Module II-C: Discovering Plants and Animals In Aquaculture:
  Determining Morphology, Anatomy and Physiology
  of Aquaculture Organisms .................................................................1

Content and Procedures...............................................................................2

Presentation (Key Questions/Summary of Content, Teaching Techniques) ..........3

Review/Application/Evaluation .....................................................................13

Test .............................................................................................................14

Test Answer Key ..........................................................................................16

Handouts

H II-C-1 Laboratory Activity, The Anatomy of Decapod Crustaceans
H II-C-1 Diagram: Decapods
H II-C-2 The Anatomy of Bivalve Molluscs
H II-C-2 Diagram: The Bivalves
H II-C-3 Laboratory Activity, Gyotaku and Anatomy of Aquaculture Fish Species
H II-C-4 Laboratory Activity, Comparing the Anatomy of Aquaculture Fish Species
H II-C-4 Diagram: Fish Gill
H II-C-4 Diagram: Fish Morphology, Comparison of Structure
H II-C-5 Laboratory Activity, Macro Algae Pressing
H II-C-5 Diagram: Brown Algae
H II-C-6 Laboratory Activity, Microalgae Identification and Dichotomous Key Use
H II-C-6 Diagram: Phytoplankton: Diversity & Structure (2 diagrams)
H II-C-7 Laboratory Activity, Counting Microalgae

Transparency Masters

T II-C-1 Discovering Plants and Animals in Aquaculture: Determining
  Morphology, Anatomy and Physiology of Aquaculture Organisms
T II-C-2 Morphology
T II-C-3 Physiology
T II-C-4 Systems
T II-C-5 Crustaceans
T II-C-6 Molluscs
T II-C-7 Finfish
T II-C-8 Algae
Module II-C—Discovering Plants and Animals in Aquaculture

Problem Area: Determining Morphology, Anatomy and Physiology of Aquaculture Organisms

Estimated Time: 6-12 hours

Purpose/Goal: This problem area helps students understand the importance of anatomy and physiology in aquaculture. It will focus on how an organism’s anatomy or morphology and physiology provide an indication of how it should be cultured. Important anatomical features and functions of cultured organisms will be covered.

Learning Objectives: Upon completing this problem area, students will be able to:

- explain the meaning of morphology, anatomy and physiology;
- describe the physiology of aquatic animals;
- identify and describe the basic structure and external anatomy of crustaceans;
- identify and describe the basic structure and internal anatomy of an oyster or a mussel;
- identify and describe the external and internal anatomy of fish;
- identify and describe the basic morphology of aquatic macroalgae and microalgae.

Instructional Resources:

The following instructional resources are needed to complete this module:

Essential:

- Copies of handouts attached to this teaching plan.
- Transparencies made from the masters attached to this teaching plan.
- Dichotomous or taxonomic key of algae found in local waters. (Usually available from university libraries and other sources.)
- The following book:
  
- The following specimens:
  
  Live aquatic microalgae and macroalgae cultures from local waters or obtained from biological supply houses.

Additional: Any aquaculture books, journals or other materials, such as:

- Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms, by Bardach, Ryther, and McLarney.

- Textbook of Fish Culture: Breeding and Cultivation of Fish, by Huet.

- Commercial Catfish Farming, by Lee.
CONTENT AND PROCEDURES

Preparation
(Interest Approach):

This interest approach prepares the students for studying the structure and functions of aquatic organisms. The initial approach identifies a few human body parts and relates how these form the organism. (Morphology includes form and structure of organisms. Anatomy is the structure of organisms.)

Suggested Procedure:

1. Ask students to draw a person. (This may be a stick figure or other quick sketch. The drawings should be on a full sheet of paper and distinct enough to show to the class. Allow 5 minutes maximum for this activity.)

2. After the drawings are complete, ask students to describe their drawings. Have them identify the parts they included on their person. (Does it have arms, legs, eyes, hair, ears, etc.? Was it female or male? Did anyone put fins, horns or hoofs on the drawing?)

3. Ask the students what parts they had on their drawing characteristic of a human being.

4. After some discussion of what made the drawing a "human being," ask what parts they would have needed if they had been drawing a fish.

5. Summarize by explaining that an organism has certain arrangements of parts that make it distinct. Just as humans have a certain structure, aquatic animals and plants also have a structure unique to their species. For examples, oysters have one structure; trout another structure; and shrimp still another. Each variation in structure makes the species what they are.

6. The completion of this activity should lead into presentation of the problem area objectives.
### Key Questions/Summary of Content

*This teaching plan helps students develop a basic understanding of the anatomy/morphology of aquatic species.*

### Teaching Techniques

*Use T II-C-1 or the chalkboard to present the problem area objectives. Allow students time to record the objectives in their notebooks.*

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### I. What is morphology? Anatomy? Physiology?

**A. Morphology is a branch of biology.**
1. Biology is the natural science of living organisms.
   - Biology includes the processes that occur in an organism.
2. Morphology is the structure and form (shape) of plants and animals.
   - Morphology is used to describe the structure and form of organisms.

**B. Anatomy is a branch of morphology.**
1. Anatomy is the structure of organisms.
2. Anatomy refers to the structural makeup of an organism and any of its parts.

**C. Physiology is a branch of biology covering the functions and activities of living organisms.**
1. Physiology includes the functions and processes of the organism and any of its parts.
2. The processes are often referred to as “body functions.”
   - The “functions” often have adaptations for organisms which live in water.
   - Growth and survival of an organism require these functions work together as well as independently.

**A.** Use T II-C-2 or the chalkboard to present the definitions. Briefly review each definition and indicate a more complete understanding will occur as this lesson is studied.

**B.** Refer to the person drawn by class members in the interest approach as an example.

**C.** Use T II-C-3 or the chalkboard to present the definition of physiology.
D. The suitability of an aquatic organism for culture depends on its form and functions.

