Chapter 24

Fishes

Overview

- "Fish" has many usages extending beyond what are actually considered fish today (e.g., starfish, etc.).
- A modern fish is an aquatic vertebrate with gills, limbs (if present), in the form of fins, and usually with a skin covered in scales of dermal origin.
- Fishes do not form a monophyletic group.
- The common ancestor of fishes is also an ancestor of land vertebrates; therefore in pure cladistics, this would make land vertebrates "fish"—a nontraditional and awkward usage.
- With over 26,000 living species, fish include more species than all other vertebrates combined.

Overview

- They are adapted to live in a medium 800 times more dense than air.
- They can adjust to the salt and water balance of their environment.
- Their gills are efficient at extracting oxygen from water that has 1/20th the oxygen of air.
- A lateral line system detects water currents and vibrations, a sense of "distant touch."
- Evolution in an aquatic environment both shaped and constrained its evolution.
- "Fish" refers to one or more individuals of one species; "fishes" refers to more than one species.

History

- Fishes descended from an unknown free-swimming protochordate ancestor.
- Soft-bodied fish-like vertebrates were a paraphyletic group of agnathans.
  - Agnathans include extinct ostracoderms and living hagfishes and lampreys.
  - Hagfishes lack vertebrae and lampreys have rudimentary vertebrae.
  - Agnathans are included in subphylum Vertebrata because they have a cranium and other features.
  - Agnathans are unique enough to be assigned in separate classes.
- Remaining fish have paired appendages and join tetrapods as a monophyletic lineage of gnathostomes.

Fig. 24.1

- They appear in the Silurian fossil record with fully formed jaws, and no intermediates are known.
- The Devonian is called the Age of Fishes.
- One group, the placoderms, became extinct in the Carboniferous and left no direct descendants.

Fig. 24.2
History - Cartilaginous Fishes

- The cartilaginous fishes lost the heavy dermal armor and adopted cartilage as the skeleton.
- They flourished during the Devonian and Carboniferous.
- They nearly became extinct at the end of the Paleozoic.
- They increased in numbers in the early Mesozoic, radiating to form a modern shark assemblage.

History - Acanthodians

- These fish were well represented in the Devonian but became extinct by the lower Permian.
- They resemble bony fish but have heavy spines on all fins except the caudal fin.
- They were probably the sister group of the bony fishes.

History - Bony Fishes

- These are the dominant fishes today.
- They have two distinct lineages: the ray-finned fishes and the lobe-finned fishes.
- The ray-finned fishes radiated to form modern bony fishes.
- Lobe-finned fishes are a relict group with few species today, but include the sister group of the tetrapods.

Living Jawless Fishes

- Living jawless fishes are represented by hagfishes and lampreys.
- About 43 species of hagfishes are known and about 41 species of lamprey are described.
- Members of both groups lack jaws, internal ossification, scales or paired fins.
- Both groups share porelike gill openings and an eel-like body.
- Hagfishes are least derived; lampreys are much closer to gnathostomes.
- Therefore, the grouping Agnatha is a paraphyletic assemblage of jawless fishes.

Class Myxini: Hagfishes

- Hagfishes are entirely marine.
- They are scavengers and predators of annelids, molluscs, dead or dying fishes, etc.
- The hagfish enters a dead or dying animal through an orifice or by digging inside using keratinized plates on its tongue to rasp away bits of flesh.
- It is nearly blind but can locate food by an acute sense of smell and touch.

Feeding

- To provide leverage, the hagfish ties a knot in its tail and passes it forward to press against the prey.
- Special glands along the body secrete fluid that becomes slimy in contact with seawater.
- The body fluids of a hagfish are in osmotic equilibrium with seawater.
Reproduction and Development

- The larva lives first on its yolk supply and then drifts downstream to burrow into sandy areas.
- The larva is a suspension-feeder until it metamorphoses into an adult.
- Change to an adult involves eruption of eyes, keratinized teeth replacing the hood, enlargement of fins, maturation of gonads and modification of gill openings.

Parasitic Lampreys

- They attach to a fish by sucking the mouth and sharp teeth rasp away flesh as they suck fluids.
- They inject anticoagulant into a wound to promote flow of blood.
- When engorged, the lamprey drops off but the wound may be fatal to the fish.
- Parasitic freshwater adults live 1-3 years before spawning and dying; anadromous forms live 2-3 years.
- Nonparasitic lampreys do not feed, their alimentary canal degenerates as an adult, and they spawn and die.

