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CHAPTER 4

ORNAMENTAL FISH

Ornamental fish present an unusual paradox in that they are both well known and unknown to veterinarians. These animals are well known because they can be seen every day in the home aquarium, ornamental pond, pet store, and public aquarium,[1] while at the same time they are unknown because knowledge regarding their health care is limited (e.g., in the areas of antibiotic residuals, antibiotic resistance, emerging diseases, antiquated or undocumented diagnostic and surgical techniques, and pain management issues). The purpose of this chapter is to address some of the current and former issues related to the health and well-being of ornamental fish.

COMMON SPECIES KEPT IN CAPTIVITY

Fish represent the largest class of vertebrates, with more than 20,000 different species. This group also represents the largest number of species kept in captivity. While there may be tens or even hundreds of different species from another class of vertebrates kept in captivity, there are likely more than 1000 different species of fish that have been maintained in captivity. A visit to a local pet store will often reveal 50 to 100 different species of fish available for sale at any given time.

There are three major groups of fish kept in captivity: freshwater, brackish water, and saltwater. The fundamental difference among the three groups is the relative density of the water in which they live. Some fish can move between freshwater to brackish water or saltwater to brackish water, but relatively few fish can live in the two extremes (freshwater and saltwater). The various physiologic and anatomic characteristics among freshwater and saltwater fish will be addressed in the following sections.

FRESHWATER

It would be impossible and impractical to categorize every species of freshwater fish in a single book chapter, so we will present information about the two major groups of fish that are commonly kept in the captivity (freshwater temperate and tropical species) and refer to them as a general classification of bony fishes known as Actinopterygii. In addition, we will also provide more detailed information regarding three of the important groups of captive freshwater fishes: catfish, cichlids, and cyprinids.

Freshwater Temperate Fish

Most of the major taxonomic groups are represented by the freshwater temperate species.[2] For many, this group represents the species commonly considered as sport fish in the United States. The most common genera of freshwater temperate fishes maintained in captivity include the sturgeon (*Acipenser* spp.) (Figure 4-1), paddlefish *(Polyodon spathula)*, eels (*Anguilla* spp.), pike (*Esox* spp.), bass (*Micropterus* spp.), sunfish (*Lepomis* spp.), walleye *(Sander vitreus)*, mullet (*Mugil* spp.), spotted sea trout (*Cynoscion* spp.), salmonids, and cyprinids. Although many of these fish are raised by hobbyists, the majority of these species require much larger systems as might be represented in a public aquarium display. Consult an introductory ichthyology text for a more detailed description of the major taxonomic groups of freshwater temperate fish.

Freshwater Tropical Fish

Freshwater tropical fish represent the largest numbers of animals typically found in home aquaria. Generally, this group of fishes is readily available for a small to moderate investment and can be easily maintained by the novice aquarist or hobbyist. Families of freshwater tropical fish include characins (e.g., tetras: *Gymnocorymbus* spp., *Hemigrammus* spp., *Hyphessobrycon* spp., *Paracheirodon* spp., *Moenkhausia* sp.), cyprinids (barbs: *Barbus* spp.), catfish (e.g., *Corydoras* spp., *Pimelodus* spp.), killifish (e.g., *Aphyosemion* spp., *Fundulopanchax* spp.), rainbowfishes (e.g., *Iriatherina* spp., *Melanotaenia* spp., *Glossolepis* sp.), gouramies (e.g., *Colisa* spp., *Osphronemus* spp., *Trichogaster* spp.), livebearers (e.g., *Alfaro* spp., *Poecilia* spp., *Xiphophorus* sp.), and cichlids (e.g., *Pseudotropheus* spp., *Labidochromis* spp., *Iodotropheus* sp., *Dimidichromis* sp., *Copadichromis* sp., *Neolamprologus* spp., *Apistogramma* spp., *Microgeophagus* sp., *Aequidens* spp., *Cichlasoma* spp.).[2,3]

Figure 4-1 The sturgeon is a primitive freshwater temperate species. This genus has a wide range of species, representing relatively small sized animals to one of the largest freshwater species of fish. Although they are best known for their eggs (e.g., caviar), at least one species is offered for sale in the pet trade, and several others are routinely maintained in public aquaria.

Catfish

Catfish (e.g., *Ictalurus* spp., *Lacantunia* spp., *Corydoras* spp., *Ancistrus* spp., *Pimelodus* spp., *Arius* spp., *Kryptopterus* spp., *Phractocephalus* spp.) represent one of the largest groups of freshwater fishes, with more than 2000 species. Catfish have a cosmopolitan distribution. Catfish are an important group because they serve many different roles, including as ornamentals (Figure 4-2, *A*), as food fish in aquaculture (Figure 4-2, *B*), as research animals, and for sport fishing. Most catfish are found in freshwater, although there are two families that contain saltwater species.[2,3] Although catfish have a cosmopolitan distribution, more than 50% of all catfish species are native to South America. There is a high degree of variability in the size and weight of these fish, with animals ranging from 10 cm to over 2 m in length and 10 g to over 300 kg in weight. Most species of catfish are nocturnal. Catfish are primarily benthic or bottom-dwellers. Because of their benthic lifestyle, catfish have sensory structures, barbels that assist them with characterizing food and nonfood items and substrate types in a low-light setting.

A

B

Figure 4-2 **A,** *Corydoras* sp. **B,** *Ictalurus* sp. Catfish represent a diverse group of fishes, with a significant amount of variability in morphology and physiology among genera. Although both are benthic, the catfish in **A** and **B** are shaped very differently.

Figure 4-3 Cichlids represent one of the most popular groups of ornamental freshwater fishes kept in captivity.

Figure 4-4 Koi (*Cyprinus carpio*) represent one of the most coveted groups of fish. These animals are prized for their color, size, and longevity. Their desirability is reflected in their value, with prized individuals selling for tens to hundreds of thousands of dollars.

Cichlids

The cichlids represent one of the most diverse groups of fish, with representation in North America, Central America, South America, and Africa. These fish are prized for their diversity in size, shape, and color. African lake cichlids are one of the most evolutionarily diverse groups in the world, as many different species have evolved within limited ecologic niches (Figure 4-3). With this rapid evolution have come highly variable morphology, feeding strategies, and dietary needs. Although cichlids can look highly variable from genus to genus, they all have a common "break" in their lateral line system. The lateral line is a mechanosensory structure that assists fish with interpreting events in their environment (e.g., shifts in water pressure suggesting a predator is approaching).

Cyprinids

Goldfish *(Carassius auratus),* koi *(Cyprinus carpio),* and carp (*Cyprinus* spp.) are members of the largest family (>2200 species) of freshwater fish, Cyprinidae. Cyprinids have the widest area of distribution of any of the freshwater fish. Southeast Asia is the center of origin for this family of fish; however, many species have been introduced around the world and have readily adapted to these new environments.[2] The carp are the largest species from this family and may hybridize with goldfish. Koi (Figure 4-4) are colorful domestic mutations of carp that are highly valued by hobbyists and the commercial pet trade. The koi can be divided into two major classifications: the nonmetallic koi and the metallic koi.[2] This division is based on typical color patterns, scale types, shape, and size. Goldfish are not koi but rather descendants of the Crucian carp *(Carassius carassius).*[2] Goldfish remain one of the most popular ornamental species and are often found in garden ponds and home aquaria. These fish generally do best if kept in cool waters (55°-68° F, 12°-20° C) with abundant plant life and adequate aeration. There are more than 30 varieties of ornamental goldfish available in the pet trade today.

SALTWATER

Many marine fish species exist, and, again, it would be impossible to cover the diversity of these fishes in a single chapter. Therefore, this chapter will focus on the species most commonly seen in captivity, including marine tropical fish, marine coldwater fish, and the elasmobranchs (e.g., sharks, skates, and rays).[2-4]

Marine Tropical Fish

There are approximately 23 categories of marine tropical fish. These 23 groups can be arbitrarily divided into four major groups by their feeding attributes and compatibility with other species (Figure 4-5). Most of these groups are well represented in the aquarium trade and in public aquaria.

The first category of marine tropical fish is the "rapid eater" and includes the angelfish (e.g., *Pomacanthus* spp.), damselfish (e.g., *Amblyglyphidodon* spp.), squirrelfish (e.g., *Holocentrus* spp.), triggerfish (e.g., *Balistapus* spp., *Balistoides* spp.), and groupers (e.g., *Cephalopholis* spp., *Variola* spp.).[2] These fish do well if kept at low densities in the aquarium or if they are provided a large area where overcrowding is not an issue (e.g., large reef tanks in public displays). Hostile interaction is a major concern for these animals, as they can be very food aggressive.[2-4] These animals may be kept together quite readily if provided an abundance of food and a diverse diet. Often they are kept in live coral reef tanks with anemones and other species of animals from the same group.[2,3]

The slow eaters represent the largest subgroup of marine tropical fish. This group includes, but is not limited to, the

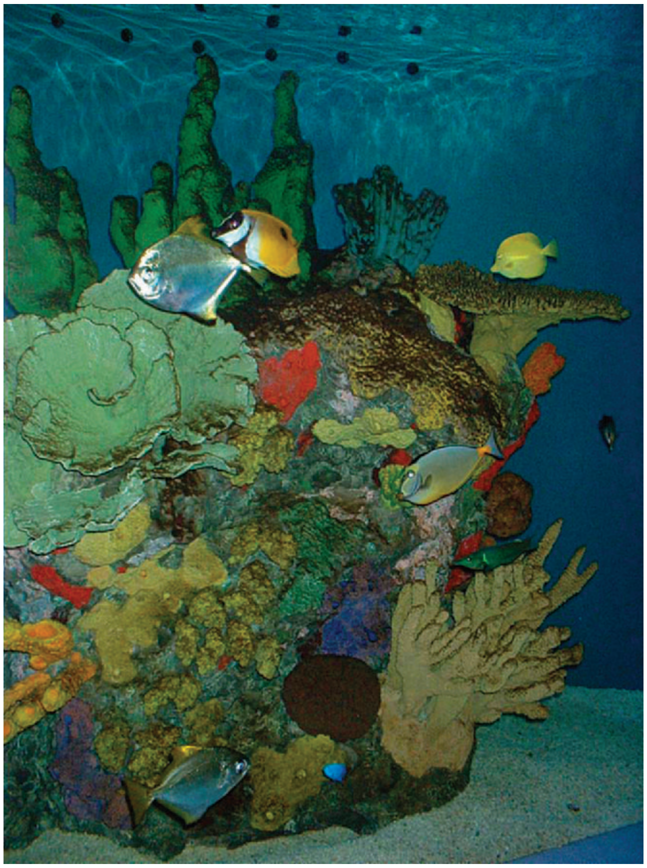


Figure 4-5 Marine tropicals should be housed based on their feeding strategy. This figure represents the typical setting for "rapid eaters."

anemone clown fish (e.g., *Amphiprion ocellaris*), parrotfish (e.g., *Sparisoma* spp.), puffers (e.g., *Carinotetraodon* spp., *Tetraodon* spp., *Colomesus* spp.), surgeonfish (e.g., *Acanthurus sohal*), wrasses (e.g., *Cheilinus* spp., *Halichoeres* spp., *Hemigymnus* spp., *Thalassoma* spp.), and trunkfish (e.g., *Aulostomus* spp., *Strophiurichthys* spp., *Ostracion* spp.). Compatibility is an issue with this group of animals, and they do best if maintained in large displays with a large amount of hiding area. Although these fish are grouped based on their feeding strategy, there remains a great deal of variability in the diets of these animals.

Another group extreme in feeding habits includes those animals that have difficulty competing for food. This group of animals includes some of the more unusual species, such as the seahorses (*Hippocampus* spp.), jawfishes (*Opistognathus* spp., *Stalix* spp., *Lonchopisthus* spp.), pipefish (*Stigmatopora* spp., *Lissocampus* spp., *Corythoichthys* spp.), and batfish (*Dibranchus* spp., *Halieutea* spp., *Halieutichthys* spp., *Malthopsis* spp., *Ogcocephalus* spp., *Zalieutes* spp.). Many of these fish are slow swimming and are easily outcompeted by faster swimming fish. Members of this group should be housed together with similar species and monitored closely to ensure that they obtain sufficient calories.

The last group of animals to be categorized as marine tropicals includes the snappers (e.g., *Lutjanus* spp., *Pristipomoides* spp., *Nemadactylus* spp., *Etelis* spp.) and grunts (e.g., *Haemulon* spp.). These are reasonably large, territorial schooling fish that are, for the most part, kept at public facilities. They can best be described as "gluttons," not only for the manner in which they feed but also for the almost insatiable hunger they exhibit. They are virtually fearless in their feeding habits and will attempt to remove food from the jaws of even large predators.[2]

Marine Coldwater Fishes

Although some of the smaller marine coldwater species are used for public display, many are too large to be accommodated in anything other than large aquaria. The majority of the species in this general category are used as commercial food fish. The first group, which represents approximately 70 different species, includes the gadids or cod (e.g., *Gadus* spp.), haddock (e.g., *Melanogrammus* spp.), hake (e.g., *Urophycis* spp.), and pollock (e.g., *Theragra* spp.). These species are valued as food and for their medicinal value. There are very few public aquaria that exhibit these large species, because they require systems in excess of 1 million gallons of seawater. Tuna (e.g., *Thunnus* spp., *Euthynnus* spp., *Katsuwonus* spp.) have become popular in large open ocean exhibits at public facilities, but only through improved and advanced life support technology and husbandry techniques has it been possible to exhibit this spectacular group of animals. By far the most common category of fish in this group is the flatfish. This group includes, but is not limited to, the flounder (e.g., *Platichthys* spp., *Scophthalmus* spp., *Limanda* spp., *Pleuronectes* spp., *Atheresthes* spp.), halibut (e.g., *Hippoglossus* spp.), and rock sole *(Lepidopsetta bilineata)*. The sablefish *(Anaplopoma fimbria)* and lumpfish *(Paraliparis fimbriatus)* are also in this group of fish and are only occasionally represented in public displays.

Elasmobranchs

There are more than 350 species of sharks in the world, and only a small percentage are represented as display animals or kept by private aquarists and hobbyists. The species that are found occasionally in home aquaria include the carpet sharks (e.g., *Parascyllium* spp.) (Figure 4-6), catsharks (e.g., *Galeus* spp., *Scyliorhinus* spp.), and horned sharks (e.g., *Heterodontus* spp.). Most of the other species of sharks are much too large to be kept in anything less than a public aquarium or large commercial facility. Many public facilities display saw sharks (e.g., *Pristiophorus* spp.) and multiple species of ornamental sharks, including angel sharks (e.g., *Squatina australis*), dogfish (e.g., *Squalus* spp., *Scymnodon* spp., *Deania* spp., *Centroscymnus* spp.), and frilled sharks (e.g., *Chlamydoselachus* spp.).

Skates and rays are closely related to sharks; however, they are markedly different in appearance (Figure 4-7). There are both freshwater and saltwater varieties of stingrays. The skates and rays are dorsoventrally flattened animals and usually have at least one venomous spine on the dorsal caudal fin (tail).

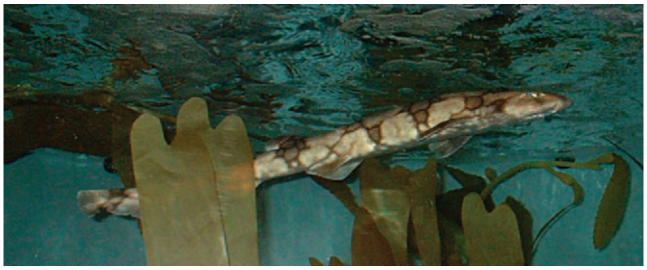


Figure 4-6 The carpet shark (*Parascyllium collare*) is one of the few species of elasmobranchs that can be kept in captivity by hobbyists.

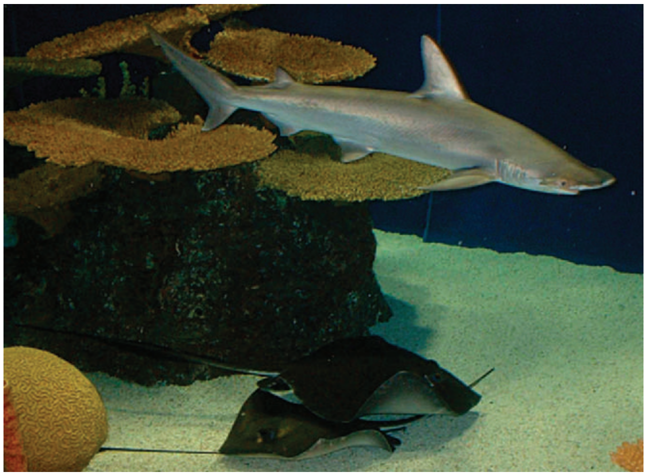


Figure 4-7 Sharks and stingrays have distinct morphologic features. Note the dorsoventrally flattened shape of the benthic (bottom-dwelling) ray compared to the streamlined pelagic (open water–dwelling) shark.

Figure 4-8 Freshwater stingrays are routinely found for sale in the pet trade. These animals originate from South America.

There are multiple freshwater species (Figure 4-8) that are small enough to be kept by the private aquarist; however, the majority of these animals are also found in public facilities. There are a number of ornamental species of saltwater rays, such as the guitarfish (e.g., *Rhinobatos* spp.), butterfly rays (e.g., *Gymnura* spp.), and cow-nose rays (e.g., *Rhinoptera* spp.), that have been maintained and successfully reproduced in public facilities. Many of the larger, saltwater rays, such as the southern stingray *(Dasyatis americana)*, Atlantic stingray *(Dasyatis sabina)*, eagle ray *(Myliobatis aquila)*, and giant manta ray *(Manta birostris)*, are also now being kept in public aquaria.

UNIQUE ANATOMY AND PHYSIOLOGY

When veterinarians begin to work with a new species of animal, it is imperative that they develop a basic understanding of the animal's anatomy and physiology. A background knowledge of anatomy and physiology will prove beneficial when collecting diagnostic samples or administering therapeutics. The following is a review of unique anatomic and physiologic features of fish. (See other resources for additional information regarding this subject.[2])

Fish are covered with a mucous coat that is produced by cells in their integument. This mucous coat is an important component of the innate immune system and serves as the first line of defense against pathogenic organisms (e.g., bacteria, fungi, and viruses). The mucous barrier contains various sized proteins (e.g., immunoglobulins) that bind pathogens and prevent invasion. If this protective barrier is penetrated, fish have minimal protection against pathogens. To ensure that this barrier remains intact and undamaged, fish should be handled only when necessary.

