1.0 Anatomy and Physiology of Salmonids

1.1 Introduction:

This template is intended for use by instructors to train the Department of Fisheries and Oceans (DFO) staff and students in the anatomy and physiology of salmonids. Templates are used to provide the minimum requirements necessary in a training exercise, but the instructor may add additional material.

An experienced instructor must demonstrate the methods outlined in this template. Hands-on training of staff is a requirement for facility approval by the Canadian Council on Animal Care, of which DFO is a member. This template is part of a comprehensive DFO Science Branch series on training for users of aquatic research animals.

1.2 Rationale:

There are over 50 species of fish and shellfish used as laboratory animals by the scientific community in Canada alone. Salmonid species are among the most common laboratory animals and include but are not limited to: Rainbow trout, Cutthroat trout, Atlantic salmon, Brook trout, Steelhead salmon, Brown trout, Arctic char, Lake trout, Chum salmon, Sockeye salmon, Pink salmon, Coho salmon and Chinook salmon.

In order to properly identify abnormalities and signs of disease or distress in fish maintained for the purposes of scientific study, it is important to recognize and understand the basic anatomy and physiology of the species being studied. An understanding of anatomy is critical and ensures proper and humane methods are used for procedures such as blood sampling and tagging or marking with minimal long-term effect on the fish.

1.3 Authority:

The staff, consultant veterinarian or Animal Care Committee is responsible for providing information about anatomy and physiology of the fish species used for scientific study in their respective regions. Staff must be trained in the identification of the anatomy and the basic function of the organs and systems of the fish species being studied prior to initiation of any research study.

1.4 Goal of this training exercise:

1. Identify all the major external features of salmonids.
2. Identify all major internal structures of salmonids.
3. Understand the function/physiology of external and internal anatomical features of salmonids.
4. Perform a complete dissection of a salmonid species in a systematic manner.
5. Recognize gross abnormalities that may indicate compromise in the health of salmonids.

1.5 Theoretical Training – to be completed before hands on session

1. Completed 'The Experimental Fish'
2. WHMIS training
3. Summary theory material provided with this training template (Appendix A)

1.6 Details of the Procedure:

Species of fish, which may be included in the training session, are:

1. Atlantic salmon
2. Rainbow trout
3. Brook trout
4. Steelhead salmon
5. Brown trout
6. Arctic char
7. Lake trout
8. Chum salmon
9. Sockeye salmon
10. Pink salmon
11. Coho salmon and transgenic Coho salmon
12. Chinook salmon
13. Cutthroat salmon

1.6.1 Time Estimate:

Set up: 1 hour
Instruction: 3 hours

1.6.2 Equipment Required:

Fish: number will depend on the number of trainees in a session; salmonid species used and size will depend on availability and the requirements of the facility.

Fish euthanized for the euthanasia of finfish template can be used for training in this template.

- Dissecting boards
- Disposable gloves
- Dissecting instruments (forceps, scalpel, scissors)
- Paper towel
- Disinfectant
- Dissecting microscope(s)
- Glass or clear plastic Petri dishes

1.6.3 Procedure:
The instructor should demonstrate all procedures prior to trainees attempting them. It is recommended that trainees perform the following dissections on a variety of salmonid species of various sizes (i.e. fry, fingerlings, smolts, adult) as availability permits.

A table to record all gross observations is attached for the trainees to use in this exercise.

1.6.3.1. Preparation

- Prepare the examination area by cleaning and disinfecting the area with a disinfecting agent.
- Be sure there is plenty of workspace.
- Arrange material and equipment to suit the surroundings and allow for easy access.
- Trainees should wash hands thoroughly with a disinfecting soap and put on a pair of the gloves provided.

1.6.3.2 External Examination

- Note the overall condition and appearance of the fish (i.e. excellent to emaciated).
- Note any lesions, hemorrhagic areas, exophthalmia (popeye), or other signs of abnormalities.
- Perform a detailed dissection on all organs and tissues of the fish as follows:

Fins

- Examine all fins for fraying, erosion, necrosis, or small-discoloured spots. These findings often indicate a parasite infection.
- Record findings.

