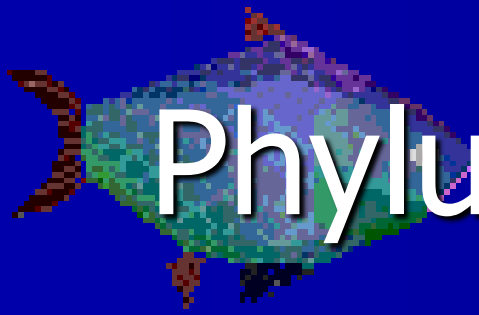
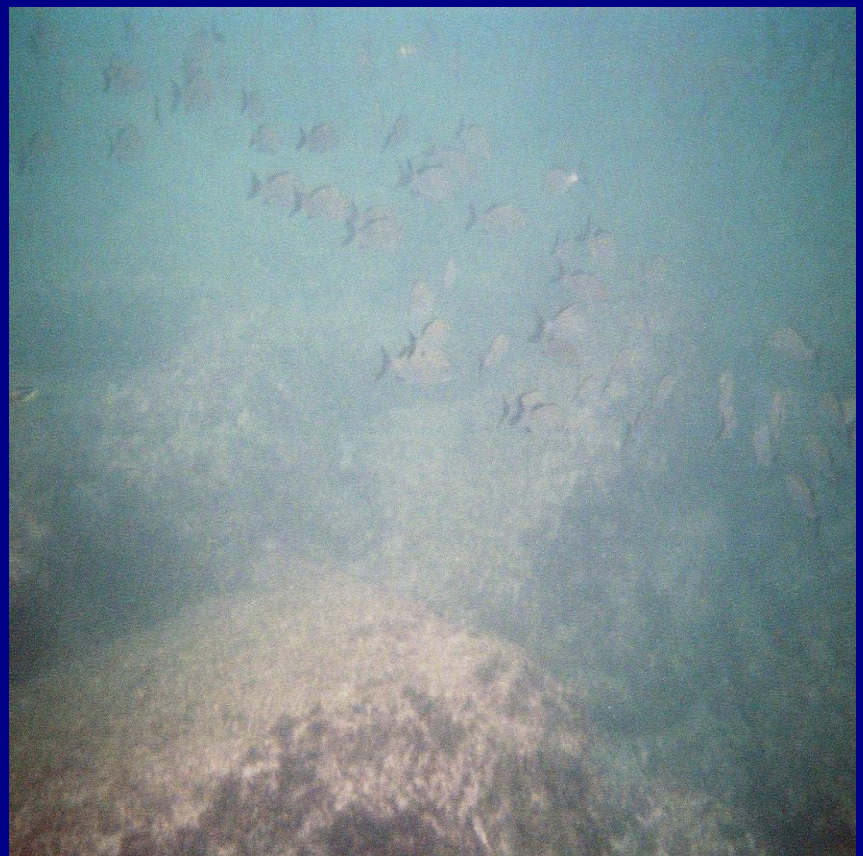


Phylum Chordata

All members of the Phylum Chordata must have had at one time in their development:

