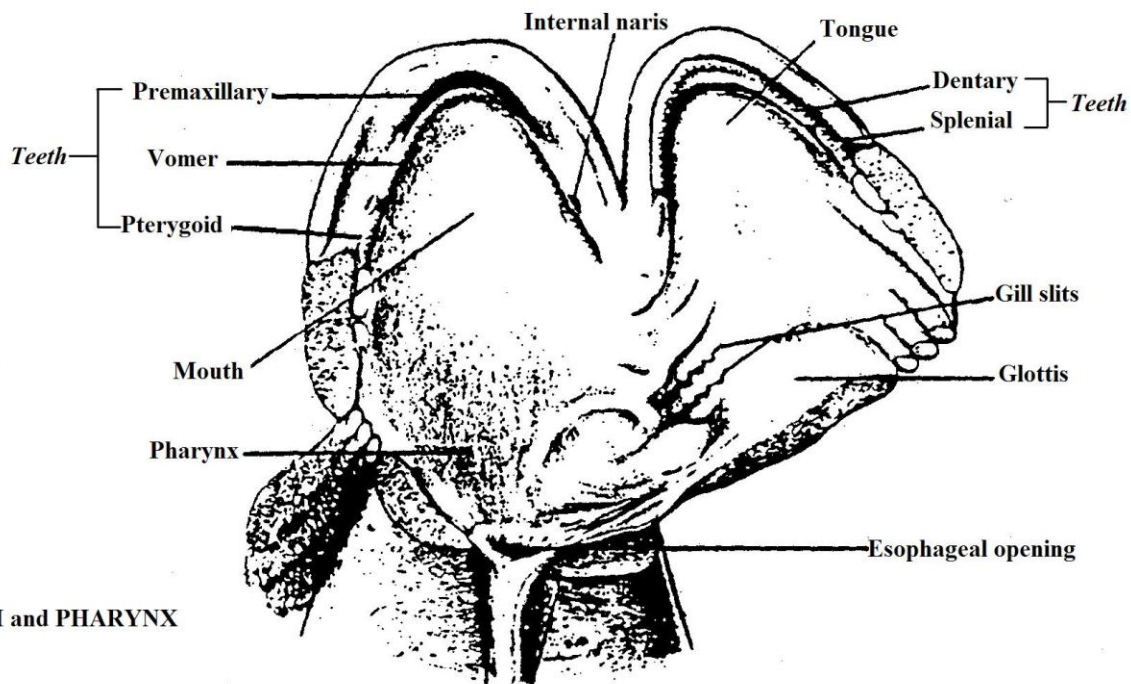
DIGESTIVE SYSTEM

The digestive system of the mud puppy differs very little from that of the dogfish shark. There are, however, several evolutionary advances. A spiral valve is no longer present and, to compensate for the resulting reduction in internal surface area, there has been an increase in the length of the small intestine. The terminal portion of the digestive tract, the rectum or large intestine, has become differentiated into a more structurally distinct organ. Thus, the digestive tract of the mud puppy illustrates the early tetrapod stage, but it retains many larval features, such as a vertical transverse septum, gill slits and poorly formed tongue.

Mouth and Pharynx

Insert one blade of a pair of scissors into the right corner of the mouth and then cut posteriorly along the side of the head to a point just central to the gills. Then turn the floor of the mouth toward the right to identify the parts of the oral and pharyngeal cavities.

- *Mouth:* The oral cavity is bordered externally by the lips and internally by the pouch between the hyoid and gill arches.
- *Teeth:* These are fish-like teeth, being small, conical and homodont. Two V-shaped sets are located on the upper jaw. An outer set of premaxillary teeth is present on the premaxillary bones and an inner set of vomerine teeth on the vomer. A very short additional set of pterygoid teeth project from the palatopterygoid bones and lies in line with the vomerine teeth from which it is separated by a short toothless gap. The lower jaw has a single arch-shaped row of dentary teeth and a short set of splenial teeth at each end of the arch.
- *Internal nares:* These are the openings from the nasal cavity to the oral cavity. Each can be seen immediately lateral to the groove separating the vomerine from the pterygoid teeth. Each naris, which is covered by a fleshy flap, may be explored using a very fine probe.
- *Tongue:* It is well developed but immovable and is supported by the hyoid arch.
- *Pharynx:* This chamber lies posterior to the oral cavity.
- *Gill slits:* A pair on each side open directly to the outside from the pharynx. They are guarded by short projections called gill rakers that prevent large particles from passing through the gill slits.
- *Glottis:* The very small slit-like opening in the middle of the floor of the pharynx. The glottis opens into the larynx.
- *Esophageal opening:* The posterior opening from the pharynx.



