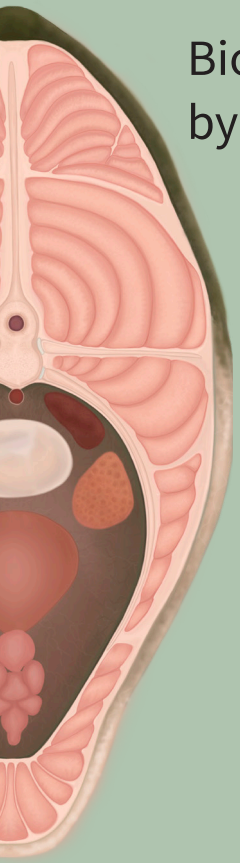
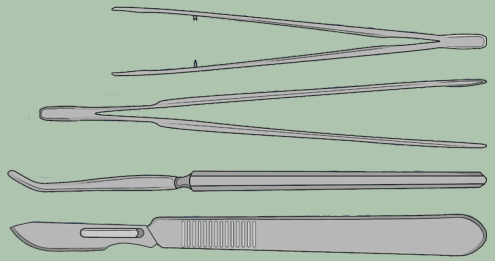
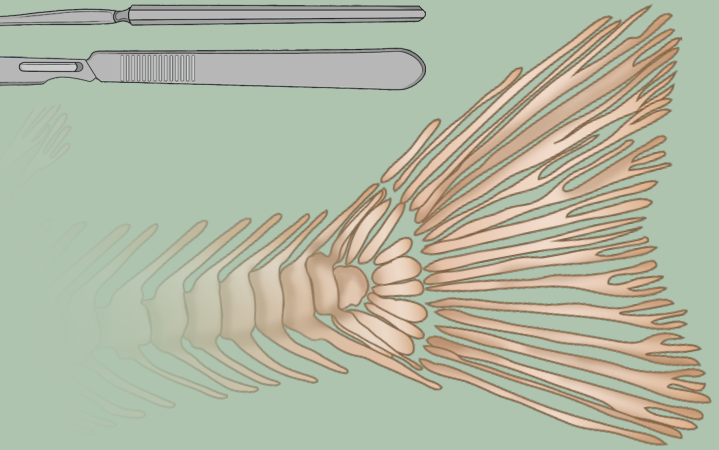
Illustrated Dissection Manual of the Blue Tilapia

Biomedical Art BFA Thesis
by Alex Prenatt







Cleveland
Institute of Art
Class of 2020

Project Book

Illustrated Dissection Manual of the Blue Tilapia

a Biomedical Art BFA Thesis Project
by Alex Prenatt

Cleveland Institute of Art
Class of 2020

Defended May 5th, 2020

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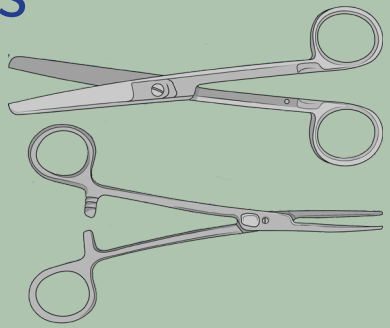
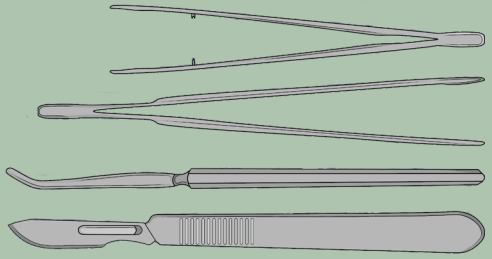




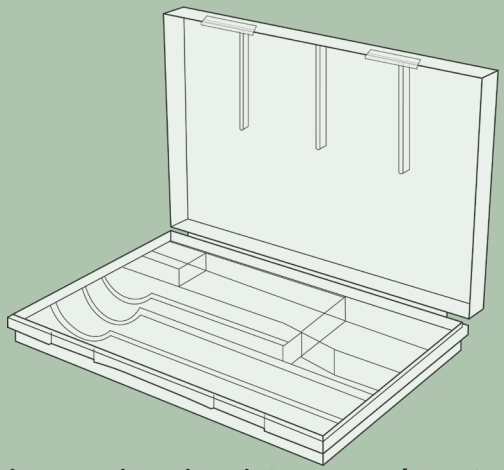
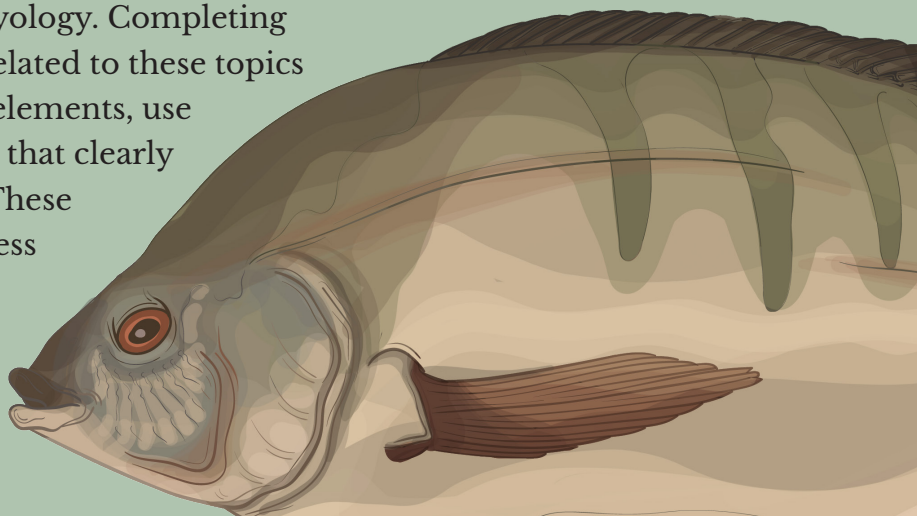


Figure 2: Dissection Kit (CWRU Bookstore)

Artist Statement

Throughout my 4 years of study at the Cleveland Institute of Art within the Biomedical Art major, I have developed an interest, passion and strong understanding of material relating to aquatic biology and, more specifically, ichthyology. I have been taking science courses at a college level for 6 years now and I have used these courses to expand my knowledge not only of the course subject, but the literature, fieldwork, and issues of importance within the fields. My technical art based courses have assisted me in refining the process of completing large multi step projects. These projects typically begin with a complex, unfamiliar topic which requires research and concludes with final piece that is both visually appealing to the viewer and clearly communicating the educational relevance of the topic. I have focused many of my projects on the fields of aquatic biology and ichthyology. Completing these various pieces has made my work related to these topics more cohesive in illustration and design elements, use of color palettes and rendering, and work that clearly communicates each informational unit. These are all skills that I have utilize in the process of creating my senior thesis project, a dissection manual for the Blue Tilapia for use by the Case Western Reserve University Ichthyology course.



2 Inspiration

CWRU Ichthyology Class Spring 2018

This project was inspired by my experiences in the CWRU Ichthyology course in the spring semester of 2018. I enrolled in the ichthyology course after taking Aquatic Biology through CWRU as well, and became interested in the field especially as it relates to fish. Ichthyology was a lab and lecture based course that instructed students in identifying fish, fish anatomy and physiology, habitat and behavoir, phyologeny, fisheries sciences, aquaculture, overfishing, and other relevant topics. Of all of the content in the course, the first laboratory activity of the semester was to dissect and learn the internal and external anatomy of the fish from both preserved and fresh specimens. That laboratory assignment was the inspiration for this BFA project. After the defense of this thesis it will go on to be used as a reference for the CWRU Icthyology course fish laboratory assignment.

