An Illustrated Dissection Guide to the Lamprey
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Introduction

The lamprey belongs to the most ancestral group of living vertebrates. Although commonly referred to as a "fish" and lamprey do not belong to either Class Chondrichthyes (sharks, skates, rays) or Class Osteichthyes (bony fish), the two groups of "true" fish. Unlike all other vertebrates, lamprey have no jaws. Because of this feature, many scientists refer to lamprey as Agnathans, which means "without jaws". They also have no true bone or paired fins. The lamprey is an excellent example of the simple body design and basic anatomy of the earliest vertebrates.

The species used to represent a typical lamprey is the Sea Lamprey, *Petromyzon marinus*. The current taxonomic description of the Sea Lamprey would place it in:

Phylum: Chordata
Subphylum: Vertebrata
Class: Cephalaspidomorphi
Order: Petromyzontiformes
Family: Petromyzontidae
Genus and **Species:** *Petromyzon marinus*.

There are about forty living species of lamprey worldwide. Lamprey have an interesting life cycle. All lamprey spawn in cool, clear streams, where they construct nests of small stones that they collect with their mouths (Petromyzon means "stone sucker"). The adults die after spawning, a condition called **semelparity**. The eggs hatch into small larvae called **ammocoetes**. The ammocoete larvae look very different from the adults. They are filter feeders who live for up to ten years in small burrows in the mud found on the stream bottom. At some point, the larvae undergo **metamorphosis** - a dramatic change in body structure and function

which transforms them into the next stage of their life cycle. Some lamprey (non-parasitic species) will metamorphose directly into spawning adults, but the majority of species transform into a parasitic form that actively feeds on the flesh, blood, and body fluids of other fishes. Rapid growth occurs during this phase of the life cycle. Eventually, lamprey cease feeding, become sexually mature, migrate to appropriate spawning grounds, and the cycle is repeated.

Although lamprey do not usually deplete the population of prey species in their native environment, ecological disaster can result when parasitic species of lamprey are introduced into new environments. Fish species that did not coevolve with lamprey are more vulnerable to fatal attack than fish familiar with lamprey. The accidental introduction of the Sea Lamprey into the Laurentian Great Lakes of North America contributed towards the commercial extinction of many species of economically and ecologically important native fishes. After the implementation of programs to control lamprey, populations of some of these fish species have recovered. However, the lamprey have not been eradicated, and expensive lamprey control measures must be continued in order to maintain viable populations of the most susceptible fish species.

EXTERNAL ANATOMY

Terminology

Anatomists have developed terminology which provides accurate descriptions of the location of structures and which is helpful for stating concise directions needed for successful dissections. Here are some definitions which may be useful to you throughout this guide:

Anterior/cranial/rostral/cephalic/cephalad—towards the front or head
Posterior/caudal/caudad—towards the rear or tail
Dorsal—towards the top of the body, near the spinal cord
Ventral—towards the belly or underside of the body
Lateral—towards the sides of the body
Medial—towards the middle of the body or midline
Proximal—near the base of a structure
Distal—further away from the base of a structure