MOUTH and PHARYNX

Digestive Organs

Insert two incisions, one on each side of the mid-ventral line, in order to leave a strip of tissue about one-fourth inch wide between the two cuts. Each incision should extend posteriorly from just in front of the pectoral girdle through the pelvic girdle, to the level of the cloaca. Leave the median tissue strip intact to protect certain blood vessels and points of mesenteric attachment in the mid-ventral line. Now make a lateral cut through the body wall from the middle of each longitudinal incision. This will permit greater access to the viscera.

- *Esophagus*: This part of the digestive tract is short. It extends from the esophageal opening in the pharynx to the stomach. The epithelium that lines the inside of the esophagus is ciliated.
- *Stomach*: The beginning of this elongated organ is not sharply demarcated from the esophagus. The cranial two-thirds of the stomach has a greater diameter than the caudal third. The entire organ runs in almost a straight course to terminate at the constricted pylorus.
- *Duodenum*: The anterior part of the small intestine is about one inch in length. It receives the opening of the bile and pancreatic ducts. The duodenum continues posteriorly for a short distance and then turns forward and to the right to join the next part of the intestinal tract.
- *Ileum*: The continuation of the small intestine from the duodenum resembles a loosely coiled tube. It extends as far as the rectum.
- *Rectum*: This short straight terminal part of the gut ends at the cloaca. It is also known as the large intestine. It will be necessary to cut through the pelvic girdle to see its full extent.

