Classification of Fishes

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Diagram showing the classification of fishes:

- Cephalochordates
- Hagfishes
- Lampreys
- Sharks
- Rays, skates
- Rattfishes
- Ray-finned fishes
- Coelacanths
- Amphibians
- Mammals
- Turtles
- Snakes, lizards
- Crocodiles
- Birds

Prokaryotes

Eukaryotes

Domain Bacteria

Domain Archaea

Common ancestor

Kingdom Animalia

Kingdom Fungi

Kingdom Plantae

Domain Eukarya
Marine Fish

• Marine fish are vertebrates
• Some have vertebra made of cartilage, while others have bony vertebra
• Of the 24,000 known species of fish, about 15,000 species are marine
• Fish are the oldest of vertebrates (found farther back in the fossil record)
• Fish are by far the largest group of vertebrates in terms of species and abundance
• About half of all vertebrate species are fish
Types of Marine Fish

1. Agnatha (jawless fish)
   - Hagfish
   - Lampreys

2. Chondrichthyes (cartilaginous fish)
   - Sharks
   - Skates
   - Rays
   - ratfish

3. Osteichthyes (bony fish)
   - Lobe-finned fishes
   - Ray-finned fishes
Types of Marine Fish

• Agnatha
  – These jawless fish have a muscular, circular mouth with rows of teeth in rings
  – Long, cylindrical body
  – Lack paired fins and scales seen in other fish
  – Two types of jawless fish exist- hagfish and lampreys
Types of Marine Fish

• Hagfishes
  – 20 species
  – Exclusively marine
  – They feed on dead and dying fish and marine mammals primarily
  – Live in burrows in soft sediments
  – Produce large quantities of mucous from glands in the skin to protect them while feeding
Types of Marine Fish

• Lamprey
  – 30 species
  – Live in freshwater and salt water
  – Adults of some species spend a large portion of their life in the sea, but return to freshwater to breed; adults normally die after breeding.
  – Other species live in freshwater lakes
  – They feed on living fish by rasping into the sides of fish with their sucker-like mouth and consuming blood, tissue and body fluids.
More Advanced Groups of Fish

• Fishes in the Chondrichthyes and Osteichthyes are considered to be more advanced.

• General Characteristics (advancements) seen in these groups:
  – Highly efficient gills
  – Scales cover the body
  – Paired fins
  – A wide variety of jaw and feeding types
  – Lateral line and other sensory organs
  – Streamlined body
Types of Marine Fish

- **Chondrichthyes**
- General Characteristics of Group:
  - About 1000 species
  - Sharks, rays, skates and ratfishes are members of this group
  - Skeleton of cartilage (as the name implies)
  - Movable jaws with well-developed teeth
  - Placoid scales and paired fins
  - 5-7 gill slits open directly into the water in most species
  - Spiracles in many species (openings on head used to bring water directly in for respiration without opening the mouth)
  - Males in most species have projections of the anal fin called claspers that are used in copulation
Types of Marine Fish

• More specific details about Sharks
  – Primarily marine, but do travel up the mouths of rivers into freshwater in some species
  – The population numbers in many species of sharks are declining due to harvesting sharks for meat, oil, skin and fins
  – In addition to the lateral line, sharks have a sensory organ called the Organ of Lorenzini;
    • this organ is used to detect electrical currents when sharks are close to an object (the movement of muscles – even those used in respiration – emit a small electrical charge) – this allows sharks to detect living prey even it is hidden from their view if they can get within a few feet of the organism
Types of Marine Fish

More specific details about Sharks

– Most species possess 2 dorsal fins
– Reproduction in sharks is varied – some have live birth (known as vivipary); some lay egg cases (ovipary); while others have an internalized egg that hatches while still in the female before the young are expelled from the female’s reproductive system (ovovivipary)
– Many are carnivorous, some planktonic
– About 350 species currently exist
Types of Marine Fish

- **More specific details about Rays**
  - Rays always have live birth
  - Pectoral fins are expanded into “wings” and entire body is dorsoventrally flattened
  - Gill slits (5 pairs) mouth are on the underside of the body
  - Spiracles are located on the top of the body
  - Rays spend much of their time on the bottom (demersal) partially covered in sand
  - Large flattened teeth for feeding on molluscs and arthropods
  - Most have long whip-like tails; in sting rays, there is a spine at the base of the tail with an associated poison gland
  - Venom from this gland is delivered to other organisms if they make contact with this spine by stepping on a ray or making contact with the ray in some fashion
  - Electric rays have organs that produce electricity on either side of head
Types of Marine Fish