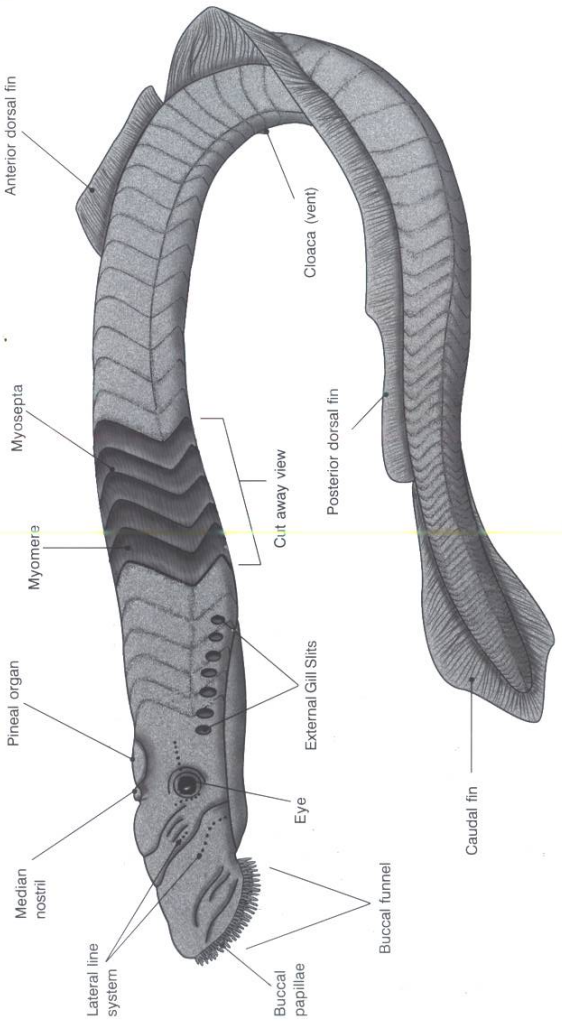


Figure 1: External anatomy of the lamprey.

The lamprey has an elongate body with no appendages (see Figure 1). Its "eel-like" body is typically divided into three regions: the ***head***, which extends forward from the branchial (gill) area; the ***caudal*** region, which extends backwards from the vent, and the ***trunk*** region, which is the main body of the lamprey between the gill and vent openings.

External Anatomy: Head Region

At the front of the lamprey head is the **buccal funnel** (see Figures 1 and 2). The **buccal funnel** lacks jaws; it is fringed with sensory **papillae**, which also function like a gasket to assist in forming a water-tight seal for attachment to prey, substrate, or other objects. The buccal funnel is also lined with keratinized **horny teeth**, which are epidermal in origin and composed of cornified cells and therefore are not homologous to the true teeth of other vertebrates. The protrusible **tongue of the lamprey is attached to the** ventral side of the **mouth**, which is at the center of the buccal funnel (Figure 4). The tongue is provided with **lingual teeth**, similar in structure to those lining the buccal funnel. During feeding, the lamprey scrapes a hole in the prey's body by rasping with these toothlike structures. On the sides of the lamprey's head, you will see seven pairs of **external gill slits**, which lead to the respiratory gill pouches, and one pair of **eyes** (Figure 1). Unlike the eyes of higher fishes, lamprey eyes are connected directly to the surrounding skin and - though eyes are connected directly to the surrounding skin and - though equipped with muscles for eye rotation - their movement is limited. On the top of the lamprey's head is the single **median nostril** or **naris**, which functions purely for olfaction

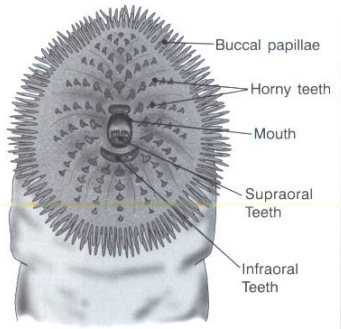


Figure 2:
Lamprey Head and Buccal Funnel.

(smell), not respiration. Immediately behind the median nostril lies a smooth, circular, unpigmented patch of skin which is the **pineal cornea**, which protects the underlying **pineal organ** or **pineal gland**. The pineal eye plays a role in both endocrine function and in setting the lamprey's "biological clock" on diurnal (daily) and seasonal bases.

If you examine the head carefully after drying it, you may be able to see a series of small pores, which are external openings to the **lateral line system** or **cephalic canal system** (Figure 1). It may be necessary to use a dissecting scope to see these pores. There are many lateral line pores, but the three most conspicuous arrangements of these pores that can be seen are: 1) extending backwards in a line from the posterior margin near the top of each lateral eye, 2) originating under each lateral eye, extending anterior-dorsally, and 3) on the ventral sides of the head, just posterior to the buccal funnel.