Sea Lamprey Invasion of the Great Lakes Region

- No lampreys were in the U.S. Great Lakes west of Niagara Falls until the Welland Ship Canal was built in 1829.
- A century later, sea lampreys were first seen in Lake Erie, then spread to all of the U.S. Great Lakes in the 1940s.
- Lampreys preferred lake trout and destroyed this commercial species.
- They have turned to rainbow trout, whitefish, burbot, yellow perch and lake herring.
- After decimating these populations, they resorted to chubs and suckers.
- The lamprey populations declined both from depletion of food and from control measures.
- Chemical larvicides were used in spawning streams; release of sterile males is also being used.
**Class Chondrichthyes: Cartilaginous Fishes**

- Nearly 850 living species are in the class Chondrichthyes.
- Although a smaller and more ancient group, their well-developed sense organs, powerful jaws and predaceous habits helped them survive.
- Although calcification may be extensive, true bone is completely absent throughout the class.
- Nearly all are marine; only 28 species live primarily in freshwater.
- After whales, sharks are the largest living vertebrates, reaching 12 meters in length.

**Subclass Elasmobranchii: Sharks, Skates and Rays**

- There are nine orders of elasmobranchs with about 815 total species described.
- Order Carcharhiniformes contains the coastal tiger and bull sharks and the hammerhead.
- Order Lamniformes contains large, pelagic sharks such as the white and mako shark.
- Dogfish sharks commonly studied in comparative anatomy classes are in the order Squaliformes.
- The order Rajiformes includes skates, sawfish rays, electric rays, stingrays, manta rays & others.
- There are authenticated cases of attacks by the great white, mako, tiger, and hammerhead sharks, and casualties are more common in tropical and temperate waters of the Australian region.

**Form and Function**

- Sharks are among the most gracefully streamlined of fishes; the body is fusiform.
- The front of the ventral mouth is the pointed rostrum.
- The tail has a longer upper lobe; this pattern is called heterocercal.
- Fins include paired pectoral and pelvic fins, one or two median dorsal fins, a median caudal fin, and sometimes a median anal fin.

- In males, the medial part of the pelvic fin is modified to form a clasper used in copulation.
- The lateral eyes are lidless; behind each eye is a spiracle, a remnant of the first gill slit.
- The tough, leathery skin has placoid scales that reduce water turbulence.
- Upper and lower jaws are equipped with sharp, triangular teeth that are constantly replaced.

**Senses**

- Sharks track prey using sequence of sensitive senses.
- Prey detected at a distance by large olfactory organs sensitive to 1 part/10 billion.
- Prey may also be located from long distances sensing low frequency vibrations in the lateral line.
- The lateral line consists of neuromasts in tubes and pores on the side of the body.
- At close range, sharks switch to vision.
- Up close, sharks guided by bioelectric fields.
  - Electroreceptors, the ampullae of Lorenzini, are located on the shark’s head.
Reproduction and Development

- All chondrichthyes have internal fertilization; maternal support of the embryo is variable.
- Those that lay large, yolky eggs immediately after fertilization are oviparous.
- Some ovoviviparous sharks and rays lay a capsule or “mermaid’s purse” that catches onto kelp with tendrils.
- The embryo is nourished from the yolk for up to two years before hatching as a miniature adult.
- Sharks that retain embryos are ovoviviparous if the embryo is nourished by yolk.
- True viviparous reproduction occurs where embryos receive nourishment from the maternal bloodstream from nutritive secretions of the mother.
- Prolonged retention contributes to the success of this group but there is no further parental care.

Subclass Holocephali: Chimeras

- Members of this small subclass are remnants of a line that diverged from the earliest shark lineage.
- There are 31 extant species.
- Fossil chimaeras first appeared in the Carboniferous and reached a zenith in the Cretaceous and early Tertiary, and then declined.
- In the early to middle Silurian, a lineage of fishes with bony endoskeletons gave rise to a clade that contains 96% of living fishes and all living tetrapods.
- More than 1/2 of elasmobranchs are rays, most specialized for benthic life.
- In the heart chambers provide the standard circulatory flow through gills and body.
- Elasmobranchs retain nitrogenous compounds in the blood to raise blood solute concentrations and eliminate the osmotic inequality between blood and seawater.

Other Systems

- The dorsoventrally flattened body and enlarged pectoral fins are used as wings in swimming.
- A lung or swim bladder is present that was evolved as an extension of the gut.
- The heart chambers provide the standard circulatory flow through gills and body.
- Elasmobranchs retain nitrogenous compounds in the blood to raise blood solute concentrations and eliminate the osmotic inequality between blood and seawater.
- The rectal gland secretes sodium chloride and in this regard assists the opisthonephric kidney.
- The spiral valve in the intestine slows passage of food and increases absorptive area.
- A liver and pancreas open into the short, straight intestine.
- The mouth lacks teeth but has large flat plates for crushing food; the upper jaw is fused to the cranium.
- The food is a wide range of seaweed, molluscs, echinoderms, crustaceans and fish.