1. Example One: The type of mouth and its location determine how organisms feed and what they eat.
   - Fish with small, upturned mouths generally are herbivores and/or surface feeders. Example: tilapia.
   - Fish with downturned mouths are generally bottom feeders. Example: catfish.

2. Example Two: External body structure must be considered in selecting a species for culture in a water facility.
   - Fish with single-lobed (homocercal) tail fins are slow swimmers and can survive well in water that is free of much movement.
   - Fish with forked (heterocercal) tail fins are fast swimmers and prefer flowing water.

3. Example Three: Body form is a factor in culturing aquatic species and must be considered along with other characteristics.
   - Fish that have a fusiform body shape (long and tapered toward the ends much like a torpedo) are the best swimmers and need water space in which to move about. Example: salmon.
   - Fish that are ventrally compressed (wide and flat) tend to stay on the bottom and require a lot of bottom space for growth. Examples: flounder and shark. They may have forked tails and exert sudden bursts of speed to capture food. Efforts to culture flounder have shown a lot of bottom surface is required since they don’t spend much time swimming.
   - Fish that are laterally compressed (rounded and thin from side-to-side) tend to hover in the water and are not particularly fast swimmers, regardless of tail fin shape. Examples: bream and angel fish.

1. Bring specimens to class for students to observe structural differences.

2. Bring fish with different tail fins to class. Compare shape with the environment preferred by the species.

3. Bring fish with different body forms to class. Compare the forms and have students name species with the different forms. Discuss how the form may relate to culture.

- Using the database of aquaculture species developed in Module II-A, have students name species of fish that are ventrally compressed; laterally compressed.
II. What is the physiology of common aquatic crops?

A. The physiology of aquatic species may be described as systems, or body systems.
   1. The systems carry out certain functions required for survival and growth.
   2. Aquatic species have special system adaptations that allow them to live in water.

B. Nine systems are found in aquatic species.
   1. Skeletal system — This is the rigid framework of the body that gives it shape and protects the organs.
      • The skeleton is made of bony or hard material and cartilage.
      • Tissues and organs are attached to the skeleton.
      • Skeletal systems may be internal (example: fish) or external (examples: oysters or shrimp). Internal skeletal systems are also called endoskeletons. External systems are also called exoskeletons.
   2. Muscular system — This system provides movement internally and externally for the organism.
      • The system is made up of muscles of varying strengths and functions.
      • The muscles are comprised of tissues and cells that contract and expand to cause movement.
      • Movement is needed for the organs to function, such as to obtain oxygen and eliminate body wastes.
      • Movement is needed for many species to obtain food.
   3. Digestive system — This system converts food into a form that can be used by the body.
      • It is comprised of all of the parts of an organism involved in taking food into the body and preparing it for assimilation (incorporation into the body).

B. Use T II-C-4 or the chalkboard to list and define the systems.
   1. Exhibit the skeleton of a fish, an oyster shell, and the shell of a shrimp or crawfish. Ask students to describe what they see and indicate if the specimens are exoskeletons or endoskeletons.
   2. Observe fish specimens for the presence of muscles. (The larger muscles are along the sides of the tail and help the fish swim. Smaller muscles operate the heart and other internal organs.)
   3. Use a local fish specimen and observe the parts of the digestive system. Have students trace the process of digestion through the digestive system of the specimen. Option: have students draw the digestive system of the specimen in their notebooks and identify the major parts.
• With most animal species, it includes the mouth, esophagus, stomach, intestines and anus.

• Digestive systems vary in the kinds of foods that can be used. (Herbivores eat plants; carnivores eat animals; omnivores eat plants and animals.)

4. Excretory system — This system eliminates wastes from the body.

• It is typically comprised of the kidneys, urinary ducts, urinary bladder and urinary opening.

• The kidneys filter wastes from the blood.

• The wastes are held in the bladder until excreted through the urinary opening.

5. Respiratory system — This system carries oxygen to the tissues and cells and gives off carbon dioxide.

• Gills are the respiratory organs of fish.

• Water is taken in through the mouth and forced out over the gills where oxygen is removed by diffusion into the blood of the fish.

6. Circulatory system — This system circulates blood throughout the body.

• The system is usually comprised of a heart, veins and arteries.

• The heart’s pulsating motion causes blood to flow through the arteries to the gills where it picks up oxygen and carries it to the rest of the body.

• Blood passes through the veins back to the heart and gills where it gives up carbon dioxide (CO₂).

7. Nervous system — This system conveys sensation impulses between the brain or spinal cord and other parts of the body.

• The system is comprised of the brain, spinal cord (with invertebrates) and many nerve fibers. (It is a complex process!)

• The sense organs receive stimuli which are conveyed as sensations by the nerve fibers to the brain.

4. Using a fish, identify the major parts of the excretory system.

5. Dissect a fish to observe the parts of the gill.

6. Observe the parts of the circulatory system, particularly the heart.

7. Have students touch a live fish and determine the response made by the fish. Ask students to explain what was involved in the fish’s response.
- The brain (or spinal cord) may send responses to the stimuli by way of the nerve fibers.
- Example: If a fish senses detect danger, the sensation is sent to the brain and an appropriate response is sent, such as to rapidly swim away.

8. Sensory system — This system includes sight, touch, taste, smell and sound (hearing).
- Most fish have eyes which assist in locating food and other activities.
- Some species have enhanced senses of touch, such as those with barbels.
- Sound is picked up as water vibrations by ear bones in the skull. (Most species do not have ears.)
- Taste is a function of the digestive system and is important to the aquafarmer in preparing and selecting foods for aquatic species.

- Fish have lateral lines containing nerves that detect water vibrations and motion, and help keep them in schools. (The lateral line runs along the side of fish much like a pencil stripe and is easy to observe on most species of fish.)
- Research is needed to more fully understand the sensory systems of aquatic species.

