LIFE SPAN AND PROCESSES

All organisms are living things until death. Aquatic organisms are no exceptions. To be in the living condition, they must carry out life processes. The nature of these processes tends to vary, but all organisms must carry them out.

LIFE SPAN

Life span is the length of an organism's life. Some life spans are long; others are short. Every species has a normal life span. Events in an organism's environment influence the length and quality of a life span.

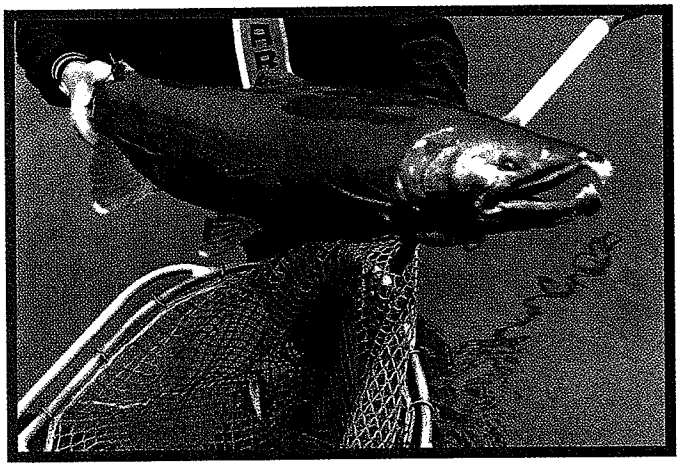
4–2. Most aquatic animals reproduce by laying eggs. This shows eyed salmon eggs that will soon hatch.

Span Stages

All organisms typically go through five life-span stages:

1. Beginning—Every organism has a beginning point. The beginning varies by species, depending on how the species reproduces.
2. Growth—Growth occurs most rapidly in young organisms. It declines as maturity nears. Young organisms often need special nutrients to meet their needs for creating new cells and growing rapidly.

3. Maturity—This is the stage at which an organism is said to be fully developed. Growth has stopped except for the repair of worn or damaged cells. This is also the stage at which reproduction normally occurs.
4. Decline—As an organism ages, it passes through maturity into a time of deterioration. Animals may not be as active, and their flesh may not be as appealing for food. Plants may become dry and turn brown. Decline is a part of increasing age.



4–3. A mature male coho salmon at a fish hatchery in Washington.

5. Death—Death occurs when life processes stop. An organism is no longer capable of replenishing itself. Sometimes hazards in the environment (e.g., lack of oxygen in water), accidents, or other events (e.g., harvesting) cause death before an organism has passed through all the life-span stages. No aquaculture producer wants desired animals or plants to die. The goal is to promote life processes to achieve a desired product.

Life Cycle

Life cycle is the changes that an organism goes through from a given stage until the same stage recurs in the next generation. Life cycles vary by species. Life cycle is often viewed as the stages involved from the time an organism reproduces until the next generation of organisms reproduces.

LIFE PROCESSES

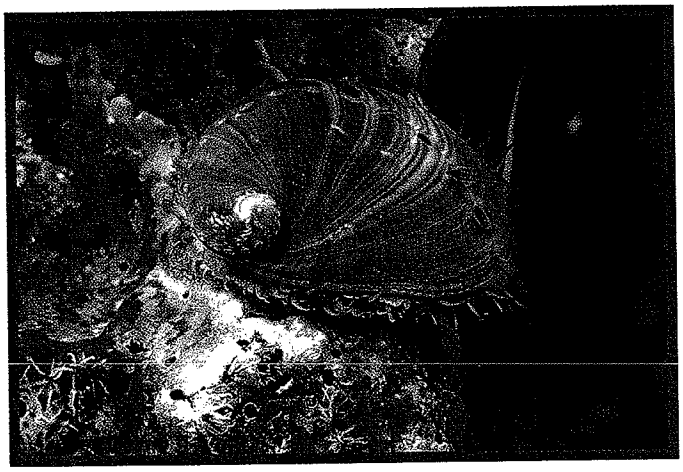
A ***life process*** is an essential activity for an organism to remain in the living condition and perpetuate its species. Without activities of this type, organisms are threatened. The life of an individual would end if some of the processes were not carried out.

The eight life processes are briefly covered here.

Getting and Using Food

Food provides the energy and other nutrients needed for growth and activity. The need for food is continuous in the life of an organism. How organisms acquire food and the kinds of materials used for food vary. This is also true for aquatic animals and plants.

Animals ingest (eat or consume) their food. The food is digested to break the materials into simpler forms that can be used by the body. Absorption is the process of food nutrients entering the bloodstream and occurs in the small intestines. This process produces wastes. Elimination is the process of expelling wastes from the body. Aquatic animal producers must understand the processes of the species they are producing and provide needed food materials.



4–4. Underwater view of an abalone showing it feeding on plants, algae, and other materials scraped from rocks in the water. (The abalone is a species of marine snail found along the West Coast of the United States.)

Plants take in nutrients (primarily through their roots) and convert them to food through photosynthesis. An aquatic plant producer must understand the nutrients needed and how nutrients are acquired and used. This will vary somewhat between species.

Wild aquatic organisms obtain food from their habitats. Cultured aquatic organisms rarely obtain sufficient natural food. A producer promotes growth by assuring sufficient food and/or nutrients for food making. Later sections of this chapter, along with other chapters, have content related to food.

Movement

Movement is of two kinds: internal and external. Internal movement is needed to carry out life processes. ***Locomotion*** is the process of moving from one location to another. It is a kind of external movement.

In an animal, a heart moves blood through vessels to provide oxygen and nutrients to cells and to remove wastes. Movement also includes motions of the lungs or gills, eyes, and other organs. Most animals are also capable of locomotion, such as a fish moving about by swimming in the water. Some aquatic organisms move very little, such as oysters that attach themselves to objects in the water.

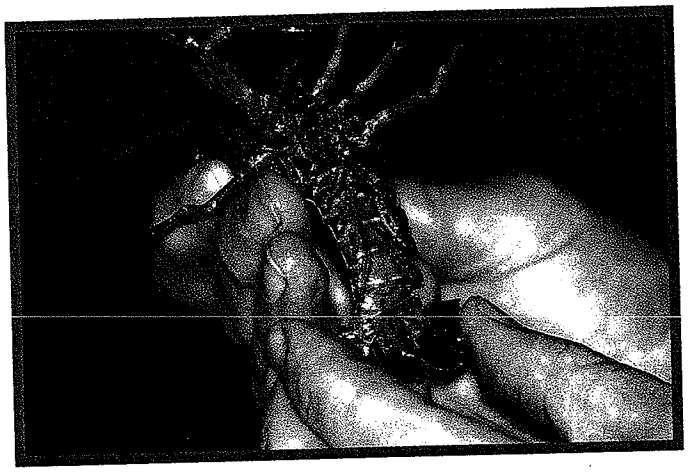
Movement in plants is to circulate food substances and adjust to changes in light, such as when leaves of a plant turn toward sunlight. Movement also includes opening of flower buds, dispersal of fruit or seed, and other motions, depending on the species.

Circulation

Circulation is closely related to internal movement. Food nutrients, digested food, and other materials move within an organism.

An animal has a circulatory system. The heart uses a squeezing motion to move blood through vessels to organs and tissues throughout the body. If circulation fails, the animal will not survive.