Introduction

Dissection of fresh and preserved specimens is a common method of instruction in reference to the anatomy of species. Specifically in the context of fish, these dissections are most typically performed on preserved specimens of dogfish shark. Dissection offers students the chance to see anatomy in situ, gain a visual understanding of the anatomical relation of three dimensional forms in anatomy, and have a better comprehension of the physiological correlations to the anatomy. Many of these topics can be quite complex and the need for a manual or dissection guide is prominent in any vertebrate zoology laboratory. These manuals all approach the anatomy, procedure, and physiology of the specimen differently. These differences can be noted in the use of text, images, organization of content, and physical form of the manual itself (size, binding, paper quality, etc.). This review will analyze 7 different dissection and anatomy manuals, ranging from general vertebrate zoology atlases to specific dogfish dissection manuals meant for laboratory use. The goal of this analysis is to compare and contrast the content and its presentation and evaluate whether it is a functional aid for use in laboratory dissection.

Guiding Question

In reference to preexisting anatomy and dissection manuals for college-level biology dissection labs, what content, both textual and visual, is provided to instruct and guide students through the lab? Which features of these manuals are successful in supporting student learning?

4 Thesis Statement

Problem Statement

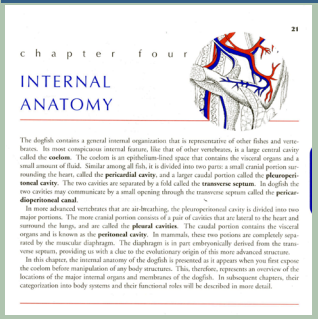
Laboratory dissection is a necessary activity in higher level biology courses for understanding specimen anatomy. According to a poll of 40 respondents with varying experience in laboratory dissection, all agreed that it is easier to operate and learn in laboratory settings when utilizing visual aids. Fish are a frequent laboratory specimen for dissection, despite this there are currently no dissection relevant visual aids for the most widely available fresh fish specimen, the Blue Tilapia.

Solution

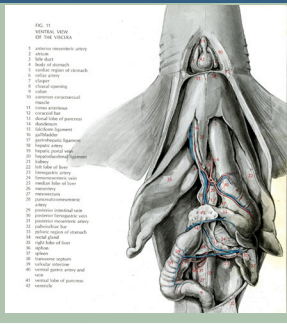
My thesis aims to provide students with a more thorough and comprehensive understanding of the anatomy, physiology, and dissection of the Blue Tilapia. This will be provided in the form of a visually descriptive laboratory manual and anatomical guide. A series of digital paintings will be created, detailing the anatomical structures of the Blue Tilapia as well as depicting dissection procedures. These illustrations, along with labels and keys, and original text, will all be used to create a clear and simple manual suitable for education and laboratory use.

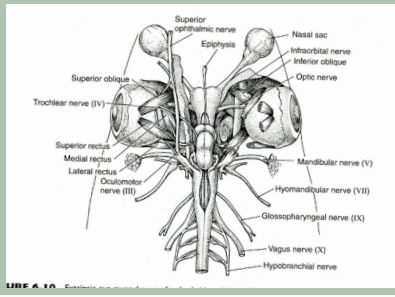
Production Board 5

My literature review and production board worked hand in hand. My literature review was oriented around preexisting dissection manuals and reviewing the content and design of those manuals based on a certain set of criteria. Just as I began to model my content and information based on the knowledge I was gaining from the literature review, I was reviewing the differing art styles of various manuals for my production board. Between photographic references, photo realistic illustration, flat-color, black and white, line work illustrations, and diagrams there were many approaches to visual representation of specimen dissection. In addition to my personal review styles, I polled a group of 40 respondents with varying experience in laboratory disection on their opinions of visual styles. Overall respondents agreed with my findings of manual reviews for the literature review, that detailed colored illustrations were best at capturing the details necessary for an educational manual. From there, the production board was helpful in establishing a color scheme around the local colors of my photo referencces from dissection. Lastly, the review of content for my production board was helpful in establishing a design style for my own manual.


chapter four

INTERNAL ANATOMY





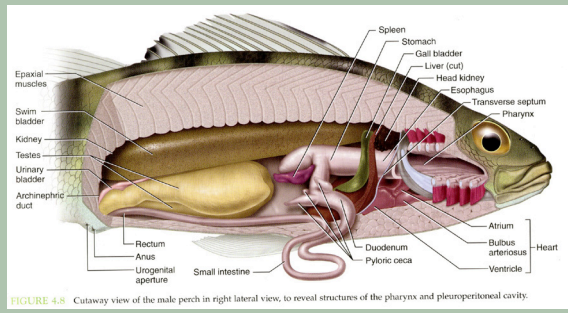


FIGURE 4.8 Cutaway view of the male perch in right lateral view, to reveal structures of the pharynx and pleuroperitoneal cavity.

6 Dissection

Documenting the Tilapia Dissection

In order to better understand the anatomy and dissection of the Blue Tilapia, a dissection of a fresh specimen was performed with Professor of Ichthyology Ronald Oldfield.
Before begining to ilustrate and explain the process myself, having a reference for the process and identificaiton of structures was imperative. The dissection performed by Professor Oldfield was recorded both in video and photographs in order to document every element of the dissection. The photos and video were later used as reference for anatomical structures, color, procedure, and physiological context described by Professor Oldfield during the dissection.

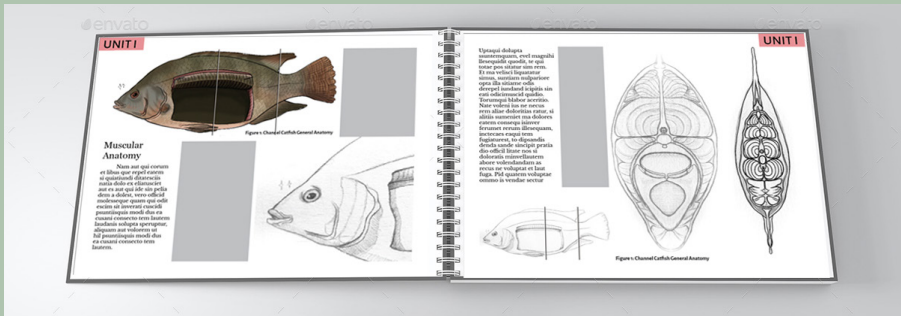
Dissection of the Blue Tilapia
Assisted by Professor of Ichthyology Ronald Oldfield & CWRU Laboratory Manager Owen Lockhart
10/14/19 & 10/18/19
MILLIS 320 CWRU

For this project three programs from the Adobe Suite, Photoshop, Illustrator, and Indesign, were utilized. Photoshop was used to generate highly rendered, clean, and descriptive illustrations. Illustrator was used for line work, dissection procedural drawings, tools, and some design. InDesign was used for the final manual design including type styles, content layout, design elements, and publishing the final pdf.

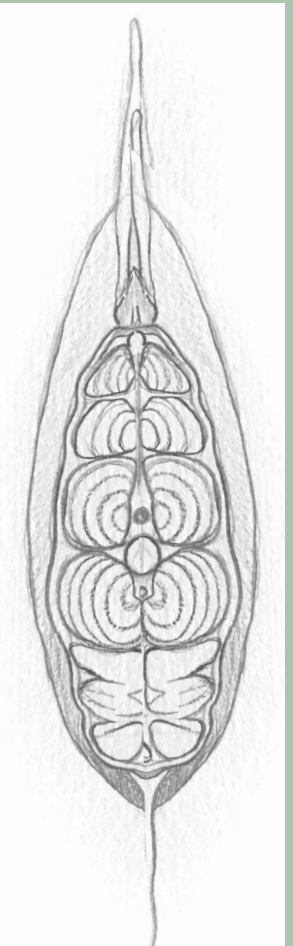
The manual may be printed as a 12 page 8.5x11 booklet which can then be spiral bound and laminated if desired.