9. Reproductive system — This system includes the process by which new organisms of the same species are generated.
- The process involves the union of male and female sex cells.
- Most species have male and female sexes.
- Males have testes which produce sperm that fertilize the female sex cell, known as an egg.
- Females have ovaries which produce the ova (eggs).

8. Observe a specimen for external sensory organs, such as eyes and barbels.
- Have students compare the sensory system of fish with that of humans.

- Have students compare the smell of fish food. Ask them to describe how the fish would respond to the food. Example: some species of fish prefer food that contains fish byproducts.
- Have students locate the lateral line on different species of fish.

9. Have students identify the sex of fish specimens based on external characteristics. (The students will need to look up the secondary sexual characteristics in reference materials.)
- Dissect male and female fish to observe the sex organs. Explain that the sex organs are the most reliable means of sex determination.
• Fertilization occurs when the sperm unites with the egg to form a new zygote. Zygotes develop into new organisms after an incubation period.

• Aquafarmers must be able to distinguish the sexes when reproducing most aquacrops. (They often rely on secondary sexual characteristics in making sex determinations. These vary with the species involved.)

III. What is the structure and external anatomy of crustaceans?

A. Crustaceans are aquatic animals that have an exoskeleton (outside skeleton) made of chitinous (like your fingernail) material.

   1. Examples include shrimp, crabs, lobster, crawfish and prawns.

   2. The crustaceans most often considered for aquaculture are known as decapods.

   3. As crustaceans grow, the shell is cast off in a process called molting.

   • When the shell is off, they are known as softshell animals.

   • A few farmers specialize in producing softshell species, such as crawfish.

   • Without the shell, they are subject to attack by other aquatic animals, including their own species.

   • No more than a day is usually required to regrow the shell.

B. The bodies of crustaceans are divided into three sections:

   • Head;

   • Thorax (carapace);

   • Abdomen.

   1. Each segment has a pair of appendages.

   2. The head has two pair of antennae.

C. Crustaceans can re-grow limbs that have broken off.

   1. This is known as regeneration.

A. Use T II-C-5 or the chalkboard to summarize crustacean anatomy.

   1. Display examples of crustaceans found locally or obtain specimens from a biological supply house or, in some cases, local supermarket.

   3. Ask if any students have eaten softshell crawfish or crab.

   • Ask students why the softshell form is vulnerable to attack.

B. Use H II-C-1 to study the anatomy of crustaceans and conduct the laboratory activity. (Carefully prepare students for the activity. Demonstrate how to perform the dissection. Discuss all safety practices to be observed and, if necessary, give a test on the safety practices in the laboratory. File the test as documentation. Always be present in the lab and follow procedures to ensure student safety.)
2. To produce crab legs, one claw is removed and the crab is returned to the water to grow another.

D. Decapods have simple blood, nervous and excretory systems.

E. The life cycle is fairly complex.
   1. The larval stage is most difficult to culture.
   2. Dietary requirements change as they pass through life stages.
   3. Juvenile and adult stages are essentially benthic (bottom-dwelling) organisms.
      - They are omnivores (feed on animal and plant substances) and/or detritivores (feed on loose particles resulting from the decay or wearing away of organic particles).
      - Some live at great depth at the bottom of oceans.

3. Take a field trip to an aquafarm that produces crustaceans or to a museum or laboratory where they are studied.

IV. What is the structure and external anatomy of molluscs?

A. Molluscs species most common in aquaculture are oysters and clams in the United States and mussels in Europe.
   1. Bivalve molluscs have two shells composed of two parts that can be closed to completely enclose the animal.
   2. The shell is made of a calcareous material and forms an exoskeleton.
      - Calcareous materials resemble limestone.
      - Calcareous materials are very hard.

B. As adults, oysters and mussels anchor themselves to objects in the water.
   1. Since molluscs are anchored, they feed by filtering organic matter from water through a complex system dependent on the use of cilia (small hair-like structures).
   2. Molluscs have simple digestive, circulatory and nervous systems.
   3. The gills not only act as a respiratory system, but filter matter from the water that is consumed or discharged.

A. Use T II-C-6 or the chalkboard to summarize molluscs anatomy.
   - Display examples of molluscs found locally or obtain specimens from a biological supply house or local market.

2. Use H II-C-2 to study the anatomy of molluscs and conduct the laboratory activity.
C. Molluscs reproduce with eggs and sperms.
   1. Eggs are typically released into the water and fertilized by water-borne sperm.
   2. Some bivalves are protandrous, meaning they may change their sex one or more times during their lives.
   3. Some molluscs, such as scallops, are hermaphroditic. Individual organisms have gonads for both sexes (male and female). (They can release eggs and sperm during a spawn.)

V. What is the structure and external anatomy of finfish?

A. Virtually all fish used in aquaculture are considered as bony fishes with hard, calcium-based skeletons.
   1. The skeleton is internal and structured to give form to the fish and protect its organs from damage.
   2. The skeleton has some resemblance to that of farm animals and humans.

B. Exterior may vary in covering.
   1. Bony plates (scales) cover the skin of many fish, such as trout.
      • Scales grow as the fish grows.
   2. A few species have skin without scales, such as the catfish.

C. Oxygen is removed from the water by gills.
   1. Blood transports oxygen throughout the body of the fish.
   2. Fish suffer if the supply of oxygen in the water is too low.
   3. Oxygen is transferred into the gills by diffusion.
      • Deoxygenated blood in the gills picks up the oxygen and releases carbon dioxide.
      • Water has a higher concentration of oxygen than the blood in the gills, which causes the oxygen to enter the blood (an area of lower oxygen concentration) by diffusion.

A. Use T II-C-7 or the chalkboard to summarize finfish anatomy.
   1. Use H II-C-3 and H II-C-4 to study the anatomy of finfish and conduct the laboratory activities.
   2. Bring examples of finfish obtained locally or from a biological supply or market.