Skin

- Examine the surface of the skin for colour, texture, excess mucus, lesions, scale loss or other abnormalities.
- Identify the lateral line.
- Record findings.

Eyes

- Examine the eyes for corneal opacity and exophthalmia.

- On larger fish, remove the eye by cutting the muscles and optic nerve and place it in a Petri dish and examine with a dissecting scope.
- Make a transverse cut through the eye and lens and record any abnormalities.

Anus

- Examine the anus for any swelling, redness, or ulcerations.
- Record findings.

1.6.3.3 Internal Examination

- Place the fish on a clean dissecting board or flat surface covered with clean paper towels.
- An approach through the left side of the fish allows better access to the spleen.
- Locate the lateral line and use this as the point of reference for purposes of dissection.

Gills and Pseudobranch

- Remove the operculum with a pair of dissecting scissors or cutting shears.
- Examine the gills and pseudobranch.
- Post mortem changes affect the gills most rapidly. The gills should be bright red in healthy fish.
- Gills, which are pale or white in appearance or flared, indicate the fish is undergoing stress, is anaemic or has been dead for some time.
- Remove a portion of the gill from the second or third gill arch including 0.5 cm of cartilage. Place the tissue in a Petri dish and examine with a dissecting scope to identify the anatomical features of the gill.
- Record findings.

Body Cavity

- Open the body cavity of the fish with three incisions as shown in figure 1.

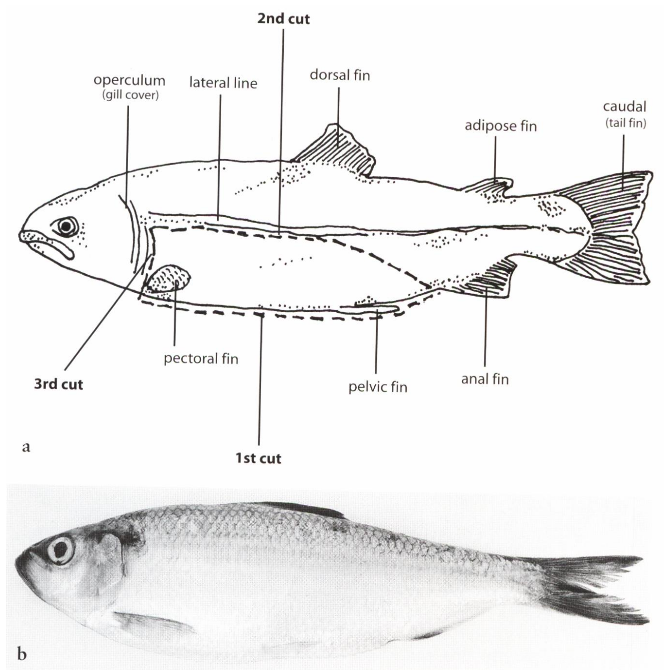

Figure 1. (a) Dissection pattern through the abdominal wall. (Graphic by J. Speiran) (b) An American shad (*A.sapidissima*) prior to dissection. (Photo by R. Hebb). Photo and graphic used with the permission of the author.

- Make a transverse incision immediately anterior to the anus.
- Insert the blunt side of scissors into the body cavity. Be careful not to penetrate the intestine with the instruments.
- First, cut anterior to the anus directed toward the ventral part of the head, ending the incision between the gill covers.
- Start the second incision at the anus and cut craniodorsally toward the lateral line, following the dorsal margin of the peritoneal cavity and end at the gill arches.
- Cut the bone near the gill arches. The third incision connects the ends of the first two cuts.
- Remove the sidewall to expose the internal organs as shown in figure 2.