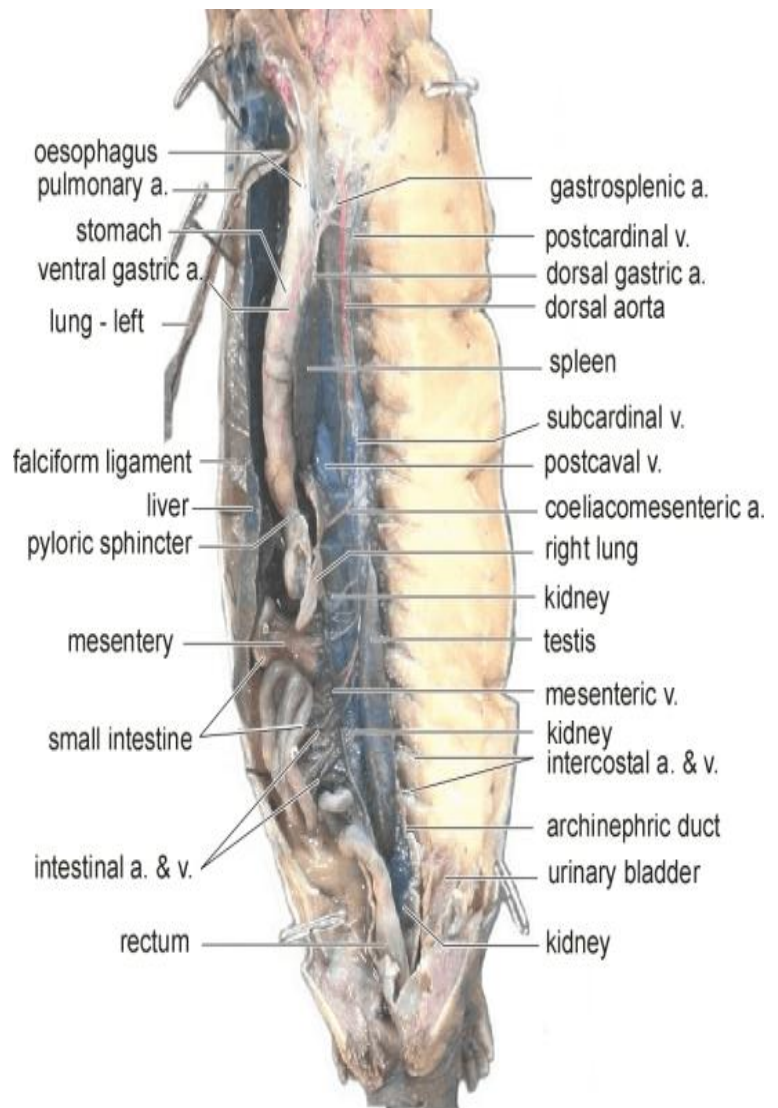


Fig. 5 -6A. Viscera of a male mudpuppy.

Digestive Gland

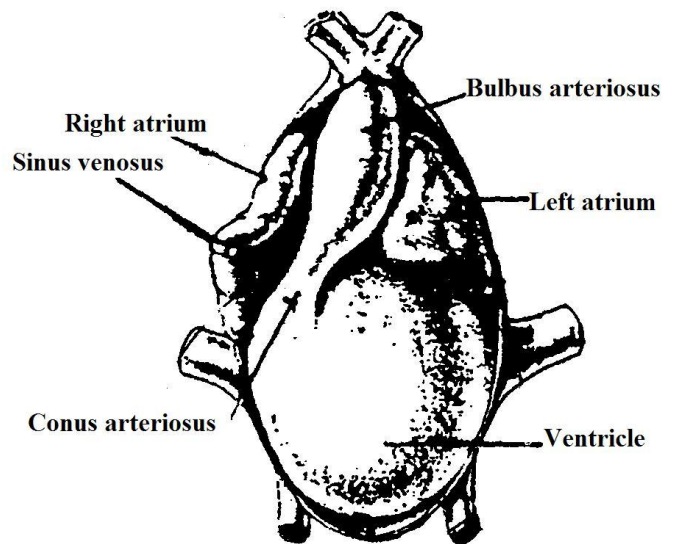
- *Liver*: The long structure that occupies a large portion of the mid-ventral region of the abdominal cavity. The sides of the liver are somewhat lobulated.
- *Gallbladder*: Located on the dorsal aspect of the right side of the liver near its posterior end. The bile duct passes from the gall bladder through the tissues of the pancreas to the duodenum.
- *Pancreas*: Irregularly shaped whitish organ lying along the length of the duodenum.
- *Spleen*: Elongated dark-colored organ that has no digestive function.

Peritoneum

The body cavity or coelom is divided by a partition, the transverse septum, into two separate compartments. The anterior pericardial cavity contains the heart and the larger posterior pleuroperitoneal cavity contains the remainder of the viscera. The following mesenteries should be identified.

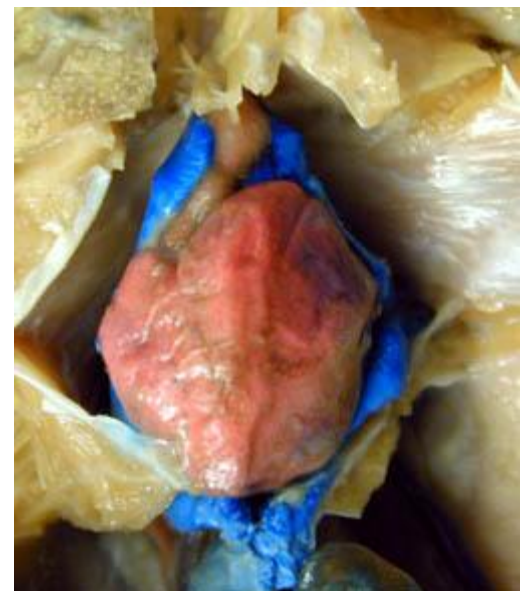
CIRCULATORY SYSTEM

Make a shallow longitudinal incision extending between the pleuroperitoneal incision and the posterior ends of the geniohyoid muscles to reveal the pericardial sac enclosing the heart. Slit the sac, expose the heart, and identify its parts. Make a longitudinal cut extending along the ventral surface of the ventricle, the conus arteriosus, and the bulbus arteriosus to reveal their internal structure.