B. Examine specimens of fish with and without scales and note differences.

C. Observe the dissected gills of a fish. Ask students how gill diseases can impair the transfer of oxygen.

   3. Use a drop of food coloring in water to illustrate how the food coloring diffuses from areas of higher concentration of color to a state where all of the water is of the same color.
• Carbon dioxide in the blood is higher than in the surrounding water and diffuses out of the blood through the gills.
• Gills function similar to cell membranes. They are very thin and semi-permeable, allowing gases to pass through.

D. Digestive systems vary depending on the type of food eaten.
1. Some finfish eat algae and detrital matter.
   • These have a small stomach and long gut (intestines).
2. Some finfish are carnivores and eat fish and other animals.
   • These have large stomachs and a short gut.

E. Fish tend to have a well-developed nervous system.
1. Fish have a brain and spinal column.
2. Lateral sensory organs are located along a fish’s lateral line to detect currents and movement in the water.
   • The lateral line and a structure resembling an inner ear are used to maintain balance and position in the water.
   • These sense organs enable fish to stay in formation when schooling.

F. Reproduction involves the fertilization of eggs laid in the water.
1. Reproductive organs are in the body cavity.
2. Sexes are fairly easy to distinguish.

VI. What is the morphology of aquatic macroalgae and microalgae?
A. Algae forms range from minute cells of a few micrometers to large seaweeds several meters tall.
   1. Some have the animal attribute of motility (capable of movement). Examples: Tetraselmis and Enteromorpha.
   2. Algae are cellular plants growing as single cells or aggregations of single cells.

D. Using the information collected in Module II-A, Database of Aquaculture Species, study the foods eaten by different species.

E. Dissect a fish specimen to determine the extent of brain development.

F. Visit a local hatchery and broodfish farm to observe spawning and artificially hatching finfish.

A. Use T II-C-8 or the chalkboard to present a summary of algae.
   1. Collect local samples and analyze closely using a microscope.
MODULE II-C

B. Some forms of algae are cultivated.
   1. Algae are used for food and livestock feed.
   2. Most culture occurs in Asia. There is very little cultivation in the United States.
      • Algae holds potential as an aquacrop in the United States.
   3. Algae are high in productivity and food value.
      • Some species are higher in food value than any other plant.
      • Rapid expansion of algae culture is occurring.

C. Macroalgae are large forms.
   1. They attach to a substrate (underlying foundation of some type).
   2. They function similarly to plants with stems.
   3. Photosynthesis occurs in the blade or thallus. (Thallus is a plant body without distinct leaves, stems and roots.)
   4. The major groups cultivated are:
      • Red algae (Rhodophytes);
      • Green algae (Chlorophytes);
      • Brown algae (Phaeophytes).

D. Microalgae are the small forms.
   1. They are very important as the food of larval fish, crustaceans and molluscs.
   2. There is considerable variation in morphology among microalgae species — only a few have been carefully studied.
   3. The three most important microalgae in aquaculture are:
      • Green-pigmented algae (Chlorophyta);
      • Blue-green algae (Cyanophyta);
      • Golden algae (Chrysophyta).

1. Ask if any students have eaten algae. If few have, arrange to have seaweed available for tasting. (Supermarkets may have seaweed available; if not, place an order.)

C. Use H II-C-4 for the algae laboratory activity. (It might be appropriate to divide the class into small groups and set up three laboratory stations. The stations would be:
   1 - H II-C-5 activity
   2 - H II-C-6 activity
   3 - H II-C-7 activity
   Sufficient preparation should go into this activity to make it a quality learning experience. This includes preparing the handouts, getting specimens and equipment, and arranging the laboratory stations.)

D. Use H II-C-5 to conduct the laboratory activity.
   Use H II-C-6 for the laboratory activity on counting microalgae.
Review

- Ask students questions about the objectives. The instructor may wish to show the objectives on the overhead projector and call on students to explain the content covered.

- Review may also include questioning students as they perform laboratory activities.

Application

Application can involve a number of approaches, as follows:

- Laboratory activities are important in reviewing the information presented in the class. These activities allow students to apply what they have learned.

- Students with aquacrops in their supervised experience program should demonstrate a better understanding of their crops as they apply the information in this teaching plan.

- The school aquaculture laboratory holds a number of opportunities to apply the information in this teaching plan.

Evaluation

Evaluation should focus on how well the students have achieved the teaching plan objectives.

- Observe the laboratory performance. (This should involve: on-task behavior of students, following proper procedures and clean up.)

- Observe performance in supervised experience programs.

- Question students in class and laboratory.

- Give a written test. (See attached example.)
Discovering Plants and Animals in Aquaculture

Problem Area: Determining Morphology, Anatomy and Physiology of Aquaculture Organisms

Instructions: Answer the following questions.
Be sure to spell correctly and provide the most complete information you can.

Name______________________________

1. Explain the terms listed below in one complete sentence each.

Morphology ____________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Anatomy _______________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Physiology _____________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

2. Name seven of the nine systems found in most aquatic animals. Briefly define each.

a. _________________________________________________________________

b. _________________________________________________________________

c. _________________________________________________________________

d. _________________________________________________________________

e. _________________________________________________________________

f. _________________________________________________________________

g. _________________________________________________________________

h. _________________________________________________________________

i. _________________________________________________________________

3. Using an “X”, indicate which of the following are characteristic of crustaceans.

   ______ have exoskeleton  ______ molting occurs during growth  ______ skin covered with scales
   ______ three body sections  ______ can regenerate appendages  ______ also known as bivalves