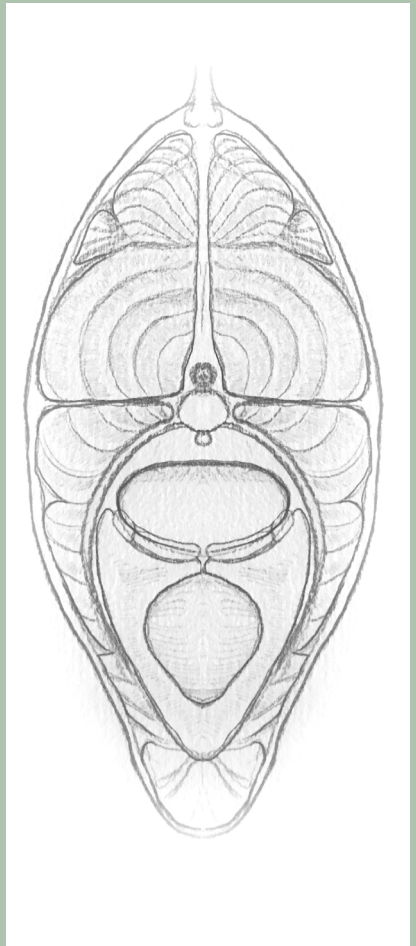
Printed Formatting: 8.5X11 landscape spiral-bound book. Production (printing & binding) at CIA Digital Ouput Center

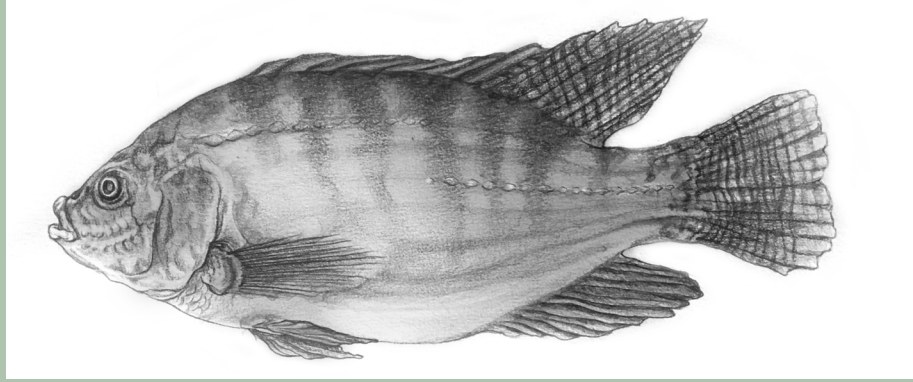
Digital Formatting: PDF available online through CWRU Canvas Ichthyology course