• More specific details about Skates
  – Like rays, skates are dorsoventrally flattened with pectoral fins modified into wings
  – Unlike rays, skates have a fleshy tail and no spine on the tail
  – Also unlike rays, skates always lay egg cases
  – After fertilization, the female lays egg cases with an embryo inside
  – The embryo develops within the protection of the egg case for weeks to months
  – They are also demersal (living on the bottom) and feed on molluscs and arthropods primarily
Types of Marine Fish

• More specific details about Ratfishes
  – Only about 30 species
  – Mostly are deep water inhabitant
  – One pair of gill slits is covered by a flap of skin (very unusual in the chondrichthyes)
  – They feed on the bottom on crustaceans and molluscs primarily
  – Heterocercal (lobes of different sizes) tail like in sharks
  – Unlike others in this group, they also have fin rays (tiny support rods) in the fins
Shark Videos

2. Naked Science: Shark Attacks (50:12)
3. 25 Species of Weird Sharks You Never Heard Of (8:13)
Types of Marine Fish

• **Osteichthyes, The Bony Fish**
  
  – As the name implies, these fish have a skeleton composed of bone
  
  – More species than all other vertebrates combined—over 23,000 species worldwide
  
  – Gills used for respiration
  
  – Hinged jaws allow for a variety of different ways of feeding
  
  – Homocercal tail (two lobes of equal size) provides forward thrust
Types of Marine Fish

Osteichthyes, The Bony Fish

- Flat bony scales (ctenoid or cycloid) protect body
- Bony operculum covers the gills (provides better protection against injury compared to gill slits for each gill)
- Lateral line used in sensory capacity and communication
- Swim bladder used for buoyancy control (some bottom dwelling fish lack swim bladder)
- Variable body plans are adapted for specific environments
Types of Marine Fish

• **Osteichthyes, The Bony Fish**
  – Coloration patterns:
  – Countershading is seen in virtually all fish species
  – In countershading, the ventral (belly) area of the fish is lighter than the dorsal area of the fish
  – This allows the fish to “blend in” with the environment
  – If a fish is seen from above, the darker coloration of the dorsal area blends in with the darker color of the ocean bottom
  – If the fish is seen from below, the lighter coloration of the ventral surface blends in with the lighter coloration of the ocean surface
Types of Marine Fish

• Osteichthyes, The Bony Fish
  – Coloration patterns:
  – Slower swimming fish often have bars or stripes that help break up the silhouette of a fish (a form of disruptive coloration)
  – This helps with predator avoidance
  – Some also have coloration that helps them blend in with environment (known as cryptic coloration)
Types of Marine Fish

• Osteichthyes, The Bony Fish
  – Coloration Patterns:
  – It is also not usually to see a fish with circular patterns on or near the caudal fin
  – This confuses predators who are not sure which end of the fish is the head
  – If the fish at right is attacked on caudal end where the black dot looks like an eye, he can probably get away with minor damage
  – However, if he is attacked on his head region, he may sustain serious, life threatening damage
  – Some fishes may also use color to advertise their bad taste or poisonous nature – this is known as warning coloration
Types of Marine Fish

• Osteichthyes, The Bony Fish
  – Body shapes vary greatly among fish dependent on the environment that fish calls home
  – For example, flounders and soles live on the bottom and cover themselves slightly with sand to camouflage themselves from potential predators as well as prey
  – The flat shape of the flounders and soles is well adapted to this lifestyle
Types of Marine Fish

• Osteichthyes, The Bony Fish
  – Body shapes, continued
  – Tuna, billfish, and other fast moving predators are long, streamlined and most of their fins serve as rudders basically (very little flexibility except in caudal fin)
  – This body shape allows these predators to cut through the water quickly
  – Notice, too, that the area of the body called the caudal peduncle (area just before the tail) is very thin – this allows all the muscles to concentrate in this area allowing for greater thrust of the caudal (tail) fin (this means FAST swimming capabilities)
Types of Marine Fish

• Osteichthyes, The Bony Fish
  – Body shapes, continued
  – By contrast, the angelfish represents the opposite environment
  – Angelfish and many other fish do not inhabit the open waters of the ocean like tunas and billfish do
  – Angelfish and the like inhabit coral reefs, oyster reefs and other similar environments
  – In these fish, the body is not as streamlined and the fins are feather-like for lots of flexibility
  – This flexibility allows for greater control around the features that would be seen in a coral reef type environment (crevices, etc)
Types of Marine Fish