4. Using an “X”, indicate which of the following are characteristic of molluscs.

   ______ adults anchor themselves  ______ have a hard, calcareous shell  ______ known as filter feeders
   ______ may change sex as adults  ______ have small stomach with long gut  ______ have three body sections
5. Using an “X”, indicate which of the following are characteristic of finfish.
   _____reproductive organs in body cavity   _____may be covered with scales   _____have gills
   _____have well-developed nervous systems   _____perform photosynthesis   _____skeleton is internal

6. Using an “X”, indicate which of the following are characteristic of aquatic algae.
   _____covered with scales   _____perform photosynthesis   _____one kind grows as seaweed
   _____low in food value   _____mostly cultivated in Asia   _____some have the animal attribute of motility

7. Indicate if the following are true or false by circling T or F.
   T F   a. Macroalgae usually attach to a substrate.
   T F   b. Fish suffer if the supply of oxygen in the water is too low.
   T F   c. Blood transports oxygen throughout the body of a fish.
   T F   d. Each segment of a crustacean has a pair of appendages.
   T F   e. Examples of crustaceans are oysters, salmon and trout.
   T F   f. The head of crustaceans has two pair of antennae.
   T F   g. Some crustaceans live on the ocean bottom.
   T F   h. Scales on fish grow in size as the fish grows.
   T F   i. Fish sexes are fairly easy to distinguish.
   T F   j. The gills of molluscs not only serve in respiration, but also filter food from the water.
1. Morphology is a branch of biology covering the structure and form (shape) of plants and animals and is used to describe the structure and form of organisms.

Anatomy is a branch of morphology covering the structure of organisms and refers to the structural make up of an organism and its parts.

Physiology is the functions and vital processes of living organisms.

Note: Any seven of the nine will be satisfactory.

2. a. skeletal | rigid framework that gives body shape and protects organs
    b. muscular | provides for internal and external movement of organism
    c. digestive | converts food into a form that can be used by the body
    d. excretory | eliminates wastes from the body
    e. circulatory | circulates blood throughout the body
    f. nervous | conveys impulses between brain and spinal cord and other parts of body
    g. sensory | includes sight, sound, touch, taste, and smell
    h. respiratory | provides oxygen to tissues and cells and gives of carbon dioxide
    i. reproductive | generates new organisms of same kind

3. X have exoskeleton
   X three body sections
   X can regenerate appendages
   X also known as bivalves
   X molting occurs during growth

4. X adults anchor themselves
   X have a hard, calcareous shell
   X known as filter feeders
   X may change sex as adults
   X have small stomach with long gut
   X have three body sections

5. X reproductive organs in body cavity
   X may be covered with scales
   X have gills
   X have well-developed nervous systems
   X perform photosynthesis
   X skeleton is internal

6. X covered with scales
   X perform photosynthesis
   X one kind grows as seaweed
   X low in food value
   X mostly cultivated in Asia
   X some have the animal attribute of motility

7. a. T
    b. T
    c. T
    d. T
    e. F
    f. T
    g. T
    h. T
    i. T
    j. T
The Anatomy of Decapod Crustaceans

**Laboratory Activity**

*Dissect a decapod crustacean to learn the form and function of its anatomy.*

**Materials**

- fresh or frozen shrimp, lobster or crawfish
- forceps
- dissecting scissors
- magnifying glass

**Procedures**

1. **External anatomy**
   
   a. Identify and list the following:
      
      - abdomen
      - swimmerets
      - maxilliped
      - carapace
      - cheliped

   b. Compare the size of the carapace to the abdomen. Which part of its body is usually eaten? What does this indicate about selecting the best species to cultivate?

   c. What feeding behavior is this crustacean designed for?

2. **Internal anatomy**
   
   a. Cut along bottom of the crustacean from the anus to the mouth. Locate and list the following:
      
      - gonads
      - hind gut
      - gills
      - abdomen muscle
Aquaculture

Decapods

Shrimp

External Anatomy

Internal Anatomy
The Anatomy of Bivalve Molluscs

**Laboratory Activity**

*Dissect an oyster or mussel to learn about its functioning anatomy.*

**Materials**
- fresh or frozen whole oysters or mussels
- pry tool or oyster shucker
- forceps
- scalpel
- magnifying glass

**Procedures**

1. **External anatomy**
   
   a. Examine the outer shell of the bivalve and take note of the byssal threads.
   
   b. What is the shell made of? What does this indicate about the water chemistry requirements?
   
   c. What are the byssal threads used for?

2. **Internal anatomy**
   
   a. Pry open the shell and cut the adductor muscle to open both halves.
   
   b. Identify and list the following:
      
      - mantle
      - gonad
      - stomach
      - gills
   
   c. Cut open the stomach and gills and observe the green or brown pigmented debris. What are the gills used for? What is this debris?
   
   d. Why do bivalves appear to be a good aquaculture species (consider food and feeding habits)?
THE BIVALVES
Internal Anatomy
THE BIVALVES

External Anatomy

Mussel
Cockle
Softshell Clam
Bent-nosed Clam

MUSSEL

INCURRING SIPHON

EXCURRENT SIPHON

SHELL

BYSSAL THREADS

FOOT

INCURRING SIPHON

EXCURRENT SIPHON

SHELL

FOOT

COCKLE

INCURRING SIPHON

EXCURRENT SIPHON

SHELL

FOOT

SOFTSHELL CLAM

INCURRING SIPHON

EXCURRENT SIPHON

SHELL

FOOT

BENT-NOSED CLAM
Gyotaku and Anatomy of Aquaculture Fish Species

In Japan, gyotaku was originally used by fishermen to record their catch. It is now a popular art form. Color, spatial arrangement and clarity of detail contribute to its scientific and artistic qualities.

Laboratory Activity

Experiment with methods of making fish prints with aquaculture species. Compare the external features and internal anatomy of common aquaculture fish species.