The scales of a fish are located in the dermis and provide protection over the musculature. There are four types of scales found on fish: placoid, ganoid, cycloid, and ctenoid. Placoid scales are found on elasmobranchs, and ganoid, cycloid, and ctenoid scales are found on teleosts (e.g., bony fishes). The ganoid and cycloid scales are common on the more primitive species of teleosts, whereas the ctenoid scales are found on the more evolutionarily advanced fish. The scales serve as a protective armor, and damage or loss of the scales may result in the introduction of opportunistic infections. Handling should be minimized to avoid traumatizing the scales.

Teleosts typically have two sets of paired fins (e.g., pectoral and pelvic) and three unpaired fins (e.g., dorsal, anal, and caudal) (Figure 4-9). Fins are used for steering, balancing, and braking. Certain species have modified fins to adapt to certain niches. For example, the anal fin of the knifefish is a large, single fin located on the ventrum of the animal. This fins serves as the animal's primary source of locomotion. Spines may be associated with some fins and serve as a defense mechanism. The lionfish *(Pterois volitans)* produces venom that can be injected into a potential predator, causing significant pain and discomfort. Knowledge of the species that produce venom is essential to prevent injury to the handler. Fish may damage their spines when captured in a net. To prevent this, fish may be scooped into a plastic cup or bucket to facilitate removal from the aquarium.

The respiratory system of fish is vastly different from the respiratory systems of higher vertebrates (e.g., reptiles, birds, and mammals). Gills are the primary respiratory organs of most fish, although certain species use accessory organs to aid in the absorption of oxygen. Gills serve to absorb oxygen, excrete waste products (e.g., ammonia and carbon dioxide), and regulate ion and water balance. Teleosts have four pairs of gills; elasmobranchs can have five to seven pairs. The gills are attached to a bony gill arch, and each gill is comprised of primary and secondary lamellae. The secondary lamellae are the site of gas exchange (Figure 4-10). Exposure to parasites and toxic compounds, such as ammonia, results in excessive production of mucus, which can impede gas exchange. The presenting symptoms of affected animals include rapid opercular movements and gulping for air at the water's surface; among these animals sudden death may occur.

Fish have a simple, inline, two-chambered heart comprised of a single atrium and ventricle. The heart is located ventral to the pharynx and cranial to the liver. Unoxygenated blood is pumped from the heart to the gills, where it is oxygenated and distributed to the rest of the body. Fish possess two portal systems: a renal portal system, which drains blood from the caudal musculature, and a hepatic portal system, which drains venous blood from the digestive tract.

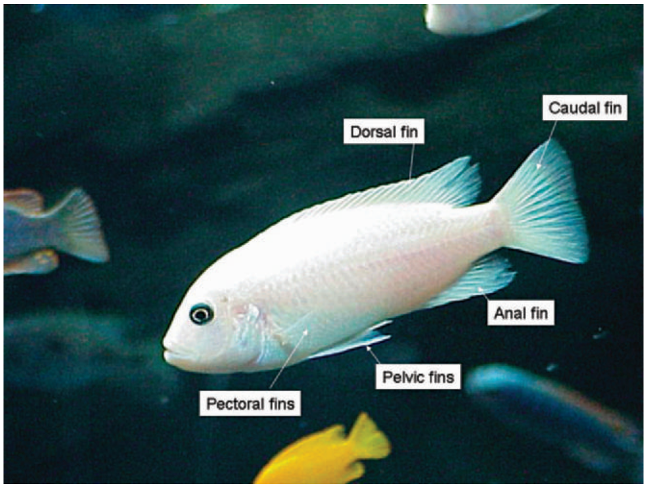


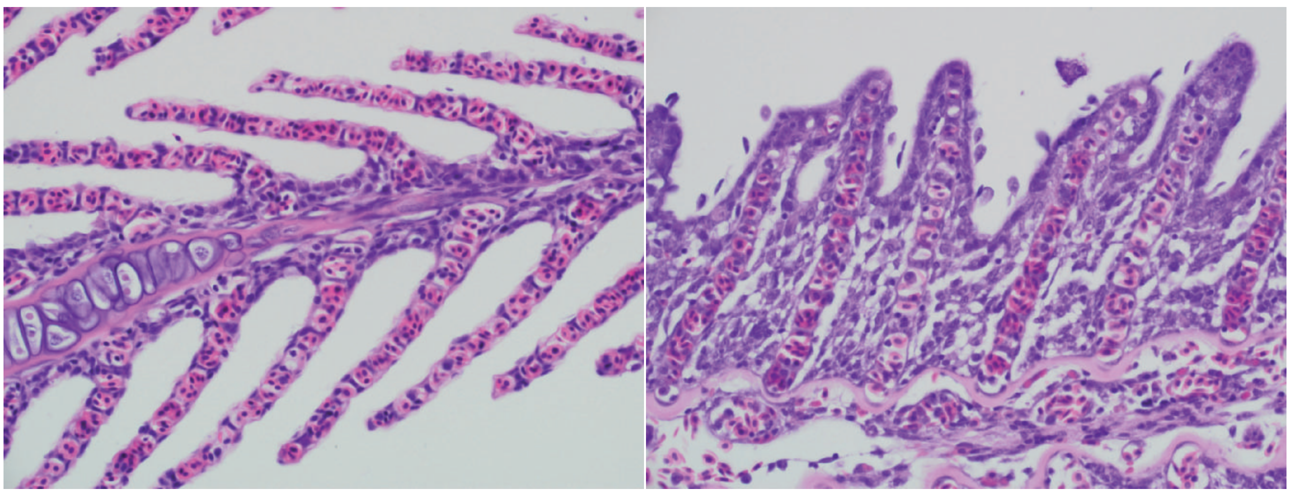
Figure 4-9 Fish generally have two sets of paired fins, the pectoral and pelvic, and three unpaired fins, the dorsal, anal, and caudal.

The lateral line is an important mechanosensory structure used by fish to detect changes in sound waves and water pressure. The lateral line originates on the head, around the eyes and nares, and extends along the lateral body wall. When maintained in captivity, certain groups of marine fish, including tangs and angelfish, may develop head and lateral line erosions. The specific causes of this syndrome have not been elucidated, but dietary deficiency, water quality, and infectious disease are all suspected.

Fish can be classified into three different feeding strategies: herbivore, omnivore, or carnivore. The length of the digestive tract can vary depending on feeding strategy. For example, the length of an herbivore's digestive tract is generally much longer than that of an omnivore or carnivore. The stomach is absent in some species, such as goldfish and carp. Pyloric cecae are found in some species of fish. These structures secrete digestive enzymes and increase the absorptive surface area of the digestive tract. Pyloric cecae are used as a taxonomic indicator in some species. The fish liver is a large structure and is located in the cranial coelomic cavity. The normal color of the liver should be red-brown; however, yellow, fatty livers are a common finding at necropsy. This finding is often the result of diets rich in fats and protein.

The fish kidney is a single structure that is comprised of two segments: anterior and posterior. The kidney is located dorsal to the swim bladder along the body wall. The fish kidney serves as both an osmoregulatory and a hematopoietic organ. The anterior kidney and the interstitium of the posterior segment serve as the primary sites for blood cell and immunoglobulin production in fish, as these animals do not have bone marrow. The posterior kidney primarily regulates electrolyte and urine output. Fish that are found in saltwater *(hypertonic)* environments tend to lose water and absorb salts.

A



B

Figure 4-10 **A,** Healthy gill. **B,** Abnormal secondary lamellae. The secondary lamellae are the site of gas exchange and ammonia excretion in fish. Damage to these gills can result in reduced gas exchange, ammonia excretion, and death. (Courtesy Dr. Wes Baumgartner.)

To prevent dehydration, these fish must drink water and excrete excess electrolytes, such as sodium and chloride, through the kidney and gills. Fish that live in freshwater *(hypotonic)* environments constantly absorb water by osmosis. To prevent overhydration, freshwater fish excrete large volumes of dilute urine.

HUSBANDRY

Environmental Considerations

It is easy to recognize aquatic facilities (institutional or pet retail) that have the most disease problems on the basis of their appearance. There is usually an accumulation of trash, dirty exhibits, dead animals, and a general "unhealthy" appearance to the collection. This does not mean that a "clean" facility is free of disease but that they traditionally have fewer and less severe outbreaks of disease.[5] The general husbandry and maintenance of the aquatic facility and ecosystems have a direct relationship to the overall health of the animals. Maintaining clean areas behind the exhibits and nonpublic areas is essential to good health practices.[3,5] The same can be said for retail aquarium facilities. Accumulation of feces, excess food, and detritus are predisposing factors to poor water quality and can serve as substrates for facultative pathogens. Cleaning and disinfecting seines, nets, buckets, and tanks are imperative to maintain a high-quality health program at a facility. A dynamic team effort is required to maintain a clean facility and healthy animals, but a clean facility will pay dividends by providing a safer workplace, reduced disease incidence, increased production, and generally healthier fish.

Given ideal environmental conditions, ecosystems require a certain amount of space to fully develop, though quantitatively how much space is a debatable matter. Generally, to place an ecosystem in a very large aquarium or other holding space is not a major ecologic problem, although it might be considered an engineering endeavor. The difficulty arises when veterinarians attempt to scale down and include many components in a much smaller space than which would normally occur in the wild. To miniaturize an ecosystem and place it into a small space for observation, education, or research, veterinarians are immediately faced with a major dilemma, which is to scale the miniature so that it can still function as a reasonable facsimile of the wild ecosystem. This question is intimately related to the entire problem of how veterinarians affect wild environments and how they restore them, as well as how they construct their aquaria.[5,6]

Creating an Aquarium

There is little biologic reason for the traditional "box type" aquarium shape; however, the common reason for its existence is associated with availability and mechanical, aesthetic, and economic convenience (Figure 4-11). For many scientists and aquarists, the ease of purchase and setup of a ready-made tank outweighs all other factors when a water-based system is desired.

The presence of tank walls that can support benthic communities or allow excessive light is undesirable. A weakly translucent cylindrical tank that minimizes attachment surface for a given volume and has a rotating, cleaning mechanism to keep

A

B

Figure 4-11 Historically, all fish tanks were rectangular **(A).** More recently, there has been a movement by commercial tank manufacturers to create new tank shapes (e.g., bow front tank) **(B).** These oddly shaped tanks do little for the aquatic ecosystem, and are primarily for aesthetics.

the surface free of sediment is highly desirable but very expensive.

For the hobbyist, aquarist, or scientist who wishes to construct an efficient model ecosystem, the materials (e.g., glass, plexiglass) are readily available to fabricate any shape or form of enclosure. Only after determining the ideal shape of the desired system, should one be concerned with the aesthetics, viewing, and construction of the aquarium.

TANK SIZE

Choosing the correct size of tank is an easy task. The main principle to remember is that bigger really is better. The smallest tank size we recommend is the commercially available 20-gallon tank (24″ × 12″ × 20″; 61 cm × 30.5 cm × 50.8 cm); however, the larger tanks provide an even more stable environment for fish. A larger tank also will offer the benefit of a much more liberal air-to-water surface area for the fish. However, with the advancements in life support technology today, it is possible to provide more than adequate life support to maintain large densities of fish in smaller aquaria while also maintaining a greater diversity of animals.[4,7,8]

TEMPERATURE

The term *tropical* places too much emphasis on the idea of "high temperature" for all exotic fishes. A number of these ornamental fish are not from the tropics, and quite a few from the tropics do not come from particularly warm water. It is important to recognize that a large number of exotic ornamental fish cannot thrive in cool, chilly water (<68° F or 20° C), because it affects their metabolic rate or immune function; other species cannot thrive in extremely warm water (>86° F or 30° C), because they need more oxygen than the water has the ability to carry. There is no exact degree of heat that is best suited to each species. Most fish tolerate a 10° F fluctuation over time and can stand a 5° F change in a short period of time (e.g., minutes) without consequence.[4,5] It is almost impossible to find a place in nature where the temperature falls into the controlled ranges that veterinarians try to achieve in the captive environment, and it would be reasonable to believe that temperature changes can be beneficial and stimulating to the animals. In practice, the aquarium environment should be geared toward the temperature needs of the species of fish that will inhabit the aquarium. It is best to create fish communities from similar ecosystems and attempt to maintain the temperature range as close as possible to the native waters of those particular species. Temperature changes will occur, but if they occur within the basic guidelines mentioned previously, these changes will be beneficial to the well-being of the animals.

FILTRATION

In nature, the waste products produced by fish are diluted into the vastness of the body of water and carried away by flowing water, reducing the potential dangers to fish. In closed systems (e.g., home or public aquarium), wastes and toxins can accumulate to levels that are harmful to fish. To avoid this problem, closed systems must be managed using some form of filtration. There are three primary types of filtration: mechanical, biologic, and chemical. These different filtration mechanisms work independently of one another and can be used in combination.

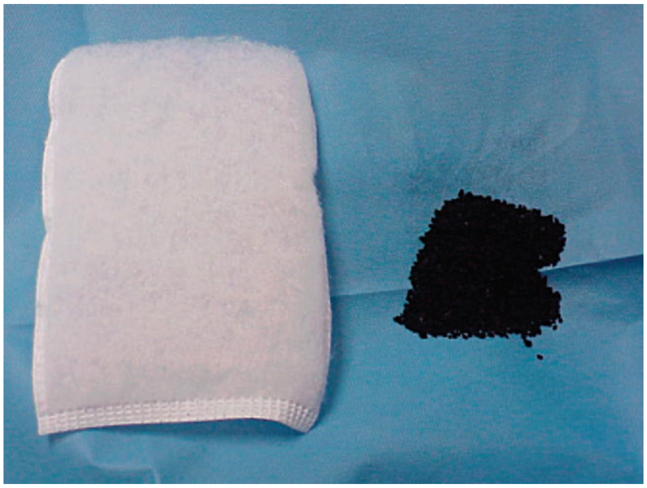


Figure 4-12 Mechanical filtration is used to remove detritus from an aquatic system. This type of filtration can be combined with the other methods to improve the overall water quality in a system. For example, this power filter cartridge is comprised of floss (mechanical) and carbon (chemical). Once in the system, it will also be colonized with nitrifying bacteria (biologic).

Mechanical Filtration

Mechanical filtration represents one of the original forms of filtration used in the home aquarium. This type of filtration removes organic debris from the water by passing it through a filter material (e.g., floss, fiber, or paper cartridge) (Figure 4-12). The amount of filtration that can be accomplished using this type of filter depends on the type and size of the filter material and rate that the water is recirculated through the filter media. A densely packed fiber or small pore size will restrict the size of waste that can pass the filter media, resulting in less waste in the aquarium. Maintenance of these filters requires cleaning or replacement of the floss or cartridge. Mechanical filtration remains an important method of filtration in home aquaria, outdoor ponds, and public aquaria. This type of filtration is best used with other types of filtration (biologic or chemical) to improve the overall quality of water in the system. When a series of filters is used inline, it is best to place the mechanical filter first. This ensures that the heavy organic material will be removed before contaminating or clogging the other filters (e.g., chemical or biologic-sand filter). Mechanical filtration does have limitations; for example, it is not effective in trapping finite particles or chemicals.

Biologic Filtration

Ammonia is the primary end product of protein catabolism in fish. In a closed system, this waste product can be fatal to fish. It was the advent of biologic filtration that led to our ability to maintain large densities of fish in small volumes of water.

Figure 4-13 Biologic filtration is essential to maintaining fish in closed aquatic systems. There are many different ways to increase the overall surface area in a system to colonize nitrifying bacteria. This filtration method uses plastic balls as a surface for the bacteria.

Biologic filtration is the most common type of filtration used in the home aquarium and outdoor pond, and it comes in many different forms (e.g., under-gravel filters, bio-wheels, sand or bead filters, and wet-dry filters) (Figure 4-13). A biologic filter should be selected based upon the expected load on the system. If a large density of fish is going to be maintained in a system or the fish are going to be fed large quantities of food to ensure growth (e.g., aquaculture), then a large surface area for bacteria is needed.

The biologic filter is comprised of nitrifying bacteria. Although there are numerous types, the two most common genera discussed are *Nitrosomonas* spp. and *Nitrobacter* spp. *Nitrosomonas* spp. are important in denaturing ammonia, the primary waste product produced by fish, into nitrite. Both ammonia and nitrite are toxic to fish. *Nitrobacter* spp. are responsible for further reducing nitrite to nitrate.

Once an aquarium and biologic filter are colonized, the system becomes self-sufficient. However, there are several factors that can affect the function of a biologic filter, including temperature, oxygen content, and drugs/therapeutics. *Nitrobacter* spp. are not cold tolerant. Therefore, in outdoor ponds when the water temperature drops below 65° F (18.5° C), nitrite will not be converted into nitrate as rapidly. During those times when the water temperature may drop below 65° F, fish should be fed less food to reduce the load on the system. *Nitrosomonas* spp. and *Nitrobacter* spp. are aerobic bacteria. In the well-aerated home aquarium, oxygen levels are often adequate for the bacteria; however, in outdoor ponds, oxygen levels can become depleted on warm summer nights. To reduce the likelihood of biologic filter failure, it is recommended that outdoor ponds be aerated during warm, summer days and nights.

A biologic filter requires time to become established. The amount of time depends upon the temperature of the water and the organic load on the system. New systems should be started slowly, adding only a small number of fish at a time. Closely monitoring the ammonia, nitrite, and nitrate levels on a daily basis is strongly recommended for new systems. Commercial microbial products (Fritzyme; Fritz Industries, Dallas, TX) are available that can expedite the establishment of the filter by seeding the system with bacteria. Water samples, filter pads, or aquarium substrates from established systems have also been used to seed a tank. However, the addition of these products to a new system may lead to the introduction of potential fish pathogens.

Chemical Filtration

There are numerous types of chemical filters in the pet trade. Chemical filtration refers to those filters that remove toxic compounds by binding them or converting them into nontoxic substances. The original form of chemical filtration was activated carbon. Carbon serves as a nonspecific binding agent for a number of different substances. When the binding sites on the carbon are full, they no longer act as filters and need to be replaced or cleaned. Other forms of chemical filtration are more specific, such as the resins that only bind ammonia. There are other forms of chemical filtration, such as ultraviolet (UV) sterilizers and protein skimmers, that alter or trap compounds. UV sterilizers expose compounds to short wavelength light, altering their form and rendering them harmless. UV sterilizers can be used to control certain pathogens and algae. A UV sterilizer has a UV bulb encased in a waterproof sheath within a cylinder. As water passes through the cylinder, the water is exposed to UV light, which can alter the DNA or RNA of the organism. The amount of time that it takes for the water to pass the bulb and the bulb wattage determine the effectiveness of the UV sterilizer. A low-wattage bulb in a short cylinder will have little effect on pathogens. These systems have also been used with great success at controlling algae and pathogens in outdoor ponds. Protein skimmers trap proteins in bubbles so that they can be separated from the water and removed. Chemical filtration, in combination with mechanical or biologic filtration, can improve the water quality dramatically, creating a “healthy” environment for fish.