External Anatomy: Trunk Region

The body musculature of the lamprey can be seen through the skin of the trunk. It consists of a series of muscle bundles, or **myomeres**. The sea lamprey has two dorsal fins; the smaller **anterior dorsal fin** lies anterior to the cloaca, and is well-separated from the taller **posterior dorsal fin** by a distinct notch. At the rear of the trunk section is the **cloaca**, a single opening which receives digestive wastes from the **anus** (which opens into the anterior portion of the cloaca) plus urinary wastes and gametes, which empty into the cloaca via the **urogenital papilla**. Examine the papilla, and attempt to locate the **urogenital aperture** at the tip, through which urine and gametes pass.

On sexually mature lamprey, sex can be determined externally with some degree of confidence: the male has a larger, externally-visible urogenital papilla; whereas the female has a small ventral fin fold or "anal fin" which is lacking in the male.

External Anatomy: Caudal Region

Note the symmetrical caudal fin, which aids in propulsion.

PERFORMING DISSECTIONS

Equipment needed for dissection:

- ❑ Large dissecting tray
- ❑ Scalpel with new blade, a sharp knife, or a single-edge razor
- ❑ Probe
- ❑ Latex gloves

To see all the internal details it is best to work in teams and prepare two specimens for dissection as illustrated in Figure 3 and Figure 4.

Cross Sections

Using a sharp blade, perform cross sections as illustrated in Figure 3; A) in the head, immediately posterior to the medial nostril and bisecting the lateral eyes; B) through a pair of external gill slits in the mid-branchial region; and C) at the middle of the first dorsal fin.

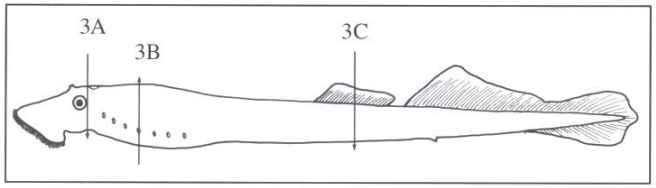
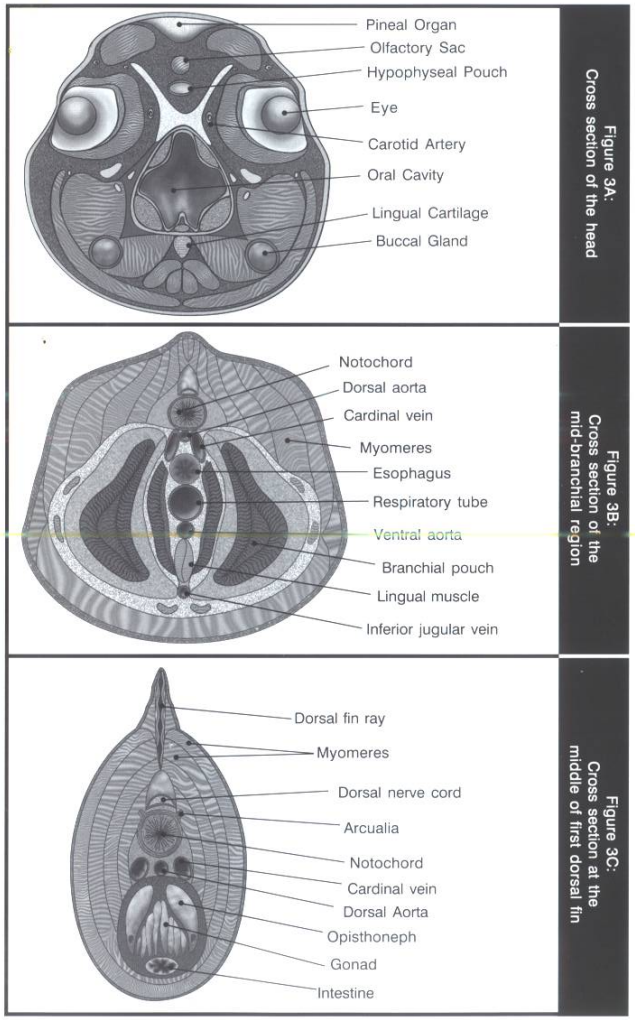


Figure 3: Dissecting cross sections.
(Refer to Figures 3A, 3B, and 3C on page 7 for cross section views.)