Materials
- newspapers
- fresh or thawed fish
- soapy water
- paper towels
- large pieces of cardboard
- ziplock bag filled with sand (optional)
- pencil
- sharp-pointed scissors or scalpel
- straight pins
- scotch tape (optional)
- plastic modeling clay
- waxed paper
- water-based block-printing ink
- paint brushes with stiff bristles
- paper for prints
- pencil
- lab notebook
- metric ruler
- watch glass
- dissecting microscope
Gyotaku and Anatomy of Aquaculture Fish Species

Procedure

1. Cover the working surface with newspaper.
2. Gently clean the outside of the fish with soapy water. Rinse, then pat dry with paper towels.
3. Cut a body-shaped “well” out of cardboard. (Or make a well in a closed bag of sand).
   a. Trace the outline of the fish, but not its fins, onto a piece of cardboard.
   b. Remove the fish.
   c. Using scissors or scalpels, cut the fish outline out of the cardboard.
4. Place the fish into the cardboard well and arrange the fins for printing.
   a. Spread the fins out. Decide how you want them to appear in your fish print. Hold each fin in place by inserting a straight pin behind the largest spine. Be sure the pin is not visible on the front of the fish. An alternative method is to tape the spread fins with scotch tape.
   b. If a fin needs additional support, insert a layer of clay between the fish and the cardboard. The clay should not be visible from the front.
   c. Position the mouth. Insert a small piece of clay or paper towel to hold the mouth open the way you want it to appear.
   d. Support the gill covers by placing a small, thin piece of clay or folded towel under the gill opening.
   e. Be sure to keep the gill opening dry by blotting it with paper towels.
   f. Place paper towel under gill opening and into anal opening to absorb excess moisture.
5. Paint the fish.
   a. Obtain a small dab of one color of paint from the class supply. Take it to your work area on a piece of waxed paper. The paint should be a thick paste, not too watery.
   b. Before applying paint to the fish, slide small pieces of wax paper under the fish all along its edges.
   These pieces will help keep paint off the cardboard.
   c. Apply a small amount of paint and brush gently from the tail to the head of the fish. Be careful not to damage the scales. Brush a thin, even coat on the fish. You may need to dilute the paint.
   d. Remove the pieces of wax paper. Make sure there is not paint on the cardboard.
6. Apply the paper to the fish.
   a. Practice the technique using newsprint, paper towel or other inexpensive paper. Later, when you are more experienced, use rice paper or other good paper.
   b. Position the paper over the fish, holding the paper in place so that it does not slide.
   c. Gently press the paper onto the painted fish. Use the handle of a paint brush to reach the curved surfaces and to bring out the features of the fins. Lightly stroke the fish in one direction only. The harder you press, the less detail you will get.
7. Remove the paper and allow the print to dry. Sign your name on the paper.
8. Examine the print. Decide how to improve your technique. Usually the second or third print is better than the first.
   a. If there are areas on the print with too little paint, decide whether you missed rubbing that area or if there was too little paint on the fish. Add paint to the fish if necessary.
   b. If there are areas of the fish with too much paint, use a piece of paper towel to lightly blot off the excess.
   c. Check for excess watery areas on the fish, especially around the eyes, gill and anal opening. Blot these dry.
9. Try new techniques. For example, use more than one color on the fish, make a grouping of several prints of the same fish printed onto one piece of paper. Try applying paint from head to tail for a different effect.
Comparing the Anatomy of Aquaculture Fish Species

Laboratory Activity

The structural anatomy of fish is directly related to their feeding habits and food types. This activity is to compare the external and internal features of the different types.

Materials (from “Gyotaku of Aquaculture Fish Species”)

Procedures

1. On one of the fish prints that is “not suitable for framing,” label the following regions: anterior, posterior, dorsal, ventral, and the following morphological features: dorsal fin, caudal fin, anal fin, pectoral fin(s), pelvic fin(s), adipose fin, mouth, lips, operculum (gill cover), lateral line, nose, eye(s).

2. On a fish specimen, examine the location and orientation of the mouth. Open the mouth.
   a. Does it open straight ahead, up or down?
   b. Is it large or small compared to the size of the head?
   c. Are the lips thin or thick?
   d. From examining the mouth, where in the environment would you expect this fish to feed? Explain your reasoning.
   
3. Open the mouth and look at the teeth. Run your finger or a probe over them.
   a. How many teeth would you estimate are there?
   b. Where are the teeth located in the mouth?
   c. Describe their structure. Are they narrow, sharp, dull, flat, etc.?
   d. From examining the teeth, what would you expect this fish to eat? Explain your reasoning.

4. Lift the operculum and examine the gill arch, gill rakers and gills. See Figure 3.
   a. Describe the size and shape of the gill rakers.
   b. What functions do the gills and gill rakers perform?
Fish Gill

5. Examine the digestive tract of the fish.
   a. Make an incision along the ventral line of the body by inserting sharp scissors at the anus and cutting toward the anterior end of the fish.
   b. Open the abdomen by cutting dorsally from each end of the incision and pulling up the flap.
   c. Observe and describe the size and arrangement of the digestive tract. Is it large, small, short, long, straight, coiled, etc.?
   d. Carefully remove the entire digestive tract by cutting the small intestine at the anal opening. Make the other cuts as far forward from the stomach as possible and remove the digestive tract.

The relative length from the intestine is a good indication of the type of food eaten by different kinds of fish.

   e. Measure and record the length of the entire digestive tract in cm.
   f. Measure and record the length of the small intestine.
   g. Determine what percentage of the digestive tract is small intestine.
   h. Is there a difference between the digestive tract of a carnivore and herbivore? What are the differences?

6. Cut open the stomach. Remove the stomach contents, put them in a watch glass and examine under a magnifying glass. What had the fish eaten recently?

7. Compare your observations with others in the class. Make a class chart for all the different fish examined. Include the following categories: name, size, lips, mouth, teeth, gill rakers, stomach, gonads, small intestine, type of food eaten, feeding type (carnivore, herbivore, omnivore), and other observations.