In a plant, circulation is primarily in a vascular system. Xylem is the part of the vascular system that moves water and nutrients. Phloem is the part that moves food from its point of manufacture to other parts where it is needed.



4–5. Crawfish have several appendages that help with locomotion. Greatest speed is backward when a crawfish uses the large telson to propel away from danger.

Respiration

Respiration is the process an organism uses to provide its cells with oxygen. The oxygen is used to release the energy from food nutrients. Respiration is a continuous process in all living cells.

In animals, various respiratory structures acquire oxygen and release carbon dioxide. Fish have a gill system for this process. Mammals, amphibians, and others have lungs or similar structures. The blood carries nutrients, oxygen, and other substances throughout the body. Chemical energy and carbon dioxide are produced by oxidation as the energy is used by an organism. Conditions must be provided so that animals have sufficient oxygen. Water aeration is often used to provide sufficient oxygen for fish and other aquatic species.

With a plant, respiration occurs both night and day. Oxygen and carbon dioxide are absorbed through stomata in leaves and stems. The vascular system moves the oxygen and carbon dioxide throughout the plant. Wastes are released through stomata.

Growth and Repair

Growth and repair occur throughout the life of an organism. Young, immature organisms add cells to increase in size. One goal of an aquaculture producer is to promote the rapid addition of

4–6. External secretions make a fish hard to hold.

4–7. A mass of fertile fish eggs will soon hatch under ideal conditions.

cells and overall growth by providing nutrients and a good environment. Mature organisms may not increase in size but use growth processes to repair and replace damaged cells.

Secretion

Secretions are juicy or watery substances in and on organisms. A good example is the slippery secretion fish produce to cover their bodies, making themselves hard to hold onto. Several body fluids are secreted internally by animals and plants. In animals, these promote digestion and respiration. In plants, secretions may be observed as sap or juice inside roots, stems, and leaves.

Sensation

Sensation is the ability of an organism to receive information and respond to it. Fish, for example, may sense something dangerous near them and quickly swim away. Plants may turn toward a light source or droop when temperatures are below normal conditions needed for growth.

Reproduction

Reproduction is the process by which new individuals of a species are created. Processes vary between plants and animals and between species of each. Some plants form seed. Others have parts that break away, such as a water hyacinth leaf, to form new plants.

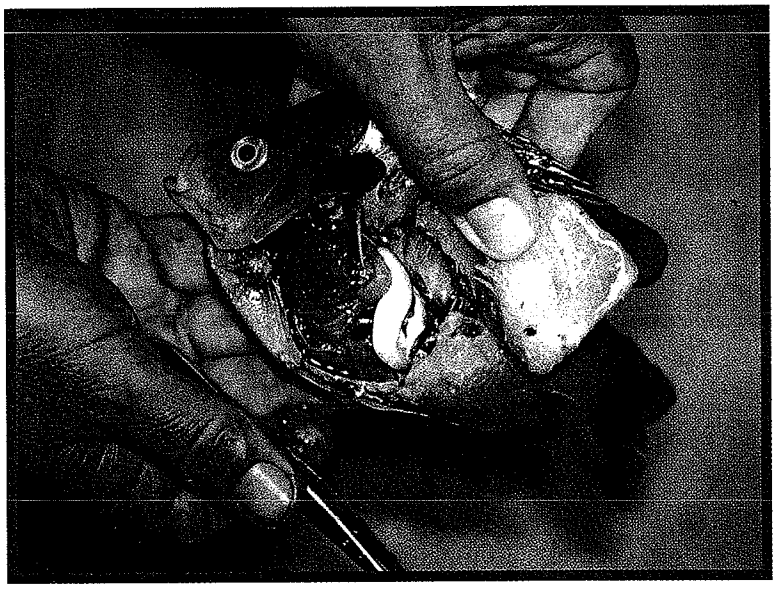
Animals may lay eggs or give birth to live young. Some organisms, such as bacteria, reproduce by cell division.

Reproduction is not needed for an organism to live. It is, however, needed for a species to continue to exist. Without reproduction, a species would become extinct when the last survivor ceases to live.

MORPHOLOGY AND PHYSIOLOGY OF AQUATIC ORGANISMS IN GENERAL

Aquatic species have body structures and systems that make life possible. Morphology and physiology help in understanding structures and processes. Knowledge gained from these branches of biology promotes better care by producers, including increased understanding of the needs and problems associated with aquatic species.

Morphology deals with the form and structure of organisms, including animals and plants. Morphology includes the study of cells, or cytology. Cells are the basic building blocks of organisms. Morphology does not include the functions of the forms and structures.



4–8. A fish has been surgically opened to reveal its internal structure.

Anatomy is included in morphology. ***Anatomy*** deals with the structure of whole organisms, including form, shape, and appearance. Both internal and external structures are studied in anatomy. Experienced people can look at an organism and instantly identify its species. That is because they know the appearance of members of that species. You can probably tell a rainbow trout by its color, spots, body shape, and arrangement of fins.

Physiology deals with the functions of cells, tissues, organs, and systems of an organism. Specialized body structures perform important physiological functions, such as ovaries, which produce eggs, and gills, which absorb oxygen.

Producers can more efficiently culture aquacrops by knowing the morphology and physiology fundamentals of the species they are culturing.

4–9. Each egg is one cell. (These turtle eggs are ready for delivery to a turtle farm.) (Courtesy, National Oceanic and Atmospheric Administration)

BUILDING BLOCKS

Organisms are made of many cells. A ***cell*** is the basic unit of a living thing. Cells contain substances that promote life processes. Most cells are very small and must be viewed with a microscope. Some cells, however, are large, such as eggs. (The information in this chapter primarily focuses on organisms that are multicellular—i.e., made of many cells.)

Cell Structures

Cells appear to be similar in plants, animals, and other organisms, but close examination reveals differences. A microscope is used to see the differences in structure. ***Cell structure*** is the general pattern of organization and relationship in a cell.

Cells have three major structural parts: cell membrane, nucleus, and cytoplasm. Each has specific functions.

The cell membrane surrounds the cell and controls the movement of materials into and out of the cell. The membrane consists of several types of substances. Its arrangement varies in plants and animals.