Midsagittal Section
(Figure 4)

This is designed to separate the lamprey into right and left "halves". Using a clean slicing motion and avoiding "sawing" motions, perform a midsagittal section of the anterior end or head section of a lamprey from the tip of the buccal funnel to approximately 6-7 cm (2½ - 3 inches) behind the last gill



slit (see Figure 4). Try to make the incision bisect the lamprey head as neatly in half as you can. On the remaining portion of the lamprey body, peel off the skin on one side to reveal the structure of the underlying musculature (save the skin for later examination); perform a mid-ventral longitudinal incision to expose the internal organs.

INTERNAL ANATOMY

Skin and Musculature

Examine the skin which you have removed from part of the lamprey's body. It consists of two layers: the glandular **epidermis** and the underlying **dermis**, the fibrous layer that attaches the skin to the underlying muscle mass.

Examine the patch of muscle that was exposed by peeling the skin away from the trunk. The bulk of the lamprey's body is composed of its muscles. The muscles on the trunk of the lamprey are arranged in w-shaped bundles called **myotomes**, which are separated from one another by membranes called **myosepta**. The myomeres of lamprey have no horizontal septum dividing them into hypaxial and epaxial muscle masses, as is seen in true fishes.

The other major muscles which you will see are in the head region of the lamprey, best seen in midsagittal section. The largest of these muscles maneuver the rasping tongue during feeding. The **retractor lingual muscle of the tongue** extends from the rear of the tongue back to near the end of the respiratory tube; it withdraws the tongue into the mouth. The **protractor lingual muscle of the tongue** is much smaller, and lies ventral to the protractor muscle; it is attached to the prominent **lingual cartilage**, and is responsible for protruding the tongue out into the buccal funnel. Additional muscles around the buccal funnel serve to modify its shape and assist in feeding and respiration.

Digestive System

Like other Agnathans (jawless fish), lamprey have no true stomach; the **esophagus** grades directly into the **intestine**, where both digestion and

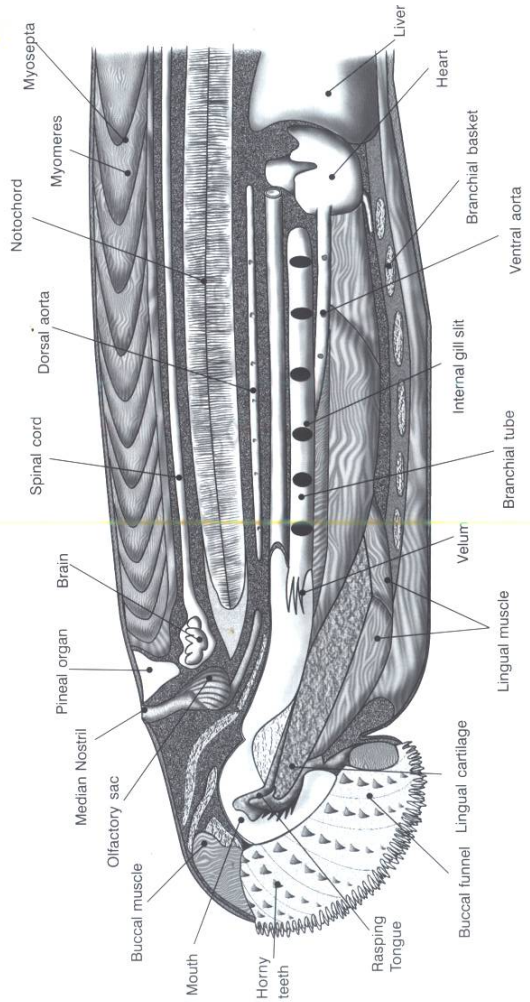


Figure 4: Mid-Sagittal Section. Internal anatomy of the lamprey.

absorption occur. Digestion of food actually begins with the addition of enzymes that are produced by the **buccal glands** (visible ventral and lateral to the buccal cavity, lateral to the lingual cartilage and lingual muscles in the first cross section; may be quite large. Refer to Figure 3A). These glands empty into the buccal cavity on the underside of the tongue as two inconspicuous pores. The secretions have proteolytic properties that initiate the digestion of host tissues and anticoagulant properties that prevent blood from clotting. Longitudinal infolding into the lumen of the intestine greatly increases its overall absorptive area (Figure 3C). In the larval stage, this is referred to as the **typhlosole**, but the spiraled course of this most prominent longitudinal fold as it passes down the intestine in adults leads some authors to conclude this fold represents a primitive **spiral valve** (found in sharks).