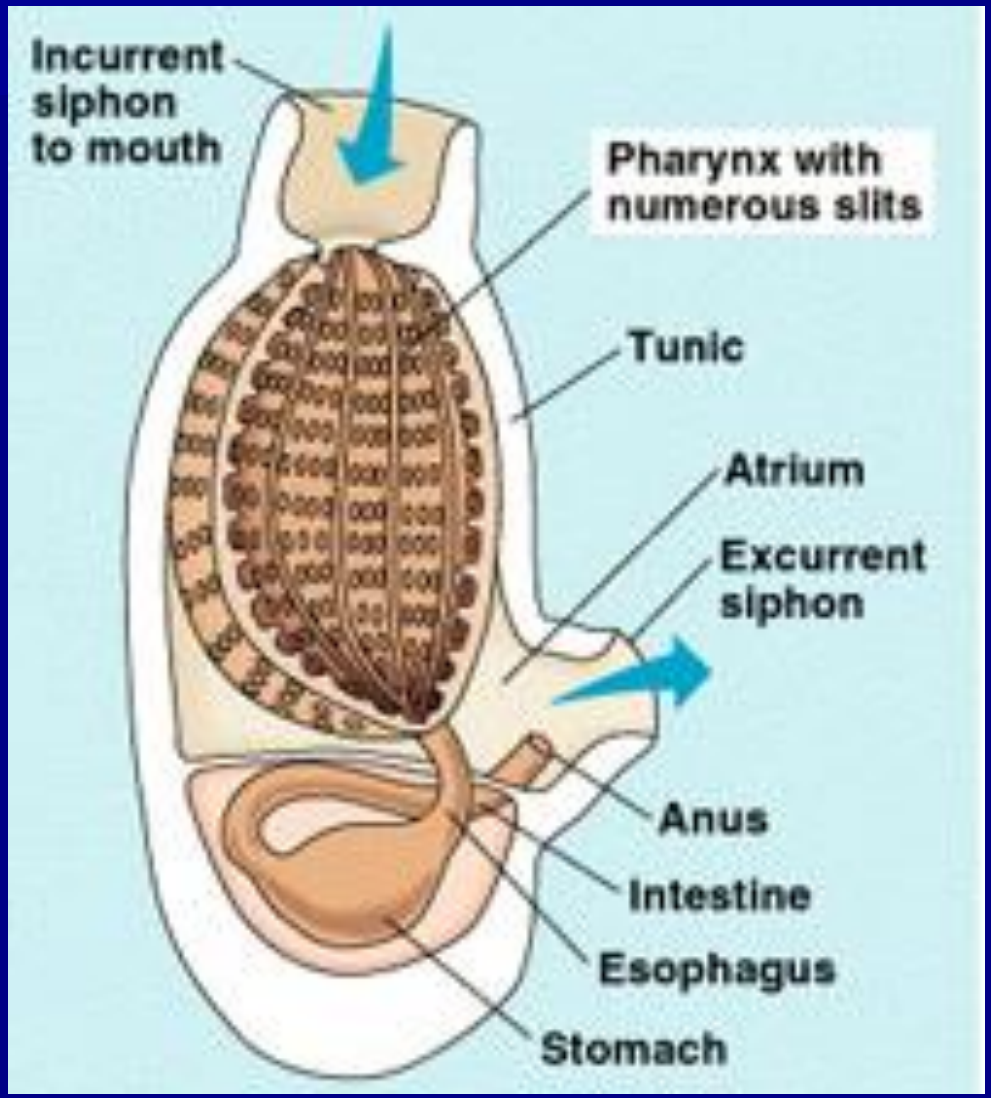
1. Dorsal hollow nerve cord
2. Notochord
3. Pharyngeal gill slits
4. Tail

- Subphylum Urochordata – Tunicates (Sea Squirts)
- Subphylum Cephalochordata – Lancelets
- Subphylum Vertebrata – Vertebrates
  - Class Agnatha
  - Class Chondrichthyes
  - Class Osteichthyes