HEART- Ventral View

- *Ventricle*: The large thick-walled posterior chamber of the heart. It is a common receiving chamber for blood entering from both atria. Blood empties from it into the conus arteriosus. Atrioventricular valves are present between both atria and the ventricle.
- *Atria*: A pair of thin walled sacs that appear on either side of the bulbus arteriosus. They are separated structurally by a perforated interatrial septum. The right atrium receives blood from the sinus venosus and empties into the ventricle. The left atrium receives blood from the pulmonary venous trunk formed by both pulmonary veins, and it too empties into the ventricle.
- *Conus arteriosus*: The single vessel that extends anteriorly from the ventricle. A row of semilunar valves are located at the junction of the conus and ventricle.



- *Bulbus arteriosus*: This represents the portion of the ventral aorta lying within the pericardial cavity is a continuation of the conus arteriosus. The bulbus is divided internally by a longitudinal septum into two channels. Outside of the pericardial cavity, it branches to distribute blood to the gills.
- *Sinus venosus*: This thin walled chamber lies dorsal to the heart. It receives blood from all parts of the body except the lungs. Blood passes from this chamber through the sinoatrial valves into the right atrium.

The circulatory system of the mud puppy differs significantly from that found in lower forms. These differences include:

1. The addition of a pulmonary circulation
2. An associated three-chambered heart.

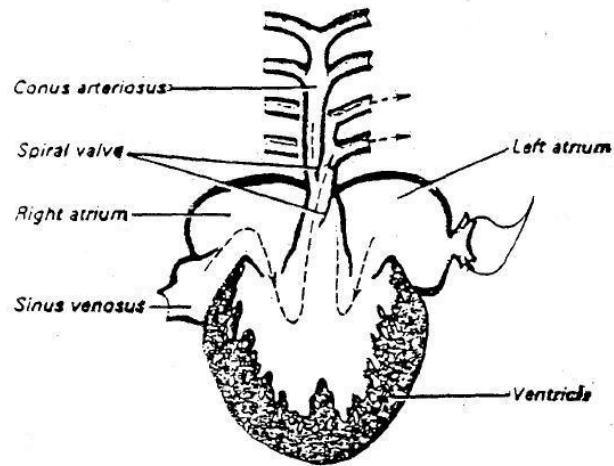
UROGENITAL SYSTEM

The breeding habits of *Necturus* are not completely understood, but presumably the male deposits a spermatophore that is picked up by the female. The spermatophores are clusters of sperm enveloped by gelatinous substance, which is secreted by a large superficial cloacal gland and by several smaller dispersed pelvic glands, all of which open up into the cloaca. A third set of glands, the abdominal, are rudimentary and nonfunctional and do not contribute to the formation of spermatophores (as they do in salamanders).

The spermatophores are probably shaped by the posterior ventral portion of the cloaca. The means by which the spermatophore is transferred to the female is unclear. Two methods of transference have been observed. The first method involves direct physical contact. In the second, the male deposits spermatophores in a stream bed and the female retrieves them with the aid of muscular movement of the lips of her cloaca. Thus, neither amplexus nor copulation occurs in *Necturus* or in other salamanders.

A dorsal diverticulum of the cloaca, the spermatheca, serves as a receptacle for the spermatozoa. Thus when the ova pass into the cloaca from the oviduct, the sperm are already present.

Although the female *Necturus* receives spermatophores in the fall, eggs are not laid until the following spring. The female hollows out a space in the sand underneath a submerged log or rock, then turns her body upside down and deposits her eggs on the underside of the solid object. The eggs, which appear as pale yellow spheres, are deposited individually and as many as 150 may be laid. The female remains in the nest guarding the eggs. This brooding instinct, in which one or both of the parents remains with the eggs, appears to be an important component of the reproductive mechanisms in higher vertebrates. In *Necturus*, however, brooding appears to be a part of a prolonged behavioral syndrome, since it has been observed that females occupy the "nests" after the young have departed. Because some adults use these nests as shelters throughout the year, the brooding of *Necturus* may be merely the result of the adult's disinclination to leave its favorite shelter.