LIGHTING

Correct lighting for the aquarium system depends on several factors, including the quality of the light emitted from the selected light source. Full-spectrum lighting is preferred. This type of lighting provides the three primary light spectrums: ultraviolet, visible, and infrared. The various spectrums can be affected by water depth, with certain spectrums (e.g., ultraviolet) being removed in the epilimnion (upper water level). Another important factor is the function of the system. If the tank is going to house deep-water African cichlids, lighting becomes less important; however, if the lighting system is needed for a reef tank that is going to be stocked with corals, a significant quantity of high-quality full-spectrum light will be required. The primary disadvantages associated with excess lighting are algae overgrowth and overheating the water in smaller systems; otherwise, it is virtually impossible to have too much light in an aquarium system.[4] A 12 hour photoperiod is considered appropriate for most fish. For those individuals interested in breeding fish, the photoperiod should be lengthened to mimic a spring/summer season.

SUBSTRATE

Historically, aquarists have tended to ignore the substrate of an aquatic system, reducing it to a noninteracting element. In the aquaria of past decades, "clean," relatively inert gravel and under-gravel filters were used to provide environments for all but the most specialized natural situations. In nature, with the exception of gravel bottoms in relatively unproductive hard rock mountain streams or sandy beaches with sandstone composition, rarely is the substrate material neutral. In most aquatic and marine environments, soft substrates are rich in organic reservoirs and harbor a myriad of important invertebrates and microbes that support rich plant growth. Limestone substrates control water chemistry, and reef corals and rocks determine the very character of the organisms growing on the surface of the reef. The interest in so-called live rock in coral reef tanks in recent years is beginning a tendency to replace sterile environments with live ecosystems. The addition of "trickle trays" with calcium carbonate pebbles also shows a developing interest in further elucidating the carbonate cycle and control over the pH. Conversely, acid, black water streams are most likely to occur in granite or sandstone areas where the natural acidity of the rain and tannic acid from the forest litter cannot be neutralized. To recreate this environment, the aquarist is advised to use hard rock and silica sand. Coarse sand or gravel is perhaps the most difficult of benthic environments for organisms to adapt to, and within sand and gravel habitats there are relatively few common species. In a stream or small lake that is not large enough for significant wave activity, or in a bay or coastal lagoon along a sandy coast, the sediment becomes progressively finer from gravel, to sand and silt, to a soupy, silty-clay mud substrate. To remain sand, the bottom must stay in constant motion; therefore, special adaptations are required by any organism to adapt to it. Even bacterial numbers tend to be limited in sand and gravel because their organic substrates are often washed out.[9,10] It can be difficult to maintain a sandy, shore style substrate in a closed, captive system, as it can have a rather long profile in the energy regime required to maintain the sand. It would be impossible to recreate a wave-break, sandy scenario within a miniature system unless the benthic community is the only one desired.

Traditionally, the general approach to filtration followed by most aquarists was to avoid the natural detrital processes in an aquatic system and to keep bacteria in filters that mimicked the benthic community. However, in a filter, the variety, density, and capability of the bacteria are limited. Thus, aquarium procedures of the past have tended to short-circuit the natural cycling processes, which resulted in the loss of valuable energy to the many members of the community. Aquaria that do not have a fine sediment component should have a separate sediment trap that can be partially drained of sediment, especially if it is intended to drive a system faster than normal for scaling. For the aquarist, fine sediment bottoms should not be ignored. Given their full reign, with the proper environment and biota available, they can be important buffering systems and provide necessary stability for a healthy environment.

ACCESSORIES FOR AQUARIA

There are a myriad of commercial accessories available for aquaria today. These accessories range from simple items, such as heaters and aeration devices, to some of the most advanced biotechnology available in the field, such as chillers and wave machines. Most commercial accessories available on the market are well made, and the deficiencies have been minimized over the years. When choosing a particular item, selection should be based on function not brand. For example, with a heater, it is important to match the wattage of the instrument to the volume of water to be heated, taking into account the general temperature required for the environment in which the aquarium is to be located.[4] There are several types of heaters available, including basic submersible heating elements, solar units, flow through units, or a combination of similar systems.

Water filtration units should be selected based on desired type of filtration, the volume requirements of a particular system, and its intended use. For example, a sand filtration unit should be selected on the basis of the volume of water to be used, the turnover rate expected for that volume of water, and the frequency with which the sand filter must be backwashed. Sometimes it is preferable, if not necessary, to combine several methods of filtration (e.g., under-gravel filtration in combination with sand filtration and power filtration). This enables the water to be "cleaned" using multiple methods. The use of multiple filters inline is particularly important in a public facility where a large water volume and bioload are used.

Most saltwater aquaria utilize some form of ozonator in combination with a protein skimmer. Protein skimmers utilize the age-old technology that has been used by sewage treatment plants for years: Minute air bubbles are passed through water with a high organic waste content, and the protein is captured and trapped as foam at the surface of the water. The greater the degree of organic pollution there is, the more stable the foam will be. The skimmer collects the foam, and the foam is then collapsed to a liquid and removed from the aquarium without tainting the water.

WATER QUALITY ANALYSIS

The aquatic environment is a very complex system that is subject to constant physical and chemical changes. A water-assessment program should be devised for monitoring an aquatic ecosystem. Many factors need to be taken into consideration when designing a water quality monitoring program, including the volume of water in the aquarium/aquaria, the number and type of animals that will be present, the type of life support system, and the period of time the aquarium has been set up. Ideally, a water-assessment program should be established before designing and setting up a system, keeping in mind that most of the water quality analysis is done to keep its inhabitants healthy.[8]

Water testing should be done daily for new aquaria until the system has cycled. When collecting a water sample, it is important to collect a mid-water sample, as samples closer to the surface or substrate will reflect more extreme values.[2,3] Portable water analysis kits use premeasured reagents and simple analytic methods that may compromise the degree of accuracy. However, they are suitable for most private aquarists and small backyard ponds. Most large, public aquaria use more advanced analytic methods, such as mass spectrometry, saturometers, and sophisticated chemical analysis, for evaluating water quality. The acquisition and utilization of many of these processes and techniques are beyond the scope of what most private aquarists can afford. Commercial water quality laboratories can perform a complete water analysis for a modest price, and it may be a good idea to submit a sample to a laboratory for a baseline measurement. This method also offers the added benefit of comparing standardized values with the parameters derived from veterinarians' own testing methods.

Water quality is very important to the health of a fish, and poor water quality can prove fatal. There are two types of systems that can be used: open and closed. In open water systems, the water in the aquarium is continually replenished using a fresh water source. An individual who lives near the ocean may collect seawater for a home aquarium, although that is not recommended because of potential contaminants in the water. Open water systems are rarely used because they are labor intensive and require regular exchange of the entire system. The majority of home aquaria utilize closed recirculating systems, which recirculate the same water over and over again using a filter. In the closed system, fresh water is added only after evaporation or at the time of a water change.

Ammonia, Nitrite, and Nitrate

Ammonia is produced in fish as an end product of protein catabolism. This waste product is primarily excreted via the gills, although some excretion in the feces also occurs. Ammonia is also generated in the aquatic system from the breakdown of uneaten food and detritus. Ammonia nitrogen can occur in two forms: ammonium (NH_4^+) and ammonia (NH_3). Ammonia is the more toxic form for fish.[11] The relative concentration of each form varies with pH and water temperature.[12] Ammonia is soluble in water, and minimal amounts are lost through evaporation. In a closed system, such as an aquarium or backyard pond, ammonia levels can build up to toxic quantities (>1 ppm). Even low levels of ammonia can be toxic to the gills and skin, resulting in increased susceptibility to infections. Fish suffering from ammonia toxicity appear irritated, gasp at the water's surface, and rub against rocks in the aquarium as a result of the irritation caused by the toxin. Ammonia levels should be monitored closely in closed systems, especially those with high fish densities. Testing for ammonia should be done weekly using a standardized commercial test kit, which is available at local pet retailers. In an established system, ammonia levels should be zero. If the ammonia levels begin to rise, then the system should be reevaluated. Overfeeding and overstocking an aquarium can overburden the biologic filter. Severe temperature fluctuations and insufficient oxygen levels may also result in a significant loss of the biologic filter. This is especially common in ponds that have significant summer algal blooms. New systems require time to become established, and new fish should be added gradually to prevent an overload of the biologic filter.

Because ammonia is a common waste product in the aquarium, most problems can be prevented by limiting the numbers of fish in the aquarium and regulating the amount of feed being offered. A general rule of thumb for feeding fish is to only offer what they can eat in a 2- to 5-minute period. In cases where ammonia levels are creating problems, the first recommendation is to remove 25% to 50% of the water from the system and replace it with fresh, dechlorinated water. There are commercial products available that can chelate the ammonia source, but they are only a temporary solution. The primary cause of the elevated ammonia levels must be diagnosed and corrected.

Ammonia is a colorless, odorless substance that can cause significant mortalities in a home aquarium. Most inexperienced aquarists tend to single out infectious diseases when they experience fish losses; however, poor water quality (e.g., excessive ammonia or nitrite) is often a primary/secondary cause of mortalities in these animals and should be tested on a regular basis.

The nitrogen cycle eliminates ammonia by converting it to less toxic compounds. The first step in the cycle is to convert ammonia to nitrite. *Nitrosomonas* spp. are the primary bacteria associated with this process. Unfortunately, nitrite is also toxic (>0.1 ppm) to fish and can be rapidly absorbed across the gills. Affected animals may develop a methemoglobinemia and have a characteristic "brown blood." This blood dyscrasia leads to reduced erythrocyte oxygenation and respiratory compromise. Fish with nitrite toxicity may behave similarly to fish with ammonia toxicity, and be found gasping for air at the water surface and die suddenly. When fish show clinical signs associated with nitrite toxicity, they should be removed from the toxic water and placed into a fresh, dechlorinated, well-oxygenated system. A significant water change (25%-50%) should be made in the original aquarium or pond and the biologic filter reestablished. Salt can also be used to diminish the toxicity associated with salt.

The second step of the nitrogen cycle occurs when *Nitrobacter* spp. oxidizes nitrite to nitrate. Nitrate levels less than 0.5 ppm are generally regarded as safe; levels less than 5.0 ppm are associated with stress and may predispose fish to opportunistic infections; levels greater than 10 ppm are considered toxic for some species. Reports of nitrate toxicity are rare in freshwater and saltwater fish, but at elevated levels they may be stressful and predispose the animals to opportunistic pathogens. Nitrate is utilized by plants and algae as a food source. Nitrate can be removed from an aquatic system by performing regular water changes.

Ammonia and nitrite levels in an aquatic system may rise soon after treatment of the water with antibacterial compounds or a reduction in water temperature. Antibiotics added to the water are nonselective and may kill both pathogenic and commensal organisms. If these compounds kill enough of the bacteria associated with the biologic filter, then oxidation of ammonia and nitrite may stop. *Nitrosomonas* spp. are more temperature tolerant and will recolonize before *Nitrobacter* spp., so ammonia levels should be expected to decrease before nitrites. Therefore, elevated nitrite levels are often detected soon after a reduction in water temperature.

"New Tank" Syndrome

"New tank" syndrome is a common occurrence with beginner aquarists and primarily occurs when fish are overstocked in a new aquarium. If large numbers of fish are added to an aquarium, and the biologic filter is not established, the system will be unable to eliminate the ammonia produced by the fish. In most cases, the owners report an acute mortality event with clinical signs consistent with ammonia and nitrite toxicity. These problems can be prevented if the new owner is patient and realizes the importance of providing a break-in for the filter (4-6 weeks). Fish should be stocked gradually, usually one to two fish per week. A standard rule of thumb for a freshwater stocking density is 1 to 1.5 inches of fish per gallon of water; in saltwater systems, the stocking density should be 2 to 2.5 inches of fish per gallon of water. With the advent of new filtration systems, stocking densities will continue to increase; however, if the filter becomes compromised or fails, the results would be disastrous.

Oxygen

In the aquatic system, oxygen diffuses into water at the surface when the surface tension of the water is broken. For home aquaria, this occurs regularly when external filters are used that "drop" the water back into the tank like a waterfall or when airstones are used. The amount of available or dissolved oxygen (DO) within the system can be measured using special equipment. In most cases, a DO greater than 5 ppm is sufficient to maintain fish. For the home hobbyist, oxygen depletion is generally only a major problem with outdoor ponds during the summer months. During the day, plants produce their own food (photosynthesis) by removing carbon dioxide from the water and using energy produced by the sun. As plants make their food, they release oxygen into the water. During the night when plants or algae cannot undergo photosynthesis, they actually consume oxygen. In ponds with a large number of plants or algae, the oxygen levels in the water can fall to dangerously low levels (<3 ppm) for the fish. Another factor that may affect oxygen levels in the water column is temperature. Oxygen is lost to the atmosphere more rapidly in warm water than cold water. The use of aerators or fountains, especially at night, will help maintain adequate levels of oxygen in a pond.

Water pH

The pH of water is measured by taking the negative logarithm of hydrogen ions in the water. In simplest terms, pH can de divided into three categories: acid, neutral, and basic. The range of pH values fits on a scale of 1 to 14. Values below 7.0 represent acidic water, values between 7.0 and 7.9 are neutral, and values above 8.0 are basic. The pH in most aquaria and ponds should fall between 6.5 and 8.5. In the extreme ranges (<4.0 or >10.0), water would be so acidic or basic that it would burn the fish. This means that the difference between 7.0 and 8.0 is much more significant than expected, because the pH values are based on a logarithmic scale. Therefore, if the pH is allowed to fluctuate, fish will become stressed and more susceptible to disease. The pH of natural bodies of water varies based on the substrate, water shed, and other environmental factors. Fish from Central America and South America thrive in water that is neutral or slightly acidic, whereas fish from Africa and Asia thrive better at neutral to alkaline water.

Water should always be tested before replacement into an aquarium. There are a number of factors that may affect the pH in an aquarium or pond, including the biologic filter, fish density, vegetation, and algae. Biologic filtration actually produces acid when ammonia is converted into nitrite. If the water has a low buffering capacity, and the aquarium or pond biologic filter is converting a large amount of ammonia, the pH could become very acidic. Fish produce carbon dioxide (CO_2) as a waste product. When an aquarium or pond is heavily stocked with fish, the amount of CO_2 can build up in the water. Carbon dioxide promotes acid production and can actually decrease the pH (acidic). Plants and algae, which use photosynthesis during the day to make energy, utilize CO_2. However, at night, plants and algae utilize oxygen (like fish) and expel CO_2 as a waste product. In a system with a large number of plants and a large amount of algae, the pH can drop to a dangerously low level. Fish die-offs in ponds are often associated with high CO_2, low pH, and low oxygen levels. When plants or fish die, they also release compounds that can lower the pH. To prevent this from becoming a problem, always immediately remove dead fish or plants.

Chlorine

Chlorine is an elemental gas that is added to municipal water as a disinfectant. Unfortunately, chlorine is also toxic to fish. Fish that are exposed to chlorinated water can develop life-threatening respiratory distress. Chlorine readily crosses the gills of fish and blocks the animal's ability to absorb oxygen. Fortunately, chlorine can be removed from the water by allowing it to de-gas for 48 to 72 hours or by adding a dechlorinator (e.g., sodium thiosulfate). Chlorine levels in municipal water can fluctuate with the season; thus, questions about the timing or the amounts of chlorine that are being added in a specific municipality should be directed to the local water company. Chlorine levels in a water sample can be tested using a commercial test kit purchased from a local pet retailer.

Chloramine

Chloramine represents another disinfectant that is routinely added to municipal water for sterilization purposes. Chloramines are a combination of chlorine and ammonia. Commercial dechlorinators can still be used to remove the chlorine from this molecule, but they do nothing to the ammonia. Because ammonia is toxic to fish, it is important that levels of this compound do not reach levels greater than 1 ppm. Fortunately, a functional biologic filter will prevent this from occurring.

Hardness

Hardness measures the quantity of divalent cations (e.g., calcium and magnesium) in the water. In natural waters, the divalent ions are derived from the limestone, salts, and soils. The general range for hardness in freshwater systems is 0 to 250 mg/L, whereas in saltwater systems, hardness can exceed 10,000 mg/L.[13] The divalent cations that represent hardness, calcium and magnesium, play an intricate role in water quality conditions. Calcium can alter osmoregulatory function in fish during times of low pH or elevated ammonia.[13] Calcium and magnesium are both important for growth and development in fish fry.[14] These minerals can also protect fish against heavy metals by competing for gill absorption sites. Copper is routinely used to treat parasites. Calcium and magnesium compete with the copper for absorption sites, reducing the effectiveness of the copper. Distilled water should never be used to replenish water in an aquarium because it is deficient in these essential cations.

Alkalinity

In natural aquatic systems (e.g., lakes, ponds, rivers, streams), fish are exposed to a relatively stable pH because of buffers. The most common buffers in aquatic systems are bicarbonate (HCO_3) and carbonate (CO_3^{2-}). Other buffers that may occur in water in lesser amounts include hydroxide (OH^-), silicates, phosphates, and borates. The quantity of buffers within a system depends upon the source of the water. Some municipal water supplies contain relatively low concentrations of buffers, whereas others may have large concentrations. In cases where the water has a low buffering capacity, commercial buffers can be purchased from a local pet store and added to an aquarium to create a more stable pH.

Total alkalinity can also play a protective role against potential heavy metal toxins. Heavy metals (e.g., copper and lead) in the water can be absorbed at the level of the gills, build up to toxic levels, and lead to the eventual death of an affected fish. Bicarbonate and carbonate can protect against heavy metals by chelating them in the water, rendering them harmless. This is important to remember when treating fish with nonchelated copper. If the alkalinity is high, the nonchelated copper may be bound and rendered useless.

MONITORING WATER QUALITY

New Tanks

Water should be tested daily for ammonia, nitrite, nitrate, and weekly for pH, alkalinity, and hardness. Testing should continue until the parameters show a consistent pattern. Allow 4 to 6 weeks for the biologic filter to become established. Only one to two fish should be added at one time to ensure that the biologic filter is not overloaded. If municipal water is being used, it is important to test it regularly to ensure that there is no major fluctuation in the various water quality parameters, especially chlorine and chloramines.

Established Tanks

Routine water changes are important to maintaining a healthy closed aquatic system. Approximately 10% to 20% of the water should be changed every 1 to 3 weeks. The frequency of the water change will ultimately depend on the load placed on the system. For example, smaller aquaria and highly stocked aquaria should have their water changed more frequently. Routine monitoring of the water (e.g., ammonia, nitrite, nitrate) is an excellent way to determine whether the frequency of water changes is sufficient for a system.