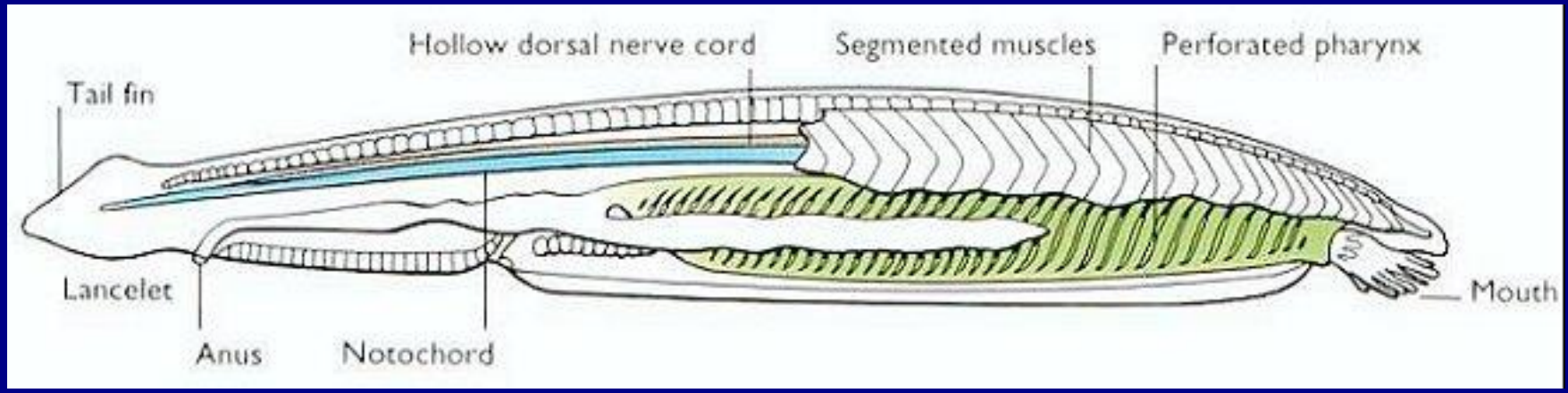
Subphylum Urochordata

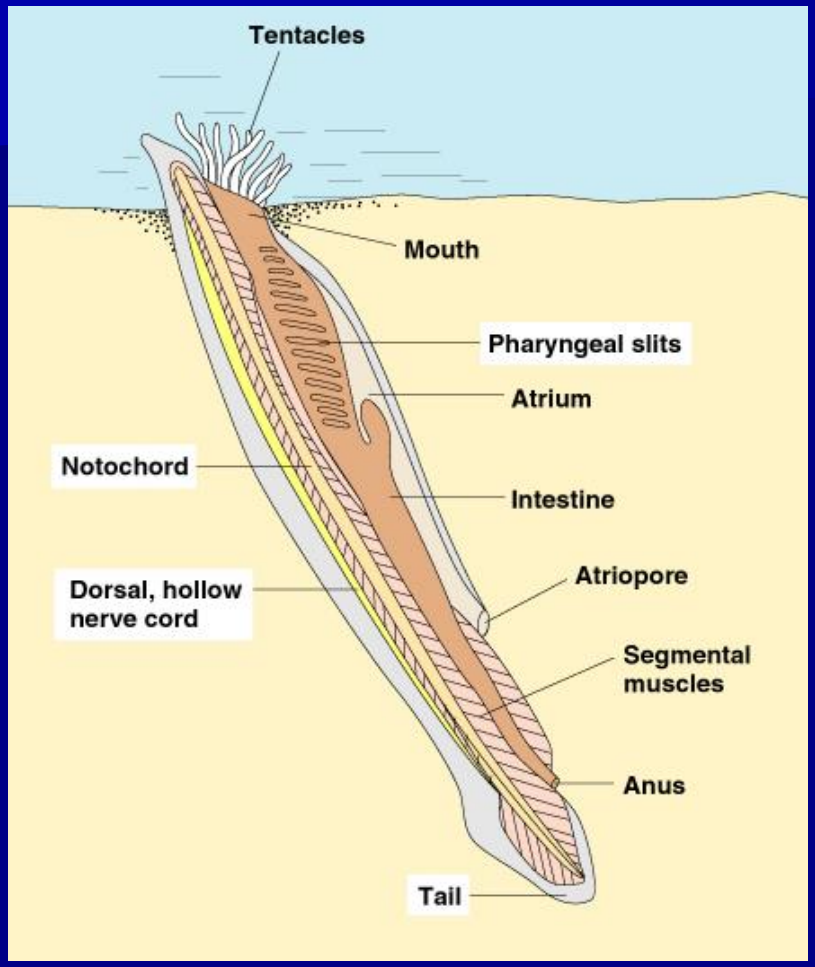
- Primitive chordates
- Tunicates or sea squirts
- Cling to substrate
- Squirt water when disturbed
- Covered by clear tough membrane (tunic)
- Incurrent & excurrent siphon
- Hermaphroditic
- External fertilization