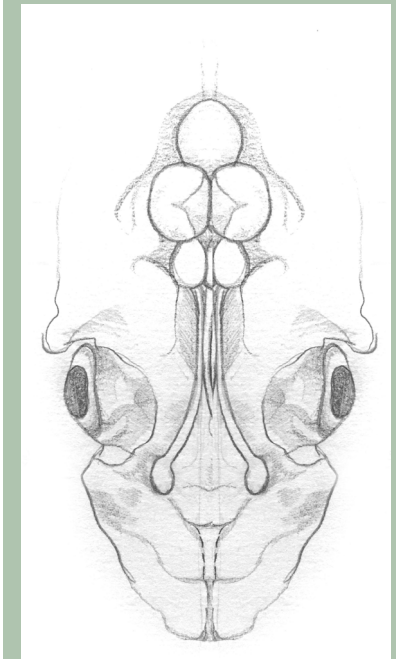


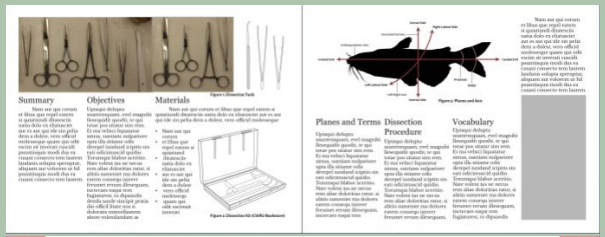
8 Sketches & Precomps

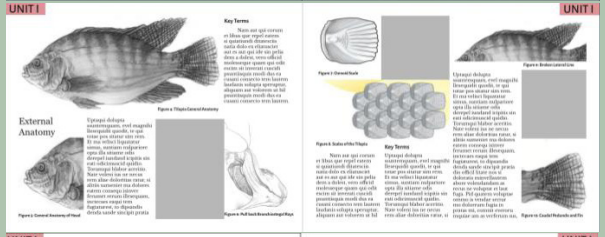


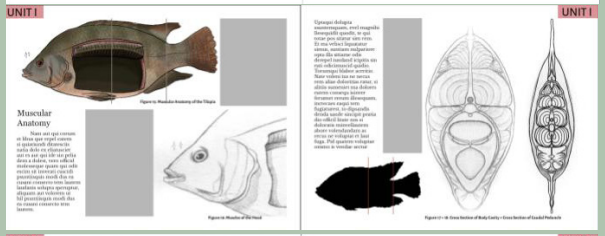


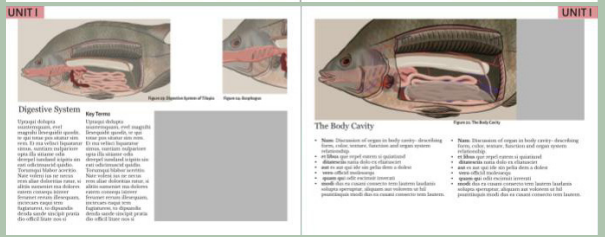


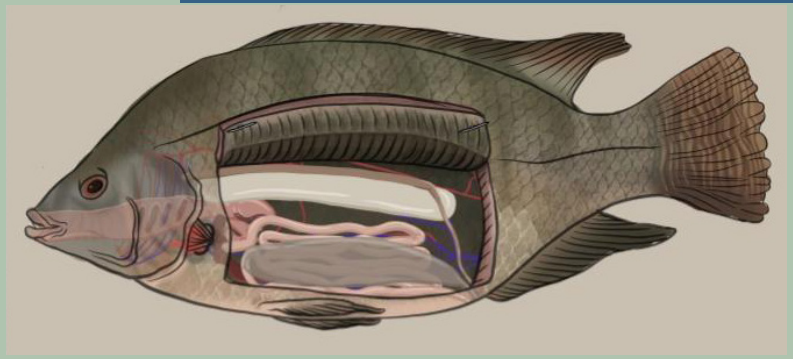


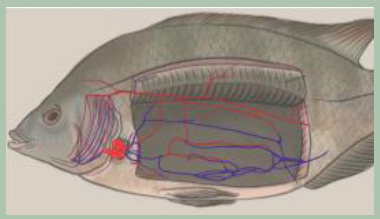


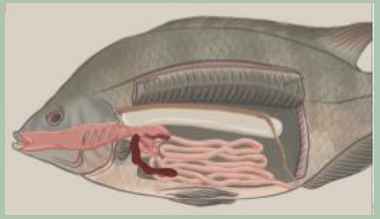






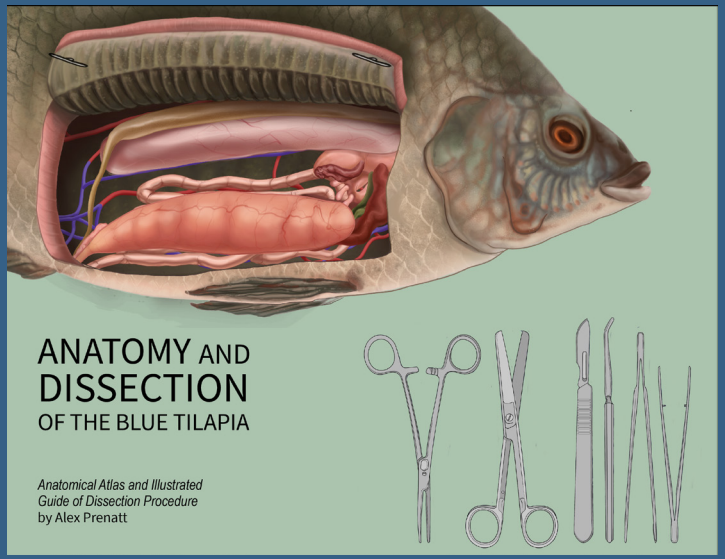






Sketches were made based off of video and photo references from the dissection performed by Professor Oldfield for this project. Sketches and photos were used to design the first drafts of the layout. Once the images needed for the manual were finalized, local color was added to create precompositions.

10 Final Manual Design



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Anatomy and Dissection
of the Blue Tilapia

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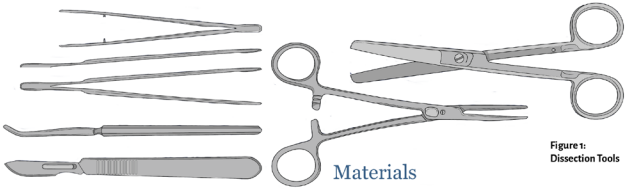

Figure 1:
Dissection Tools

Summary

The Blue Tilapia, *Oreochromis aureus*, is an example of a bony fish, Teleostei, and exemplifies the general physical features of most bony fishes. Tilapia is a popular fish in aquaculture and thus is widely available for purchase, fresh if not live in local markets. The freshness, wide availability for purchase and the general anatomy of the fish make it the perfect specimen for lab dissection.

Objectives

The goal of this dissection is to orient you with the general external and internal anatomy of fishes. This knowledge will aid in your understanding of evolution, identification, physiology, and behavior of fishes.

Working by yourself or with a team, observe the external features of the specimen, complete the steps of the dissection, and identify as many internal structures as possible while completing the written and visual elements of the assigned handout.

Materials

The materials for fish dissection lab are:
PPE: nitrile gloves, eye protection such as safety goggles, and lab coat.
Dissection Kit: (recommended McCoy Health Science Supply Biology Dissecting Kit- available for purchase at CWRU bookstore): includes:

- 4.5" scissors
- #4 scalpel handle (snap-fit)
- #21 blade
- 5" thumb dressing forceps
- 2 straight teasing needles
- White 6" vinyl ruler
- Set of 6 T-pins

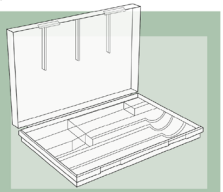

Figure 2: Dissection Kit (CWRU Bookstore)

Figure 3: Planes and Axis

Planes and Terms

There are several ways to measure the length of fishes.

Fork length measures the distance from the tip of the fish's closed mouth to the center point of the forked tail of the fish.

Standard length measures the length from the tip of the fish's closed mouth to the end of the caudal peduncle, directly anterior to the start of the caudal fin.

Total length is the common measurement of biologists and natural law enforcement personnel. Total length measures from the tip of the fish's closed mouth to the tip of the fish's caudal fin when compressed vertically to extend the fish to its longest point.

Anterior: The front end of an organism's body; or at or towards the front.
Posterior: The behind or end of an organism; on or towards the rear.
Dorsal: The back of an organism; or, towards the back
Ventral: The bottom of an organism; or, towards the bottom
Lateral: The sides of an organism

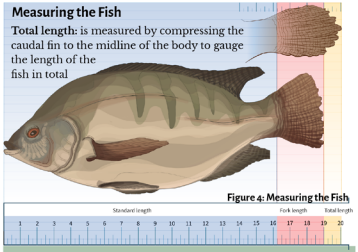

Figure 4: Measuring the Fish

•Use a ruler to measure the standard length, fork length, and total length of the fish.

Adult Tilapia size range around 20 inches (50.8 cm) in length
Adult Tilapia weight range 5-6 pounds (2.26-2.72kg).
NOTE: Female tilapia are usually smaller than males of the species

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Figure 5: Tilapia General Anatomy

External Anatomy

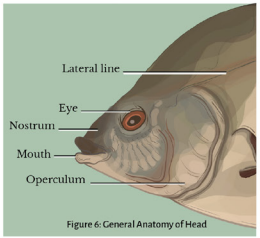

Figure 6: General Anatomy of Head

In general appearance the adult Blue Tilapia will have a deep, laterally compressed body shape that is colored blue-gray with dark vertical banding on the dorsal half of the body. Body-color gradually lightens ventraly, becoming near to white on the ventral belly.

Young tilapia will grow rapidly for the first few months of development, then slow somewhat but ultimately reach 5-6 pounds by age 3-5 yrs. Adult fish typically weigh from 2-4 pounds, though they can range to around 10 pounds at largest.

Identifying External Characteristics

Appearance:

•Gill Rakers	18-3
•Anal Spines	6
•Anal Soft Rays	3
•Dorsal Spines	8-11
•Dorsal Soft Rays	14-17

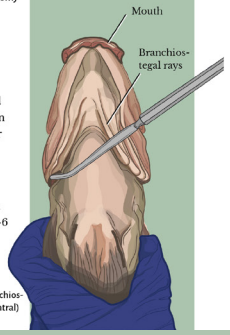

Figure 7: Branchios-tegal rays (ventral)

Identifying Characteristics

Anatomy of the Ctenoid Scale

Ctenoid Scales: scales are similar in shape to cycloid but are characterized by a ridge of small grooves and teeth on their posterior edge. This comb-edge is found specifically on higher teleost fishes such as perch.

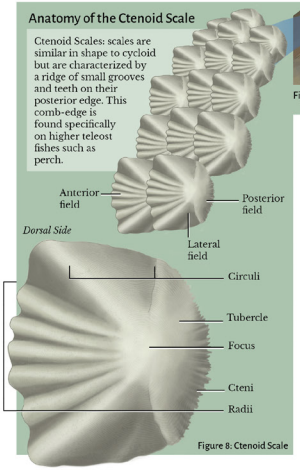

Figure 8: Ctenoid Scale

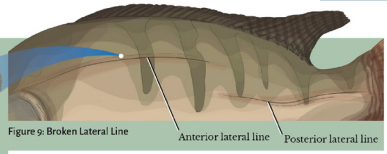

Figure 9: Broken Lateral Line

Broken Lateral Line and Truncate Caudal Fin:

A significant defining trait of *Oreochromis aureus*, and all others in the cich is the broken lateral line which starts posteriorly to the head of the fish, running to around the end of the dorsal fin, picking up again after a few scales to end at the posterior-most point of the caudal peduncle.

The Tilapia possesses a truncated (or squared) caudal fin that demonstrates a pink/red coloration on the distal margin. This coloration can be found on both the dorsal and caudal fins during breeding when the female exhibits a more orange color while the male's turn an intense deep red.