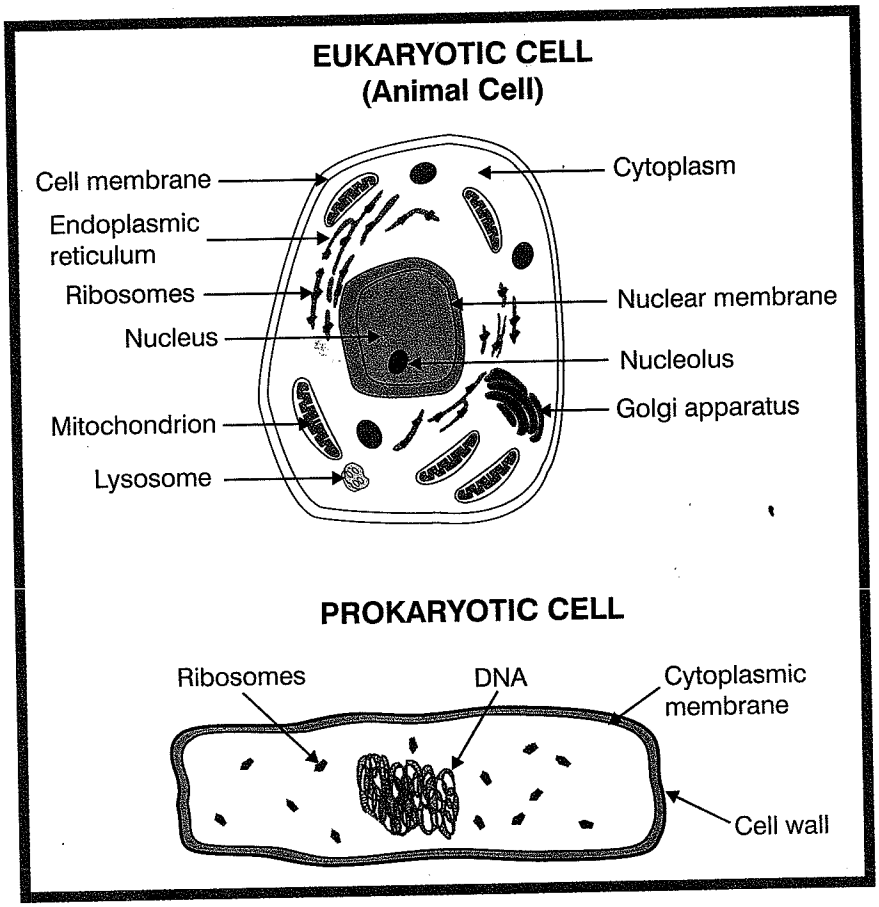
In a plant cell, a wall outside the cell membrane provides rigidity and protects the cell. The cell wall contains materials that make aquatic plant foods appealing and tasty.

Animal cells, as in fish and shrimp, do not have walls. To provide body structure, many animals have skeletons. Skeletons give rigidity and body shape. Since their cell membranes are soft and pliable, animals can move about more easily than plants.

The nucleus contains genetic information. It is usually near the center of a cell. This organelle (little organ) is made up of several materials, including a type of protoplasm known as nucleoplasm and fine strands of chromatin. Chromatin is the substance that forms chromosomes, which are the structures in cells that carry the material that determines gender (male or female) and other characteristics. A chromosome is made up of proteins and nucleic acid. Chromosomes have the DNA and genes.

Cytoplasm is a thick, semifluid material that surrounds the nucleus. It contains the rest of the organelles.

The remaining organelles in a cell are the endoplasmic reticulum, mitochondria, lysosomes, Golgi apparatus, plastids, and vacuoles. Each has specific functions. (Refer to an agriscience or biology book for more details.)



4–10. A comparison of a eukaryotic cell and a prokaryotic cell is shown here. (A eukaryotic cell has at least one membrane that encloses the nucleus. A prokaryotic cell does not have a separate membrane enclosing the DNA or other internal parts. Plants and animals have eukaryotic cells; bacteria are prokaryotic cells.)

Cell Processes

Cells perform a number of processes in an organism: using food materials, sensing and responding to stimuli, and growth. Most likely, growth is most important in aquaculture production.

Organisms grow through division. ***Division*** is the duplication process in which one cell splits into two cells. The original cell is the parent cell. The new cells are daughter cells. The two kinds of division are mitosis and meiosis.

Mitosis. ***Mitosis*** is cell division for growth and repair. Each parent cell produces two daughter cells with identical genetic material. The number of cells in an organism increases by mitosis, with the outcome being a larger organism or the replacement of damaged cells.

3. Anaphase II—The centromere duplicates, which divides the chromosomes, with each half pulled by the spindle fibers to the poles.
4. Telophase II—A cell membrane forms between the two developing nuclei. The nucleolus and the nuclear membrane reform. Cytokinesis occurs. Four daughter cells are produced, containing the haploid number of chromosomes.

MULTICELLULAR ORGANISMS

Organisms may consist of one or more cells. Many aquatic organisms, such as oysters, clams, fish, and shrimp, are ***multicellular organisms*** (i.e., have many cells). The cells are organized to form other structures, known as tissues, organs, and organ systems.

Cell specialization is the development of cells for a particular purpose or function. The grouping of specialized cells forms unique organisms. If all cells were alike, organisms would not exist as we know them. Clusters of specialized cells form tissues.

4–13. A fish has millions of cells specialized into organs that perform specific functions. What cell specialization do you see in this fish?

Tissues

A ***tissue*** is a group of cells that are alike in structure and activity. The cells in tissues are specialized. This means that the cells are suited to specific kinds of activities. In animals, tissues include muscles, nerves, and bones.

Tissues have specific jobs to do in an organism. For example, the cells in muscle tissues provide motion. These specialized cells do not perform other jobs.

Organs

An ***organ*** is a collection of tissues that work together to perform a specific function, such as the gills of a fish. Although, the tissues may differ in the jobs they do, each contributes to the overall function of an organ. Examples of organs in animals are the skin, heart, lungs, stomach, and liver. In plants, organs include roots, leaves, and stems.

Organ Systems

An ***organ system*** is the association of several organs that work together to perform an activity. These are the major systems of the bodies of many animals. For example, the digestive system is made up of several organs: mouth, stomach, small intestine, large intestine, and others. Organ systems are typically found in complex animal organisms. An example of an organ system in a plant is the vascular system.

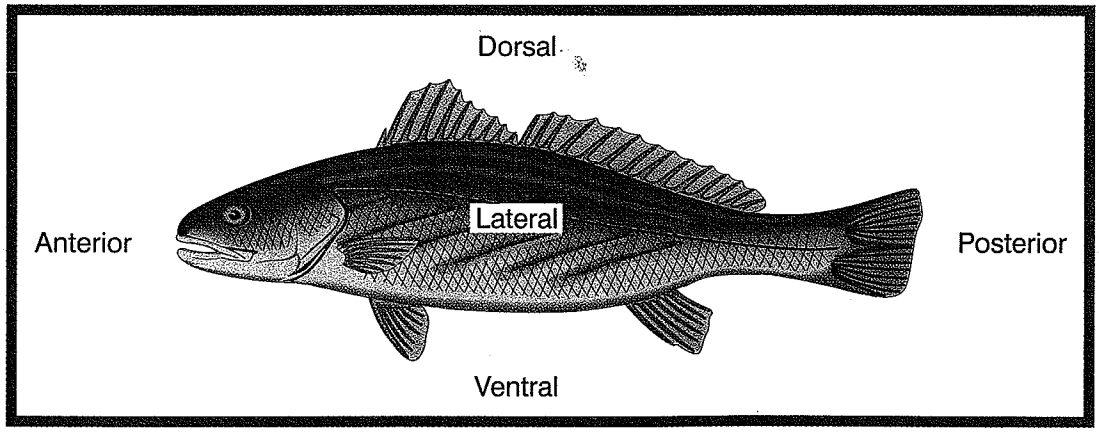
MORPHOLOGY AND PHYSIOLOGY OF FINFISH

Morphology and physiology are important in providing the cultural practices needed for success in finfish aquaculture. A finfish is any fish that has fins. This encompasses a large number of fish species.

BILATERAL SYMMETRY

Most fish are ***bilaterally symmetrical***; that is, they could be divided into two mirror-identical halves. Anterior refers to the front of a fish (the end with the mouth and head). Posterior refers to the tail end of a fish. The belly plane of a fish is ventral. The back plane, or the opposite of ventral, is dorsal. The side of a fish is lateral.