NUTRITION

Providing appropriate nutrition and good quality water are probably the two most difficult aspects of maintaining a successful aquarium. Because there are hundreds of different fish species in the aquarium hobby, ornamental fish nutrition is an art and a science that must be approached systematically and holistically. Examining species-specific anatomy and natural history are useful starting points.[15] Food fish research can be used to provide fundamental nutritional information, but food fish are not ideal research models for all confined species.

Dietary Requirements

Information on the nutritional requirements of many ornamental fish is still relatively unknown, as compared to the nutritional requirements of many cultured food fish. Examining the nutritional value of a diet being fed to confined fish, and comparing it with known nutritional requirements of the fish, can assist in the diagnosis of malnutrition related to disease processes.[15,16]

Natural diets of most fishes are rich in protein. The gross protein requirement for those fish in which the requirements have been established range from 25% to 56%. However, just measuring the protein quantity is not enough, as the protein quality, digestibility, and amino acid availability also must be considered to ensure that the protein content of a prepared ration is sufficient to meet the needs of the species being fed. Dietary fats represent a significant source of energy for fish. Phospholipids and steroid components of visceral organs rely on dietary lipids to synthesize specific fatty acids that are essential for health and growth. Optimal levels of dietary fats for ornamental fish have not been established at this time. Fish digest carbohydrates at a lower rate than do higher vertebrates. Natural diets of carnivorous fish are generally lower in carbohydrates. These fish utilize proteins and fats more efficiently than carbohydrates.[5,6,15,16] The carbohydrate molecular structure of prey species influences the digestibility of the feed stuff in carnivorous fish. Excess digestible carbohydrate in the diet of fish can increase blood sugar, liver glycogen storage, and liver mass, sometimes to pathologic levels.[6,17]

Little or no energy is expended by most fish to maintain their body temperature or position in the water, as the normal body temperature for most fish is about the same as the environmental temperature.

Vitamins essential to the survival of ornamental fish must be supplied in sufficient quantities and intervals to provide the minimum requirements for that particular fish species. Diets specifically formulated for ornamental fish should attempt to

Figure 4-14 Foods depicted here represent only a sample of the commercially prepared foods that were available during a visit to a local aquarium store. It is important that veterinarians working with these animals carefully read the nutritional analysis and ingredient lists of these foods to determine their value for a specific population of fish.

incorporate a minimum quantity of essential vitamins (e.g., water soluble and fat soluble) and trace minerals. Veterinarians working with these species should make a habit of reading the nutritional analysis and ingredient lists of these diets (Figure 4-14). Ingredient lists should include natural components of the fish's diet. For example, fish meal would be an important ingredient for piscivorous fish, whereas cornmeal would not. Vitamin deficiencies may result in well-defined disease syndromes, with the possibility of high mortalities. Even partial deficiencies may result in increased susceptibility to disease.[16] Information on the quantitative vitamin and trace element requirements of specific species of fish that have been studied is often used to extrapolate dietary vitamin requirements for other fish that have a similar physiology.[3,6,18] Fish require the same mineral elements as higher animals, and each mineral has a similar function. Although dietary sources of vitamins and minerals are important for fish, their aquatic medium can also serve as an important source of the essential nutrients. This is especially true for fish fry. When fry are raised in water with a low hardness, they can develop calcium and magnesium deficiencies. Marine fish maintained in synthetic seawater can develop signs of hypovitaminosis or mineral deficiency because of a reduction or complete lack of vitamins and trace elements in the water. Routine diet and water analysis can alleviate problems associated with hypovitaminosis and mineral deficiency by monitoring for, and correcting, any deficiencies before the deficiencies become apparent in the fish.

PREVENTIVE MEDICINE

Preventive medicine is the concept of instituting preemptive measures for raising animals under conditions that optimize growth rate, feed conversion efficiency, reproduction, and survival, while minimizing problems related to infectious, nutritional, and environmental diseases.[3-5] In an aquatic environment, there is a profound and inverse relationship between environmental quality and the disease status of the fish. As environmental conditions deteriorate, severity of infectious diseases increase; therefore, sound health maintenance practices can play a major role in maintaining a suitable environment where healthy fish can be raised. The application of preventive medicine programs is a positive concept that aids in disease prevention, emphasizes interruption of a disease cycle, and results in healthier, more productive animals. Its goal is to improve the health and well-being of animals that appear to be healthy. This is accomplished by several means, which include, but are not limited to, quarantine; routine diagnostic testing; and prophylactic treatment with dips, immersion baths, and/or parenteral treatment at acquisition and before release from quarantine. It also requires routine examination and review of acquisition and accession protocols. If sound health management and preventive principles are followed, the animals will be more productive and in better health.

Quarantine Essentials

An essential part of any preventive medicine program is a good quarantine system. All animals should be quarantined regardless of point of acquisition. However, the requirements for the length of quarantine may vary to a great degree. For example, wild-caught animals require a longer period of quarantine than captive-reared species. It makes sense that animals in the wild would have a much greater chance of being exposed to parasites and infectious diseases. Although there may be significant differences in protocols, a typical plan might recommend isolating animals in a clinical system for a minimum of 30 to 45 days. Before introducing fish to this clinical system, the animals should be closely examined and treated for external and internal parasites.

Stress plays a major role in the mortality rates of recent acquisitions. Fish can experience stress due to handling, transport, poor environmental quality, overstocking, mismatching species, and exposure to disease. The stress response exhibited by fish can cause several physiologic changes, resulting in an increased susceptibility to disease. Fish experiencing physiologic stress can have elevated corticosteroid and glucose levels, which can result in a depression of the immune response and increased susceptibility to disease. Most quarantined animals will show signs of disease shortly after transport in direct response to elevated stress levels. Some animals are more resistant than others in responding to the aforementioned stimuli and will not require any further attention. Animals that are showing clinical signs of disease should be treated accordingly.

Before release from quarantine, all animals should receive a second physical examination and series of diagnostic tests. Animals should only be removed from quarantine if they are found to be normal on examination and if the diagnostic tests are negative. We usually treat fish with a final immersion bath before introducing them into the resident population of the aquarium. This is a final step in reducing the likelihood of introducing pathogens into a display exhibit or home aquarium.

Preventive Measures

A preventive health maintenance program should be in place when an aquatic facility opens or when the home hobbyist acquires numerous aquaria. Health issues should be addressed on a daily basis, not just when a problem arises. When problems are encountered, a treatment regime should be implemented that identifies a short-term resolution to the problem with a long-range plan in mind.[3] Often a chemical can be added to the water and/or feed, which will result in a positive response and cessation of mortality. The effect of these treatments may be temporary, however, and disease may recur unless a commitment is made to seek and eliminate all predisposing factors.[5] The list of possible therapeutics can be found in Table 4-1. Although preventive health maintenance is important in controlling fish disease, it is not a "cure all." Some fish diseases are less preventable through environmental management than others, and for some there is no prevention or treatment at all. However, there is a large arsenal of treatments that are currently available and quite effective (see Table 4-1). No health maintenance program is perfect, but emphasis on disease prevention is well worth the effort.

Routine Examinations

The handling of aquatic animals both in and out of their natural environment almost always creates great difficulties. Struggle during capture, and even minimal handling, can have adverse effects on both the physiology and behavior of these animals. Consequently, it is often necessary to immobilize or chemically restrain animals for routine examination. For some procedures sedation may be necessary to eliminate or at least minimize stress or physical harm to the animal. Always determine before a procedure whether the benefit of the procedure outweighs the risk involved.[19] In many cases, a simple visual inspection of the animals is sufficient. For example, it might be beneficial to visually inspect small, schooling fish as a group to gain information about their general health.

RESTRAINT

Gross physical damage is a major concern when handling aquatic animals. The skin of a fish is very thin and easily damaged. There are also many delicate external appendages (e.g., fins) that may be easily damaged. This is a factor that is often overlooked, especially when the procedures are brief and the clinician believes it is void of consequences. In theory, if performing anything other than a visual inspection, sedation is advised.[3,19]

Manual Restraint

Manual restraint may be utilized if certain precautions are taken. It is feasible to move smaller animals with little or no direct contact with their skin. Nets, seines, buckets, acrylic transport containers, and plastic sleeves are all viable options. Latex gloves should always be worn when there is a possibility of contact with the skin of aquatic animals. Bony fishes are extremely sensitive to contact with human skin, as are many species of aquatic invertebrates. Precautions should be taken to ensure that the latex gloves are thoroughly rinsed before having direct contact with the fish.

Chemical Restraint

An extensive range of drugs has been used for sedating and anesthetizing fish. However, describing all of the potential methods of aquatic animal restraint is beyond the scope of this chapter, and another text is recommended for that purpose.[19] Dose rates for sedating or anesthetizing fish can vary from one species to another, so it is important to be prepared for radically different dose responses from different species.

One of the most popular drugs used for fish anesthesia is tricaine methane sulfonate or MS-222 (Argent Laboratories, Redmond, WA). It is readily available, inexpensive, and very safe. MS-222 is an acidic compound and should be buffered (before use) to a neutral pH (7.0-7.5). A dose of 100 to 200 mg/L can be used for induction and 50 to 100 mg/L for maintenance. MS-222 can be conveniently stored as a 10 g/L (10,000 mg/L) stock solution.[20]

An alternative to MS-222 is eugenol, the active ingredient in clove oil. Eugenol is not completely soluble in water but may be diluted 1 : 10 in 95% ethanol for a 100 mg/ml stock solution. Eugenol produces similar effects to MS-222 at lower doses and can be administered at 40 to 100 mg/L (high end for induction, low end for maintenance).[20] One disadvantage associated with the use of eugenol is that it appears to have a narrower safety range.

There is very little information with supporting pharmacologic data on injectable anesthetics for fish; however, there has been some recent work in this area with selected species.

Transporting Fish to the Veterinary Hospital

Fish should be transported in a plastic, sealed container. The container should be used exclusively to transport fish and never reused to carry human food items. The container should be cleaned with warm, soapy water, and rinsed thoroughly after each use. Bleach should never be used to clean the container. The water used to transport the animal should come from the home aquarium. A separate container of aquarium water should also be brought to the veterinary hospital in case of spillage and for water quality testing. The fish should be transported immediately to the veterinary hospital. Special precautions should be made during the winter and summer to prevent water temperature fluctuations, such as preheating or cooling the transport automobile in the winter and summer, respectively. Signs of transport stress may not be apparent for several days after the move, so animals should monitored closely for 3 to 5 days following transport.[21]

TABLE 4-1 **Compounds Commonly Used to Treat Fish**

Drug	Dosage	Indication
Acetic acid	0.5-2.0 ml/L, 30 s, every other day ×4 treatments	Protozoa, trematodes, nematodes
Acyclovir	25 mg/L, daily ×15 days	Antiviral
Amikacin	5 mg/kg, IM, q24h	Bacterial diseases
Amprolium	10 mg/L	*Eimeria* spp.
Aztreonam	100 mg/kg, IM, ICe, q48h ×15 days	*Aeromonas salmonicida*
Chloramphenicol	50 mg/kg, PO, IM once, then 25 mg/kg, q24h	*Aeromonas salmonicida* in goldfish
Chloroquine	10 mg/L, indefinite	Protozoa
Copper sulfate	2.3-4.0 mg/L, indefinite	Algae control
Enrofloxacin	5-10 mg/kg, IM, ICe, q48h ×15 days	Broad-spectrum antibacterial
Florfenicol	40-50 mg/kg, PO, q24h ×10 days	Broad-spectrum antibacterial
Formalin	37% solution only, 0.04 ml/L ×1 h	Protozoa, mycosis, good aeration, continuous monitoring during treatment
Freshwater	3-15 min	Ectoparasitism, marine fish only
Furazolidone	20-60 ppm, continuous, indefinite	Antibacterial, inactivated by light
Hydrogen peroxide	17.5 ml/L, 10 min	Protozoa
Iodine	7% tincture	Wound rinse
Itraconazole	1-5 mg/kg, q24h in feed 1-7 days	Systemic mycosis
Kanamycin	750 mg/L, 2 h, 4 times daily	Bacteria
Ketoconazole	2.5-10.0 mg/kg, PO, IM, ICe	Systemic mycosis
Malachite green	0.1 mg/L, every 3 days ×3 treatments	Freshwater fish protozoa, mycosis
Methylene blue	3 mg/L, prolonged bath	Mycosis
Metronidazole	50 mg/L, ≦24 h	*Hexamita* sp., other protozoa
Miconazole	10-20 mg/kg, PO, IM, ICe	Systemic mycosis
Nalidixic acid	13 mg/L, indefinite	Quinolone, Gram-negative bacteria
Neomycin	66 mg/L, every 3 days ×3 treatments	Bacteria
Nitrofurpyrinol	2 mg/L, 19 h	Antiprotozoan
Oxolinic acid	20-30 mg/L, indefinite	Quinolone
Oxytetracycline	10-50 mg/L, 1h bath	Topical bacterial infections
Potassium permanganate	5 mg/L, 30-60 min	Mycosis, freshwater bacterial infections, toxic high pH
Praziquantel HCl	2 mg/L, 5 days, repeat in 2 weeks	Monogenetic trematodes
Quinine HCl	10 mg/L, 3 days	*Cryptocaryon irritans*
Ribavirin	20 mg/L	Antiviral
Sarafloxin	10-14 mg/kg, PO, q24h ×10 days	Fluoroquinolone
Silver sulfadiazine	Topical q12h	Topical bacterial treatment, 30-60 s contact time required
Sodium chloride	1-3 mg/L, indefinite	Osmoregulatory stress
Sodium thiosulfate	100 mg/L	Chlorine exposure
Sulfamethazine	100 mg/L, 1 h ×7 days	Bacteria
Toltrazuril	50 mg/ml, 20 min, once	*Trichodina*, *Apiosoma*
Trichlorfon	0.25-0.5 mg/L, q12h ×3, 24 h between treatments	Trematodes, crustaceans
Trimethoprim-Sulfamethoxazole	28 mg/L, 6-10 h	Broad spectrum antibiotic
Virazole	400 mg/L, indefinite	Antiviral

HCl, hydrogen chloride; ICe, intracoelomic; IM, intramuscular; PO, per os.

HISTORY AND PHYSICAL EXAMINATION

A physical examination on a fish should follow the same procedure used to perform a physical examination on any other terrestrial animal. The exam should always begin with a complete history detailing the animal's husbandry and health problems. For fish, it is important to have the client submit a water sample from the animal's aquarium for a complete water chemistry analysis as part of the examination.

History

The history, or *anamnesis,* is the first attempt the veterinarian has to identify and organize the potential problems facing fish and their aquatic environment. Many of the problems that lead to disease in fish are directly related to their environment. There are four key areas that must be addressed in the history: the owner's general knowledge, the aquarium environment, the water, and the fish. Questions regarding the owners' general knowledge of aquarium management should include the length of ownership, if there are multiple aquaria, where the fish were obtained, the time spent viewing the fish, and the weekly maintenance program. The history of the aquarium environment should include questions about tank volume, tank placement, tank top, lighting, heating, filtration, substrate, and aquarium decorations (e.g., plants, rocks, logs, and toys). Tank volume is important because it allows the veterinarian to determine the relative stocking density of the aquarium. The placement of the tank within the home may provide insight into problems associated with algal overgrowth (e.g., direct sunlight exposure) or toxins (e.g., cleaning sprays). Some fish owners do not cover their aquaria with a top. Tanks without tops experience faster evaporation and are more prone to fish losses because of jumping. There are a number of different lighting systems available for the home aquarium. Owners should be asked whether they have fluorescent or incandescent lighting, the bulb wattage, and the amount of time the lighting remains on during the day. Incandescent lights exert radiant heat and are associated with increased water temperatures. Fluorescent lighting, especially full-spectrum lighting, is preferred for live aquatic plant systems. Most aquaria are heated with thermostatically controlled heaters. Questions regarding heater usage (yes or no), type, and wattage size should be asked. Owners should also be asked if they use a thermometer, and if so, the temperature in the aquarium. Fish are poikilotherms and must be provided an appropriate environmental temperature. Because there are a number of different types of filters, questions should be asked to determine the types of filters, length of usage, and the owners' general knowledge of filtration. Information should be ascertained regarding the aquarium decorations, such as plants, rocks, logs, and toys. The addition of new, live plants may serve as an introduction of disease.

Most aquarium clients have a limited knowledge of water chemistry. Questions regarding water quality should focus on the source of the water, the frequency with which the water is changed, and the water quality tests that have been performed. Veterinary hospitals that work with ornamental fish should have water quality test kits and should perform the appropriate water tests during the visits.

The final series of questions should focus on the fish. Questions related to the types and numbers of fish, the problem the fish are being presented for, and the duration of the problem are all important. Detailed information regarding the diet of the fish, including specific types of foods being offered, frequency food is offered, and whether dietary changes have occurred, should also be asked. Finally, information related to the preventive health program, previous treatments, recent additions, and routine maintenance of the system (e.g., frequency of water changes) should be obtained.

BOX 4-1 Calculations Used to Estimate the Body Weight of Fish

(Number of fingerlings) × (initial weight of fingerlings) = Initial total fingerling weight

(Total pounds of feed fed) ÷ 1.75 (approximate conversion ratio) = pounds of gain

(Initial total fingerling weight) + (pounds of gain) = Current weight of fish

(Current weight of fish) ÷ (number of fish) = Average current weight of fish

Performing the Physical Examination

Fish presented to the veterinarian should first be visually inspected for physical and behavioral abnormalities. For a complete physical examination, the fish must be sedated. Once sedated, the animal may be weighed, measured, and examined for signs of external parasites. Box 4-1 provides a useful guide for estimating fish weight. While the fish is sedated, blood should be collected for analysis, biopsies of the skin and gills collected (if indicated), and a fecal sample collected. Radiographs and ultrasonography can also be performed at this time. A problem list should be made that prioritizes problems with regard to any immediate threat to life, primary disease considerations, and treatment options. An initial short-term plan for treatment should be identified and a long-term treatment and management plan developed.[3]

Common Abnormalities Found on Physical Examination

Sick fish often congregate, separating themselves from their healthier cohorts. Weak fish will often be found near a water outlet, skimmer box, or sump. They may also exhibit behavioral changes, such as staying near the surface if hypoxic, scraping their bodies because of external parasite infestation, and gill flashing. Color changes often occur in sick fish. Another common clinical sign observed in diseased fish is abdominal swelling, which is commonly found in fish with coelomitis regardless of etiology. Abdominal swelling may also be seen with morbidly obese fish, renal failure, and neoplasia. Abdominocentesis and cytology can be done to either confirm or rule out a diagnosis. Lesions of the eye, such as exophthalmia, are common in both infectious and noninfectious disease problems. Unilateral lesions often indicate a traumatic cause, whereas bilateral lesions are more typical of barotraumas or an infectious etiology. Cataracts are most often associated with either trauma or nutritional disease. Skeletal deformities are especially common in the vertebral column and are often seen in rapidly growing fish. Other skeletal lesions can be the result of a variety of disease entities, including infectious, nutritional, parasitic, and toxic insults.[3,6]

DIAGNOSTIC TESTING

Blood smears, fecal examinations, and skin scrapings should initially be reviewed in the veterinary hospital. With experience, the clinician will learn to identify many common problems with standard light microscopy. If detailed cellular or chemical analysis is required, it is best to collaborate with a commercial laboratory that is familiar with aquatic species and has specialized staining and culture capabilities. University and state aquatic diagnostic laboratories are also excellent resources for the aquatic animal veterinarian. Submitting specimens to specialized pathology services (Northwest Zoopath, Monroe, WA) for necropsy, histopathology, cultures, or special staining techniques should be considered when the clinician believes it is necessary or is beyond his or her level of expertise.