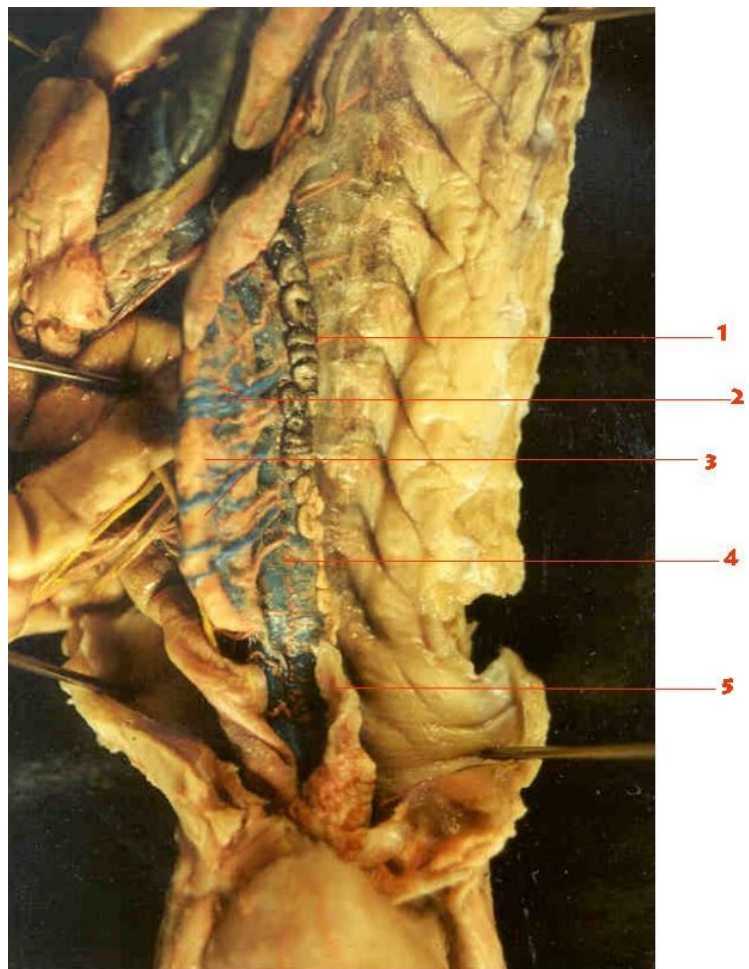


Amphibian heart (ventral view of front section).

The eggs take from six to nine weeks to hatch, after which time the larvae are less than one inch in length. It takes as long as about eight years for the animals to reach maturity. They can live for as long as 25 years.

Male Urogenital System

- *Testes*: Elongated organs, located on each side of the mid-dorsal line above the kidneys.
- *Mesorchium*: The mesentery that attaches each testicle to the dorsal surface. By holding up the mesorchium to the light, a number of small white tubules, the efferent ductules can be seen passing from the testes into the kidney. These tubules convey sperm.
- *Kidneys*: A pair of brown, narrow, elongated organs that lie in the posterior part of the body cavity close to the dorsal body wall. They are intraperitoneal rather than retroperitoneal structures being entirely enclosed by visceral peritoneum. The more slender anterior parts of the kidneys are genital in function since the tubules in this region of the kidney are modified for sperm passage. The broader posterior parts are urinary in function.
- *Mesonephric ducts*: These lie on the lateral border of each of the kidneys. Each is tightly coiled in the genital region, is straight in the urinary region and terminates in the cloaca. These ducts convey both sperm and urine.
- *Cloaca*: The common terminal sinus of the digestive, reproductive, and excretory systems. The mesonephric ducts open dorsally into the cloaca on either side of the midline, just posterior to the opening of the large intestine. Papillae are present on the posterior ventral wall of the male cloaca.
- *Urinary bladder*: This structure arises as a ventral outpocketing from the wall of the cloaca. Since the mesonephric ducts do not terminate in the bladder, the urine passes into this organ by gravitational flow.



Necturus Male Urogenital System

1. Archinephric ducts
2. Mesorchium
3. Testis
4. Opisthonephros
5. Urinary bladder

The bladder is probably of the greatest importance during the breeding season when the cloaca is plugged by the swollen cloacal gland and its gelatinous secretions. The gland opens into the cloaca by means of several very small ducts. If these small ducts cannot be found, it is probable that the gland was removed during dissection of the pelvic muscles.