Fish producers need to understand the meaning of anterior, posterior, ventral, dorsal, and lateral as related to the species they produce.

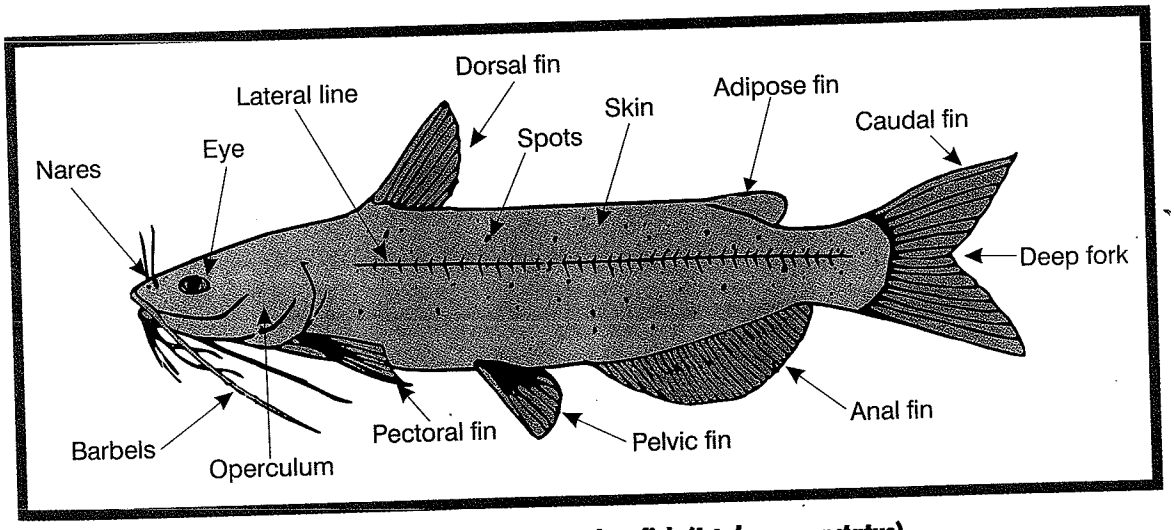


4–14. Locations of the common sides of a fish.

EXTERNAL FEATURES

The body of a fish can be divided into three parts: head, trunk, and tail. The head begins at the nose and ends at the posterior end of the operculum (gill cover). The snout is located between the anterior end of the premaxillary (outer jaw bone) and the eye. The nares, or nostrils, are located on the snout, usually one on each side. The dorsal part of the head is called the nape. The ventral part is called the thorax.

The trunk begins at the posterior end of the operculum and extends to the anus. The humeral area is the side of the trunk. The trunk contains the dorsal fin, a pair of pectoral fins, and a pair of pelvic fins. The length of the trunk varies widely among different fish. The trunk of the channel catfish is very short when compared with that of the rainbow trout, for example.



4–15. External parts of channel catfish (*Ictalurus punctatus*).

The tail extends from the anus to the posterior tip of the caudal fin. The tail contains another fin, the anal fin, which is located just posterior to the anus. The tail may also have an adipose fin, a fleshy fin found on salmon, trout, and catfish.

The fins on a fish are supported by soft rays and sometimes by spines. The spines, if present, will be located anterior to the soft rays of a fin. The shapes and number of rays in fins are often used as the basis for identification.

The lateral line, visible on the trunk and tail, is a series of pores on a linear series of scales. On a fish without scales, the lateral line shows up as a small crease or indention running the length of the trunk and tail. The lateral line is part of the sensory system of the fish.

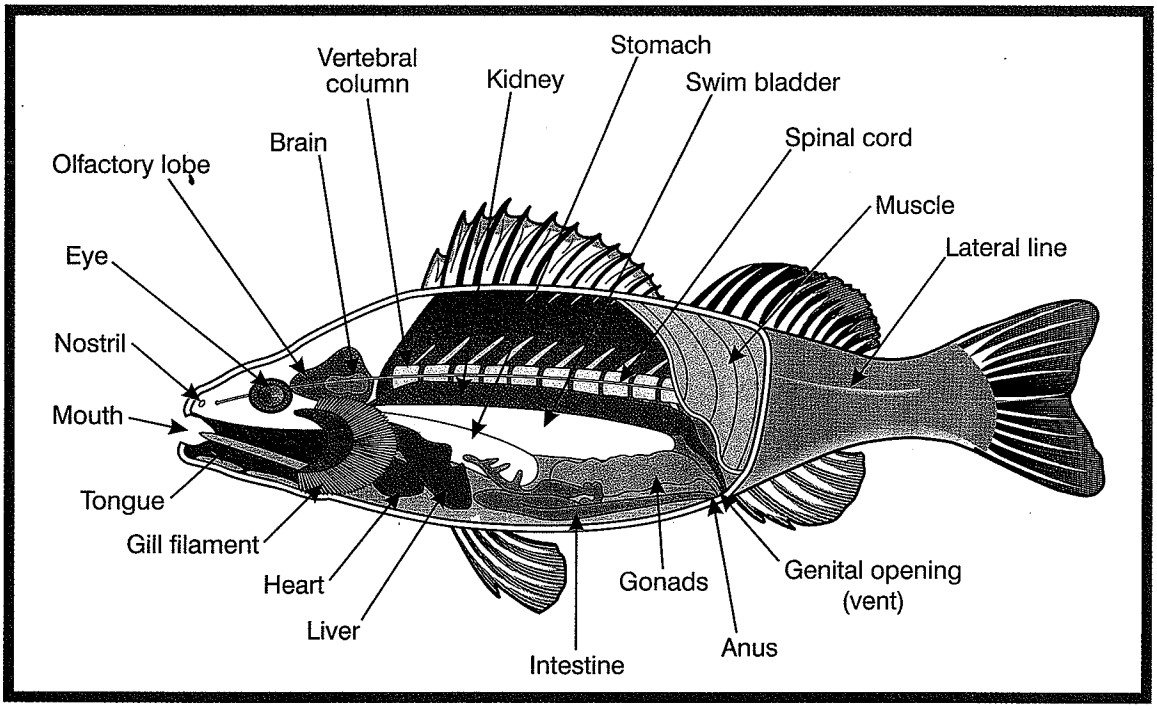
SYSTEMS

Fish have several body systems. Each system has specific duties to perform. Good health is needed to assure that the systems perform as they should. Disease sometimes damages systems so that they fail. A producer needs to understand systems and take steps to promote good health.

Nervous System

The nervous system of a fish has two major parts: the central nervous system and the peripheral nervous system. The central nervous system contains the brain and the spinal cord. The peripheral nervous system contains two types of paired nerves. Nerves that branch from the spinal cord are called spinal nerves, and nerves that branch from the brain are called cranial nerves.

Sensation is associated with the nervous system. Stimuli are detected by sensation, and the fish responds in a particular way. If the sensation is hazardous, the fish tries to escape. If the sensation is pleasant, such as the appearance of food, the fish moves to continue the sensation, such as by consuming the food materials.



4–16. Major internal parts of a finfish.

Sensory System

The sensory system of fish consists of the eyes, the ears, the nares (with olfactory sacs), and the skin (and its appendages). The eyes will vary, depending on the type of fish. Fish that must see their food, such as trout, have larger eyes. Fish that find food by their sense of smell, such as catfish, have smaller eyes. Most fish do not have external ears but sense vibrations through the ear bones in their heads. The sense of smell is accomplished through the olfactory sacs, which open through the nares, usually located between the eyes and the snout.