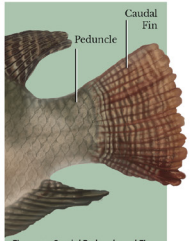

Figure 10: Caudal Peduncle and Fin

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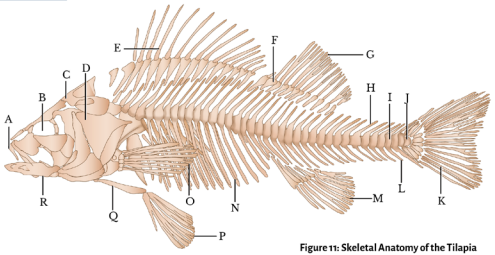


Figure 11: Skeletal Anatomy of the Tilapia

Key:

- A Upper jaw
- B Orbit
- C Skull
- D Opercular
- E Ray of ant. dorsal fin
- F Radial cartilage
- G Ray of post. dorsal fin
- H Neural spine
- I Vertebra
- J Hypural
- K Caudal fin ray
- L Hemal spine
- M Anal fin ray
- N Rib
- O Pectoral fin ray
- P Pelvic fin ray
- Q Pelvic girdle
- R Lower jaw

Skeletal Anatomy

The skeletal system of bony fishes such as the Blue Tilapia, is composed of bones and cartilage. The skeletal system provides support, protection, and a source for red blood cell production.

The fish skeleton can be divided into the vertebral column, ribs, intramuscular bones, cranium, and jaw. The head of the tilapia is defined by a narrow preorbital bone, fused lower pharyngeal jaws forming a tooth plate. This plate functions as a second set of jaws to distribute the labor of food processing. The mouth of the tilapia is superior, oriented upwards, protrusible and containing a row of conical teeth.

Structures of the Caudal Fin

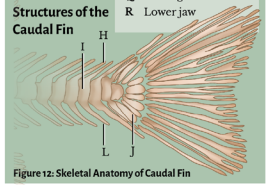


Figure 12: Skeletal Anatomy of Caudal Fin

Skeletal Structures of the Head

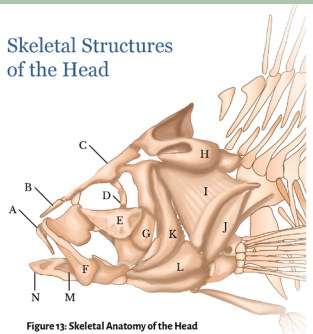


Figure 13: Skeletal Anatomy of the Head

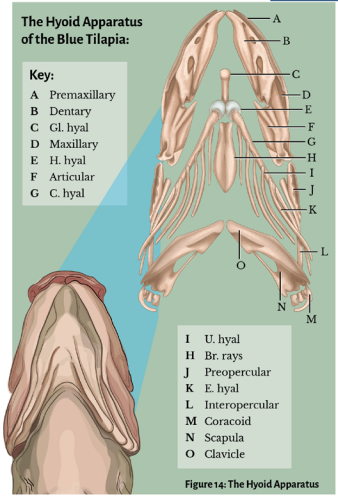
Key:

- A Premaxillary
- B Vomer
- C Frontal
- D Infraorbital ring
- E Preorbital
- F Maxillary
- G Posttympanic
- H Suprascapula
- I Opercular
- J Subopercular
- K Preopercular
- L Interopercular
- M Mandible
- N Dentary

The Hyoid Apparatus of the Blue Tilapia:

Key:

- A Premaxillary
- B Dentary
- C Gl. hyal
- D Maxillary
- E H. hyal
- F Articular
- G C. hyal



- I U. hyal
- H Br. rays
- J Preopercular
- K E. hyal
- L Interopercular
- M Coracoid
- N Scapula
- O Clavicle

Figure 14: The Hyoid Apparatus

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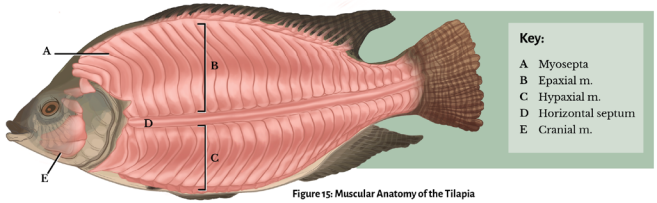

Figure 15: Muscular Anatomy of the Tilapia

Muscular Anatomy

The majority of the Tilapia's muscular system from the caudal peduncle through the trunk of the fish consists of muscle blocks running on either side along the spine, referred to as myotomes or myomeres. These muscle blocks typically resemble a letter "W" oriented on its side with thin connective tissue layers called myosepta separating each myotome running along the trunk and peduncle of the fish.

There are more complex muscle groups found in the head of the fish. This includes the muscles of the jaw primarily responsible for adduction (closing the jaw) and abduction (opening the jaw).

Additionally, there are muscles associated with each fin (dorsal, pectoral, anal, and caudal). These muscles are responsible for adduction and abduction, which move the fins away from and back to the body, as well as erector muscles providing structural stability in the fin.

Structural Component of Muscular System

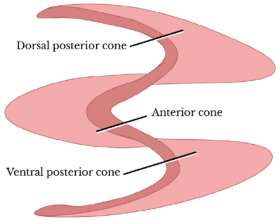

Figure 16: Structural Component: Myomere

Cross Section of Muscular Structures

At the level of the spinal cord, a stronger more dense connective tissue layer called the horizontal septum separates the superior (dorsal) and inferior (ventral) myotomes. There is an additional vertical septum separating the left and right dorsal muscles at the body's midline.

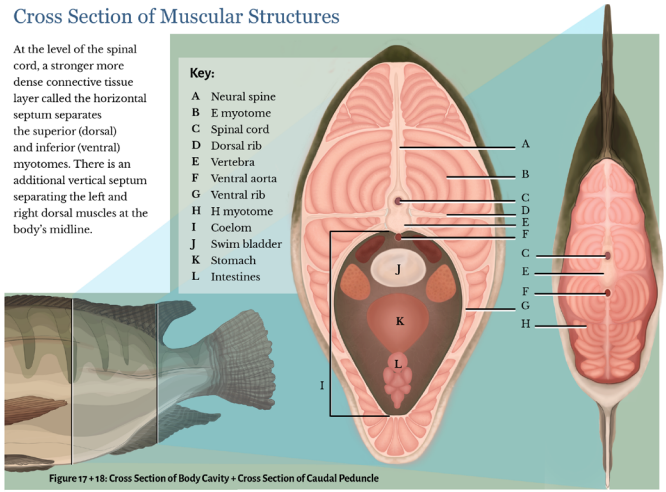

Figure 17 + 18: Cross Section of Body Cavity + Cross Section of Caudal Peduncle

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Beginning the Dissection

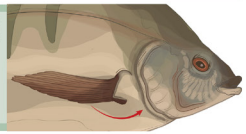
Introduction:

The majority of the dissection of the Blue Tilapia will take place in the body cavity. The body cavity provides an access point to view nearly all the organs of the cardiovascular, digestive, and urogenital systems.

NOTE: All incisions should be made on the right side of the body

Placement of Pectoral Fin: Figure 19: Placement of Pectoral Fin

Locate the right pectoral fin and operculum abduct and rotate fin superiorly.



Once rotated, lift the operculum and tuck the fin beneath so that it is held in place.

This will ensure the fin does not interfere with the body around the site of incision.