Special Diagnostic Tests

A gill biopsy can be performed to assess the gill status in animals maintained in poor water quality or to diagnose ectoparasites. Fish should be anesthetized for a gill biopsy to provide appropriate sedation and analgesia. MS-222 or eugenol can be used to anesthetize the patient. Once a fish is anesthetized, it can be removed from the anesthetic solution using a gloved hand and placed onto a dechlorinated, moist paper towel. A pair of fine iris scissors should be inserted under the operculum and gently lifted, enabling the handler to insert his or her thumb under the operculum to provide direct visualization of the gills (Figure 4-15). Iris scissors should be reinserted under the operculum and three to five gill filaments collected. The gill filaments should be placed onto a slide with 0.9% saline and reviewed under a microscope. Once that procedure has been completed, the animals should be recovered in dechlorinated, fresh water.

A skin scrape can be performed to diagnose pathogens on the surface of a fish. Once again, the animal should be anesthetized to reduce stress. The animal may be restrained by hand or placed on a moistened paper towel. A microscope slide should be placed on the skin at a 45-degree angle caudal to the operculum and gently dragged in a caudal direction (Figure 4-16). The fish should be recovered in dechlorinated water.

A fin biopsy should be performed to evaluate specific lesions on the animal's fins. A fish undergoing this procedure should be anesthetized. A pair of iris scissors should be used to cut a sample of the affected fin between the fin rays, if possible (Figure 4-17). The sample should be mixed with 0.9% saline

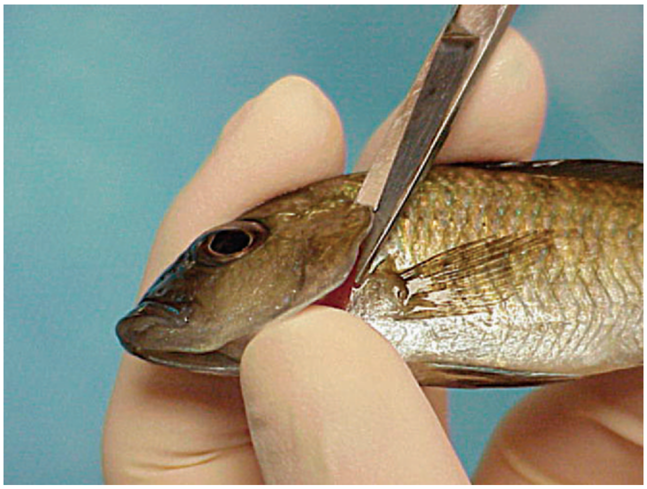


Figure 4-15 A gill biopsy can be used to collect samples to evaluate the condition of the gills. To collect the sample, insert a thumb under the operculum, expose the gills, insert a pair of iris scissors, and clip the gills.

Figure 4-16 A skin scrape can be done to collect samples to evaluate bacteria and ectoparasite burdens on the skin. To collect the sample, place a glass slide on the skin surface and pull it in a cranial to caudal direction.

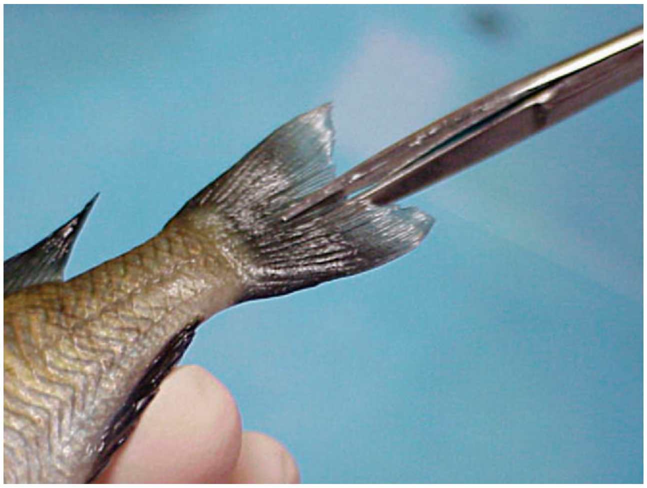


Figure 4-17 A fin biopsy can be used to assess fin lesions. To collect a sample, excise a piece of fin that includes both the lesion and healthy fin.

Figure 4-18 Blood samples can be collected from the ventral tail vein. This vein is located on the ventral aspect of the caudal tail vertebrae.

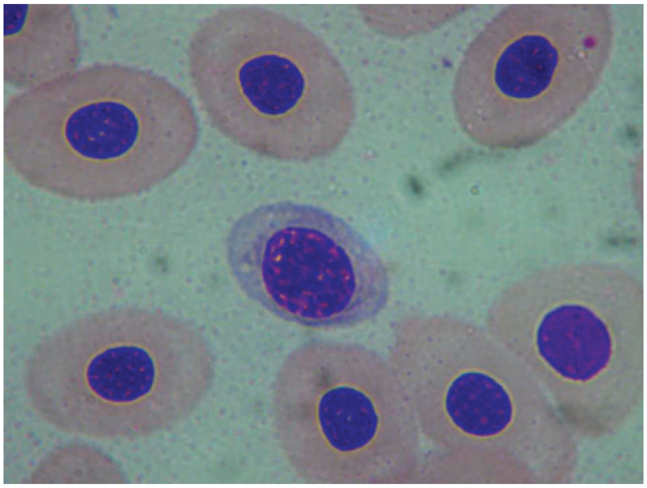


Figure 4-19 Mature and immature *(center)* erythrocytes from a bull shark.

on a microscope slide, covered with a cover slip, and evaluated under a microscope. The fish should be recovered in dechlorinated water.

Clinical Pathology

Fish have evolved to mask their illness; however, they can not hide abnormal conditions in their blood. Therefore, examining blood samples can provide insight into the general health of the animals, which might not otherwise be obvious on physical examination. The volume of blood that can be collected from a fish has been estimated to be similar to that of mammals, approximately 0.8 to 1.0% of the body weight.[2] Always preload the needle with heparin to prevent blood clotting. The primary site of venipuncture in the fish is the caudal tail vein, although the heart can also be used. The caudal tail vein is located ventral to the vertebral column and runs parallel to the spine (Figure 4-18). A 1-ml or 3-ml syringe with a 25- to 30-gauge needle is recommended for sample collection. The needle should be gently inserted at a 45-degree angle (between scales) into the caudal peduncle at the level of the lateral line and walked off the ventral edge of the vertebral column until a flash of blood is visualized in the needle. The blood sample from the caudal tail vein can also be collected from the ventral approach. The animal should be held in dorsal recumbency and the needle inserted in the ventral midline of the caudal peduncle at a 90-degree angle. The needle should be inserted to the level of the vertebral column and gently walked along the spine until a flash of blood is visualized.

The blood cells of fish are more closely related to lower vertebrates (e.g., amphibians and reptiles) than higher vertebrates (e.g., mammals). The erythrocytes of fish are oval shaped and have a pale cytoplasm and a centrally located nucleus (Figure 4-19). Fish leukocytes may be divided into two groups:

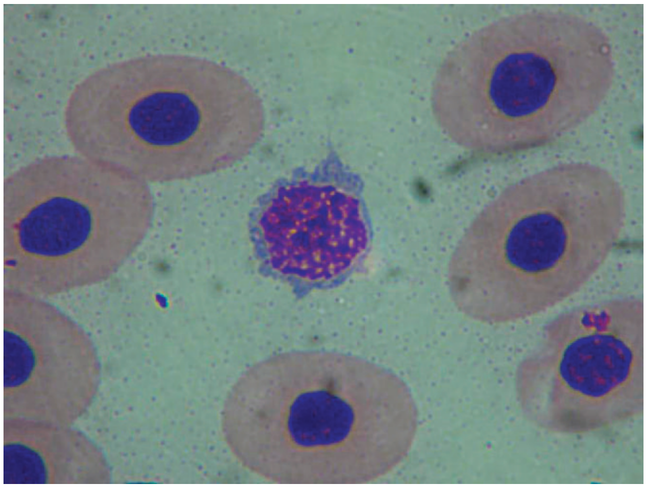


Figure 4-20 Lymphocyte from a bull shark.

agranulocytes (e.g., lymphocyte, and monocyte) and granulocytes (e.g., neutrophil/heterophil and eosinophil). Thrombocytes have a small nucleus and a spindle-shaped cell. These cells are analogous to platelets in mammals and are responsible for blood clotting. Lymphocytes are the most common cell type in fish and are morphologically similar to those found in mammals (Figure 4-20). Monocytes are the largest leukocyte and have a pale, blue-gray cytoplasm (Figure 4-21). Their primary role is to phagocytize pathogens and process the antigens for lymphocytes. Monocytes are commonly found with chronic inflammatory responses. Neutrophils/heterophils possess rod-shaped granules and are weakly phagocytic (Figure 4-22). These cells are primarily associated with acute inflammatory responses. Eosinophils exist in some species of fish, but their function is unclear (Figure 4-23). It is likely that they play some role in hypersensitivity and parasite control as in higher vertebrates. The existence of basophils is controversial.

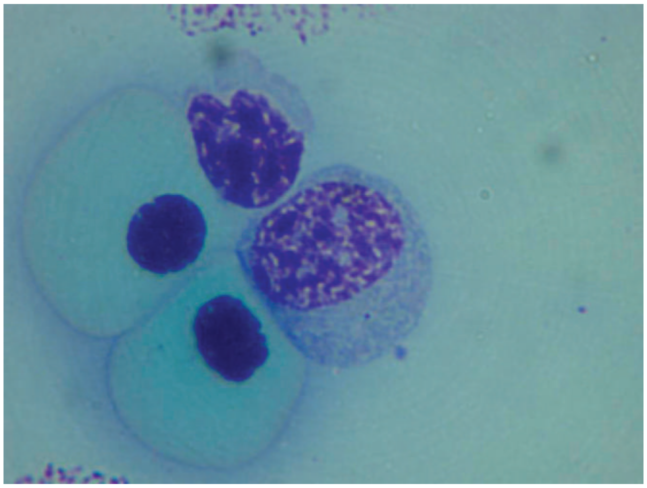


Figure 4-21 Monocyte from a bull shark.

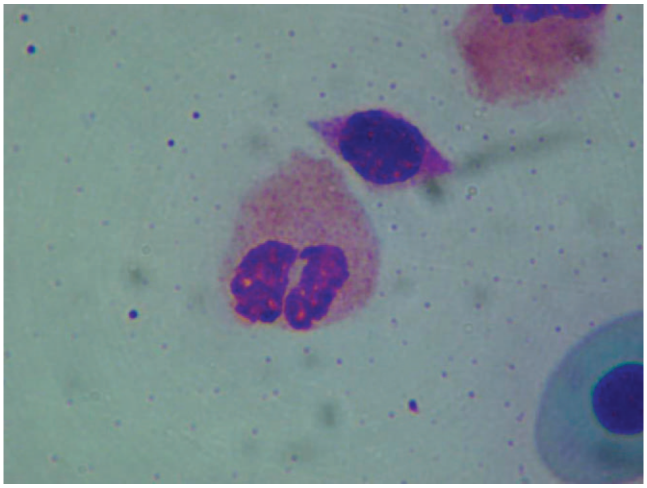


Figure 4-22 Heterophil from a bull shark.

Pathology

It is not intended that this chapter should encompass all aspects of pathology, as there are already many suitable medical and veterinary textbooks on this subject.[3,5,6] Many of the accepted clinical techniques currently in use for mammals require modification for use in fish pathology. However, there have been significant developments in many aspects of cellular biology, and new histologic techniques that until only recently were utilized by the mammalian pathologist are now available for the fish pathologist. For best results, only freshly dead or moribund fish should be considered for necropsy. Strict attention must be paid to handling biologic materials to be used for histology from fish. Fish have a very rapid rate of autolysis compared to mammals, and samples must be handled properly in order to avoid rapid degenerative changes.

Proper fixation is fundamental to satisfactory histologic preparation. If the fixation is unsatisfactory, the end product will reflect this. The primary objective of fixation is to preserve

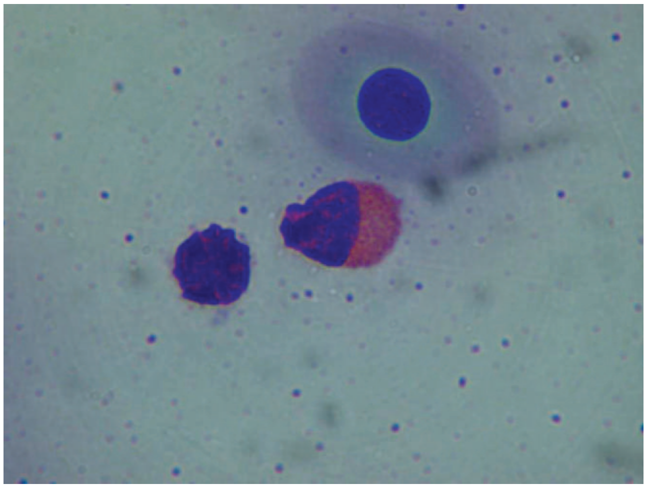


Figure 4-23 Eosinophil from a bull shark.

the morphology of the tissues to reflect the state of the tissues in the living animal. Formalin is the most widely used fixative. This fixative is not suitable for use in its concentrated form and therefore must be diluted to a 10% solution. Some pathologists will request special fixatives depending on the tissue being evaluated or a suspected etiology. We recommend contacting the laboratory before sample submission to obtain any specific guidelines for sample processing.

Diagnostic Imaging

For fish diagnostic imaging, the radiograph machines found in most veterinary clinics are adequate for routine examination. Portable units are beneficial if fieldwork is being done or if the ability to work at multiple sites is desired. The two major limiting factors associated with portable units are the ability to penetrate maximum thickness images on larger species and the lack of portability of the film processing unit. Recently, the technology in this area has developed more powerful, lightweight, and economically available radiograph machines and processor units. Portable digital units are also available and allow the veterinarian to review the image on a laptop computer. The radiograph films in use today are placed in cassettes, which must be adapted for use in a "wet" environment. This can be accomplished in a variety of ways. Smaller fish can be radiographed while being held in a small volume of water in either a glass or acrylic container placed on top of the film cassette. Larger species can be anesthetized and placed directly on a cassette for a brief period of time; however, advanced preparation is necessary for this method. Another technique for taking radiographs is to place the cassette in a watertight acrylic cassette case and place the cassette beneath the animal in a shallow pool or holding area. This has been an effective method for radiographing large predatory species.

Diagnostic ultrasound has become commonplace in human and veterinary medicine. Ultrasonography provides a safe, noninvasive method for visualizing the internal anatomy of many species. Ultrasound provides instantaneous results, and

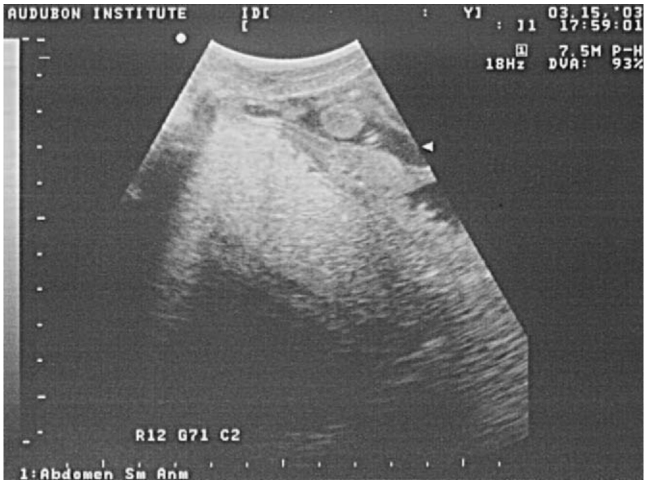


Figure 4-24 Ultrasound image of a freshwater stingray embryo.

protective apparel is not required.[22] Another advantage of using ultrasound is that serial views can be taken over time, and to date, there have not been any negative effects associated with this. There are a number of economic and efficient ultrasound units available that are capable of providing three-dimensional images and can operate off of a 12-volt direct current. Ultrasound imaging of aquatic species has become very popular in the past decade, from its initial use with marine mammals to its current applications with elasmobranchs and teleosts. Ultrasonography allows for the accurate measurement (e.g., width and depth) of structures by utilizing internal calipers and varying the orientation and penetration of the transducer. Many units can provide three-dimensional color images and perform volume and flow calculations. Ultrasound is useful in monitoring reproductive function, follicular changes, ovarian irregularities, sex determination, anatomic abnormalities, and monitoring embryonic growth rates (Figure 4-24). Since a fluid interface is required for quality imaging, it has been our experience that imaging procedures are easier to obtain and perform on animals that are already in an aquatic medium rather than utilizing gels or some other synthetic interface.

Microbiology

Microbiologic samples may be collected from a fish during an antemortem or postmortem exam. Antemortem samples are routinely collected from specific lesions on the skin, fins, or eyes. Contamination is a significant concern is these cases, and results should be interpreted accordingly. A sterile swab may be rubbed over the affected area to collect the sample. The sample should be refrigerated until it is plated, which should occur within 24 hours. Postmortem cultures routinely involve internal organs. To ensure sterility, the necropsy should be performed in a consistent manner. Seventy-percent ethyl alcohol should be applied to the ventral surface of the fish and the area flamed. Once the alcohol has burned off, samples can be collected using either a sterile swab or sterile biopsy techniques.