The skin and its appendages, such as barbells and cirri, give fish a sense of touch. The skin secretes a substance that makes fish slimy, or slippery. Also, on some fish, the scales are developed from the embryonic cells of the dermis, the inner layer of the skin. The outer layer of the skin is called the epidermis.

Circulatory System

A fish has a heart and various blood vessels similar to other higher animals. Both white and red blood cells are present in the circulatory system. ***Arteries*** carry blood from the heart. The primary arteries in fish are the dorsal aorta, the ventral aorta, the carotid artery, and the coelicomesenteric artery. ***Veins*** carry blood to the heart. The portal system transports blood to the liver, from where it is then transported to the heart through the hepatic vein. Other primary veins are the portal vein, the caudal vein, and the anterior cardinals.

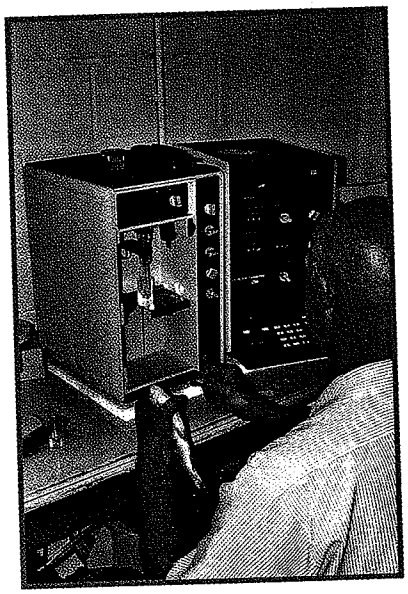
CONNECTION

GRASS CARP TESTING

Grass carp are sometimes used in fish ponds to control unwanted vegetation. Occasionally, these carp escape into nearby natural streams and lakes, where they reproduce rapidly. They will consume and destroy natural habitat for wild fish. The result is that the native fish will not thrive and the streams and lakes will no longer have native fish.

To prevent a takeover by escaping grass carp, carp eggs are treated at spawning, making the resulting fish functionally sterile. This means that they do not reproduce. These fish are known as triploid grass carp because of the genetic alteration caused by the treatment chemical. The cells of the fish have three sets of homologous chromosomes rather than the usual two sets.

Here a fish producer is determining triploidity of a fish. The equipment being used is a coulter counter with monitor. It uses a tiny amount of blood to test quickly for size of blood cell. Small blood cells indicate that the fish is diploid and capable of reproduction. Large blood cells indicate that the fish is triploid and therefore sterile. Only triploid grass carp are released into fish ponds for vegetation control.



Skeletal System

The skeletal system of a fish consists of two major parts: the axial skeleton and the appendicular skeleton. The axial skeleton contains the skull (the cranium, which protects the brain) and the visceral skeleton, which is made up of the jaws and gill arches. The remainder of the axial skeleton is composed of the vertebrae and ribs.

The appendicular skeleton consists of the girdles of the paired fins and the bones supporting the fins.

Muscular System

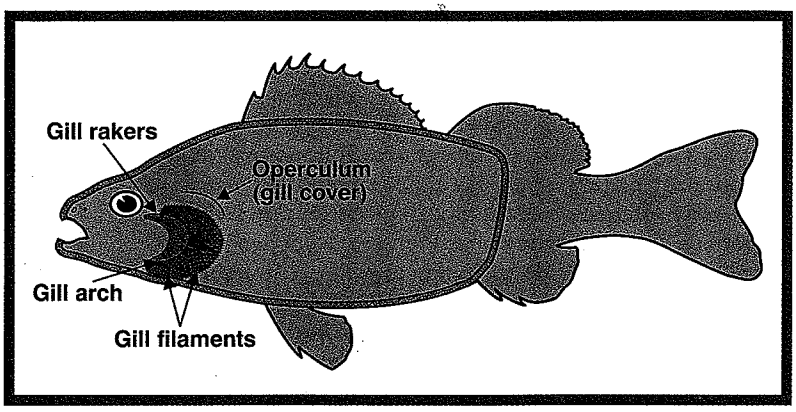
Fish move through the water by undulating their bodies. The muscular system is composed of a series of myotomes, or muscle segments, arranged in the shape of a "W" lying on its side. The myotomes are separated by connective tissues called myosepta.

The muscle tissue of fish is the desired food product. Growers consider the quantity and quality of muscle tissue when selecting a species to culture. Of course, other factors are also important, such as adaptability to the climate.

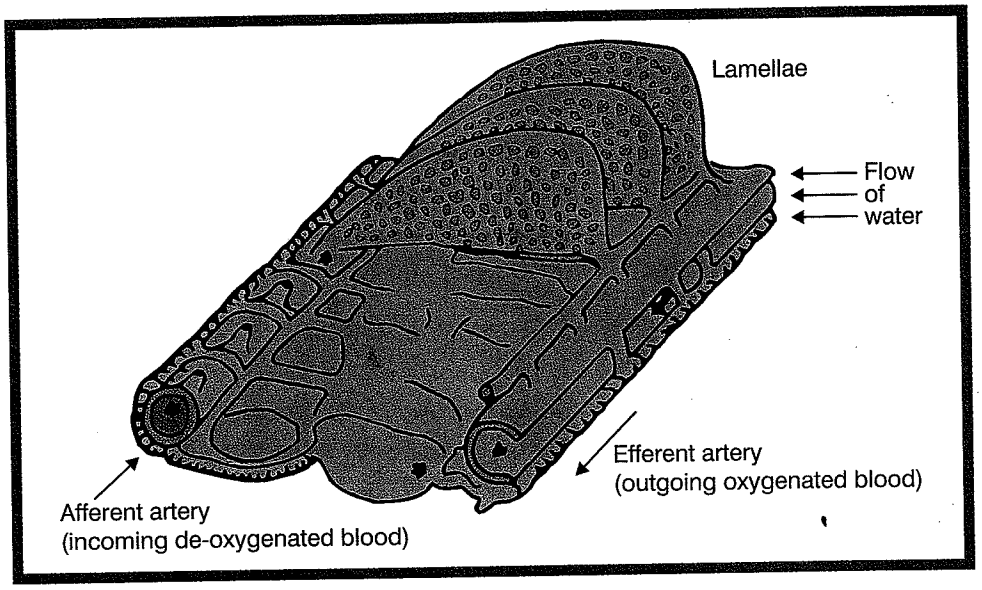
Respiratory System

In fish, the primary organs that oxygenate the blood and exchange carbon dioxide are the ***gills***. Gills are blood-filled membranes located under the operculum. The lamellae have spaces through which blood moves rapidly. The afferent artery carries blood to the gills, and the efferent artery carries oxygenated blood back to the heart.

As the fish swims, water is forced through the mouth and passes over the gills, where the oxygen–carbon dioxide transfer occurs. The oxygenated blood is then transported to the heart and the rest of the body to continue the cycle.



4–17. Location of gills on a fish.



4–18. Parts of a gill filament.

Digestive System

The digestive system of a fish is composed of the mouth, the esophagus, the stomach, the intestine, and the anus. The food moves through the mouth and the esophagus to the stomach, where most of the digestion occurs. The digestive process is completed in the intestine, and wastes are excreted by the anus.