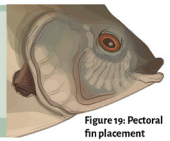


Figure 19: Pectoral fin placement

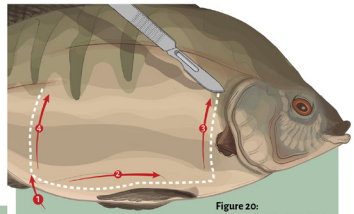


Figure 20: Incision Lines for Body Flap

Primary Incision:

In order to access the body cavity of the fish, a flap must be cut along the length of the trunk.

- (1) Hold, rotate ventrally and locate the anus of the fish.
- (2) Use scissors to cut along the ventral surface of the fish, from the anus to a point aligning with the pectoral fin.
- (3) Use scissors or scalpel to cut from the posterior side of the ventral cut superiorly to a point around the lateral line level.
- (4) Repeat on the anterior side of the ventral cut.
- Clear any connective tissues or debris until the flap is freely mobile.
- Pin the flap to the body with T-Bar head dissection pins.

Inside the Body Cavity:

The body cavity is the region of the fish around the midline of the body, which represents the fish's largest girth. An incision around this area reveals the muscle, skeletal, and external anatomy which must be pulled back in order to view its contents. Once the incision has been made and the flap has been pinned above to prevent obstruction, the cavity must be cleaned. This cleaning away is relevant primarily to fat and connective tissue between the cavity wall and the structures contained within.

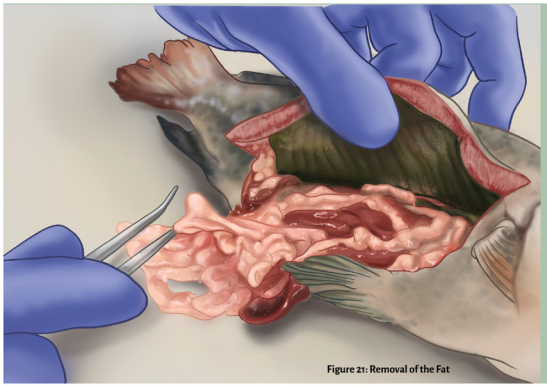


Figure 21: Removal of the Fat

Cleaning the body cavity:

Use tweezers and/or a probe to sort through the contents of the body cavity. Reference figure 22 "the body cavity" to note the location of relevant anatomical structures. Note vasculature and nervous systems where possible as well.

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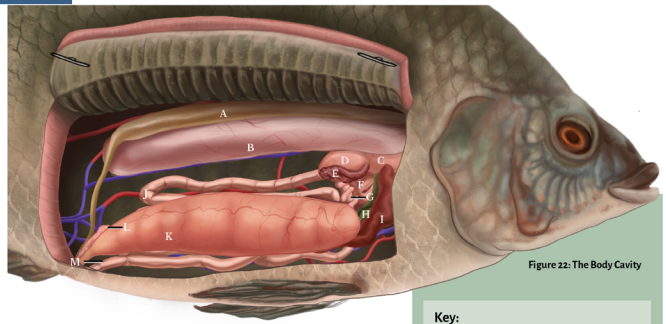

Figure 22: The Body Cavity

The Body Cavity

The majority of the dissection of the Blue Tilapia will take place in the body cavity. The body cavity provides an access point to view nearly all the organs of the cardiovascular, digestive, and urogenital systems.

Once the body flap has been opened and the fat has been cleaned away, it is important to inspect and locate the various anatomical structures. This understanding of the anatomy as interconnected three-dimensional structures is important to have before proceeding to organ removal.

Key:

A	Kidney	**H**	Gall bladder
B	Swim bladder	**I**	Liver
C	Esophagus	**J**	Intestine
D	Stomach	**K**	Gonad (ovary)
E	Spleen	**L**	Urinary bladder
F	Pancreas	**M**	Anus
G	Pyloric caeca		

Dissection Note:

Use probe and tweezers to sort through the contents of the body cavity

probe

Use this guide to locate the following structures:

tweezers

Expanded Key:

•Kidneys

Appearance: Located directly inferior to the backbone, these organs run laterally along the body cavity and are a brownish color.

Function: Secretes bile and other fluids which aid in food digestion

•Swim bladder

Appearance: Whitish, yellowish, opaque sac both smooth and flexible.

Function: Acts as a buoyancy regulator based on the amount of air in the gas-filled chamber

•Stomach

Appearance: Smooth and fleshy, colored a yellowish pink.

Function: Receives food from the esophagus and secretes digestive fluids that break it down for digestion

•Spleen

Appearance: An elongated organ that sits in the intestinal lining, appearing red and pulpy. The organ can be seen when the stomach is moved aside.

Function: Assists in filtering the blood of impurities

•Pancreas

Appearance: A spongy gray-pink organ.

Function: Secretes digestive enzymes into the intestine to help break down food

Contents of the Body Cavity

•Pyloric caeca

Appearance: Lateral blind sac canals coming off the stomach/intestinal junction, increasing the surface area.

Function: Aids in the breakdown of food in the intestines

•Gall bladder

Appearance: Thin-walled and smooth, appearing dark green, almost black; if punctured the body cavity fills with blackish green bile

Function: Stores and concentrates bile for use in digestion

•Liver

Appearance: A deep brownish-red organ with a rubber-like texture.

Function: Produces bile which is then sent to the gall bladder where it is stored; it is also a center for red blood cell production

•Intestines

Appearance: The intestines of bony fishes are relatively short, about 1.5 times the length of the fish when stretched. Color and thickness may vary based on the presence of digestive matter in the system.

Function: Breaks down and absorbs nutrients from food; transports fecal matter to the anal canal

•Gonads

Appearance: Paired organs varying in appearance due to sex, maturation, and spawning season.

Function: Stores and releases eggs and roe in female and male fishes respectively

•Urinary bladder

Appearance: Thin, translucent channel running from the kidneys to the urogenital aperture.

Function: Acts as a reservoir and passage for urine from the kidneys to exit the body.

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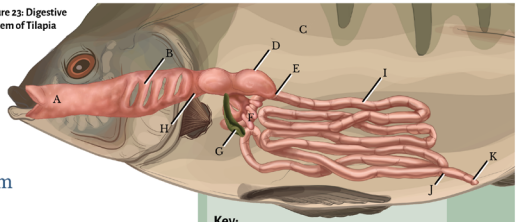
Figure 23: Digestive System of Tilapia



Digestive System

The Blue Tilapia feed primarily on phytoplankton, zooplankton, and plant matter. The digestive system begins with the esophagus. The esophagus is a muscular organ that can expand and contract to take in varying sizes and types of food.

The tilapia possesses a terminal shape mouth. This means that both the top and bottom of the jaw terminate at the same anterior point. This mouth shape is suitable for midwater feeders.

Both the food ingested by the mouth and water entering from the gills travel through the esophagus and on to the stomach where absorption occurs.

Key:

A	Oral cavity	G	Gall bladder
B	Pharyngeal cavity	H	Oseophagus
C	Swim bladder	I	Intestine
D	Stomach	J	Ileorectal valve
E	Pylorus	K	Anus
F	Pyloric caeca		

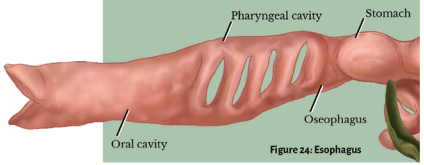
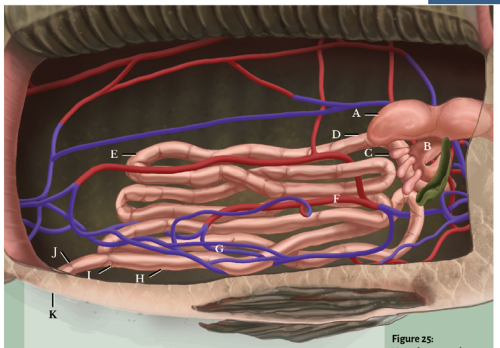


Figure 24: Esophagus

Organs of Digestion and Vasculature:

The stomach of the fish is a muscular tube bent in a "U" shape that receives food from the esophagus. Gastric glands within the stomach release acidic substances that break food down for digestion. This digestion is continued in the blind sac centers called pyloric caeca which increase the area of breakdown within the gut.