Subphylum Cephalochordata

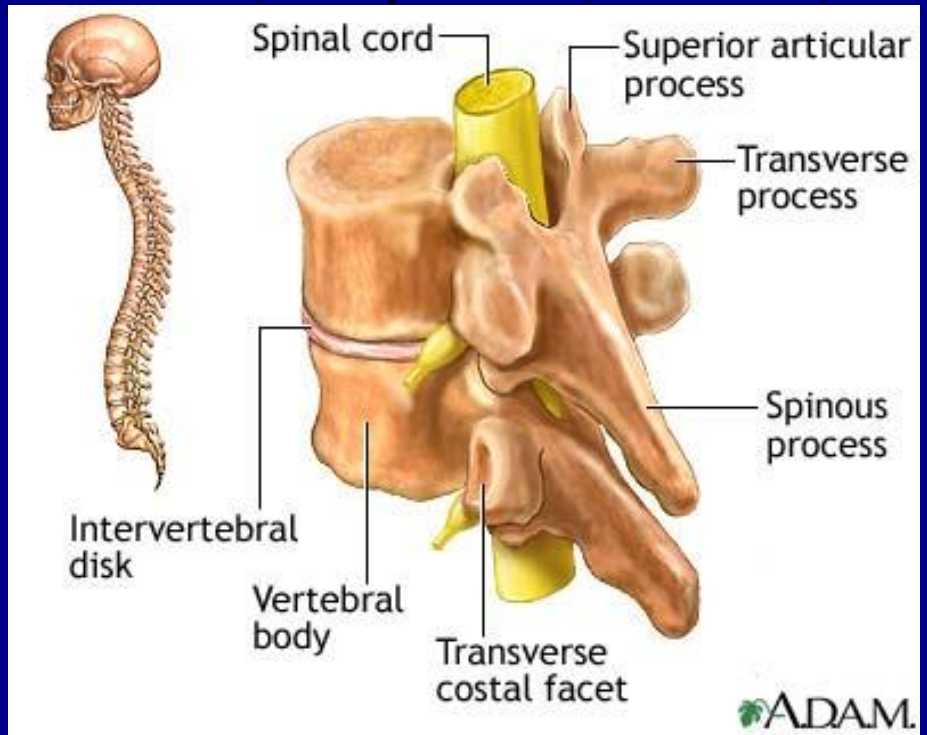
- Lancelets
- Tiny, transparent, fishlike
- Live half buried in sand
- Filter plankton
- Separate sexes
- External fertilization & dev.



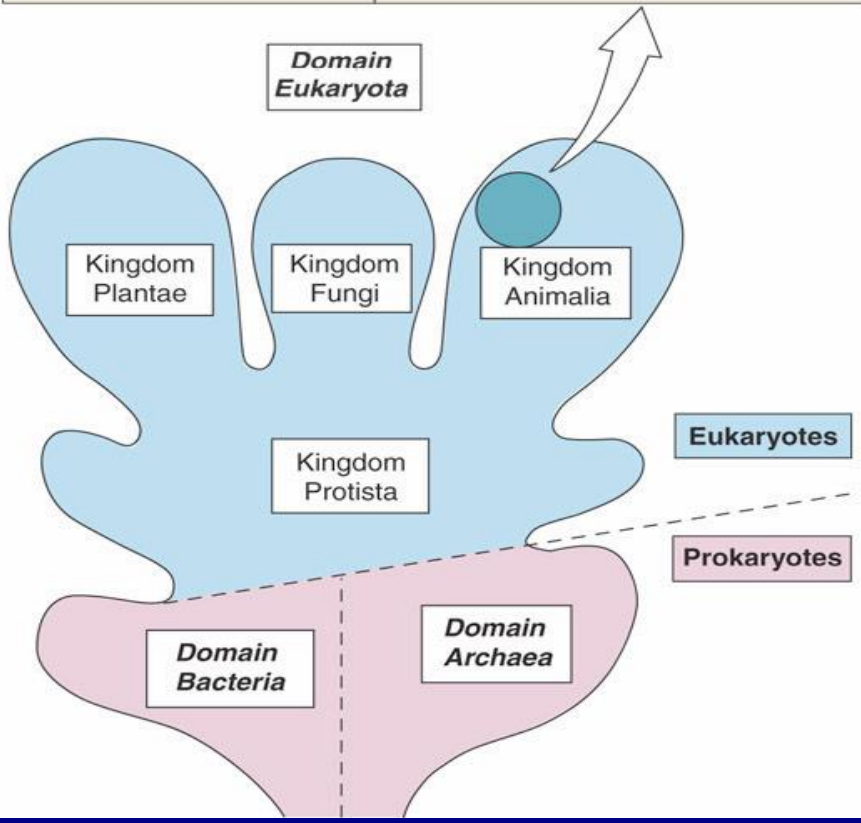

Tentacles
Mouth
Pharyngeal slits
Atrium
Notochord
Intestine
Atriopore
Dorsal, hollow nerve cord
Segmental muscles
Anus
Tail

Subphylum Vertebrata

- Skeletons with backbones
- Skull
- Brain
- Fish, amphibians, reptiles, birds, mammals



CLASS AGNATHA (jawless fishes)	CLASS CHONDRICHTHYES (cartilaginous fishes)	CLASS OSTEICHTHYES (bony fishes)
 Lampreys	Subclass Elasmobranchii	Subclass Dipnoi
	 Sharks	 Lungfishes (freshwater)
	 Rays	Subclass Crossopterygii
 Hagfishes		 Coelacanths
	Subclass Holocephali	Subclass Actinopterygii
	 Ratfishes	 Ray-finned fishes