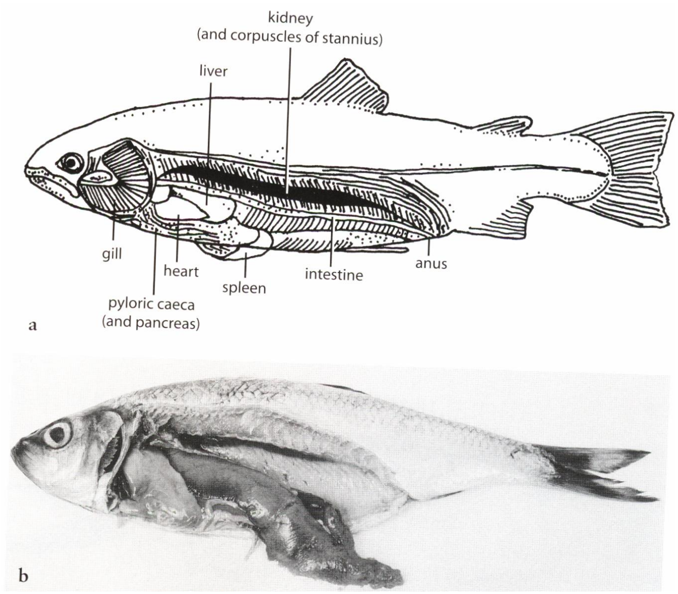

Figure 2. (a) General location of internal organs of a typical fish from an abdominal incision approach. (Graphic by J. Speiran) (b) View of the internal organs of an American shad (*A. sapidissima*) following the removal of the abdominal wall. (Photo by R. Hebb). Photo and graphic used with permission of the author.

- After the sidewall has been removed, the organs become visible. Observe their position, examining for the presence of fluid in the cavity and free parasites. If fluid is present, record the amount, colour, and turbidity of the fluid; i.e. opaque, clear, red, etc.

Peritoneum and Mesenteries

- The peritoneum and the mesenteries are normally transparent, smooth and glistening, and moist.

- Any abnormalities such as haemorrhages, parasites, turbidity, thickening, etc. should be recorded.

Digestive System

- Sever the esophagus at the oral cavity and hindgut at the anus. Disconnect the liver from the pericardial walls. Remove the digestive tract and visceral organs, disconnecting them from the mesenteries, leaving only the air bladder, gonads, heart, and kidneys intact.

- Separate the liver and gallbladder from the digestive tract and observe their colour, surfaces and margins. Thickened margins may indicate an increase size due to edema, degeneration, infiltration, etc.

- Cut the liver and observe for colour, consistency and presence of opaque nodules or parasites. A healthy liver is pinkish-brown in colour, soft, and easily ruptured.

- Examine the gall bladder. An enlarged gall bladder may be indicative of starvation or the presence of parasites.

- Examine the pyloric caeca for haemorrhage or excess fat.

- Open the digestive tract with scissors.

- Observe the amount and appearance of its content, paying attention to the quantity and colour of any mucus present or parasites or tapeworms. A digestive tract that yields excess mucus is a signal that the fish is off feed and is a risk for disease.

- Check the size, colour and margins of the spleen. A healthy spleen is small, dark reddish-black in colour and can be triangular or oval in shape with defined edges.

- Record all findings.

Swim Bladder

- Remove the air bladder and check its contents and the appearance of the inner surface for the presence of parasites by observing the bladder against a dark background and record findings.

- Note any blockage of the duct or damage to the swim bladder wall. Blockage or ruptures can result in the fish's inability to swim properly.

Kidney and Corpuscles of stannius

- Visually examine the entire kidney and locate the corpuscles of stannius.

- Note any haemorrhages, white pustules, lesions, colour, etc. and record findings.

Heart

- Grasp the anterior aspect of the bulbous arteriosus, pull caudally very gently, and sever the connection to the ventral aorta.

- The heart can now be pulled far enough out of the body to expose and sever the sinus venosus.

- Examine the heart for any raised or discoloured lesions and record findings.

Brain

- Examine the brain by opening the skull just dorsal to the eye and record the findings.
- If it is difficult to find the brain, remove both eyes and follow the optic nerve caudally.
- Remove enough of the bone to fully expose the brain.
- Cut the spinal cord and gently tease the brain away from the neural connections.

Musculature

- Randomly cut the musculature and examine for any abnormalities and record findings.