The food travels next to the long coiled intestines responsible for the absorption of nutrients from the food. The pancreas secretes digestive enzymes into the intestine. After absorption of nutrients, food exits the intestines via the anus.



Key:

A	Stomach	G	Intestinal venous network
B	Pylorus	H	Ileum
C	Pyloric caeca	I	Iliorectal valve
D	Duodenum	J	Rectum
E	Intestine	K	Anus
F	Superior Mesenteric a.		

Figure 25: Vasculature and Digestive structures

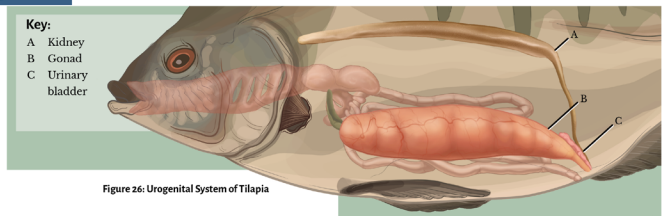


Figure 26: Urogenital System of Tilapia

Urogenital System

The Blue Tilapia is an ovophilic fish species, meaning that during mating, eggs are fertilized externally. Females deposit anywhere from a dozen to over 100 eggs in singular clutches, which she will then mouthbrood in numbers up to 2000.

Freshwater fish such as the tilapia (though they can also be found in brackish water) have a higher salinity in their tissues than the water in their surrounding environment. Water is constantly entering the fish's body through its skin and gills. As the fish does not require the water for hydration, it instead produces and discharges large amounts of diluted urine.

Urogenital Anatomy Key:

The Blue Tilapia, like all bony fishes, have the following urogenital system characteristics.

Ovaries that are laterally compact, located at the inferior most point of the body cavity and which discharge eggs into the coelom.

Kidneys that are located superiorly in the body cavity adjacent to the swim bladder. The kidneys are long tubular structures responsible for the removal of metabolic waste from the body and which maintain the pressure of internal fluids. They are also a source for red blood cell production so the organ is dark reddish-brown in appearance.

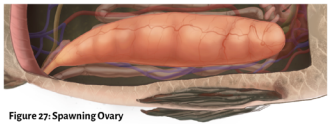


Figure 27: Spawning Ovary

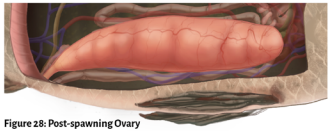


Figure 28: Post-spawning Ovary

The Ovaries and Gonads

When locating the gonads in dissection, use this guide to determine the sex and spawning stage of the specimen:

In the **mature female** tilapia, the ovaries have two stages, **spawning** and **post-spawning**.

- **Spawning females** ovaries are large and swell with the developing eggs, appearing bumpy and spongy with a yellowish pinkish color.
- **Post spawning females** have flattened ovaries that are pink-brown in color.

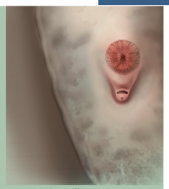
In the **male** Tilapia, the gonad has two stages, spawning and post-spawning.

- **Spawning males** possess gonads that are large and milky pinkish colored.
- **Post spawning male** gonads appear flattened, and lightened and more translucent in color.

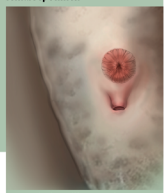
Anatomy and sexual dimorphism of the urogenital papilla:

Both urine and gametes are expelled from the body from the common opening near the anus of the fish, called the urogenital aperture. This opening is located on the urogenital papilla.

The urogenital papilla of the female is smaller and more rounded than the male papilla and covers the opening to the vaginal orifice.



Urogenital papilla on female specimen



Urogenital papilla on male specimen

Figure 29: Location and Sexual Dimorphism of Urogenital Papilla

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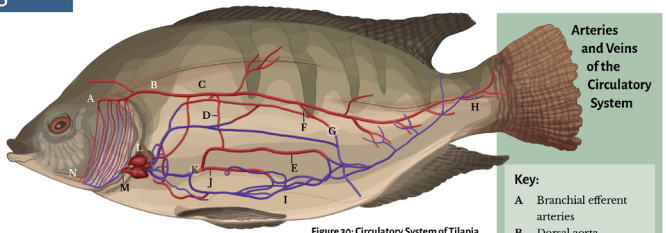

Figure 30: Circulatory System of Tilapia

Arteries and Veins of the Circulatory System

Key:

- **A** Branchial efferent arteries
- **B** Dorsal aorta
- **C** Posterior vena cava
- **D** Coeliac artery
- **E** Gonadal artery
- **F** Renal artery
- **G** Renal portal system
- **H** Caudal vein
- **I** Intestinal venous system
- **J** Superior mesentaric artery
- **K** Hepatic portal system
- **L** Heart (atrium and ventricle)
- **M** Ventral aorta
- **N** Branchial afferent arteries

Cardiovascular System

The cardiovascular and respiratory systems of the Blue Tilapia are one and the same.

The system consists of a two-chamber heart, a network of arterial and venous vessels, and the gill structures of the fish. These structures work to deliver oxygen throughout the body. Fishes receive dissolved oxygen from water, which they take in through the mouth and expel via the gill openings.

The gill filaments found in the gill openings are responsible for the absorption of oxygen from the water. Gill filaments are supported by gill raker structures. A network of arteries and veins run along the gill filaments providing the pathway for deoxygenated and oxygenated blood throughout the body.

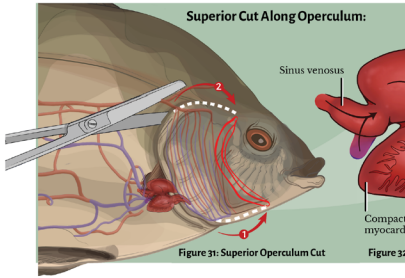

Figure 31: Superior Operculum Cut

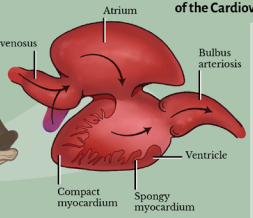

Figure 32: Blood Passage Through the Heart

Use scissors to create an anterior cut along the operculum toward the head of the fish

Locate the following structures:

- •Gill filaments
- •Gill Rakers
- •Heart
- •Sinosus venosum
- •Conus arteriosus

- **•The heart:** Has two chambers, an atrium, and ventricle Preceding the venous side of the heart is the sinus venosus, and following after the heart on the arterial side is the bulbus arteriosus.
- **•The sinus venosus:** Collects the oxygen-depleted blood from the body's venous network and transfers the blood to the atrium of the heart via a valve.
- **•The atrium:** The muscular atrium heart chamber receives deoxygenated blood from the sinus venosus and pumps it into the ventricle.
- **•The ventricle:** The largest, thick-walled chamber of the heart, the ventricle, fills with blood and constricts to force the blood to the bulbus arteriosus.
- **•The bulbus arteriosus:** Blood flows from the bulbus arteriosus to the ventral aorta via a series of valves controlling the blood flow.
- **•The ventral aorta:** Transports the deoxygenated blood from the heart to the gill filaments.
- **•The gill filaments:** Capture oxygen from the water passing over them and transfer this oxygen to the deoxygenated blood running along with the intricate arterial network.
- **•The arteries, veins, capillaries:** Transport oxygenated blood throughout the body and carry back deoxygenated blood from the body to the sinus venosus.