The **liver** is a large, single-lobed, triangular-shaped structure located just below the intestine and behind the heart. The connection with the intestine, the **bile duct**, is resorbed at metamorphosis in many lamprey, and becomes inconspicuous in others.

There is no discrete pancreas in lamprey. The endocrine and enzyme-secreting functions of the **pancreas** are carried out by diffuse patches of cells on the lamprey intestine and liver.

Reproductive System

The **gonad** is large and unpaired, supported by a dorsal mesentery, and occupies most of the body cavity in mature adults. Lamprey have impressive reproductive capacity: a single female can contain up to 250,000 eggs or more for her single lifetime spawning act. Permanent genital ducts are lacking; sperm and eggs enter the body cavity and are discharged via the paired **genital pores** (at the posterior end of the body cavity), which open into the **urogenital sinus**, and exit via the **urogenital aperture**.

Skeleton and Support System

Compared to other vertebrates, the lamprey skeleton is very simple. It contains no true bone, as it is purely cartilaginous. It consists of relatively ew structures. Although special preparation is required to see most of these

structures in detail (you may not be able to see them in your specimen), they are crucial components in the mechanics of locomotion and respiration in lamprey.

In addition to a cartilaginous endoskeleton, lamprey rely on the **notochord** for body support. Higher chordates do not retain a large, functional notochord in the adult state, but it remains a prominent feature in the adult lamprey. The non-cartilaginous, fluid filled cells of the notochord, encased in sheath of connective tissue, act as a hydrostatic skeleton, aiding in locomotion. It will be the most prominent structure you will see running the length of the lamprey body in the midsagittal section.

Endoskeleton

The **branchial basket** is a complex structure which supports the **gill arches**. The compressible yet resilient quality of the cartilage of the branchial basket facilitate pumping and ventilation of the respiratory pouches.

The **chondrocranium** or **neurocranium** (including the medial, unpaired **olfactory (nasal) capsule** and the paired **otic capsules**) houses and protects the brain and associated chemosensory and hearing organs. Ventral to the neurocranium are the **lingual cartilage** and **buccal cartilage**, that support the lamprey's feeding structures.

The **arcualia**, are metamerically (serially repeated) arranged cartilaginous structures above the notochord that partially surround the spinal cord (laterally). They are possibly homologous to the neural arch of higher vertebrates, because they resemble neural arches that are open dorsally. A similar series extends ventrally in the caudal region, and may be homologous to the haemal arches of higher vertebrates. **Ray supports** for the fins are anchored in the plane of the lamprey body. These will be visible in cross sections in the dorsal and caudal fin regions.

Circulatory System

The **heart** (Figure 5) of the lamprey is a large structure, found just anterior to the liver and inside the **pericardial cavity**. You may not observed all of

the structures mentioned here, but knowledge of them is important for gaining an understanding of the path taken by blood as it courses through the circulatory system in the lamprey. Deoxygenated blood drains from the liver into the **hepatic vein** and from the head via the **inferior jugular vein** (which lies ventral to the tongue musculature in the floor of the branchial region in the first and second cross sections) and the paired **anterior cardinal veins** into the heart's thin-walled, tubular **sinus venosus**. After the sinus venosus, blood passes into the heart's single **atrium**, and finally enters the **ventricle**, a muscular structure which actively pumps blood into the **ventral aorta.** From the ventral aorta, blood travels to the capillaries of the gill lamellae for gas exchange. The **afferent branchial arteries** branch from the ventral aorta into the gill arches, and the **efferent branchial arteries** carry the oxygenated blood away from the gill arches. Blood continues either to the head via the **carotid arteries** or caudad via the **dorsal aorta** for distribution to the rest of the body (in the caudal region, the dorsal aorta is called the **caudal artery**). Valves prevent the backflow of blood from each of the heart's chambers. See Figure 5 for a schematic diagram of blood flow in the lamprey.