Form and Function of Rays

- Water for respiration is taken in through spiracles on top head.
- Teeth are adapted for crushing prey: molluscs, crustaceans and sometimes small fish.
- Electric rays have a whiplike tail with spines and venom glands.
- Stingrays have a whiplike tail with spines and venom glands.
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Osteichthyes: Bony Fishes

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- Other early fishes are now known to also have had bone.
- Three features unite bony fishes and tetrapod descendants.
  - Endochondral bone is present that replaces cartilage developmentally.
  - A lung or swim bladder is present that was evolved as an extension of the gut.
  - They have several cranial and dental characters unique to this clade.

Digestion

- A liver and pancreas open into the short, straight intestine.
- The spiral valve in the intestine slows passage of food and increases absorptive area.
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Classification

- **Osteichthyes** does not define a natural group and is a term of convenience rather than a valid taxon.
- By the middle of the Devonian, bony fishes developed into two major lineages.
  - The ray-finned fishes, class Actinopterygii, radiated to form modern bony fishes.
  - Seven species of lobe-finned fishes, class Sarcopterygii, include lungfishes and the coelacanth.

Adaptive Characteristics

- The operculum increased respiratory efficiency; outward rotation helped draw water across the gills.
- The gas-filled structure off the esophagus helped in buoyancy and also in hypoxic waters.
- Specialization of jaw musculature improved feeding.

Class Actinopterygii: Ray-finned Fishes

- Over 23,600 species of ray-finned fishes constitute the most familiar bony fishes.

**Morphological Trends**

- Heavy dermal armor replaced by light, thin, flexible cycloid and ctenoid scales.
  - Some eels, catfishes and others completely lost scales.
- Fins changed to provide greater mobility and serve a variety of functions: braking, streamlining and social communication.
- The **homocercal** tail allowed greater speed and buoyancy.
- The swim bladder shifted from primarily respiratory to buoyancy in function.
- The jaw changed to increase suctioning and protrusion to secure food.

Teleosts

- Teleosts constitute 96% of all living fishes and half of all vertebrates.
- Perhaps 5,000-10,000 remain undescribed, many are from remote areas but some live in North America.
- Teleosts range from 10 millimeters to 17 meters long, and up to 900 kilograms in weight.
- They survive from 5,200 meters altitude in Tibet to 8,000 meters below the ocean surface.
- Some can live in hot springs at 44°C while others survive under Antarctic ice at -2°C.
- Some live in salt concentrations three times seawater; others in swamps devoid of oxygen.
Class Sarcopterygii: Lobe-finned Fishes

- Only seven species are alive today; six species of lungfishes and the coelacanth.
- Early Sarcopterygians had lungs as well as gills, and a heterocercal tail.
- During the Paleozoic, the tail became symmetrical with a continuous fin known as diphycercal.
- The fleshy, paired lobes appear to have been used to scuttle along the bottom.
- Their skin was covered with heavy scales consisting of cosmine overlaid by thin enamel.

The Coelacanth

- Coelacanths arose in the Devonian, radiated, reached a peak in the Mesozoic and dramatically declined.
- Thought to be extinct 70 myrs, a specimen was dredged up in 1938.
- Eventually more were caught off the coast of the Comoro Islands, and in 1998, in Indonesia.
- The living coelacanth is a descendant of Devonian freshwater stock.
- The tail is diphycercal with small lobe between the upper and lower lobes.
- Young coelacanths are born fully formed after hatching from eggs up to nine cm in diameter.

Locomotion in Water

- Speed
  - Most fishes swim maximally at ten body lengths per second; a larger fish therefore swims faster.
  - Short bursts of speed are possible for a few seconds.

Mechanism

- The trunk and tail musculature propels a fish.
- Muscles are arranged in zigzag bands called myomeres; they have the shape of a W on the side of the fish.
- Internally the bands are folded and nested; each myomer pulls on several vertebrae.
- Fish undulations move backward against the water, producing a reactive force with two parts.
- The thrust pushes the fish forward and overcomes drag.
- The lateral force makes the fish’s head “yaw”; a large and rigid head minimizes yaw.
- The swaying body generates too much drag for fast speed.
- Fast, oceanic fish have swept-back sickle-like tail fins, similar to high-aspect ratio wings of birds.

Economy

- Swimming is the most economical form of motion because water buoy the animal.
- The energy cost per kilogram of body weight for traveling one kilometer is 0.39 Kcal for swimming, 1.45 Kcal for flying and 5.43 for walking.
- It is yet to be determined how aquatic animals can move through water with little turbulence.
Neutral Buoyancy and the Swim Bladder

- Fish are slightly heavier than water.
- To keep from sinking, sharks must continually move forward.
- The shark liver has squaline, a fatty hydrocarbon, that acts to keep sharks a little buoyant.
- The swim bladder, is the most efficient flotation device.
  - A fish can control depth by adjusting the volume of gas in the swim bladder.
  - Due to pressure, as a fish descends, the bladder is compressed making the total density of the fish greater.
  - As a fish ascends, the bladder expands making the fish lighter and it will rise ever faster.