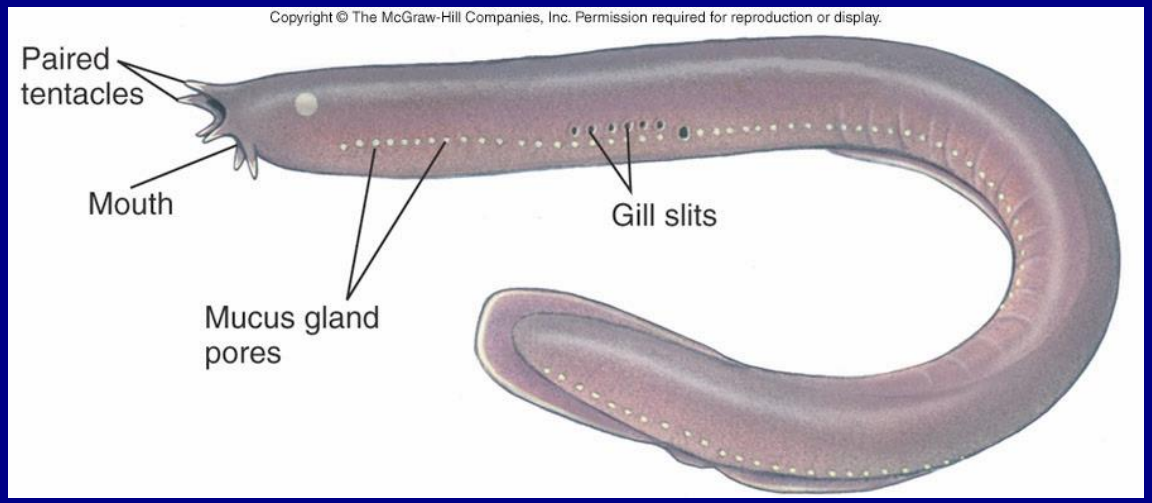


Class Agnatha

- Jawless fish
- Lamprey and Hagfish
- Parasitic – teeth/rasping tongue make hole in host, suck blood & tissue
- No scales
- Eel-shaped, fins are reduced

Hagfishes "slime eels"

- Agnathans that feed primarily on dead or dying fishes – they are scavengers; bore into the fish and eat them from the inside out
  - a.live in tunnels they dig out on the bottom
  - b.cold water at moderate depths
  - c.20 known species, maximum length is about 2.6 feet



Pacific Hagfish

Atlantic Hagfish

Both can burrow into body of dead or dying fish!

Lampreys (*Petromyzon*)

- lives in estuaries
- unlike most other fish, doesn't have any scales
- prior to the building of locks on the St. Lawrence River, there were many Atlantic Salmon which bred in freshwater areas in the upper reaches of the river; the locks allowed the lampreys to move from the inner Great Lakes region out through the St. Lawrence seaway, devastating the natural Atlantic Salmon population

Sea Lamprey

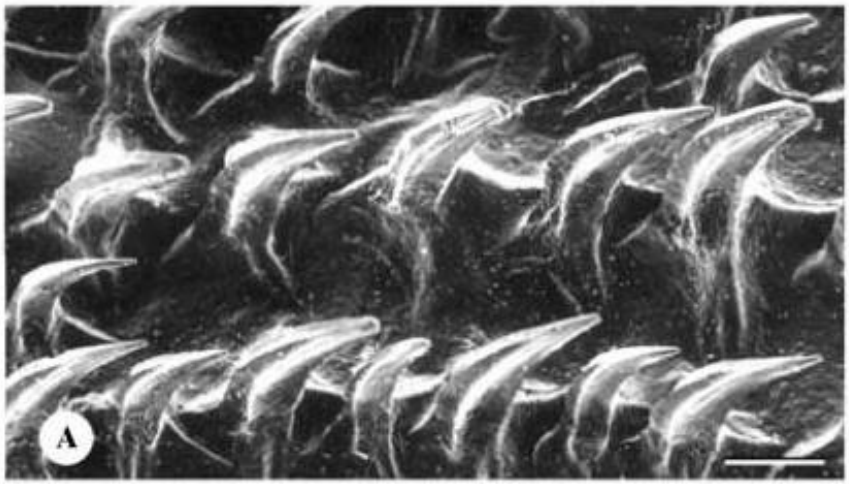
Sucking disc allows them to attach to living fish in estuaries!