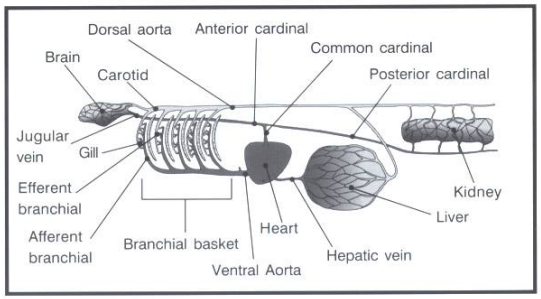


Figure 5: Heart and schematic diagram of blood flow.

In cross section, the unpaired dorsal aorta is situated just ventral to the notochord and between the two **posterior cardinal veins**, which return deoxygenated blood from the trunk and tail. Unlike true fishes, the cardinal veins in lamprey do not form a renal portal system or pass through the kidneys. The anterior and posterior cardinal veins empty into the **common cardinal vein**, which drains into the sinus venosus of the heart.

The spleen - an important part of the circulatory and immunological system of higher vertebrates - is absent from the lamprey.

Respiratory / Osmoregulatory / Excretory Systems

In lamprey, the **gill lamellae** are the primary sites of respiration (gas exchange) and excretion, and also play a crucial role in osmoregulation.

In the adult lamprey, the **respiratory pharynx** is well separated from the **esophagus**, which leads to the intestine. The pharynx, or **respiratory tube**, conducts water from the mouth down to seven pairs of valve-lined **internal gill slits**. Each of these in turn opens into seven pairs of **gill pouches**. Each unit of the gill consists of highly vascularized **gill lamellae**, arranged in **anterior** and **posterior hemibranchs** and together are called a **holobranch**. The two hemibranchs are separated from one another by a **gill slit**. Gill pouches are separated by membranes, called **interbranchial septa**. Run a blunt probe inside an external gill slit to observe where it enters the respiratory tube.

The lamprey is able to breathe differently when it is swimming then when it is attached to prey and feeding. While swimming, water enters the mouth of the lamprey and passes back to the **velum**, an arrangement of finger-like projections surrounding the opening of the respiratory tube. The velum functions like a valve to direct incoming fluids either towards the respiratory tube or the esophagus; while swimming, the water will pass into the respiratory tube, then into the gill pouches, and exit the body via the external gill slits. While feeding, the velum clamps shut, separating the respiratory tube from the esophagus. This prevents host blood from entering the respiratory pouches and fouling the lamprey's sensitive gill lamellae while simultaneously preventing the dilution of ingested blood with water. To breathe, lamprey alternate compression and relaxation of the branchial

basket to force respiratory water to enter and exit via the external gill slits. Compression is achieved via contractions of the pharyngeal and gill pouch musculature, which expels water from the gill pouches; relaxation of these muscles allows the resilient branchial basket to rebound to its normal position, creating negative pressure and drawing water into pouches through external gill slits.

Nitrogenous wastes in lamprey are broken down to ammonia and the primary site of removal is at the gills. The ammonia diffuses into the surrounding water. Also present on the gill lamellae are **chloride cells**, which play a crucial role in helping the lamprey regulate salt concentration in its body fluids. A lamprey in fresh water will experience a passive net influx of water via osmosis and a net loss of salts via diffusion across permeable body membranes. Conversely, a lamprey in sea water will experience passive loss of water and net gain of salts. To compensate for these osmoregulatory problems, a lamprey's body will function differently in the two habitats. In fresh water, the chloride cells use energy to acquire additional salts from the surrounding water; in a saltwater environment, they secrete excess salts from the body.