Respiration

- Fish gills are filaments with thin epidermal membranes folded into plate-like lamellae.
- The gills are inside the pharyngeal cavity and covered with a movable flap, the operculum.
- The operculum protects the delicate gill filaments and streamlines the body.
- Pumping action by the operculum helps move water through the gills.

- Although it appears pulsatile, water flow over gills is continuous.
- Water flow is opposite to the blood flow; this countercurrent exchange maximizes exchange of gases.
- Some bony fishes remove 85% of the oxygen from water that passes over their gills.
- Some active fishes use ram ventilation; forward movement is sufficient to force water across gills.
- Such fishes are asphyxiated in a restrictive aquarium even if the water is saturated with oxygen.

Fishes Out of Water

- Lungs of lungfishes allow them to respire from air.
- Eels can wriggle over land during rainy weather; they use skin as their major respiratory surface.
- A bowfin uses gills at cooler temperatures and its lung-like swim bladder at higher temperatures.
- The electric eel has degenerate gills and gulps air through its vascular mouth cavity.
- The Indian climbing perch spends most of its time on land, breathing air in special chambers.

Osmotic Regulation

- Freshwater has far less salt than is in fish blood; water tends to enter the body of the fish and salt is lost by diffusion.
- The scaled and mucous-covered body is mostly impermeable, but gills allow water and salt fluxes.
Freshwater fishes are hyperosmotic regulators.
- The opisthonephric kidney pumps excess water out.
- Special salt-absorbing cells located in epithelium actively move salt ions from the water to the fishes’ blood.
- These systems are efficient; a freshwater fish devotes little energy to keeping osmotic balance.
- About 90% of bony fishes are restricted to either freshwater or seawater habitats.
- Euryhaline fishes live in estuaries where salinity fluctuates throughout the day.

Marine bony fishes are hypoosmotic regulators.
- Marine fishes have a much lower blood salt concentration than in the seawater around them.
- Therefore, they tend to lose water and gain salt; the marine fish risks “drying out.”
- To compensate for water loss, a marine teleost drinks seawater; this brings in more unneeded salt.
- Unneeded salt is carried by the blood to the gills and secreted by special salt-secretory cells.
- Divalent ions of magnesium, sulfate and calcium are left in the intestine and leave the body with the feces or enter the bloodstream and are excreted by the kidney.
- Marine fish excrete divalent ions by tubular secretion; glomeruli are small or missing.

Feeding Behavior
- Fish devote most of their time searching for food to eat and feeding.
- With the evolution of jaws, fish left a passive filter-feeding life and entered a predator-prey battle.
- Most fish are carnivores that feed on zooplankton, insect larvae and other aquatic animals.
- Most fish do not chew food since it would block water flow across the gills.
  - Most swallow food whole; this is easy with water pressure that sweeps food in when the mouth opens.

Reproduction
- Most fishes are dioecious with external fertilization and external development.
- Guppies and mollies represent ovoviviparous fish that develop in the ovarian cavity.
- Most sharks are viviparous with some kind of placental attachment to nourish young.
- Most oviparous pelagic fish lay huge numbers of eggs; a female cod may release 4-6 million eggs.
- Near-shore and bottom-dwelling species lay larger, typically yolky, nonbuoyant and adhesive eggs.
- Some bury eggs. Many attach them to vegetation and some incubate them in their mouths.

Feeding Behavior
- Some fish are herbivores and eat plants and algae; they are crucial intermediates in the food chain.
- Suspension feeders are a third group, and crop the abundant microorganisms of the sea.
- Many of the plankton feeders swim in large schools and use the gill rakers to strain food.
- Omnivores can feed on both plant and animal food.
- Scavengers feed on organic debris.
- Parasitic fishes suck the body fluids of other fishes.
Reproduction

- Many benthic spawners guard their eggs; usually the male is the guard.
- Freshwater fishes produce nonbuoyant eggs; the more care provided, the fewer the eggs produced.
- Freshwater fishes may have elaborate mating dances before spawning.

Development

- The fish hatches carrying a semi-transparent yolk sac to supply food until it can forage.
- The change from larva to adult may be dramatic in body shape, fins, color patterns, etc.
- Growth is temperature dependent; warmer fish grow more rapidly.
- Annual rings on scales, otoliths, etc. reflect seasonal growth cycles.
- Most fish continue to grow throughout life and do not stop at maturity.

The End.