• Osteichthyes, The Bony Fish
  – Body shapes, continued
  – Other fish have a shape that allows for camouflage in their environment
  – For example, fish like the toadfish and the stonefish actually look like rocks or “scenery” and thus can go undetected by predators or prey
Swimming Patterns

• Fish exhibit an “s-shaped” swimming pattern
• Bands of muscle along the body called myomeres drive this swimming motion
• Depending on the type of fish, different fins may be used primarily for the forward movement
Swimming Patterns

• In sharks, a swim bladder is absent (although there is a large lipid-rich liver to help in buoyancy) – therefore, sharks tend to sink when not in motion and there is no lift from the swim bladder while swimming either

• While swimming, sharks are aided by the “lift” provided by the position and stiffness of the pectoral fins
Swimming Patterns

• In bony fish, pectoral fins are not needed for lift and thus are normally not stiff in construction (exception: fast swimming species like tuna, billfish, etc)
• In contrast, the pectoral fins in many bony fins are flexible and used for maneuverability
• In some slower-swimming species, forward movement is mainly provided primarily by the pectoral fins
Swimming Patterns

• In other species, all the fins may be flexible and highly modified for camouflage (example: sea horses and sea dragons)

• This means that the fins will not allow for significant forward movement
Fish Gills

• The construction of the gill is the same in all fish – gill arch supports the entire structure, gill rakers are on the forward surface of the gill arch and gill filaments trail behind the gill arch.

• Like in the human lung, exchange of oxygen and carbon dioxide takes place on these surfaces.
Acquiring and Processing Food

• Mouth structure also reveals the dietary preferences of fish
• As an example, the “beak” (fused teeth) seen in parrotfish allows for these fish to scrape algae and other organisms off of hard surfaces
• The butterfly fish uses its long tube-like mouth to feed on corals
• While the barracuda uses rows of sharp teeth and a wide mouth to capture its prey – other fish
Acquiring and Processing Food

• The position of the mouth is also important
• A strongly forward facing mouth is important in fish who chase down their prey (as seen in barracuda)
• A downward facing mouth would be seen in fish feeding at/near the bottom
Acquiring and Processing Food

• Digestion of food in fish is completed with the aid of a stomach, intestine (with anus), liver, pyloric caeca and pancreas
• The stomach is structured very similarly to the human stomach – stretch receptors in the wall of the stomach indicate when a meal is present and needs to be mechanically digested by the churning motion of the stomach wall
Acquiring and Processing Food

• The intestine, pyloric caeca, pancreas and liver all secrete digestive enzymes to aid in the digestion process

• The intestines of carnivorous fish tend to be short and straight while the intestines of herbivorous fish are longer and more coiled (plant and algae material is more difficult to process, so it needs to stay in the intestines longer)
The Circulatory System

• Fish have a two chambered heart that serves to pump blood throughout the body (in contrast to the 4 chambered heart seen in mammals)
• A system of arteries, veins and capillaries takes blood to the body tissues and returns it for re-oxygenation by the gill filaments
• Oxygen and carbon dioxide will diffuse across the thin membranes of the capillaries either in the gills or at the tissues of the body
Fluid Balance in Fish

• Remember from earlier studies that the forces of osmosis and diffusion are always at work in an organism

• Solutes and gases will travel from areas where they are more concentrated to areas where they are less concentrated

• Since marine fish are living in an environment where the water is very solute-rich, these fish have a tendency to gain solutes and lose water

• Therefore, fish need to have mechanisms to combat this issue – this is called osmoregulation
Fluid Balance in Fish

• **Osmoregulation** is the term given to the process of managing internal water/solute balance

• Fish have evolved a variety of ways to osmoregulate including:
  – Many fish swallow seawater but then expel the solutes in the digestive process (this allows them to keep the water and lose the solutes)
  – Most marine fish pass very little urine
  – This urine (processed by the kidneys) is highly concentrated with solutes with very little water content
Fluid Balance in Fish

• Osmoregulation continued:
  – In cartilaginous fish, the blood is kept at about the same concentration as seawater
  – This is accomplished by keeping urea in the bloodstream (this toxin is filtered out of the blood by other organisms)
  – This means that no solutes are gained (or water lost) because the concentration internally and externally match
(a) Cartilaginous fishes