8. What generalizations can you make about the anatomy of carnivores, herbivores and omnivores as related to their food and feeding habits?
COMPARISON OF STRUCTURE
Bony Fish

- Olfactory Lobe
- Brain
- Nostril
- Eye
- Tongue
- Gill Filament
- Heart
- Liver
- Stomach
- Intestine
- Gonads
- Anus
- Muscle
- Rib
- Swim Bladder
- Vertebra
- Spinal Cord
Macroalgaes Pressing

Laboratory Activity

Make a collection of pressed algae.

Linum pressing is the primary means for documenting and storing algae samples in herbariums.
The pressed algae also makes excellent decorative stationery.

Materials

- pencil
- lab notebook
- variety of different, thin-walled macro algae (preferably seaweeds)
- white paper or botany paper
- 2 probes or skewers
- razor blade, scalpel or scissors
- pan, at least 30 cm x 30 cm x 5 cm
- water
- eyedropper or camel-hair brush
- plastic sheet
- clean newspapers
- pieces of waxed paper (12 x 20 cm), or clean cloths
- plant press or 2 boards
- corrugated cardboard
- weight or rope

Procedures

1. In your lab notebook, record data about the macroalgaes specimen. Include location, date, depth, substrate, algae name and name of collector.

2. Examine the specimens for characteristics that make algae different from vascular, or higher, plants. Algae do not have roots, stems, leaves, flowers, fruits and seeds as land plants do. They live in, rather than on, their growth medium.

Refer to figure 1 on the structure of seaweed.

a. Select one of the algae. Identify its major structures (see fig. 1). Are all these parts obvious in your specimen? Which are and which are not?

b. Place a sample of the algae in water in a watch glass. Place the watch glass on the stage of the dissecting microscope.

c. Examine the algae for the presence of veins resembling those in leaves. Do you notice any? Why or why not?

d. Examine the algae for the presence of small animals and plants living on or attached to it. Make sketches in your lab notebook and identify the other organisms living with the algae.
3. To press algae specimen:

   a. Center the specimen on white paper. If the paper is to be punched and put in a binder, leave a wide margin on the left side and leave space in the lower right corner for a label.

   b. Arrange the specimen to show all important details. Use fingers, probes or skewers to position the specimen. Using the two probes, separate the branches on the blades with a razor blade, scalpel or scissors.

   c. For finely branched or hairlike algae, float out the algae by submerging the paper and the specimen in a pan of seawater or freshwater about 1 cm deep. Use jets of water from an eyedropper or a camel-hair brush to arrange algae on the paper.

   d. Insert plastic sheet under paper. Gently lift paper and plastic carrier out of the pan by holding one side or one corner and allowing the water to drain away slowly.

   e. Holding the paper horizontally, inspect the position and arrangement of the specimen. Repeat Procedure #2c to expose plant features as needed.

4. To dry the algae specimen:

   a. Place the wet sheet with the mounted specimen on top of half of an opened newspaper about four pages thick. The newspaper absorbs excess water. Cover the specimen with waxed paper or clean cloth. Then close the newspaper over the specimen and write your name on the outside.

   b. Stack specimens like sandwiches on a desk, on the floor or between two boards. Insert a piece of corrugated cardboard between every fourth specimen-sandwich. Limit the height of the stack to about 30 cm because the paper on which the specimens are mounted tends to crinkle in stacks higher than 30 cm.
BROWN ALGAE

Rockweed
Oar Weed
Feather-boa Kelp

OAR WEED

FEATHER-BOA KELP
Microalgae Identification and Dichotomous Key Use

**Laboratory Activity**

The dichotomous key is used to identify common microorganisms found in ponds and in cultures at The Oceanic Institute’s aquaculture site in Kona, Hawaii, and other locations throughout the world. This key will familiarize students with some of the vocabulary used for these organisms and provide organism identification insight. In aquaculture, it is often important to know what microalgae species inhabit the same water as farmed species since these algae may be beneficial or harmful. The drawing provided with each name should tell the students whether they have made the correct identification. Students will observe organisms not included in this key. If the drawing does not match the organism observed, the students should:

1. Note there is an unidentified organism.
2. Draw the organism.
3. Note any unique features which distinguish it from the other organisms. What is its shape? Color? Does it swim differently?
4. Determine where this organism should be placed in the key.

This information can then be used to update and improve the dichotomous key.

**Materials**
- dropper
- pond water
- microscope slide
- coverslip
- compound microscope
- pencil
- lab notebook
- Figure 1. Dichotomous key for identifying pond microorganisms

**Procedures**

1. With a clean dropper, take a sample of pond water. Place the sample on a microscope slide and cover it with a coverslip. Position it on the stage of the compound microscope. Starting with low power (4X) locate the material. Move carefully to high power (10X) and focus. Examine the sample for the presence of microalgae.

2. When one of the microalgae is clearly in view, identify it using the key.
   a. Read the two descriptions in the first section of the key. The microalgae you are attempting to identify fits either one or the other description. When you have decided which of the two descriptions best fits your specimen, go on to the next section and continue until you have identified your specimen.
   b. Verify your choice with the illustrations provided, and record the name in your lab notebook.
   c. If there is a specimen that is not in the key, make a sketch in your lab notebook and identify it using the reference materials provided.