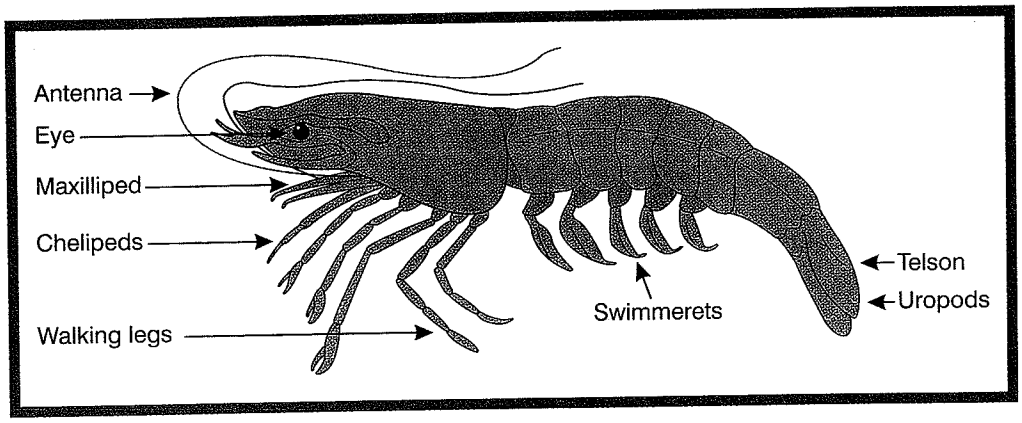
The size and shape of the parts vary according to the type of fish and its natural diet. For example, the catfish, a bottom feeder in its natural habitat, has an inferior mouth, while the rainbow trout has a terminal, or normal, mouth. A fish that is strictly a surface feeder usually has a superior mouth. A fish that feeds on algae and microorganisms will have a small stomach and a long intestine. A carnivorous fish (one that eats other animals) will have a large stomach and a short intestine.

MORPHOLOGY AND PHYSIOLOGY OF DECAPOD CRUSTACEANS

Shrimp, crawfish, and lobster are three important decapod crustaceans. They are sometimes referred to as decapods. They are part of the same order as insects, and their body parts may be observed in much the same way.

EXTERNAL FEATURES

The three primary body parts of a crustacean are the head, the carapace (similar to the thorax in an insect), and the abdomen.



4–19. External parts of a shrimp.

The head of a decapod contains the antenna, the eyes, and the maxilliped. These parts may look quite different, depending on the species.

The carapace consists of the chelipeds (clawed appendages) and the walking legs.

The abdomen is the body part that has most of the "meat" of a crustacean. The swimmerets (short legs that help in swimming) are part of the abdomen. The "tail" of a decapod is made up of the uropods and the telson.

Nervous System

The decapod's nervous system is similar to that of vertebrates but not nearly so complex. A decapod has a central nervous system with a brain (or at least a ganglionic mass) and a ventral nerve cord. Several ***ganglia*** (masses of nerves) branch from the ventral nerve cord to serve the major appendages.

Sensory System

Decapods are very responsive to light and to movement. The primary sense organs include the eyes, the antennae, and the tactile hairs. The antennae and the tactile hairs are responsive to the tactile stimuli of contact with other organisms or movement of water. Lobsters and crabs have very good vision, which helps them find prey.

Circulatory System

A decapod has an open circulatory system with a single-chambered heart. The blood, or hemolymph, flows freely through the hemocoelic cavity. The heart pumps the blood, but circulation also occurs as the result of movement and gut contractions. The decapod has arteries to carry blood away from the heart, but it lacks veins. Blood returns to the hemocoelic cavity through passages called sinuses.

Skeletal System

Every decapod has an ***exoskeleton***, which means that the skeleton is outside the body. The exoskeleton is made of a chitin-protein material secreted by the epidermis. The epidermis is a single layer of skin cells.

Decapods, such as the lobster, blue crab, shrimp, freshwater prawn, and crawfish, all grow by the process of molting. ***Molting*** refers to an animal's shedding its outer shell (exoskeleton) and increasing in size as it develops a new one. A blue crab, for example, increases about one third in size at each molt. Molting stops when an organism is mature.

Molting is an important phase in the production of some species. The softshell crab, for example, is a crab harvested during molting. The crab has lost its exoskeleton and has not developed another.

4–20. The crawfish is an example of a decapod crustacean. Note the hard outer skeleton called the exoskeleton. (Courtesy, National Oceanic & Atmospheric Administration)

Muscular System

Crustaceans have a well-developed system of muscles for various types of locomotion. Decapods have evolved so that those special appendages, all the same on lower crustaceans,

have specialized functions and muscles to control those functions. The cheliped, the large claw on a lobster, for example, is used for protection and for tearing some foods.

The appendages on the abdomen, the swimmerets, are obviously used for swimming. Between these, the walking legs have developed for terrestrial (land) movement.

Respiratory System

When in water, decapods breathe through their gills. The water may be moving from front to back or from back to front. The decapods have appropriate openings for either case. In shrimp, the carapace moves, creating a negative pressure to draw the water in. Respiration also occurs through cell diffusion in the exoskeleton.

Digestive System

The basic digestive system of decapods consists of a foregut, a midgut, and a hindgut. The foregut varies, depending on the diet of the particular species. It may be a simple esophagus or a series of straining or filtering mechanisms. The midgut normally contains various outpockets, referred to as ceca, midgut glands, and diverticula. The hindgut is usually very short and similar to an intestine. It ends at the anus.

MORPHOLOGY AND PHYSIOLOGY OF COMMON MOLLUSKS

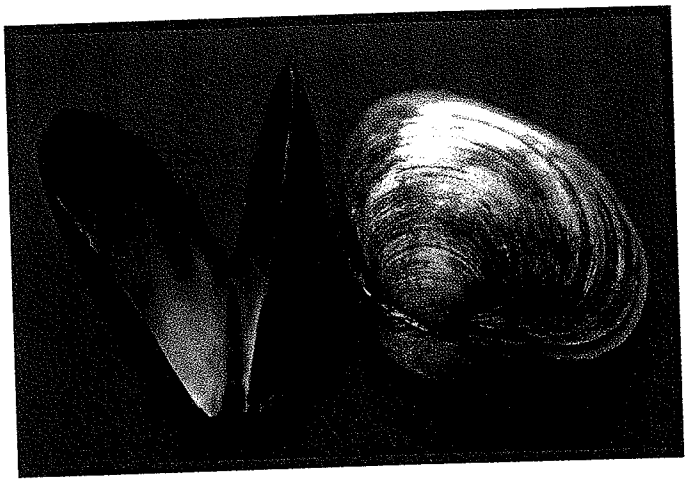
Oysters, clams, and mussels are common mollusks that may be cultivated. Snails, scallops, and other species are also cultivated. Some species are freshwater; most are saltwater.

EXTERNAL FEATURES

Although clams and mussels are cultured in some areas, the most important mollusks to aquaculture are the oysters *Crassostrea virginica* and *C. gigas*. The oyster is a bivalve mollusk. This means it has two sides of a shell hinged together by a ligament. The ligament is located at the pointed end of the shell, called the beak or anterior region. The rounded posterior end of the shell has an oval-shaped, pigmented (colored) area called the muscle scar. The muscle scar is from the adductor muscle. The oyster uses the adductor muscle to pull the shell closed when it senses danger.