There are many different options relative to the appropriate culture media and incubation temperatures to isolate bacterial pathogens from fish. A standard blood agar plate may be used as the initial plate, or other specialized plates may be used if a specific pathogen is suspected. Salt should be added to a plate when attempting to isolate pathogens from marine fish. Plates should be incubated between 20°-25° C and 37° C. Many fish pathogens can grow at a range of temperatures; faster growth can be expected at higher temperatures. Culture plates should be evaluated for growth at 24- and 48-hour time periods. A Gram stain should be performed on any isolate. Biochemical identification of the organism should follow standard microbiologic protocol.

Marine microbiology has evolved from a fringe discipline to one of the most exciting areas of aquatic animal medicine.[9] There has been a great deal of advancement in the field in the past decade, primarily in the area of diagnostic test development and emerging technology. New optics, radio tracing, and advanced molecular methods have enabled scientists to identify microbes that would have been impossible to detect a short time ago.

Early and accurate diagnosis of an infectious process is essential for maintaining healthy fish.[3] It is important to be able to recognize clinical signs of disease and have infected animals examined and treated as early as possible.[4] In most disease processes, mortalities are initially low but can be followed by a gradual increase in losses. As soon as the first moribund animal appears, an aggressive diagnostic plan should be implemented. Although early and accurate diagnosis is important for all infectious fish diseases, it is absolutely crucial in bacterial infections to implement treatment early. As with any disease situation, the earlier the diagnosis is made, the sooner corrective measures or treatment can begin and losses can be minimized.[3]

To be able to identify populations of bacteria in aquatic systems is of fundamental importance; however, there are several problems to overcome. Standard laboratory methods, or some variation of them, can often be applied, but in many cases, the method used will be determined, at least in part, by experimental design.[10] Dilution and plating is a relatively straightforward and technically simple method of swabbing surfaces or lesions and placing them into suitable diluents, serially diluting them, and plating for viable counts. This technique has been utilized successfully for a long time despite the obvious drawbacks of the technique. Light microscopy should be utilized to observe surface populations while advanced laboratory requests are pending. An even better method would be the use of phase contrast microscopy, as this would be suitable for rapid counts of organisms. Alternatively, Gram stains, Diff-Quick, and Wright's stain may be used to characterize the different types of bacteria present and other cellular anomalies. Photometric methods, which are routinely used in laboratories to estimate bacterial numbers in liquids, may also be used to determine surface densities of some substrata. After fixing samples and applying suitable staining, the optical density of liquid medium can be measured and the surface population can be estimated. Since the adenosine triphosphate (ATP) assay method was developed, extractable ATP has been used extensively to determine bacterial biomass in a variety of samples. ATP is rapidly lost from dead cells; consequently, any delay between sampling the population and performing the assay must be kept to a minimum. Therefore, the application of the method to surface populations is difficult unless the ATP can in some way be extracted in situ or if the experimental system is specifically designed around the ATP assay. The use of radioisotopes to perform bacterial counts has not attracted much attention. The reasons for this are self-evident. Dispersing labeled compounds into the environment is simply not acceptable, and this means that the technique can be applied only to closed laboratory systems.[18]

Many advances have occurred in the field of analytic biotechnology in recent years, including the use of biochemical methods for estimating microbial biomass. The rationale is that if a veterinarian can identify a key component for a particular group of organisms, then, provided a suitable assay is available, it should be possible to use that component as a means of assaying the biomass. The advantages of this type of approach to biomass estimation are that (1) microbial biomass can be estimated without the need for further microbial culture, and (2) as chemical extractions are performed, there is no requirement for the quantitative recovery of microorganisms from colonized surfaces. The disadvantages associated with this method are attributed to the limited sensitivities of the techniques used and the chemical extraction method.[10,18]

Parasitology

Wild populations of fish are usually infested with parasites. Although infested, the majority of fish species in the wild experience no serious disease effects as a result. However, in captive fish populations, parasites may cause disease outbreaks. Maintaining dense populations of fish in a particular ecosystem may promote very high levels of parasitic infestation. The number of parasites required to cause health issues in fish varies considerably with the size and health status of the host. Many parasites are host specific or are capable of infecting only one or a limited number of host species. There are many individual parasite species that have widely different effects on the host species. Life cycles of fish parasites demonstrate enormous diversity and may involve one or more intermediate hosts. These types of complex life cycles are necessary to disseminate the infective stages to the final host. Intermediate hosts often form part of the diet of the final host or the next intermediate host to ensure the parasites progress onto the next life stage. Free living stages may be released from the intermediate host to actively invade or be consumed by another host. Many fish parasites have a portion of their life cycle that is spent outside of the host as free swimming larvae. These particular parasite species have a direct life cycle and will infect other hosts by means of eggs, which are ingested. Knowledge of the life cycles of a particular parasite species is imperative to their control and/or eradication. Ectoparasites are frequently found on the gills, skin, and fins. Biopsies (e.g., fin or gill) or scrapings (e.g., skin) should be collected to confirm the presence or absence of ectoparasites. Endoparasites are generally found on fecal direct saline smears. Successful parasite control can be achieved by intervening in some aspect of the parasite life cycle. Fortunately, some parasite life cycles require an intermediate host, and these invertebrates are often not found in the captive setting. There are a variety of antiparasitics that can be used to treat parasites, and these are discussed elsewhere in this chapter.

Miscellaneous Diagnostic Tests

There are very few serologic tests that have been developed or are available for diagnosing infectious disease exposure in ornamental fish. Serologic studies have been performed on cultured food species and animals used in experimental studies to determine the presence of antibodies to specific pathogens, but these assays have limited value for ornamental fish. Nucleic acid probes can be designed with the specificity to differentiate between two antigenically related organisms, but they have differences in their nucleic acid sequences that alter the pathogenicity of the organisms. From a diagnostic perspective, probes are extremely valuable because they can be developed to characterize pathogens at the generic, species, or strain-specific level, depending on which portion of a nucleic acid sequence they are designed to detect.[10] Once a probe has been developed, it can be used to detect nucleic acid that is extracted from a sample and attached to a membrane, or it can be used to detect pathogen specific nucleic acid in a section of paraffin-embedded, formalin-fixed tissue that has been processed for histopathologic evaluation. In situ hybridization using pathogen-specific nucleic acid probes is particularly effective when a pathogen is present in relatively small numbers or produces a lesion that histologically resembles lesions induced by other pathogens.[18] In situ hybridization using viral-specific DNA probes can quickly and correctly determine which of these viruses induce histologic lesions (e.g., inclusion bodies). When compared with antibody staining techniques used for identifying pathogens in tissues, nucleic acid probes are more specific and more sensitive than other pathogen detection techniques. They also detect organisms that may have been antigenically altered during processing. In addition to confirming the presence of a pathogen in tissue, in situ hybridization can also be used to detect the type of cell infected and whether the pathogen's nucleic acid is present in the cytoplasm or nucleus of the host cell.[9,10,18] In infected tissues where high numbers of an organism are present, the use of DNA probes to detect the presence of an organism's nucleic acid is fairly straightforward. In contrast, detection of a pathogen in an excretion/sample where numbers of the organism may be small often requires further processing. To increase the likelihood of finding an organism in a diagnostic specimen, a sample to be tested is often subjected to a group of reactions that will amplify the number of pathogen DNA molecules in the sample, thus improving the ability of the probe to detect the organism.

Polymerase chain reaction (PCR) is the most commonly employed method for detecting portions of DNA by amplifying short nucleotide sequences within the DNA genome. PCR can be used for the detection of pathogens in cell culture, tissues, secretions, lavages, and other biologic samples. PCR requires oligonucleotide primers that are complimentary to the sequence being amplified.[18] Fortunately, there are a variety of generic level primers for many of the bacteria, fungi, and viruses that commonly infect fish.

COMMON DISEASE PRESENTATIONS

Disease can be caused by an etiologic (specific cause) or a nonetiologic (contributing cause) agent. Etiologic agents can be classified as either inanimate or animate. Inanimate etiologic agents are factors that can occur endogenously or exogenously. Endogenous, inanimate factors are those associated with genetic and/or metabolic disorders of the host. Exogenous, inanimate agents include trauma, temperature shock, electrical shock, chemical toxicity, and dietary deficiencies. These etiologic agents may serve as sublethal stressors that predispose fish to infectious disease.[3] Animate etiologies include living communicable infectious agents, such as viruses, bacteria, fungi, protozoa, helminthes, and copepods.[5]

Nonetiologic causes of disease are characterized as either extrinsic or intrinsic. Extrinsic factors are usually associated with trauma, environmental conditions, or dietary problems, whereas intrinsic factors include age, gender, heredity, and fish species. Both fish species and strain of fish are important because not all fish are equally susceptible to a specific disease organism. Feed quality, water quality factors, and water temperature extremes can be classified as either etiologic or nonetiologic extrinsic factors and can contribute to disease.[5]

Infectious Diseases

Fish diseases are caused by a wide range of infectious organisms, including viruses, bacteria, fungi, protozoan and metazoan parasites. Bacteria are responsible for the majority of the infectious diseases diagnosed in captive fish, with many acting as secondary opportunistic invaders that take advantage of diseased animals by overwhelming their natural host defense response. Opportunistic bacteria are widespread in the aquatic environment and represent a threat every time a fish is exposed to a stressful event (e.g., handling). However, their harmful effects rarely persist and generally cease with the removal of the original stressful event.

Bacterial Diseases

Many aquatic bacteria are facultative or obligate pathogens, and all fish culture systems suffer outbreaks of primary bacterial infections from time to time. The main groups of bacteria involved in fish mortalities in captivity are listed in Box 4-2.

Gram-negative bacteria are the primary pathogens isolated from fish. These pathogens are responsible for the majority of the acute, septicemic infections diagnosed in fish.[9] Chronic infections, which progress more slowly and may result in granulomatous internal lesions, are more commonly associated with Gram-positive bacteria (e.g., *Mycobacterium* spp.). Of the Gram positive bacteria, *Mycobacterium* spp. and *Nocardia* spp. are more often associated with chronic infections. *Mycobacterium marinum* has been associated with granulomatous lesions and zoonotic infections. Attempts at therapy of such infections are rarely reported. When considering treatment for Gram-negative or non–*Mycobacterium* sp. Gram-positive pathogens, it is best to base the therapeutic plan on the results of an antimicrobial sensitivity assay.

BOX 4-2 Principle Bacterial Pathogens Isolated from Captive Fish

Pathogen	Disease
Enterobacteriaceae (Gram-negative)	
Edwardsiella tarda	Red pest disease
E. ictaluri	Enteric septicemia in catfish
Yersinia ruckeri	Enteric red mouth
Vibrionaceae (Gram-negative)	
Vibrio anguillarum	Vibriosis
V. salmonocida	Hitra
V. viscossus	Winter ulcer disease
Vibrio spp.	Larval infections
Aeromonas salmonocida	Furunculosis
A. hydrophila	Septicemia
Pasteurellaceae (Gram-negative)	
Pasteurella piscida	Pseudotuberculosis
Pseudomonadaceae (Gram-negative)	
Pseudomonas anguilliseptica	Red spot disease
Flavobacteriaceae (Gram-negative)	
Flexibacter columnaris	Columnaris
Flavobacterium psychrophilium	Coldwater disease
Mycobacteriaceae (Gram-positive, acid-fast)	
Mycobacterium spp.	Tuberculosis
Nocardiaceae (Gram-positive)	
Nocardia kampachi	Nocardiosis
Nocardia spp.	Nocardiosis
Coryneforms (Gram-positive)	
Renibacterium salmoninarum	Bacterial kidney disease
Cocci (Gram-positive)	
Streptococcus spp.	Septicemia
Aerococcus viridans	Gaffkemia
Rickettsia-like organisms	
Piscirickettsia salmonis	Piscirickettsiosis

Mycotic Diseases

Mycosis is significant in all ornamental species. Fungi do not use photosynthetic pathways and are therefore considered saprophytic or parasitic. Oomycetes produce superficial infections in freshwater fish, particularly if under stressful conditions or where superficial wounds and abrasions occur. *Saprolegnia* spp. is a common water mold isolated from tropical ornamental fish and cold-water aquaculture species. Water molds are primarily opportunists; they often infect open wounds, although primary infections are also possible. Affected fish generally present with white, cotton-like lesions on fins and skin. A skin scrape or biopsy of an affected area can be used to confirm diagnosis of water molds, which are classified based on their branching nonseptate hyphae.

Such infections are susceptible to chemotherapy, such as malachite green. These infections are responsible for a broad range of serious and economically important diseases in fish. There are more than 100,000 species of fungi, and they are morphologically diverse. The ichthyoparasitic species are relatively few in number and difficult to classify.[10] Fungi considered important pathogens of fish are listed in Box 4-3.

Viral Diseases

The study of fish viruses has become important for wild and cultured fish. Diseases that were once attributed to bacterial diseases are now being found to be viral in origin. With the advent of comparative molecular biology for viruses, improved methods for virus detection, and experimental pathogenesis studies, emerging viruses can be expected to be diagnosed at an increased rate in the future.

Viruses multiply within the living cells of a host by utilizing the components of the host cell for their own reproduction. In the extracellular phase of the virus particle, or *virion,* the virus is metabolically inert. The virion carries the viral genome from the cell in which it had been produced to another cell where it can be introduced. Once the virus particle is inside the new cell, replication or infection occurs. Histologic changes associated with viral infection include cell swelling and loss of cytoplasmic detail, followed by irreversible changes and cell death.[10,18] If sufficient cell loss occurs, loss or damage to a particular physiologic function and/or transformation to a neoplastic state can occur. Infection may persist after early signs are evident or may be integrated into the genome with intermittent shedding.[6]

Once the virus spreads beyond a few host cells, a variety of nonspecific host defense responses will be elicited. The extent of disease experienced by a host depends on how effectively these responses contain the virus and minimize host cell and organ damage. Infected fish can develop either (1) clinical disease with morbidity (and mortality) that is recognized by the clinician or pathologist, or (2) infection with no clinical signs (e.g., a silent infection).

Viral diseases in ornamental fish are rare. The pathogenicity of viruses can vary with temperature. Most viral infections in fish are host specific. In many cases, young, naive fishes become sick and older animals become carriers. The most commonly reported virus in ornamental fish is lymphocystis, an iridovirus that infects fibroblasts.[23] Affected animals develop large, coalescing nodules that can occur anywhere on the body. The virus is self-limiting. In most cases, the fish resolves spontaneously; however, in cases where the lesions affect the eyes or mouth (e.g., its vision or the ability to eat), the animal may die. Lymphocystis can be diagnosed on gross examination or histopathology. There is no effective treatment, although the mass may be removed surgically if the tumor affects the animal's ability to eat, see, or swim. Box 4-4 represents a list of the major viral groups that affect ornamental and cultured fish species. For additional information regarding fish viruses, see other texts.[2,3]

Culture remains the most common and definitive method of diagnosing viral disease in fish.[6,18] Cytopathic effects in the cell culture represent the anticipated consequence of viral growth in the cell monolayer and form the basis of an initial positive diagnosis. However, positive culture of a virus should always be confirmed by a second diagnostic procedure. With the advent of advanced molecular diagnostic testing, there are now a number of other diagnostic tests available (e.g., polymerase chain reaction assays) that can be used to confirm a diagnosis of viral disease in fish.

BOX 4-3 Fungi Commonly Isolated from Captive Fish

Class	Order	Genus
Mastigomycotina		
Oomycetes	Saprolegniales	*Saprolegnia*
		Achyla
		Aphanomyces
		Branchiomyces
Chytridiomycetes	Chytridiales	*Dermocystidium*
Zygomycotina		
Entomophthorales		*Basidiobolus*
Deuteromycotina		
Hyphomycetes	Moniliales	*Exophiala*
		Aspergillus
Coelomycetes	Sphaeropsidales	*Phoma*

Parasitic Diseases

Both ectoparasites and endoparasites are routinely identified on or in imported ornamental fish. When parasitized animals are added to an established aquarium, the parasites can quickly spread to the other tank inhabitants. To prevent the introduction of parasites into established systems, all newly acquired animals should be quarantined.

Protozoa are responsible for the majority of the opportunistic and obligate parasitic infections in fish. These parasites

BOX 4-4 Viral Diseases of Fish

DNA Viruses

Iridoviruses
- Lymphocystis
- White sturgeon iridovirus disease
- Redfin perch iridovirus disease
- Rainbow trout iridovirus disease
- Catfish iridovirus disease
- Pike perch iridovirus disease
- Red sea bream iridovirus disease
- Cod ulcus syndrome
- Turbot iridovirus disease
- Eel iridovirus disease
- Cichlid iridovirus
- Viral erythrocytic necrosis
- Cyprinid iridoviruses
- Grouper iridoviruses
- Large mouth bass iridovirus

Adenoviridae
- Cod adenovirus
- Sturgeon adenovirus

Herpesviridae
- Channel catfish herpesvirus
- Salmonid herpesviruses: Types I, II, and III
- Cyprinid herpesvirus
- Herpesviral hematopoietic necrosis
- Acipenserid herpesvirus
- Herpesvirus vitreum
- Angelfish herpesvirus
- Turbot herpesvirus
- Pike epidermal proliferation
- Smooth dogfish herpesvirus
- Atlantic salmon papillomatosis
- Japanese flounder herpesvirus
- Pacific cod herpesvirus

RNA Viruses

Reoviridae
- REO-respiratory-enteric-orphan disease

Aquareviridae
- Not associated with any known disease

Birnaviridae

Picornaviridae
- Salmonid picornavirus

Nodaviridae
- Viral nervous necrosis
- Striped skipjack nervous necrosis
- Viral encephalopathy
- Viral retinopathy

Togaviridae
- Pancreas disease
- Erythrocytic inclusion body syndrome

Orthomyxoviridae
- Infectious salmon anemia

Rhabdoviridae
- Infectious hematopoietic necrosis
- Viral hemorrhagic septicemia
- Hirame rhabdovirus disease

Lyssavirus-like group
- Snakehead rhabdovirus
- Eel virus B12
- Carpione rhabdovirus

Vesiculovirus-like group
- Spring viremia of carp
- Pike fry rhabdovirus I
- Pike fry rhabdovirus II
- Ulcerative disease
- Eel rhabdovirus EVA/EVX

Reverse Transcribing Viruses

Retroviridae
- Walleye dermal sarcoma
- Walleye discrete epidermal hyperplasia
- Plasmacytoid leukemia of chinook salmon
- Atlantic salmon swim-bladder sarcoma
- Atlantic salmon papilloma
- *Esox* sarcoma
- Esocid lymphosarcoma
- Pike epidermal proliferation
- Damselfish neurofibromatosis
- *Xiphophorus* sp. hybrid neuroblastoma
- Hooknose fibroma/fibrosarcoma
- Viral erythrocytic infection of seabass

can cause both external and systemic disease. The clinical signs associated with parasite infestation will vary depending upon the location of the parasite. Fish with gill flukes *(Dactylogyrids)* may become hypoxic with heavy infestations and may be found "gulping air" at the water surface. Fish infested with skin parasites, such as ich *(Ichthyopthirius multfiliis),* rub against hard surfaces, lose scales, and hemorrhage in the area of parasite attachment. Fish with endoparasites are often anorectic, in poor condition, and fail to thrive. Systemic protozoan infections (e.g., *Myxosporidia* and *Microsporidia*) in fish are responsible for the most serious losses. These parasites are generally refractory to treatment, and their practical significance is thus enhanced by the lack of effective chemotherapy. The life cycles of these parasites are often poorly understood, and only recently has it been recognized that one stage of their life cycles requires tubificid worms as alternate hosts.