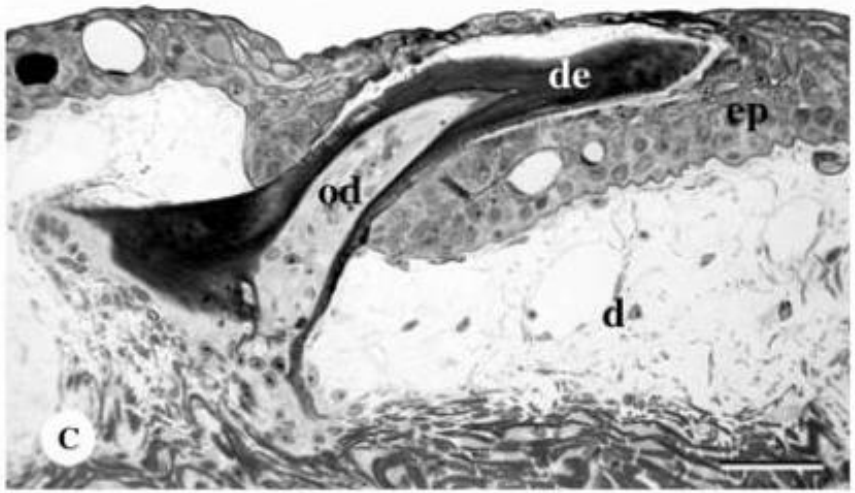
Why are lampreys and hagfish referred to as primitive fishes?

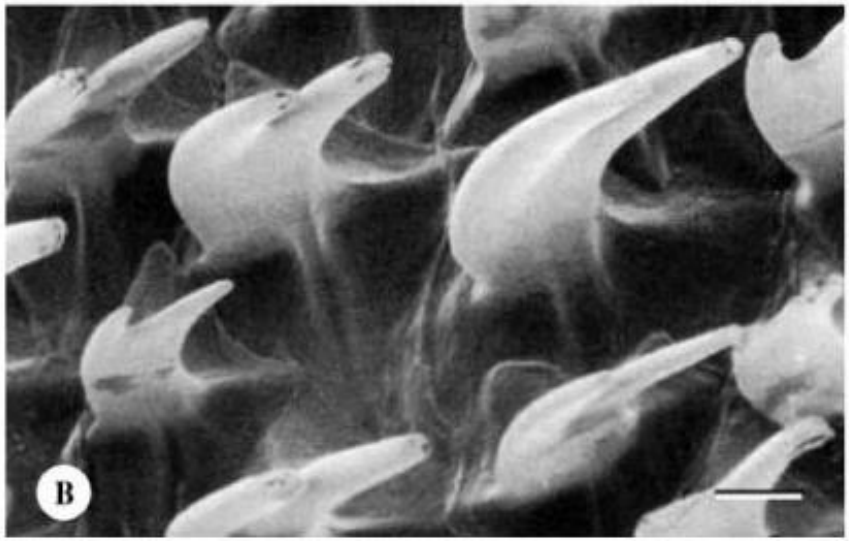
Class Chondrichthyes

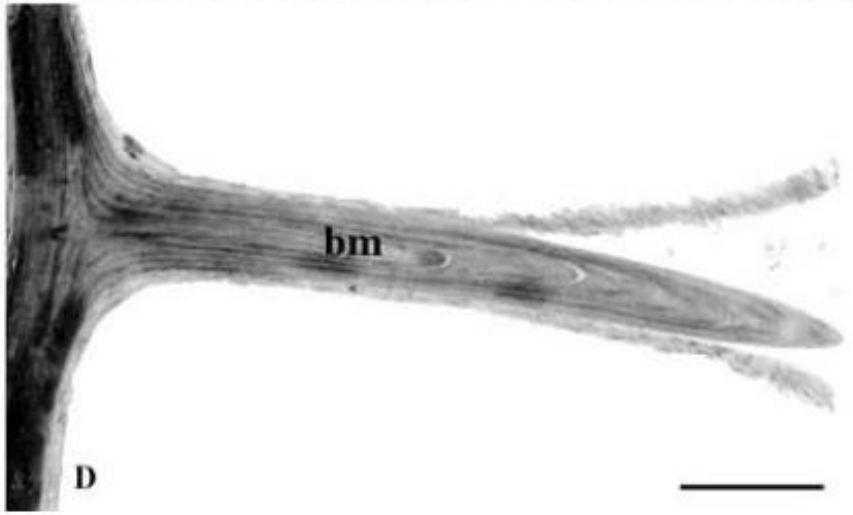
- Sharks, skates, rays
- Cartilaginous skeleton
- About 700 species
- Placoid scales (tiny teeth)
- Visible gill slits
- Spiracles