The adductor muscle must be cut before the shell can be opened to expose the inner parts of the oyster. This is usually done with a specialized oyster knife. Cutting muscle and opening the shell is known as shucking.

With the shell opened, the oyster will look like a mass of flesh. Closer inspection, however, will reveal the gill, mouth, stomach, intestine, gonad, and anus.



4–21. The bivalve mollusk shell on the left (mussel shell) is open, and the one on the right (clam shell) is closed.

Skeletal System

The shell is created by the mantle, a double fold of the body wall that lines the surfaces of the valves. While using elements from the water to create the shell, the mantle also protects the inner organs.

The shell consists of three layers: the periostracum, the prismatic layer, and the nacreous layer. The periostracum is made of an organic material called ***conchiolin***. The periostracum protects the rest of the shell from erosion caused by sand and water. Other organisms are often found attached to this outer layer.

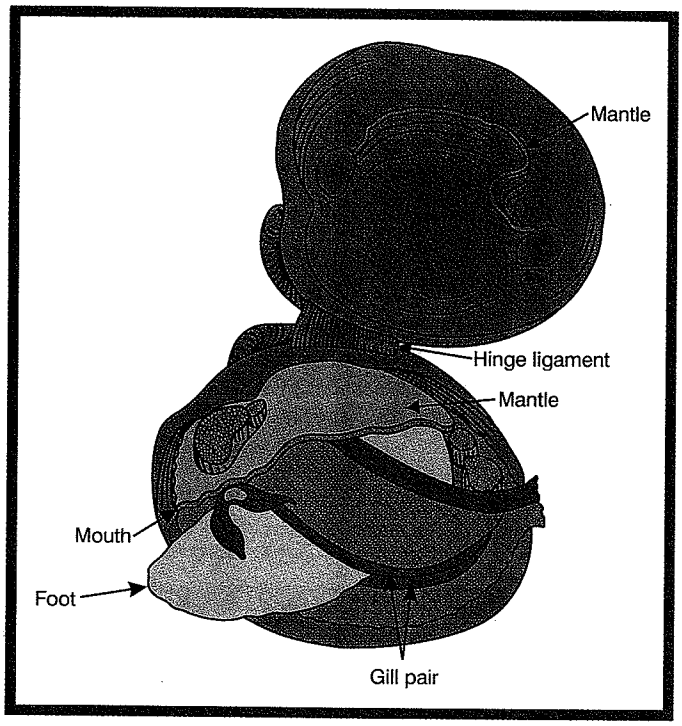
4–22. An opened oyster on half of its shell.

The middle layer, or prismatic layer, is made of alternating layers of calcium carbonate and conchiolin.

The inner layer, or nacreous layer, is commonly known as mother-of-pearl. It is composed of plates of calcium carbonate. A pearl is formed when the oyster secretes several layers of nacre around a foreign object, such as a grain of sand. The oyster's purpose in creating a pearl is to prevent the soft inner parts from becoming irritated. The *Crassostrea virginica* produces poor-quality pearls and thus is not usually cultivated for this purpose. Asian oysters produce most of the pearls that have value as jewelry.

Nervous System

An oyster does not have a true brain. Instead, it has two masses of nerves called ganglia. Small nerves radiate from the ganglia to all parts of the oyster.



4–23. Major parts of an oyster.

Sensory System

Oysters do not need eyes or ears since they do not move around. They can detect changes in light, however, and will close their shells when a shadow falls over them. The most notable evidence of senses in an oyster is the formation of a pearl when a foreign substance enters the shell.

Circulatory System

An oyster has a three-chambered heart located just above the adductor muscle. Blood is forced out the ventricle to the gills for oxygenation. Some blood returns to the heart from the mantle, while the rest is purified in the very small kidney before returning to the heart. Oyster blood has a bluish tint because of the copper content.

Muscular System

Oysters do not have a complex muscular system. Because oysters are sessile animals (they do not move around in search of food), they have no need for a well-developed muscular system. The primary muscle of the oyster is the adductor muscle, which, as mentioned earlier, keeps the shell closed when necessary.

Respiratory System

The gills accomplish respiration in oysters, just as in fish. Oxygen (O_2) diffuses from the water, flowing across the gills into the bloodstream, to be carried to the rest of the body. At the same time, carbon dioxide (CO_2) is released into the environment. Some oxygen–carbon dioxide transfer occurs in the mantle, which is a tissue covering the internal organs of the oyster.

Digestive System

Oysters, clams, and other mollusk species are filter feeders. A ***filter feeder*** is an organism that filters small particles of food materials from the water. The mantle filters out the

larger particles and allows microorganisms to pass through. The organisms, usually single celled, are often collectively referred to as plankton. The plankton particles are trapped in mucus from the gills and moved to the mouth of the mollusk.

The mouth accepts the food unless there is too much or the particles are too large. Then, the excess is rejected to a cavity that is emptied when the shell closes.

The food particles move from the mouth through a short esophagus to the stomach, where nutrients are absorbed. The fecal material moves through the intestine and out the anus. The anus empties into the cavity where excess food is rejected by the mouth.

REPRODUCTIVE PROCESSES

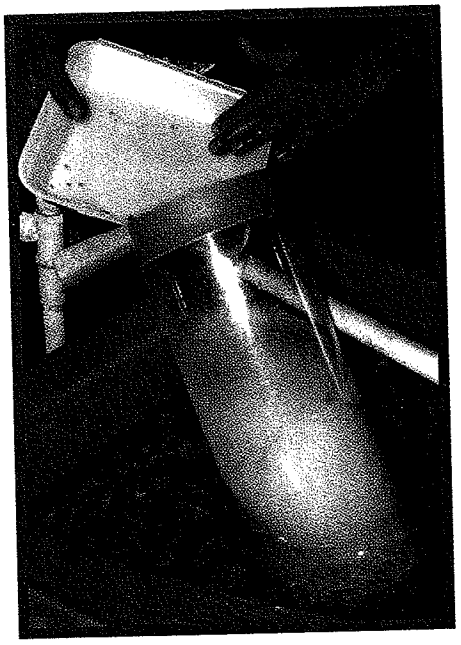
Reproduction is either sexual or asexual. ***Sexual reproduction*** is the production of a new individual from the union of a male sex cell and a female sex cell. The specific processes vary somewhat among the aquatic species, but the general process is constant. Hatchery operators are well aware of the processes in sexual reproduction.

Asexual reproduction is the production of a new individual without the union of a male sex cell and a female sex cell. It is the same as cloning. Asexual reproduction occurs naturally with some organisms, such as many kinds of water plants. A water hyacinth, for example, may send out growth structures that develop roots and separate from the parent plant.