Gross Observations:

Tissue	Examined (Y/N)	**Description/Findings** **Note: NSF (No Significant Findings)**
Overall external appearance		
Dorsal fin		
Pectoral fins		
Pelvic fins		
Adipose fin		
Anal fin		
Caudal fin		
Skin		
Lateral line		
Scales		
Eyes/Lens		
Anus		
Gills		
Pseudobranch		
Operculum		
Peritoneum and Mesenteries		
Stomach		
Pyloric caeca		
Intestine		
Liver		
Gall bladder		
Spleen		
Esophagus		
Swim bladder		
Kidney		
Corpuscles of stannius		
Heart (sinus venosus)		
Heart (atrium)		
Heart (ventricle)		
Heart (bulbous arteriosus)		
Brain		
Musculature		

1.6.4 After Dissection:

- Trainees should have clear instruction for carcass disposal.
- Anaesthesia baths must be disposed of in accordance with local waste management regulations.
- Disinfect the area where fish were handled (provide trainees with site biosecurity SOP).
- Trainees must wash hands with disinfectant soap.
- Update drug use records to include anaesthetic use.
- Update inventory records to reflect the number of fish euthanized for this session (if any).

1.7 ACC Notes

- Locally significant differences required in training (e.g. species).

- Authorization required to teach/list of possible instructors for your region.

- Any other requirements for your region.

APPENDIX A: Review theory for Anatomy and Physiology of Salmonids

References:

Branson, E. (1993). Basic Anatomy and Physiology, In: Aquaculture for Veterinarians (ed) Brown, L. Pergamon Press, New York, USA.

Stoskopf, M.K. (1993). Fish Medicine, editors: Stoskopf, M.K., Published by W.B. Saunders Company, Philadelphia, Pa. USA.

Whitman, K.A. (2004). Finfish and Shellfish Bacteriology Manual – Techniques and Procedures, Published by Blackwell Scientific, Iowa State Press, Iowa, USA.

Definitions:

Anatomy: The branch of morphology concerned with the structure of animals. The science dealing with the form and structure of living organisms.

Caudal: Pertaining to the posterior or tail end of a fish.

Dorsal: Pertaining to the back region, opposite of ventral.

Lateral: Located to one side of the central axis of the body. Pertaining to a side.

Metabolism: Vital processes involved with the release of body energy, the building and repair of body tissue, and the excretion of waste materials. It is a combination of anabolism and catabolism.

Necrosis: The dying off of cells or tissues within a living body.

Physiology: The study of the life processes of living things.

Ventral: The underside of the body relating to the lower abdomen area. Pertaining to the abdomen, opposite of dorsal.

Anatomy & Physiology of Salmonids

- Salmonids are ectothermic animals. Their internal temperature is the same as the temperature of the water in which they live. In water temperatures just above freezing, salmonids become lethargic (lack energy) as cold temperatures slow their metabolism.

- Salmonids do not do well at water temperatures above 25^{o}C, as warmer water may not contain enough oxygen to meet the elevated metabolic demands of fish at higher temperatures.

- Extreme temperatures may result in the inability of the fish to produce functional enzymes. Slow acclimation of salmonids to different temperatures is possible however; temperatures higher than 25^{o}C generally result in death.

- The three regions of the fish's anatomy are the head (cranial or rostral), trunk (mid-body) and tail (caudal). The head extends to the bottom margins of the operculum, the trunk extends from the operculum to the end point of the peritoneal cavity, and the tail begins at the anal/urogenital opening and extends to the posterior end of the caudal fin.

- Salmonids are fusiform (cigar or torpedo shaped) in shape.

- Salmonids have 4 unpaired fins (dorsal, caudal, adipose and anal) and 2 sets of paired fins (pectoral and pelvic).

- The dorsal fin is located along the back of the fish between the tail fin and the head. It provides stability so that the fish can swim in a straight line (controlled swimming conserves energy). A fish that cannot swim well will not live very long because it will not be able to compete for food.

- The caudal fin (tail fin) is responsible for sudden forward movement (bursts of speed) and for fast swimming patterns. Fish also use their tail fin to slow forward movement and help to make turns.

- The anal fin is located on the ventral surface of the fish between the pelvic and caudal fins. The main purpose of this fin is to provide stability – it keeps the fish from rolling over and going belly up.

- The pectoral fins provide stability as a fish moves through the water, hovers, and makes slow turns. These paired fins are located near the ventral surface of the fish, directly beneath the gill openings (one on each side). Pectoral fins are used for navigation and are constantly in motion.