- Blood: about 35\% or higher
- Seawater: about 35\%_00
- Gills block loss of urea
- Ingests salts with foods
- Salts excreted by rectal gland
- Most urea retained by kidneys
- Slight water gain by osmosis through gills and skin

(b) Bony fishes

- Blood: about 14\% _00
- Kidneys retain water
- Drinks seawater
- Gains water and salts by swallowing seawater and food
- Some salts and water lost via scant urine
- Some salts pass through gut
- Salts excreted by chloride cells of gills
The Fish Nervous System

• The fish have a brain, spinal cord and numerous nerves like other vertebrates
• Fish also possess olfactory sacks (with nostrils) for smelling
• Taste buds are located in the mouth, lips, barbels and skin
• The eyes are structured slightly differently
• In humans, the lens changes shape for focusing on items
• In fish, the position of the lens changes like in a camera
The Fish Nervous System

• In some sharks, the eye is covered by a nictitating membrane that covers the eye – this clear membrane helps these predators protect the eye, especially during feeding
• Incidentally, this membrane is also seen in some reptiles
The Fish Nervous System

• All fish rely heavily on the lateral line system
• The lateral line is a series of pores and canals lined with cells called neuromasts that are specialized to detect vibrations
• These vibrations can indicate a predator or prey or the position of other fish in a school
The Fish Nervous System

• Cartilaginous fish also possess the organ (or ampulla) of Lorenzini
• This organ detects electrical charges
• All muscular system of organisms relies on small electrical charges
• Therefore, this organ can help cartilaginous fish detect prey, even if they are not visible (buried in sand, etc)
The Fish Nervous System

• The inner ears are set in fluid-filled canals with sensory cells similar to the lateral line system.
Behaviors in Fish

• Schooling
  – Schooling is used by a wide variety of fish
  – Schooling makes it possible for a group of smaller fish to appear much larger (as thus avoid detection by predators
  – It also makes it harder for a predator to capture any one fish
  – Because of this, many fish school as juveniles
  – About 4000 species school as adults
Behaviors in Fish

• Territoriality
  – Some fish are territorial by nature all the time, others are only territorial during reproduction
  – Fish maintain their territories normally by “posturing” to show their aggression
  – Posturing can include raised fins, open mouth, darting, etc.
  – Fights between individuals are actually rare
Behaviors in Fish

• Some species migrate between freshwater and saltwater at different times in their life
• Anadromous species like salmon, lampreys and sturgeon live in saltwater normally but go to freshwater for reproductive purposes
• Catadromous species like the American Eel live in freshwater but travel to saltwater for reproduction
Reproduction in Fish

- Sex hormones control the development of sperm and eggs in fish.
- The release of sex hormones can be cued by water temperature, day length, specific tide cycles, etc.
- Broadcast spawning (releases eggs and sperm directly into water for fertilization) is most common.
- Some fish do have internal fertilization (sperm is inserted directly into the female by the male).
- Complex mating behaviors are seen in some species.
Female entering territory -> Male

- Ventral mount and spawning
- Dorsal mount
- Flaunting display
- Prodding and grunting
- Leading
Reproduction in Fish

• Some fish are **hermaphroditic** (possess male and female reproductive organs)
• Some possess these structures at the same time (**simultaneous hermaphrodites**) - this is more rare
• Other species possess these structures at different times during the life (**sequential hermaphrodites**)


Reproduction in Fish

- Types of Sequential Hermaphrodites
  - In **protandry**, fish are first males and develop into females later in life.
  - In **protogyny**, fish are first females and develop into males later in life.
  - The cues for these changes are often the result of changes in social structure or environment.
  - As an example, in some species, a large male keeps a “harem” of females and he fertilizes the eggs of all.
  - When this male dies, the largest female develops into a functional male.
Reproduction in Fish

- Depending on the species, fish can either be:
  - **Viviparous** – young are born live
  - **Oviparous** - egg layers
  - **Ovoviviparous** – eggs are kept inside and “hatch” before being released from female reproductive tract
  - In most bony fish, eggs are laid by the thousands or millions and are not protected by the parents
  - In other bony fish, smaller numbers of eggs are laid and the parent(s) protect the eggs
  - **RARE:** A few species are **parthenogenic**- in this reproductive plan, young develop directly from the unfertilized eggs of the female (no DNA from males) – the young are “clones” of the female
Reproduction in Fish

• In most fish, intricate behaviors are cues for the release of eggs and sperm (this helps ensure fertilization)

• In some species, color changes or body structure changes may indicate readiness for reproduction