TABLE 4-2 Antiparasitic Drugs Used to Treat Captive Fish

Agent	Dosage	Comments
Chloroquine diphosphate	10 mg/L	*Amyloodium ocellatum*
Copper sulfate	100 mg/L, 1-5 min bath, maintain free ion levels at 0.15-0.2 mg/L tank water	Marine fish protozoa, trematode ectoparasites, must monitor copper levels daily; toxic to plants and invertebrates
Fenbendazole	2 mg/L water, every 7 days ×3 treatments; 50 mg/kg, PO, q24h ×3 treatments, repeat in 14 days	Nonencysted trematodes, nematodes
Formalin	37% formalin only, 0.4 ml/L, for up to 1h bath	Protozoa, trematode, and crustacean ectoparasites; potential carcinogen; keep tank well aerated and monitor continuously
Freshwater	3-15 min bath, repeat daily as needed	Marine fish, ectoparasites
Glacial acetic acid	2 ml/L, 30-45 s bath	Trematodes and crustaceans; safe for goldfish, but possible toxicity in smaller tropical fish
Hydrogen peroxide	17.5 ml/L, 4-10 min bath, once	Ectoparasites
Levamisole	50 mg/L, 1h bath	Ectoparasites, free living parasites; monitor closely, water change after 1 h
Malachite green	0.1 mg/L tank water, 3 treatments for 3 days	Freshwater fish protozoa
Praziquantel	2 mg/L, continuous treatment for 5 days, then repeat in 2 weeks	Monogenes
Trichlorfon	0.5-1.0 mg/L, every 3 days, 12 h intervals between treatments	Crustacean ectoparasites

PO, per os.

Many metazoan parasites of fish have been described, some having a multiple-host life cycle that cannot easily be completed under captive conditions. Some cause problems in culture systems; external parasites can proliferate in all environments where convenient fish species favor their development, and they present a constant threat in all kinds of facilities. Parasitic crustaceans find suitable conditions for their development in closed marine systems when naturally infected waters exist nearby. Under such conditions, sea lice can cause extensive damage and mortality.

To effectively control fish parasites and minimize losses, rapid diagnosis is essential. The diagnostic tests routinely used to identify ectoparasites include the skin scrape, fin biopsy, and gill clip. A fecal float and direct saline smear should be performed to evaluate endoparasite status. In some cases, only necropsy can be used to confirm the presence of an endoparasite infection.

There are a number of potential therapeutics that can be used to control and/or eliminate fish parasites; however, the range of effective treatments is limited by the margin of safety of the agent. Treatments can also be limited by environmental factors too (e.g., water temperature, hardness levels, pH). Table 4-2 represents a list of antiparasitic agents commonly used to treat captive fish.[6,9]

Nutritional Diseases

Nutritional diseases are uncommon in wild populations of fish. Although environmental factors may limit food availability and particular weather and geophysical phenomena may adversely affect the food chain, wild fish generally have the opportunity in their natural environment to acquire adequate levels of all their nutritional requirements.[15]

The same cannot be said for captive ornamental fish. There are many different types of diets available for ornamentals, including commercially prepared pelleted and flake foods, invertebrate-based foods (e.g., brine shrimp, daphnia, blood worms), and live vertebrate foods (e.g., goldfish and guppies), and the nutritional value of these foods is highly variable.

Most commercially prepared pelleted or flake foods are comprised of a combination of macronutrients and micronutrients. The levels of these different nutrients can vary between formulations, and this makes it extremely difficult to define nutritional disease in absolute terms because it is rare for a deficiency to be based on a single essential nutrient. Fish offered nutritionally deficient diets are often more susceptible to infectious conditions. The deficiency of a necessary component in the diet is only one aspect of nutritional disease, which has been defined as the deficiency, excess, or improper balance of the components present in a fish diet. The definition should also include the presence of noxious or toxic components within the food and/or endogenous antinutrient factors, as these have become increasingly significant and can also cause disease in fish.[15,16]

Although most dietary deficiencies are associated with a complexity of marginal or absolute deficiencies, confirming the specific role of a nutrient in the overall health of a fish requires detailed experimental study. In the clinical situation, however, nutritional deficiency is approached as a more general syndrome. Fish with this "syndrome" may display a range of clinical signs, including inappetence, weakness, lethargy, acute hemorrhage, infection, darkening skin color, and poor growth.[6] Artificial diets produced by major manufacturers and intended as a complete source of nutrients are usually of high quality, and it is rare that a particular mixture will be responsible for a nutritional deficiency. As a matter of fact, these commercial diets are more likely to cause problems associated with excessive nutrients (e.g., hepatic lipidosis) than a deficiency of nutrients. However, when feeding wet diets or frozen fish diets, the possibility of a nutritional deficiency or imbalance is much higher. Even high-quality diets are susceptible to nutrient loss during storage, especially if these diets are stored under conditions of high temperature and/or high humidity.

Fish are susceptible to both macronutrient (e.g., low protein, fat, carbohydrate, fiber) and micronutrient (e.g., vitamin and mineral) deficiencies or imbalances. In terms of macronutrients, most problems are associated with the lipid component of the diet. Excessive fat in the fish diet can lead to hepatic lipidosis. Among the micronutrients, any of a wide range of components can exert an effect, especially in fast-growing, younger fish.[6,16,18]

Starvation may occur in captive fish due to complete deprivation of food, inadequate feeding levels/frequency of a diet, offering a nutritionally deficient diet, or as a result of behavioral, physiologic, or mechanical limitations that prevent food intake. Inadequate feeding levels may be associated with inappropriate husbandry practices or to overstocking. The process of physiologic starvation is characterized, as might be expected, by a loss of weight and change in morphology. Affected fish become emaciated as a result of muscle loss, and the head becomes relatively larger in proportion to the body. Changes in skin color (e.g., darkened appearance) may also occur. Eventually the fish becomes anorexic. At necropsy, there is usually a general pallor (e.g., anemia) and serous atrophy of the fat and visceral organs.

Fish stocking densities, environmental water quality parameters (e.g., pH, temperature), transport, and handling all have a direct effect on the way stress affects captive fish.[5] The primary function of the aquarist is to maintain a system that is capable of minimizing the effects of these stressors. This has significant implications for growth and feed conversion, as well as susceptibility to infection. Stress induces catabolism, resulting in the breakdown of important energy reserves (e.g., fat, muscle). When this occurs, the energy required for such degradation and resynthesis is not available for growth. A number of other stressors that can play a role in determining the levels of nonspecific stress in fish are related to food and feeding. Inadequate or deficient diets, irregular feeding patterns, the presentation of feed, and buildup of detritus can contribute to the sum total pressures acting on the adaptive capacity of fish. The physiologic and biochemical changes that occur in the animal under the influence of environmental stressors, and which serve to moderate the negative effects of stressors, are termed the *general adaptive syndrome* (GAS).[6] They are neither species nor stressor specific, and are mediated by nervous and hormonal action. The end result, if the adaptive response is stimulated beyond physiologic levels and adaptive exhaustion is achieved, is that the fish are made increasingly vulnerable to infection. Opportunistic, obligate, or facultative pathogens extant in the animal's environment may cause infections in susceptible fish. Thus, many nutritional diseases in fish may be compounded by bacterial and fungal infection.[6,16]

Feeding activity is associated with a particular metabolic expenditure referred to as the cost of *specific dynamic action* (SDA).[6] The SDA is related to the metabolism associated with digestion, increased circulatory activity in the gut and related organs, production of enzymatic and other metabolic acids, and the excretion of nitrogenous metabolites. The exact process contributing to the metabolic oxygen demand created by SDA is well recognized, and at high temperatures when dissolved oxygen levels in water are reduced and the general resting metabolic oxygen demand by fish is high, feeding to satiation can result in such a high oxygen demand to satisfy SDA that oxygen starvation can occur. The clinical features associated with oxygen starvation in fish include death within 2 hours of feeding, a fixed, open mouth, and the presence of undigested food in the stomach and intestine. The likelihood for complications associated with feeding fish at high environmental temperatures is greatly exacerbated if there is underlying gill or blood pathology.[6,18] Hyperplastic or telangiectatic gill damage, which often occurs secondary to pollution, transportation, or handling, can result in a reduced ability of the gills to obtain oxygen and release carbon dioxide. It is frequently a feeding episode that places the final metabolic oxygen demand on compromised fish that leads to a mortality event.[6] Other conditions that can increase the susceptibility to SDA-mediated mortalities include fatty liver syndrome, chronic hemorrhagic conditions (e.g., warfarin toxicity), chronic viral septicemia, and infectious salmon anemia.

Neoplastic Diseases

Fish are subject to many of the same neoplastic conditions reported in higher vertebrates. The presence of neoplasms in fish can often be strongly correlated to environmental factors, which suggests that these animals can be important sentinels in aquatic ecosystems. The etiology of neoplasms is complex, and many of the factors that contribute to the growth and dissemination of tumors are unknown. Some of the contributing factors that have been identified include viruses, chemical or biologic toxins, physical agents, hormones, and the age, sex, and genetic predisposition of the animal.[6]

Neoplasms are classified on a histopathologic basis, according to cell origin (Table 4-3). Because the terminology used to classify tumors is based on the descriptions given for human neoplasia, the terms *benign* and *malignant* are routinely used to designate certain cell patterns. There is, however, no fine line of demarcation to separate these two types of descriptions in certain fish neoplastic conditions.

Miscellaneous Diseases

Gas-bubble disease (GBD) is a serious problem encountered in the captive fish setting. It was first described in aquarium

TABLE 4-3 **Classification of Neoplasms Reported in Fish**

Tissue	Benign	Malignant
Epithelial	Papilloma (papillary folds, squamous cell, basal cell, odontoma)	Carcinoma (epithelioma, epidermoid)
	Adenoma	Adenocarcinoma
Mesenchymal (nonhematopoietic)	Fibroma	Fibrosarcoma
	Leiomyoma	Leiomyosarcoma
	Rhabdomyoma	Rhabdomyosarcoma
	Lipoma	Liposarcoma
	Chondroma	Chondrosarcoma
	Osteoma	Osteosarcoma
Mesenchymal (hematopoietic)	Lymphoma	Malignant lymphoma
Neural	Neuroma (neurilemmoma, ganglioneuroma)	
Pigment	Melanoma	Malignant melanoma
Embryonal	Teratoma, Nephroblastoma	

fish by Gorham in 1898 and is typically seen in most captive fish populations at some time or another. GBD appears under a wide variety of circumstances, so determining the etiology is not always a simple matter. In its simplest form, GBD is associated with the super saturation of the tissues with nitrogen or oxygen.[6] There are many factors that contribute not only to the initial inception of the disease but also to the severity of the disease. Some of the factors associated with the disease include temperature, mechanical failures of pumps or sumps, transport, and algal blooms.[6,18] The degree of supersaturation is the most important factor in relation to both the clinical picture and eventual outcome, but duration of exposure and subsequent treatment also affect survival. Fish should be removed from the affected system and placed into a separate, unaffected system. The affected system should be thoroughly evaluated and the inciting cause of the supersaturation corrected.

Low environmental temperature (hypothermia) can increase an animal's susceptibility to certain bacteria and decrease an animal's threshold to certain toxins. Saltwater fish from higher latitudes can develop severe abdominal distension if they become hypothermic. Affected animals can retain large quantities of water in their stomach, holding as much as 40% of their body weight in water. The principle mechanism of action associated with this pathologic event is an osmoregulatory stress associated with low temperatures and high salinity. Affected animals should be gradually warmed; however, mortalities are likely to be high. Prevention is the key, and this disease can be avoided by establishing appropriate environmental temperatures with appropriate heating devices.

There are many waterborne irritants that can adversely affect fish health. Each fish species has an optimum range for pH. Many of the factors that cause rapid changes in the pH are deleterious to the gills. Certain irritants, such as dust, silt, and ammonia, can also damage the gills but may not induce immediate clinical disease. This is because the gills initially have a delayed response to these irritants; however, over time the affected fish can become more dyspneic as a result of the reduced transfer of oxygen and carbon dioxide at the level of the gills. This dyspnea can be exacerbated by high environmental temperatures and low oxygen solubility.[3,6,18]

Color anomalies observed in cultured marine fish have a genetic origin and influence the basis for ornamental varieties or strains.[6] Pseudo-albinism, a frequent feature of flatfishes, is a husbandry-related developmental anomaly.[6] Partially pigmented or reverse-pigmented animals are also present to a significant level in confined species. The exact etiology for this color pattern is unknown; however, it has been suggested that it may be related to high levels of lighting and a lack of an essential trace nutrient during early development.

Physical deformities can be derived from multiple etiologies. Congenital malformations are not uncommon in cultured fish and may be influenced by multiple causative factors. Lesions associated with genetic factors, incubation temperature, or hormonal effects are apparent from early development, whereas lesions of husbandry or nutritional origin can occur at any stage of development.[5,6,16]

THERAPEUTICS

Therapeutics may be administered to fish in a water bath, per os (PO), intramuscular (IM) injection, intraperitoneal injection, or the intravenous (IV) route. Water bath treatment protocols to treat internal infections are of little value to freshwater fish but have been used with success to treat marine fish. Marine fish actually drink water, so any medication placed in the water will be ingested (Figure 4-25). Freshwater fish do not drink water and are not likely to receive the same benefit. Carbon filters should be removed when a bath or immersion treatment is used. PO medications can be placed into food and delivered to the fish during routine feedings. Unfortunately, many sick fish are anorectic and do not benefit from medicated food. PO medications can also be administered via a stomach tube. A red rubber feeding tube may be used for this procedure (Figure 4-26). The distance from the mouth to the mid-body should be measured and marked, thereby denoting the approx-

Figure 4-25 Therapeutic bath or immersion can be used to treat marine fish.

Figure 4-27 Intramuscular injections are routinely given in the epaxial muscles.

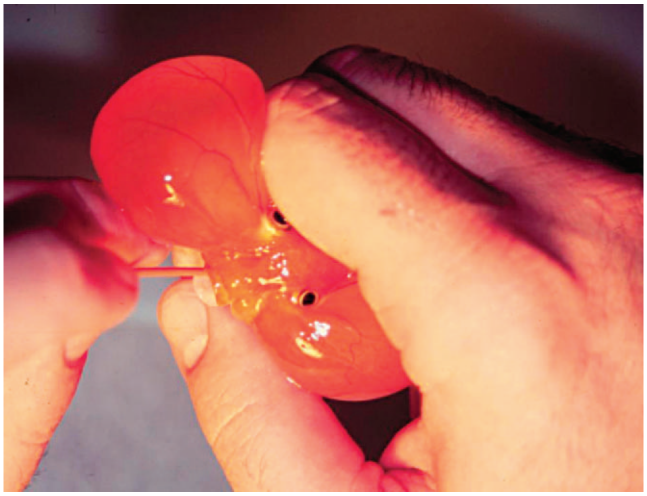


Figure 4-26 Fish that tolerate handling can be given medication per os via a tube.

Figure 4-28 Intraperitoneal (intracoelomic) injections are an excellent method of delivering medications or fluids to fish. The fish should be placed in dorsal recumbency for the procedure.

imate location of the stomach. The tube should be inserted to the level of the mark and the medication delivered.

Parenteral routes are commonly used to treat fish. IM injections are administered into the epaxial muscles surrounding the spine (Figure 4-27). The needle should be inserted between the scales. Irritating compounds should not be administered IM because they can lead to muscle necrosis. Intraperitoneal injections are a rapid and effective method for administering different medications to fish (Figure 4-28). The fish should be held in dorsal recumbency, allowing gravity to drop the viscera, and the injection administered between the scales on the ventrum of the coelomic cavity. Again, irritating compounds should not be used. IV injections are not routinely used, but they may be useful during emergency situations.

Numerous factors can alter or mediate the efficacy of drugs used to treat fish. These factors can be divided into two general categories: biologic and environmental. Biologic factors that can affect a therapeutic plan include species variation, physiologic and anatomic variation (e.g., ectotherms vs. endotherms), the presence of a renal portal system, vascular flow, high glomerular filtration rates, osmotic homeostasis, overall size/weight, sexual maturity, body condition, stress level, disease/immune status, seasonal patterns, nutritional status, and lipid content of the liver.[24] Species variation refers to body design and behavior, gill area to body-weight ratio, and positioning in the water (e.g., benthic vs. pelagic). Drug absorption, distribution, metabolism, and mode of excretion can affect each drug differently.[24,25] Environmental considerations address the specific parameters monitored in water quality, including temperature, pH, salinity, and hardness. Although it is useful to consider potential factors that may influence a response to a chemotherapeutic agent, it is not always possible to predict the clinical effect. Individual variation can create response variation within a species and may have dramatic affects on the outcome.[24]

In addition to trying to understand the effect physiologic, anatomic, and environmental influences have on fish therapeutics, it is important to consider the different properties of the drugs. Identifying certain characteristics about a drug, such as whether it is lipophilic (fat soluble) or hydrophilic (water soluble), protein bound (albumin in the blood) or not protein bound, and has specific binding sites, can influence the pharmacodynamics of a drug and whether it will or will not be effective.

The following factors should be considered when generating a therapeutic plan for a fish: (1) the pharmaceutical form of the drug, (2) the physical or chemical properties of the drug, (3) how quickly the onset of action should occur, (4) restraint of the animal, (5) behavioral characteristics of the animal, and (6) the nature of the particular condition being treated.[25] A drug is of no use unless it can be delivered to the patient in a form and at a site that is appropriate.

Fluid Therapy

Fluid therapy is a critical but inexact component of medical care for fish. Its application revolves around estimating the amount of fluid loss in a patient and, consequently, the amount of fluid that needs to be replaced. This determination can be estimated from the physical examination findings and laboratory tests (e.g., complete blood count and plasma biochemistries). There are three values that should be calculated to determine the volume of fluid to be administered: the hydration deficit, the maintenance requirement, and ongoing fluid losses. Fluids should be administered to restore the normal hydration status, replace electrolytes and nutrients, and administer medications that must be diluted in large volumes.