Adult lamprey have a typical glomerular **mesonephric kidney** that resemble two flaps suspended into the dorsal side of the coelom in the fourth cross section (at the origin of the first dorsal fin). If you look carefully near the ventral edge of each kidney, you may be able to see the **archinephric duct** that carries urine from each of the kidneys to the **urogenital sinus**. Small larval lamprey (ammocoetes) also possess a **pronephros** kidney which filters body fluids via ciliated **nephrostomes**, funnel-shaped structures which open directly into the pericardial coelom. The kidney of lamprey functions differently in fresh and salt water habitats. In fresh water, the kidney eliminates large volumes of dilute urine to rid the body of excess water, and may reabsorb salts; in salt water, the kidney conserves water, and functions mainly for the excretion of ions. Since lamprey in sea water experience constant dehydration, they must drink large quantities of sea water; the chloride cells at the gills eliminate most of the salt in this water.

Nervous System

Senses

The nostril of the lamprey opens into the **olfactory sac**, which in turn leads through the **hypophyseal canal** to a blind chamber, the **hypophyseal sac**. The hypophyseal sac lies dorsal to the pharynx and esophagus and extends under the brain and notochord, terminating near the second gill slit of the respiratory tree. The folds of tissue lining the olfactory sac are covered with sensory epithelia for chemoreception (olfaction or "smelling"). Water is constantly being drawn over the olfactory epithelium by the pumping action of the pharynx. Pharynx contractions expel water in and out from the blind-ended hypophyseal sac and therefore across the sensory epithelia lining the olfactory sac.

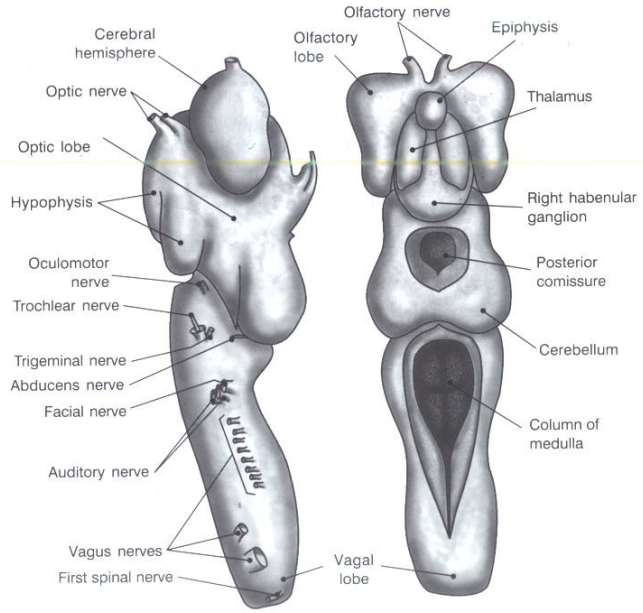


Figure 6: The brain of the lamprey.

Information from receptors in the olfactory sac is directly transmitted to the brain, so the lamprey is constantly aware of its chemoenvironment. The **eyes** that can be seen in the first cross section of the head (Figure 3A). Note the spherical, "fisheye" **lens**. Unlike higher vertebrates (in which accommodation or focusing is achieved by lens distortion), non-tetrapods typically focus an image by adjusting the distance between the lens and retina to achieve the correct focal length.

Central Nervous System

The **brain** of the lamprey is divided into three major sections: (Figure 6) **hindbrain (rhombencephalon), midbrain (mesencephalon)** and **forebrain (prosencephalon)**. Like true fishes, lamprey have ten **cranial nerves**; unlike higher fishes, lamprey have only two **semicircular canals** for orientation and balance. Detailed structure of the brain will probably not be visible on your specimen. Originating at the posterior end of the brain and running just dorsal to the notochord for the length of the lamprey's body is the **spinal cord**. This transmits nerve impulses between the brain and the body. Nerves exit at each body segment along the spinal cord, and they are completely separated into **dorsal** and **ventral nerve roots**, a feature unique to lamprey. Just dorsal to the spinal cord is a **fat column**, which may be conspicuous and dark in some specimens.

Suggested Readings

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