3. How many of the microalgae included on the key were you able to identify? Which is the most common species? Estimate what percentage of the microalgae population it represents.
Dichotomous Key

1. Cells single or, if undergoing cell division, found in pairs ......................................................... 2
1. Cells numerous, multicellular; arranged in chains, filaments or other multicellular organism ........... 9

2(1) Cells or cultures of cells green in color ......................................................................................... 3
2(1) Cells or cultures of cells not green or a shade of green; generally yellow to brown in color ........... 5

3(2) Cells motile by cilia ...................................................................................................................... 4.ciliated protozoan
3(2) Cells non-motile or motile by flagellum ......................................................................................... 4

4(3) Cells with bright green (e.g. grass green) chloroplast, larger (10 to 15 microns in diameter), oval or flattened in shape ........................................................................................................... Tetraselmis
4(3) Cells a shade of green, generally small (2 to 5 microns in diameter, spherical or oval in shape ................................................................................................................................. Nannochloropsis

5(2) Cells with radial symmetry .............................................................................................................. (centric diatoms) 6
5(2) Cells not radially symmetrical, with somewhat bilateral symmetry ...........................................(pennate diatoms) 7

6(5) Cells large, spherical or oval, usually connected in chains of two or more cells, spines not present ................................................................................................................................. Melosira
6(5) Cells smaller; square, rectangular or oval; single or in short chains, spines originating at the corner of each cell ................................................................................................................ Chaetoceros

7(5) Cells tapering to a long, thin spine .................................................................................................. Nitzschia closterium
7(5) Cell endings rounded or in a point, but not tapering to a long spine ........................................... 8

8(7) Cells bilaterally symmetrical in all views ......................................................................................... Navicula or other navicula-type diatom
8(7) Cells asymmetrical in some views ................................................................................................ Achnanthes

9(1) Cells photosynthetic, arranged in a filament, variable in color ....................................................... 10
9(1) Cells non-photosynthetic, arranged into tissues and organs, generally clear or may be pigmented......12

10(1) Cells arranged as a branching filament, green in color ................................................................. Cladophora
10(1) Cells arranged in a non-branching filament, brown in color ......................................................... 11

11(10) Cells generally in long chains of large, spherical cells, spines not present ................................. Melosira
11(10) Cells in short or long chains or smaller, square or rectangular cells possessing spines which originate at the corner of each cell ................................................................................ Chaetoceros

12(9) Body with segmented body parts, appearing shrimp-like, lacking cilia around the mouth ............ copepod
12(9) Body smooth, non-segmented, appearing sac-like, with cilia around the mouth .......................... rotifer
DIATOMS

PHYTOPLANKTON
Diversity and Structure

DIATOMS

DIINOFLAGELLATES

SPECIES OF CHAETOCECUS

C. Decipiens
C. Didymus
C. Derilis
C. Diversus
C. Denticulatus
Counting Microalgae

Laboratory Activity

Learn to use a hemocytometer to count microalgae. Determine the growth rate of microalgae over a three-day period.

Materials

• 3 cultures of microalgae at different ages fixed in Lugol’s solution
• dropper
• hemocytometer
• compound microscope
• pencil
• lab notebook

Procedures

1. Select one of the cultures to count and write the culture’s inoculation date in your lab notebook.

2. Gently mix the culture solution and remove a small sample with the dropper.

3. Bring the dropper with the sample to the side of the hemocytometer and let it flow into the counting area.

4. Position the hemocytometer on the stage of the compound microscope. Starting with lower power (4X), locate the counting grid. Move the high power objective lens (10X) into place and focus.

5. Count and record the number of microalgae in five different grids.

6. To estimate the number of cells per milliliter, take the total number of cells in all five grids and divide by 4 to obtain an average number of cells per grid. Then multiply by 10,000 to obtain the number of cells/ml.

• 1 Grid x 10,000 = cells/ml

7. Repeat for other two cultures

8. Transfer the data to a class chart and combine data.

9. Prepare a graph to show the microalgae cell count over time using the computer spreadsheet and charting programs.

10. Explain the results.

11. In marine shrimp culture, determining algae cell density is important. Larval shrimp require specific amounts of algae at different stages of their development. In the zoeal through mysis stages, they require varying densities of (100,000 - 150,000 cells/ml).
Discovering Plants and Animals in Aquaculture:

Determining Morphology, Anatomy and Physiology of Aquaculture Organisms

OBJECTIVES

- Explain the meaning of morphology, anatomy and physiology
- Describe the structure and anatomy of crustaceans
- Describe the structure and anatomy of an oyster or a mussel
- Describe the external and internal anatomy of fish
- Describe the morphology of aquatic macroalgae and microalgae
Morphology

- Branch of biology
- The structure and form of plants and animals

Anatomy

- Branch of morphology
- The structure of organisms
Physiology

• The functions and vital processes of living organisms

• Growth and survival depend on the processes
Systems

- Skeletal system — provides framework for organism
- Muscular system — provides internal and external body movement
- Digestive system — converts food into a form that can be used
- Excretory system — eliminates wastes from organism
- Respiratory system — provides oxygen to tissues and cells and removes carbon dioxide
- Circulatory system — circulates blood throughout the body
- Nervous system — conveys sensation impulses between brain and body parts
- Sensory system — provides contact with environment through senses
- Reproductive system — generates new organisms of the same species
Crustaceans

- Aquatic animals with exoskeletons
  - Skeleton made of chitinous material
- Examples include:
  - shrimp
  - crawfish
  - lobster
  - prawns
- Molting occurs during growth:
  - softshell form is vulnerable to attack
- Three body sections:
  - head
  - thorax
  - abdomen
- Can regenerate appendages
Molluscs

- Bivalves have two-part shells that can completely enclose the animal
- Examples include:
  - Oysters
  - Mussels
- Shell is calcareous
- Anchor in the water
- Filter feeders
- Reproduce with eggs and water-borne sperm
Finfish

- Bony with hard, calcium-based, internal skeletons
- Exterior covering
  - Skin
  - Skin with scales
- Gills remove oxygen from water
- Developed digestive system
  - Algae and detrital eaters (small stomach–long gut)
  - Carnivores (large stomach–short gut)
- Reproduce with eggs and sperm
Algae

- Macro - large forms
  - attach to substrate
  - function similarly to plants with stems
- Micro — small forms
  - important as food for larval fish, crustaceans and molluscs