The type of fluid to be administered should be determined on a case-by-case basis. Estimating or calculating the plasma osmolality is the best method for determining the type of fluid to use for replacement. There are a variety of commercially prepared fluids available that fall into one of several basic categories. The primary categories of fluids used in veterinary medicine are the crystalloid solutions, colloid solutions, hypertonic solutions, fluid additives, and parenteral vitamin/mineral products. The amount, type, and method of administration should be determined by the clinician responsible for the animal.[24,25] Fluid replacement in fish is generally done PO or intracoelomically.

Therapeutics Used to Treat Infectious Diseases

No matter how effective an antimicrobial agent or parasiticide has been shown to be, it has no value if it is prohibited or not permitted by national or regional regulation. Regulatory controls that require veterinary medicines to be safe and effective before being approved for use have been in development over the past 30 years. A general lack of approved antimicrobial drugs for fish inevitably means an increasing reliance on off-label use.

Ideally, the selection of an antimicrobial agent should be based on the reliable diagnosis of the disease and pathogen involved, followed by determination of the most effective drug.[3] This decision should be made based on laboratory determination of the antibiotic sensitivity of the specific pathogen, taking into account factors such as the pharmacokinetic and pharmacodynamic properties of the drug.[25] Almost all treatments can be administered by parenteral injection; however, this is the most costly method in terms of labor, time, and associated stress. Therefore, if the parenteral route is excluded, then the most practical routes of administration are immersion bath and oral medications (see Table 4-1).[25]

Emergency Drugs

There are few pharmacokinetic data available on the use of emergency drugs in fish and even less on their use in specific species.[25] In our experience, the reaction of different species of fish to emergency drugs is completely unpredictable. Furthermore, these drugs may have dramatically varied responses in the same or similar species of fish. Table 4-4 represents a list

TABLE 4-4 Emergency Drugs Used to Treat Fish

Agent	Dose	Comments
Atropine	0.1 mg/kg IM, ICe, IV	Organophosphate toxicity, hydrocarbon toxicity
Dexamethasone	5 mg/kg IM, q24h to effect	Shock, trauma, stress
Doxapram	5 mg/kg ICe, IV, topical	Respiratory depression
Epinephrine (1 : 1000)	0.2-0.5 ml IM, IC, IV, ICe	Cardiac arrest
Furosemide	2-5 mg/kg IM q12-72h	Ascites, edema
Haloperidol	0.5 mg/kg IM	Dopamine blocking agent, use with LH to stimulate egg release
Hydrocortisone	1-4 mg/kg IM, ICe	Shock, trauma, stress
Hydrogen peroxide	0.25 ml/L water	Hypoxia
Oxygen (100%)	Titrate as needed	Hypoxia, stress
Sodium bicarbonate	30 g/L bath, 4% ICe	Acidosis, capture stress, euthanasia
Sodium chloride	1-3 g/L	Freshwater fish, stress
Sodium thiosulfate	10 mg/L	Neutralize chlorine

IC, intracardiac; ICe, intracoelomic; IM, intramuscular; IV, intravenous; LH, Lutenizing hormone.

of emergency drugs known to have some effectiveness in fish; however, precautions should be taken when using these drugs in a new species for the first time.

Nutritional Support

The provision of calories to a fish suffering from a negative energy balance can be the difference between treatment success and failure. In general, an acute weight loss of more than 10% of the optimal body weight, not related to dehydration, is sufficient evidence that nutritional support is needed. The likelihood of success increases dramatically if the nutritional support is initiated early.[16] The clinician should first correct fluid, acid-base, and electrolyte imbalances before implementing nutritional support.[25] Once this is done, then the clinician can choose the most practical and appropriate type of nutritional support. If the animal is still eating, than a diet rich in protein and fat may be appropriate. In some cases, providing nutritional support simply involves adjusting the diet to a common food source that may not have been previously offered to the animal.

The methods of providing calories via a gastrointestinal tube or force-feeding whole-prey items have had a moderate degree of success. If the animal is not eating or if tubing the fish and providing calories directly into the stomach is contraindicated, then options are limited to administering fluids either via the IV or intracoeloemic (ICe) route. If IV or ICe fluids are given, a mixture of aminoplex, electrolytes, and glucose may be administered with a high fluid component. A B-complex multivitamin should also be included in the mixture.[25] This type of supplementation will suffice for several weeks in the absence of severe metabolic abnormalities. Discontinuing the IV or ICe feedings must be done gradually over a 2- to 3-day period. Keep in mind that significant day-to-day changes in weight are usually caused by alterations in fluid content rather than by body mass. The clinical status of the animal should be monitored daily and additional laboratory tests done to address any abnormalities observed by the clinician.

Regardless of the feeding method used, unless specific contraindications exist, voluntary food consumption should be encouraged. Intensive intervention is often necessary to stimulate an anabolic response sufficient for the animal to begin eating voluntarily; however, it is preferable to avoid practices that may adversely affect the nutritional status of the patient.

Appetite stimulants have generally been found to have minimal effects in fish; however, the use of steroids and nonsteroidal antiinflammatory agents have been shown to work in some cases.[6] Providing B vitamins may also have some value as an appetite stimulant.[25]

Miscellaneous Drugs

Table 4-5 represents a list of miscellaneous compounds used in fish medicine.

SURGERY

Fish surgery is still in its infancy, and there is still much skepticism regarding its value.[20] However, surgical procedures are currently performed with regularity and reasonable success. This is a direct result of the improved anesthetic techniques available for aquatic species and an increased number of training opportunities to enhance the surgical skills of clinicians that perform specialized procedures on fish. Fish surgeries are performed in research, public facilities, and more recently, by private practitioners in their veterinary clinics. There are a number of reasons why the veterinary clinician may pursue a surgical option in a fish case, including an inability to manage the case using only internal medicine, the monetary value of the animal, to provide improved aesthetics for display animals suffering from a traumatic injury or disfiguring wound, or the emotional attachment of the owner.[20,26] There are multiple published resources available on the subject of fish surgery.[6,19,20,24,26]

Surgical site preparation for fish should follow the same standards set forth for higher vertebrates. Povidone-iodine (1 : 20) or chlorhexidine (1 : 40) can be used to reduce the gross contamination on the skin surface. Aggressive disinfection should be avoided, as it can cause significant damage to the integument. Clear plastic surgical drapes should be used to reduce the amount of contact with the protective mucous layer of the skin and to provide a moisture barrier for insensible water loss. The skin should be kept moist throughout the entire surgical procedure by continuous irrigation.

The benefits and risks of special diagnostic procedures should be considered before any surgical procedure is carried out. Conventional radiography works well for diagnosing gas

TABLE 4-5 Miscellaneous Agents Used to Manage Fish in Captivity

Agent	Dosage	Comments
Activated carbon	75 g/40 L	Removal of medications and organic waste
Carp pituitary extract	5 mg/kg, IM, q6h	Use with HCG to stimulate egg release
HCG	30 IU/kg, q6h	Stimulate release of eggs
LH-A	2 ug/kg, IM, q8h	Stimulate release of eggs, use with haloperidol or reserpine
Nitrifying bacteria	Use as directed for commercial products	Seed or improves development of biologic filtration
Reserpine	50 mg/kg, IM	Dopamine blocking agent

HCG, human chorionic gonadotropin; IM, intramuscular; LRH-A, luteinizing hormone.

trapping lesions and/or foreign body obstructions, but it is more limited when assessing soft tissue masses or lesions. If more advanced diagnostics are available, such as computed tomography or magnetic resonance imaging, and economically warranted, they may prove invaluable for assessing a soft tissue lesion and determining/confirming the value of a surgical approach.

Many of the same surgical instruments used to perform procedures in domestic mammals can be used for fish too. Modified spay-neuter surgical packs or ocular/microsurgical packs may be used for smaller species. Balfour or Gelpi retractors are useful for exploring the abdomen or extended gastrointestinal procedures. Radiosurgery is an invaluable tool for fish surgery. This surgical instrument can be used to make the initial incision, collect biopsy samples, and control hemorrhage. Magnification loupes are another important surgical tool. A magnification loupe can provide the surgeon with a significantly improved field of vision for a surgical procedure.

Skin closure in fish is optimized by the use of subcutaneous or subcuticular absorbable sutures. Closure may also benefit from the addition of a surgical adhesive such as Nexaband (Abbott Laboratories, North Chicago, IL). Localized dermatitis has been reported after the use of surgical adhesives; however, we have not noted any problems associated with this particular brand of adhesive. Fish skin heals very slowly in comparison to mammal skin. For fish, it is best to leave sutures in for a minimum of 4 to 6 weeks.

With ICe surgical procedures, it may be beneficial to irrigate the coelomic cavity postoperatively with an isotonic preparation of antibiotics. This has proven particularly beneficial when performing gastrointestinal procedures where there is a high risk of bacterial contamination. However, the efficacy of prophylactic antibiotic therapy being used in this manner in fish has not been rigorously evaluated and should therefore be pursued with caution.

Fish Anesthesia

The selection of a particular anesthesia for a fish procedure should be based on the procedure being done (e.g., length of procedure, amount of analgesia required, degree of immobility required) and anesthetic availability. Table 4-6 represents a list of commonly used anesthetics for fish.

Before an anesthetic event, the fish patient should be thoroughly evaluated to ensure that it is a good anesthetic candidate. Fish that are stressed are not considered good anesthetic candidates and may have inconsistent or rough anesthetic events. Food should be withheld for a minimum of 8 to 12 hours to ensure that a fish does not regurgitate and contaminate the anesthetic solution.

Traditional fish anesthesia was barbaric, and many “fish surgeons” would rely on “bruticaine” to restrain animals for physical examination and short surgical procedures. This technique is unacceptable, as there are a number of safe, reliable anesthetic agents that can be used to appropriately restrain or anesthetize a fish.

Monitoring fish during an anesthetic procedure can be difficult. In most cases, opercular movement, loss of equilibrium (e.g., absence of righting reflex), sensitivity to painful stimuli, fin color, and gill color are used to assess the patient. In larger specimens, a pulse oximeter, ECG, or crystal Doppler may be used to monitor heart rate, although the heart of fish may continue to pump for a period of time after the animal is dead.

TABLE 4-6 Anesthetic Agents Used in Fish

Agent	Dosage	Comments
Atipamezole	2 mg/kg	Reversal agent for medetomidine
Butorphanol	0.05-0.10 mg/kg, IM	Analgesia
Carbocaine		Local anesthesia
Carbon dioxide	To effect	Euthanasia
Clove oil (eugenol)	40-120 mg/L	Stock solution 100 mg/L, 1 part clove oil to 9 parts 95% ethanol
Ethanol	1.0%-1.5% bath	Euthanasia
Halothane	0.5-2.0 ml/L	Bath or vaporize
Isoflurane	0.5-2.0 ml/L	Bath or vaporize
Ketamine	66-88 mg/kg, IM	Short procedures
Ketamine	1-2 mg/kg	Premedication
Medetomidine	0.5-0.1 mg/kg, IM	Reverse with atipamezole 0.2 mg/kg
Lidocaine	<5 mg/kg	Local anesthetic
MS-222	100-200 mg/L, induction, 50-100 mg/L, maintenance	Anesthesia, stock solution 10 g/L, buffered
Propofol	1.5-2.5 mg/kg, IV	Intravenous only
Quinaldine sulfate	50-100 mg/L, induction 15-60 mg/L, maintenance	Anesthesia, stock solution 10 g/L, buffered
Sodium bicarbonate	30 g/L, bath	Euthanasia

IM, intramuscular; IV, intravenous.

In the case of waterborne anesthetics, dechlorinated water may be used to irrigate the gills and "lighten" the plane of anesthesia.

Common Surgical Procedures

The most common surgical procedures performed on captive fish are biopsy collection (external and internal), exploratory laparotomy, and foreign body removal. Skin biopsies can be collected via an excisional (e.g., small section of tissue is removed for histopathology) or scraping procedure (see special diagnostic tests). Radiosurgery is recommended for excisional biopsies to minimize blood loss.

Exploratory laparotomy or laparoscopy is an excellent method for examining the internal organs of fish and collecting tissue biopsies for histopathology. This type of procedure can be done using a standard midline ventral approach or a laparoscope. In cases where the surgeon only expects to visualize the organs and collect biopsies, laparoscopy is preferred because it will cause minimal tissue damage. Another benefit associated with laparoscopy is that it is more aesthetically pleasing (e.g., small or no scar) and the patient can be returned to their display aquarium sooner. One limitation associated with laparoscopy in fish is the limited view that can be obtained in certain species or in obese animals. In these cases, a laparotomy is preferable.

Foreign body ingestion is a common occurrence in carnivorous fish. Diagnosing a foreign body in fish should follow the same diagnostic plan (e.g., diagnostic imaging) used for terrestrial vertebrates. In some cases, the foreign body can be removed using an endoscope or by direct visualization, whereas in others it requires a laparotomy. Before attempting a surgical procedure, it is important for the veterinarian to become familiar with the specific anatomy of their patient. The surgical procedure for removing a foreign body from a fish is similar to the procedure used for terrestrial vertebrates.

Preoperative and Postoperative Considerations

Preoperative and postoperative pain management in fish have not been studied in depth. However, butorphanol (0.1 mg/kg IM) has been used as both a preanesthetic and postanesthetic analgesic without adverse effects.[20] Fish being recovered from surgery should be placed in an isolated tank with nonanesthetic water taken from the animal's aquarium. The recovery water should be aerated to ensure appropriate dissolved oxygen levels in the water column. To prevent unnecessary trauma or accidental death, it is important to confirm that the fish has completely recovered before it is returned to a community system. External stimulation should be kept to a minimum during the recovery process to minimize stress (e.g., no excessive noise, movement, light). Some species exhibit a rebound effect to certain anesthetic agents. This is often more pronounced in cold-water species. The physiologic parameters monitored during the anesthetic event should continue to be evaluated until the fish is deemed recovered (e.g., normal heart and respiratory rates, righting reflex returned, pain response [measured by fin pinch] returned).

ZOONOSES

Humans can be exposed to ornamental fish pathogens from direct contact with the fish or their water. Most of the zoonotic diseases attributed to ornamental fish occur as a result of microbes being introduced into open wounds or puncture wounds that occur during handling. Humans with a compromised immune system may be predisposed to opportunistic infections. Most cases of fishborne zoonotic diseases result in mild episodes of disease.[27] A number of opportunistic bacterial pathogens have been associated with human illness, including *Clostridium* spp., *Erysipelothrix rhusiopathiae, Mycobacterium* spp., *Staphylococcus* spp., and *Streptococcus* spp. Members of the family Enterobacteriaceae (e.g., *Edwardsiella tarda, Klebsiella* spp., *Salmonella* spp., *Yersinia* spp.) are routinely isolated from aquatic environments and have also been associated with human illness. Fish parasites and toxins have been found to cause human illness but are not generally a problem with ornamental fish because they are not eaten. To prevent the transmission of potentially zoonotic diseases, veterinary professionals should follow standard safety protocols and wear gloves.

REFERENCES

1. Adey HW, Loveland K: *Dynamic Aquaria,* San Diego, Calif, 1991, Academic Press.
2. Stoskopf MK: *Fish Medicine,* Philadelphia, 1993, WB Saunders.
3. Noga EJ: *Fish Disease: Diagnosis and Treatment,* St Louis, 1996, Mosby.
4. Axelrod HR, Burgess WE: *Saltwater Aquarium Fish,* Neptune, NJ, 1973, TFH.
5. Plumb JA: *Health Maintenance and Principle Microbial Diseases of Cultured Fishes,* Ames, 1999, Iowa State University Press.
6. Roberts RJ: *Fish Pathology,* Philadelphia, 2001, WB Saunders.
7. Cox GF: *Tropical Marine Aquaria,* New York, 1997, Grosset & Dunlap.
8. Axelrod HR, Burgess WE: *Atlas of Freshwater Aquarium Fishes,* Neptune City, NJ, 1997, TFH.
9. Paul JP: *Marine Microbiology,* San Diego, Calif, 2001, Academic Press.
10. Austin B: *Methods in Aquatic Bacteriology,* New York, 1989, Wiley.
11. Russo RC: Ammonia, nitrite, and nitrate. In Rand GM, Pertocelli SR, editors: *Fundamentals of Aquatic Toxicology,* New York, 1985, Hemisphere.
12. Emerson K, Russo RC, Lund RE et al: Aqueous ammonia equilibrium calculations: effect of pH and temperature, *J Fish Research Board of Canada* 32:2379-2383, 1975.
13. Tucker CS: Water analysis. In Stoskopf MK, editor: *Fish Medicine,* Philadelphia, 1993, WB Saunders.
14. Piper RG, McElwaine JB, Orne LE et al: *Fish Hatchery Management,* US Department of the Interior, Fish and Wildlife Service, Washington DC, 1982.
15. Halver JE, Hardy RW: *Fish Nutrition,* San Diego, Calif, 2002, Academic Press.
16. Yanong RP: Nutrition of ornamental fish, *Vet Clin North Am Exot Anim Pract* (1):19-42, 1999.
17. Post G: *Textbook of Fish Health,* Neptune, NJ, 1987, TFH.
18. Fudge AM: *Laboratory Medicine,* Philadelphia, 2000, WB Saunders.
19. Ross LG, Ross B: *Anaesthetic and Sedative Techniques for Aquatic Animals,* Malden, Mass, 1999, Blackwell.
20. Harms CA, Lewbart GA: Surgery in fish, *Vet Clin North Am Exot Anim Pract* 3:759-774, 2000.

21. Tomasso JR, Davis KB, Parker NC: Plasma corticosteroid electrolyte dynamics of hybrid striped bass (white bass × striped bass) during netting and hauling stress, *Proc World Mariculture Soc* 11:303-310, 1980.
22. Ackerman L: *The Biology, Husbandry and Health Care of Reptiles, vol 3, Health Care of Reptiles,* Neptune, NJ, 1997, TFH.
23. Dunbar CE, Wolf K: The cytological course of experimental lymphocycstis in the bluegill, *J Infect Dis* 116:466-472, 1996.
24. Stamper AM, Miller SM, Berzins I: Pharmacology in elasmobranchs. In Smith M, Warmolts D, Thoney D et al, editors: *Elasmobranch Husbandry Manual*, Columbus, OH, 2004, Ohio Biological Survey, Inc.
25. Lewbart GA: Fish. In Carpenter JW, editor: *Exotic Animal Formulary*, ed 3, Philadelphia, 2005, Elsevier.
26. Lewbart GA: *Ornamental Fish,* Ames, 1998, Iowa State Press.
27. Nemetz TG, Shotts EB: Zoonotic diseases. In Stoskopf MK, editor: *Fish Medicine,* Philadelphia, 1993, WB Saunders.