- The lateral line is located on both sides of the salmonids body and runs from the back of the eye to the base of the tail fin. These lines are composed of small neuromasts (tiny sensory cells), which contain cilia (very fine hairs) in fluid-filled canals. These canals detect vibrations in the water, and the vibrations form an “image” inside the fish’s brain. The lateral line is believed to receive low frequency pressure waves in the water. It helps the fish locate objects in their path and in the surrounding environment that they cannot see normally due to their limited eyesight.

- The skin or integument is the first barrier or line of defence to the environment and is responsible for maintaining the osmotic integrity of the fish (i.e. keeps water out and the fish tissue fluids in). The skin is also responsible for waterproofing the fish as well as providing the armour plating of the scales. Any minor abrasions or wounds can rapidly lead to water logging of the underlying tissues in freshwater and dehydration in salt water.

- The skin is composed of two layers: an outer epidermis overlaid by a cuticle (a very thin delicate covering which is draped over the scales – often referred to as the mucus layer), and an inner dermis.

- The mucus layer is largely protective and forms the slimy outer covering of the fish. It is capable of tying up small particles of material that may irritate the fish; parasites; bacteria; and some heavy metals and salts.

- Mucus production increases when the fish becomes stressed which can make the fish difficult to grasp or hold. This mucus can be sloughed off through continuous mucus exchange.

- The inner dermis is much thicker and more complicated than the epidermis. It contains the pigment cells, blood vessels, nerves, lenses of light producing organs, and the dermal skeleton.

- The dermal skeleton may consist of various types of scales or plates.

- Salmonids have scales that develop early in the fishes’ life (i.e. at the fry stage). Once a fish has its full quota of scales, it does not develop any more as it grows. Instead, the scales grow larger as the fish grows.

- Overlaying the scales are the pigment cells (black cells are referred to as melanophores; silver cells are referred to as iridiophores; and yellow and red cells are referred to as xanthophores).

- The black cells are under both nervous and hormonal (i.e. chemical) control. When fish are in dark surroundings they emphasize their black pigment cells, and in lighter surroundings, the silver pigment cells are more obvious. When fish become stressed, either by an environment situation or by a disease-causing organism, they frequently become darker in colour. This is an important clue as to the health status of your fish.

- The salmonid eye has an anterior chamber, an iris, a lens and a vitreous chamber containing the vitreous humour (the transparent jellylike content of the back chamber of the eyeball) that is lined by the retina.

- The eyes in salmonids are flattened on the head of the fish.

- The lens is round and completely clear in healthy fish.

- Salmonids are primarily sight feeders, using a mechanism in the retina of the eye to detect movement and light contrast. Feeding ceases when critical low levels of illumination (quantity of light) are reached. If the lens becomes cloudy, this is a good indication of disease.

- The eye is also one of the sites with extremely delicate blood vessels and is therefore very vulnerable to ruptures of the capillaries by excess gases in the water (i.e. gas bubble disease as a result of supersaturated water).

- The eyes of salmonids are lidless and surrounded by bone.

- Three pairs of oculomotor muscles anchor the eye within the bony socket called the orbit.

- The gills are vascularized structures that are contained in chambers located on both sides of the throat of the head region.

- A bony flap called the gill cover or operculum protects the gill structures.

- In each chamber there are four cartilaginous (tough, elastic-like tissue) branchial (gill) arches that have forward facing teeth'' called gill rakers. The gill rakers help to guide food down the gullet rather than over the gills that would cause distress to the fish and possibly impede the breathing process.

- The gill arches also support gill filaments that are directed away from the mouth opening.

- The gill filaments are further subdivided into feather-like structures called lamellae that contain fine, flattened capillaries and are thinly covered by cells.

- The lamellae contain secondary lamellae that are essential in the respiration or breathing of the fish.

- Water is passed over the gills through the actions of a branchial pump.

- Water is drawn into the mouth (oral cavity) as the opercula closes, and is expelled across the gills where up to 85% of the oxygen is extracted by the gill filaments. The oxygen-depleted water is then quickly discarded. The process may also be accomplished by simple open-mouthed swimming, displacing water over the gills as the fish moves through the water.