Female Urogenital System

- *Ovaries*: Paired sac-like organs covering the internal end of the kidneys. They consist of masses of ovaries.
- *Mesovarium*: The mesenteries that serve to suspend the ovaries from the mid-dorsal body wall.
- *Oviducts*: Pair of large coiled ducts just lateral to each kidney and ovary. The funnel-shaped opening of the oviduct, the ostium, is located at the interior end of the pleuroperitoneal cavity dorsal to the lungs. The ostium is ciliated. The posterior end of each oviduct is somewhat expanded to form a uterus. The uteri open into the sides of the cloaca closest to the opening of the urinary bladder.
- *Mesotubarium*: The mesentery that attaches each oviduct to the mid-dorsal body wall.
- *Kidneys*: Similar to those in the male.
- *Mesonephric ducts*: These are relatively narrow uncoiled tubes that run along the lateral margin of the kidneys. Each duct empties separately into the cloaca and serves a purely excretory function.
- *Cloaca*: Similar to that in the male. Its posterior ventral wall lacks the numerous papillae that characterize the male cloaca. The papillae are replaced by smooth folds.
- *Urinary bladder*: Like that in the male, this is a ventral outpocketing. It opens into the ventral surface of the cloaca by means of a wide mouth.

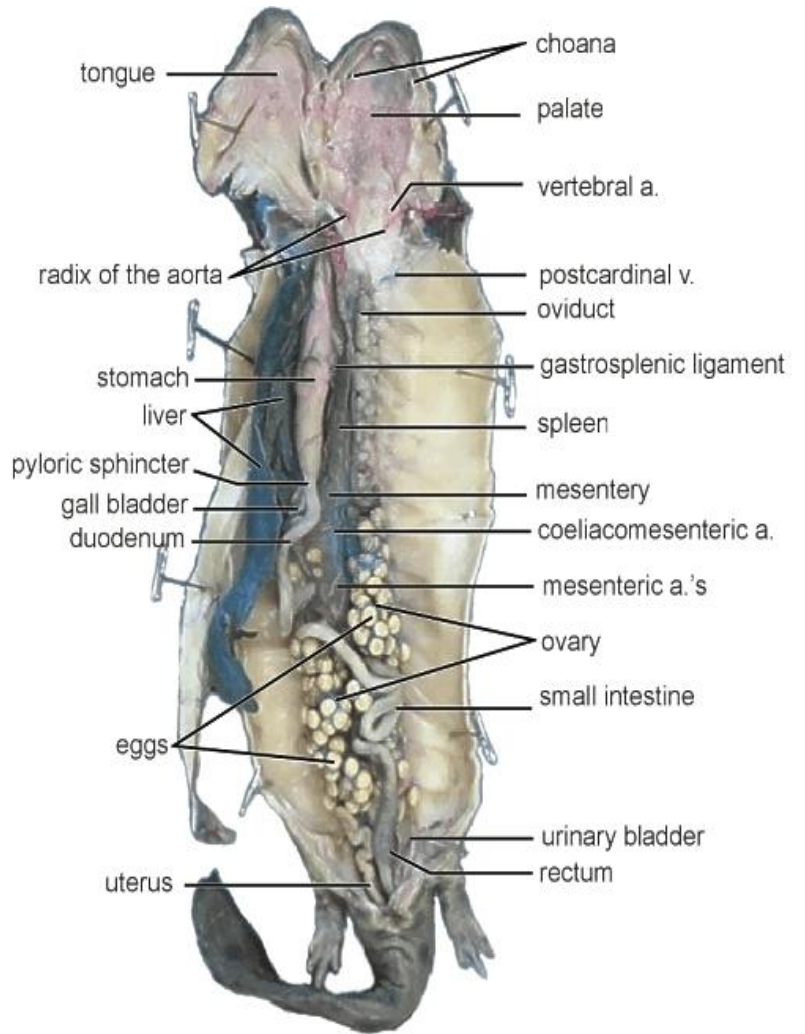


Fig. 5 - 6B. Gastrointestinal & urogenital systems of a female mudpuppy.

The female reproductive tract of *Necturus*