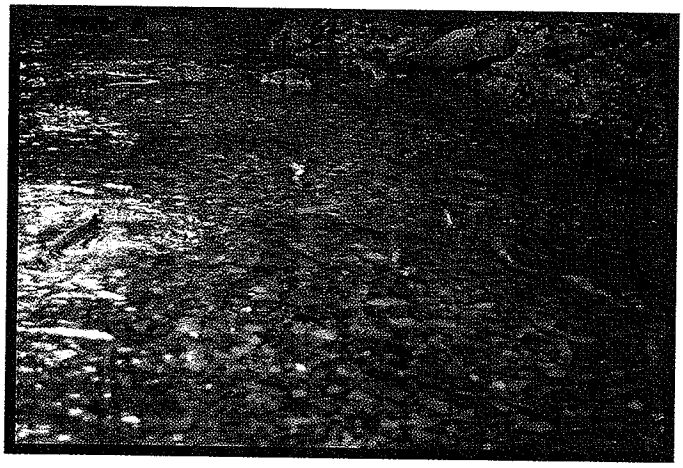
FISH

All the important aquaculture fish reproduce by spawning. In nature, the female lays her eggs, and the male deposits sperm over the eggs. After fertilization, one of them usually guards the eggs until they hatch. This is not always the female. In catfish, for example, the male guards the eggs. In some species of tilapia, the female holds the fertilized eggs in her mouth until they are hatched.

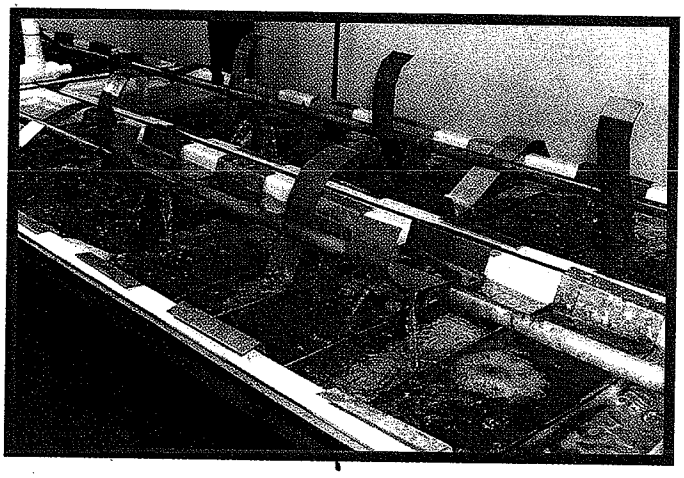
Fish vary widely in their preferred place of spawning. Some spawn on the bottom of a pond. Others, such as trout, require running water to spawn. Catfish need a cover and, in the wild, usually spawn in submerged hollow logs. In ponds, the catfish used for reproduction usually spawn in human-made barrels or boxes. If the preferred method of spawning is not available, many fish simply will not spawn.



4–24. One benefit of aquaculture is the control of spawning and hatching. Here rainbow trout eggs are being placed in a jar for hatching.



4–25. Salmon spawning in fresh water. (Courtesy, National Oceanic & Atmospheric Administration)



4–26. Egg masses in a catfish hatchery.

The tilapia is an example of a tremendously reproductive species. This causes some problems in that tilapia can reproduce before they reach harvesting size. As a result, the tilapia use too much energy for reproduction and not enough for growth. One way to reduce this problem when culturing the bottom-spawning species is to place a net that keeps tilapia from the bottom so they cannot spawn. Another remedy is to raise only fish of the same sex, usually males. This procedure is discussed in more detail in Chapter 12.

Some fish, such as salmon, live most of their lives in salt water but return to fresh water to spawn. These fish are called ***anadromous***. Fish that spend most of their lives in fresh water but spawn in salt water are called ***catadromous***.

Many cultured fish are reproduced in hatcheries. With catfish, the fertilized egg mass is removed from the tank or barrel and placed in the hatchery. In some species, the eggs are removed from the female and the sperm are removed from the male, with the fertilization being done artificially. Trout used in aquaculture are usually spawned this way.

DECAPODS

The female decapod secretes a substance (sex pheromone) that alerts the male that she is receptive to breeding. Immediately after a molt at maturity, breeding occurs. Most decapods breed by copulation. The male places the sperm in or near the female's seminal receptacle. Depending on the species, the male sometimes remains a few days to protect the female from predators and other males. The female holds the fertilized eggs until they hatch.

Most decapods must reach certain sizes before they become sexually mature. A male lobster, for example, must have a carapace of about 40 to 45 millimeters long before he can pro-

duce sperm, but he may not be able to mate with a mature female until he is about 70 millimeters in carapace length.

MOLLUSKS

Reproduction among clams, mussels, scallops, and other mollusks tends to be similar to that of oysters.

The oyster species of *Crassostrea virginica* and *C. gigas* are protandrous hermaphrodites. This means that the same oyster may be male or female at different times. Although not always, the oyster is usually male, producing sperm its first spawning season or two. After this period, the oyster will usually become female and produce eggs for the rest of its life. Although very uncommon in these two species, some oysters produce both sperm and egg cells at the same time.

Sperm produced by a male and eggs produced by a female are released into the mantle cavity, where the combination of water movement and cilia action moves them out into the water. Because fertilization and development of the offspring take place in the water, *Crassostrea virginica* and *C. gigas* are called nonincubatory oysters. In incubatory oysters, the females hold the eggs in their mantle cavities until sperm enter to fertilize them.

Each oyster produces millions of sperm or eggs, but the survival rate is low. During the spawn, the gonad becomes so enlarged that the rest of the inner parts of the oyster are extremely small. After the spawn, the oyster increases the energy spent in digestion to build its energy reserves.

REVIEWING

MAIN IDEAS

Every organism has a life span, which is the length of the organism's life. Typically, all organisms go through five life-span stages: beginning, growth, maturity, decline, and death.

Life processes are the essential activities for an organism to remain in the living condition. These include getting and using food, movement, circulation, respiration, growth and repair, secretion, sensation, and reproduction. Reproduction is not needed for an organism to live, but it is essential for a species to perpetuate itself.

Morphology and physiology deal with the structures and functions of organisms. Cells are the basic structures and carry out specific roles. Cells increase by division, or mitosis, and this is how growth occurs. Some cells are involved in reproduction. They divide by meiosis. Cells form tissues,

tissues form organs, and organs form systems. An organ system is a collection of organs that work together to carry out important life processes.

Finfish, decapod crustaceans, and mollusks are characterized by specific morphology and physiology. External and internal features promote life. Internal systems perform important processes. These systems include nervous, sensory, circulatory, skeletal, muscular, respiratory, digestive, and reproductive. Some species have internal skeletons; others have exoskeletons.

Reproduction may be through sexual or asexual processes. Most animals reproduce sexually, which involves the union of a male sex cell and a female sex cell. Plants and other species also reproduce sexually, though some reproduce asexually. Asexual reproduction is a natural cloning process.

When an aquaculture producer selects a type of aquacrop to produce, the biology of the particular species often plays an important role. For an aquafarm to be productive, it must be adapted to the different biological requirements of the species being cultured.

QUESTIONS

Answer the following questions, using complete sentences and correct spelling.

1. What is life span? What are the five stages in life span?
2. Organisms typically have eight life processes. List them and briefly explain each.
3. What is anatomy? How is it related to morphology?
4. What is the role of mitosis? Meiosis?
5. Draw a fish and label the following sides: dorsal, ventral, anterior, posterior, and lateral.
6. What are the three major body parts of a fish?
7. What are the three major body parts of a decapod?
8. Explain how an oyster makes a pearl.
9. In most aquatic animals, what purpose do the gills serve? How do they accomplish this purpose?
10. What does filter feeder mean?
11. What often determines the shape of a fish's mouth?
12. What is the most important habitat consideration of oysters? Why is this so important?
13. What happens to catfish and many other warmwater fish when the water temperature gets too cold? What happens to tilapia?
14. Why does an aquaculture producer need a knowledge of aquatic biology?