- The secondary lamellae are very delicate so that oxygen and carbon dioxide can be readily exchanged. They also contain mucus-producing cells, cells that excrete any excess salt from the blood as it passes through them, and cells which excrete ammonia from waste products. Obviously, such a delicate structure on the outside of the body of the fish is highly vulnerable to damage from exposure to foreign material in the water.

- The gills are extremely sensitive to irritation from toxic substances in the water, to clogging and abrasion by suspended material and to infection by various disease causing organisms. Any of these agents can quickly affect the health of the fish by inhibiting the respiratory exchange.

- Salmonids have a pseudobranch. The pseudobranch is found on the inner side of the gill cover. It receives oxygenated blood only and does not function in respiratory gas exchange. The pseudobranch appears, however, to secrete oxygen to the retina of the eye. There is still confusion as to the exact function of the pseudobranch.

- The function of the digestive system is to degrade large particles of food into smaller components. These smaller components are absorbed across the intestinal wall into the circulatory system for transport to the cells of the body. Cells utilize the nutrients brought by the blood as building blocks for: maintenance of existing tissues, growth of new tissue, source of energy for locomotion and metabolic processes, as components of body fluids, and for the production of enzymes and hormones.

- Salmonids possess well developed grasping and holding teeth on the jaws and surfaces of the mouth; an esophagus capable of swelling; a well-defined stomach and a relatively short intestine.

- The stomach in salmonids is U-shaped.

- The pylorus is the constriction of the digestive tract that acts as the boundary between the stomach and intestine. It has a one-way valve preventing the passage of large food particles.

- The pyloric caeca are finger-like structures that extend from the intestine just below the pylorus. They have digestive and absorptive functions and are usually surrounded by adipose (fat) tissue.

- The pancreas in salmonids cannot be identified by eye, but is contained in the pyloric caeca structure scattered throughout the fatty tissue. The endocrine component of the pancreas secretes hormones into the bloodstream. The exocrine component of the pancreas secretes digestive enzymes through the pancreatic duct into the bile duct and subsequently into the digestive tract. The pancreas is very significant in viral diseases because it is a favourite site for the multiplication of several viral agents associated with fish disease.

- The liver is the large organ located in front of the stomach. It acts as an accessory digestive organ. The liver secretes bile through a duct into the gall bladder that temporarily stores bile. The liver also performs detoxification of heavy metals, drugs, pesticides and other compounds to which the animal may be exposed.

- The gall bladder is the small green sac attached to the underside of the liver. A second duct leads from the gall bladder and discharges bile into the pyloric end of the stomach where it aids with the breakdown of food particles.

- Due to the importance of the liver in food metabolism, liver disease is very significant. Common liver abnormalities include a build-up of unhealthy fats that lead to an increase in the liver size, and parasite invasion. Parasites often inhabit the gall bladder as well.

- Salmonids have the simplest form of the swim bladder appearing as a wide, short, membranous duct with only one chamber that lies longitudinally along the ventral surface of the kidney and connected to the digestive tract by the pneumatic duct that leads off the esophagus. This is called a physostomous swim bladder.

- The gas or swim bladder is the organ responsible for maintaining hydrostatic (pressure) equilibrium within the environment.

- The peritoneum covers the internal organs and the body wall. It is the serous membrane that lines the wall of the coelomic cavity (parietal peritoneum) and invests contained viscera (visceral peritoneum); the two layers enclosing a potential space, the peritoneal cavity. The fibrous tissue that connects the organs to the body wall is continuous with the peritoneum and is called the mesentery.

- The kidney, in salmonids, is a long dark red-black structure that lies along the ventral surface of the spine and extends from the back of the head region to the anus. The kidney is retroperitoneal (between the body wall and the peritoneum) thus it is covered on one side by the peritoneum.

- The kidney is divided into three sections (anterior, mid-kidney and posterior).

- The kidney is the main filter of the body. Its primary function is to maintain the internal salt/water balance of the fish. In fish, the kidney plays only a minor role in the excretion of waste products (e.g. ammonia).