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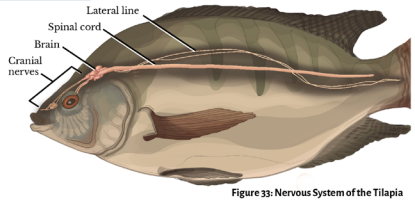

Figure 33: Nervous System of the Tilapia

Nervous System

The nervous system, including the brain, spinal cord, and nerves of the body, is far cruder in fishes than those of other vertebrates.

Primary Structures:

- **The brain:** is divided into three sections: the forebrain, the midbrain, the hindbrain.
- **The forebrain:** contributes to the olfactory sensations of the fish, this sense is especially well developed in bony fishes.
- **The midbrain:** processes vision, motor muscle response, and higher brain function like learning.
- **The hindbrain:** consisting of the medulla oblongata and cerebellum, is responsible for the balance and coordination of the fish.
- **The spinal cord:** supplies the remainder of the body with a complex network of sensory and motor nerves.
- **The lateral line:** is a conduit of skin cells that works to detect motion and pressure changes in the water.

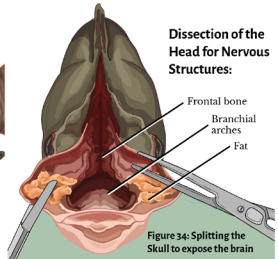

Figure 34: Splitting the Skull to expose the brain

Dissection of the Head for Nervous Structures:

- Hold the body in place and locate the median line of the head.
- Use blunt scissors to create an incision running superiorly along the median line of the head.
- Place forceps on right and left lateral corners of the mouth to expand the incision (note: request assistance for this portion of the dissection).
- Once the incision is level with the eyes, begin dissecting more carefully to preserve the brain.
- Work slowly to cut and remove bone until the brain is exposed.

Brain and Cranial Nerves

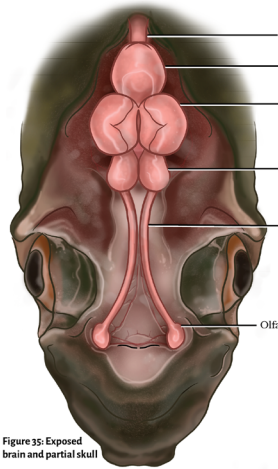

Figure 35: Exposed brain and partial skull

Nerves of the Head Key:

a	Hinbrain (cerebellum)	h	Inf. maxillary b.
b	Midbrain (cerebrum)	i	Opercular b.
c	Forebrain	j	Auditory b.
d	Olfactory g.	k	N. to gill arches
e	Olfactory n.	l	Spinal recurrent n.
f	Olfactory bulb	m	Spinal cord
g	Sup. maxillary b.	n	N. to dorsal body region

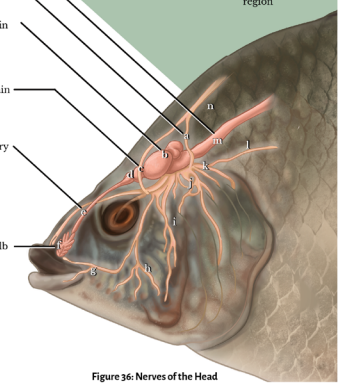

Figure 36: Nerves of the Head

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Additional Resources

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3D Fish Anatomy- Biosphera. Desktop 3D Interactive Perch Model. Biosphera3d.com

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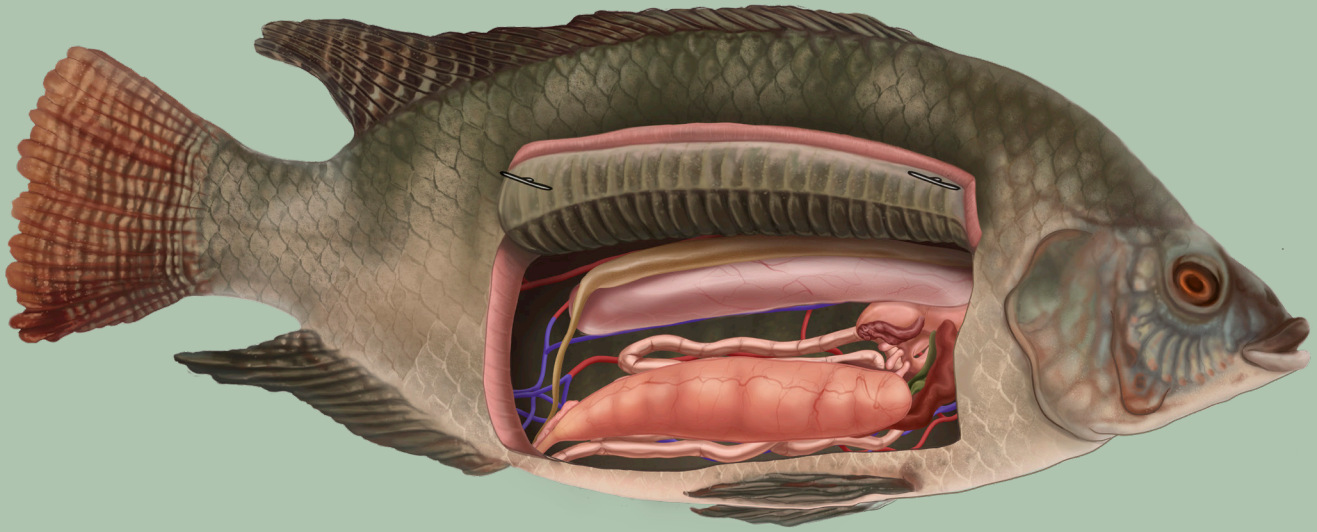

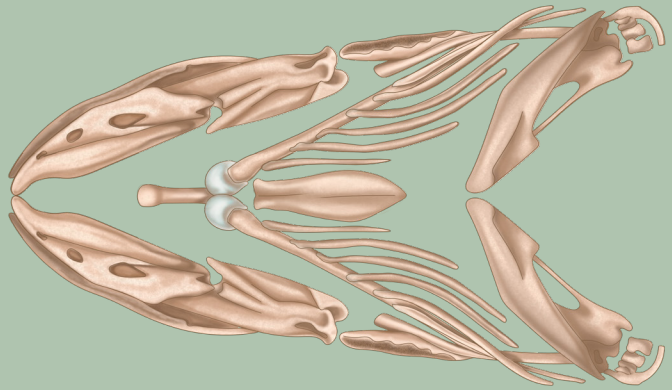

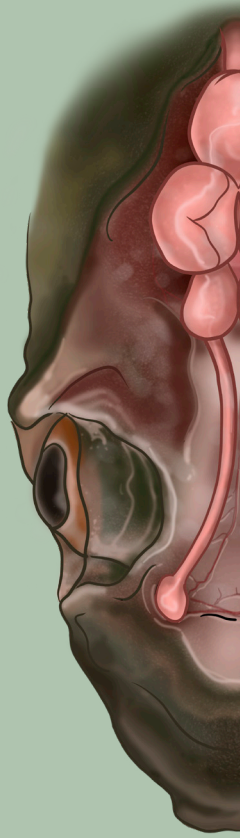

Biomedical Art

BFA Project Book

by Alex Prenatt