- The haematopoietic region, known as the "head" kidney, is important for the formation of oxygen carrying red blood cells and the white blood cells used to fight off infection. These cells are produced and stored in this region until needed.

- The middle kidney contains nephrons, or renal corpuscles, which are blood-filtering units or traps which catch any foreign material (such as bacteria) and tries to destroy them. Glucose, minerals, and other substances used by the fish are also filtered through the kidney and reabsorbed for use by the fish. Unwanted substances are filtered out and collected in paired mesonephric ducts joined at the ureter. Urine is then discharged into the urinary bladder, and voided posterior to the vent or anal opening.

- The corpuscles of stannius are small, whitish bodies located on the ventral surface of the middle kidney. They secrete a hormone called stanniocalcin into the bloodstream that reduces active calcium uptake in the gills and intestine of both freshwater and saltwater teleosts. Because of their appearance, the corpuscles of stannius are often mistaken for white pustules associated with bacterial infections.

- There is no true adrenal gland present in salmonids. The interrenal cells represent the adrenal cortical tissue. These cells are associated with major blood vessels in the anterior kidney. Both glucocorticoid and mineralocorticoid are secreted.

- The thyroid gland is an endocrine gland composed of thyroid follicles, which are distributed throughout the connective tissue of the pharyngeal area and may be observed around the eye, ventral aorta, hepatic vein and anterior kidney. The thyroid gland secretes hormones that can be involved in maturation, metabolism, metamorphic changes, and possibly osmoregulation.

- The spleen is a small dark reddish black organ that may be triangular or oval in shape and attached to the wall of the stomach or intestine. Its function is similar to that of the haemopoietic tissue of the kidney.

- The heart is a muscular two-chambered organ though four distinct regions are readily distinguishable (sinus venosus, atrium, ventricle and bulbous arteriosus). The heart is situated at the base of the throat and lies in the pericardial cavity that is completely separated from the body cavity.

- De-oxygenated blood collects from the venous system in the thin-walled sinus venosus, and enters the large chambered atrium. Muscles in the walls of the atrium contract to move the blood into the ventricle (a triangular, muscular structure); back-flow is prevented by valves called atrioventricular valves. The muscular ventricle is the main pump of the heart. Ventricular contraction forces the blood past a back-flow valve to the bulbous arteriosus. The bulbous arteriosus is an elastic-walled whitish structure that acts as a pressure balance, smoothing the pulsing flow of the oxygenated blood and delivering it to the various organs of the fish.

- The brain lies in the cranial cavity located between the eyes of the fish. It is protected by cartilage or bone surrounding the organ and spinal fluid, and by a fatty mass that fills much of the cranial cavity. Cranial nerves extend from the brain through the skull. The spinal cord, with which the brain is continuous, leaves the cranium posterior and passes down the middle of the vertebrae of the spinal column, which gives it considerable protection.

Although the basic anatomy is similar in most fish species, variations do occur between species.

- Grossly recognizable parts of the brain include the olfactory bulbs, olfactory tract, and forebrain lobes of the telencephlalon; the pineal body and pituitary gland of the diencephalons; the optic lobes of the mesencephalon; the cerebellum or the metencephalon; and the acoustic, vagal, and facial lobes of the myelencephalon.

- The brain undergoes autolysis (decomposition) rapidly once the fish dies and should be examined first if neurological issues are being examined. The major portion of fish muscle is known as striated or skeletal muscle.

- The major portion of fish muscle is known as striated or skeletal muscle. The skeletal muscle includes the trunk muscles found on both sides of the fish, also referred to as ‘white muscle’. White muscle fibres are anaerobic rapid contracting fibres that fatigue quickly; they are used in locomotion. The axillary muscles, also referred to as ‘red muscle’, are slow contracting fibres that are also involved in locomotion. The movement of the eyes, jaws, gills and fins is also a red muscle function.

- The major skeletal muscles are arranged in symmetrical fashion down each side of the body in a series of similar segments (blocks or myotomes) that are attached to the flexible spine. These segments are prominent at the surface of skinned or sectioned fish. The vertical segments in the salmonid fish are divided by the lateral line into upper (epaxial) and lower (hypaxial) sections.