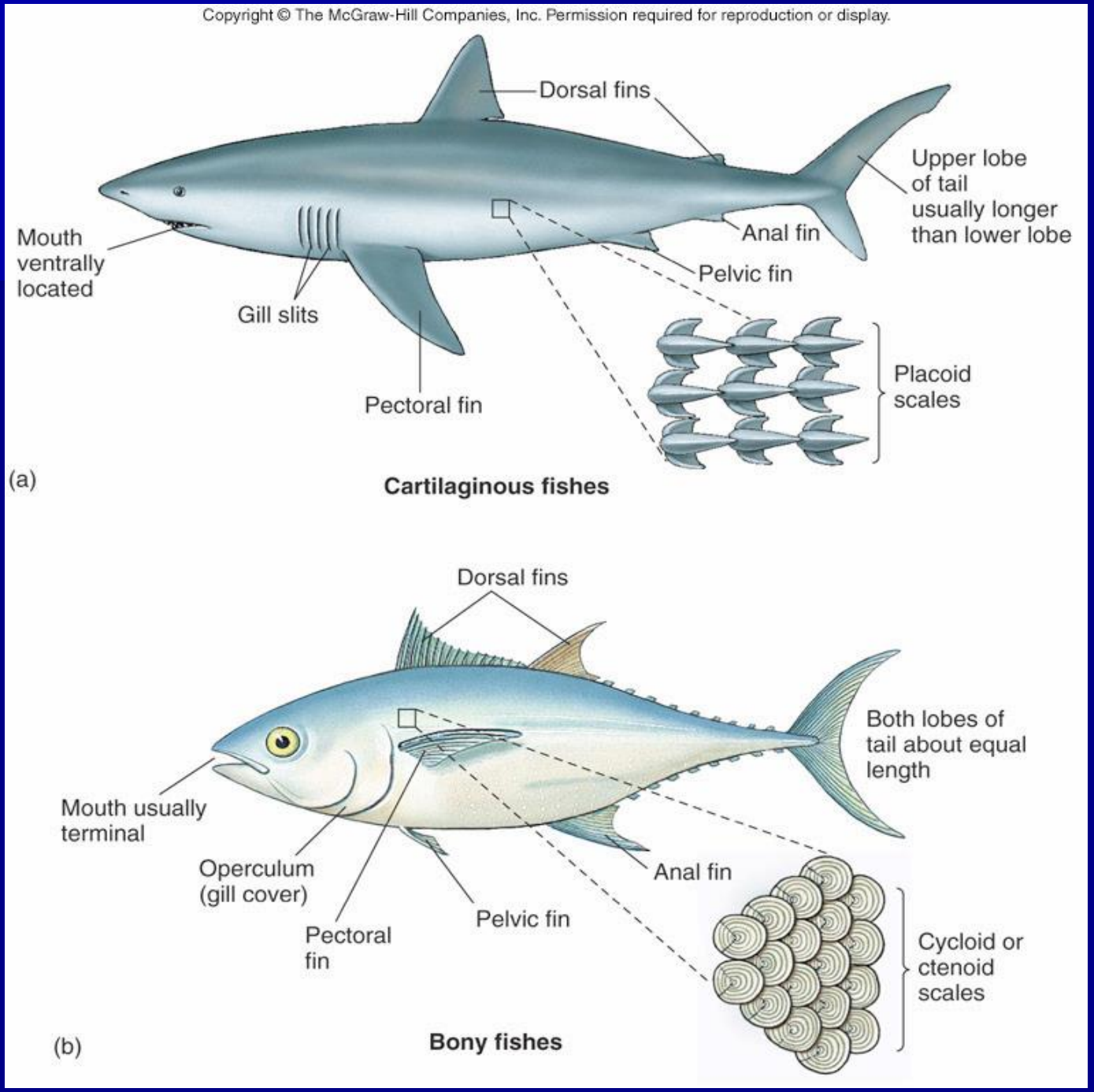
Placoid Scales





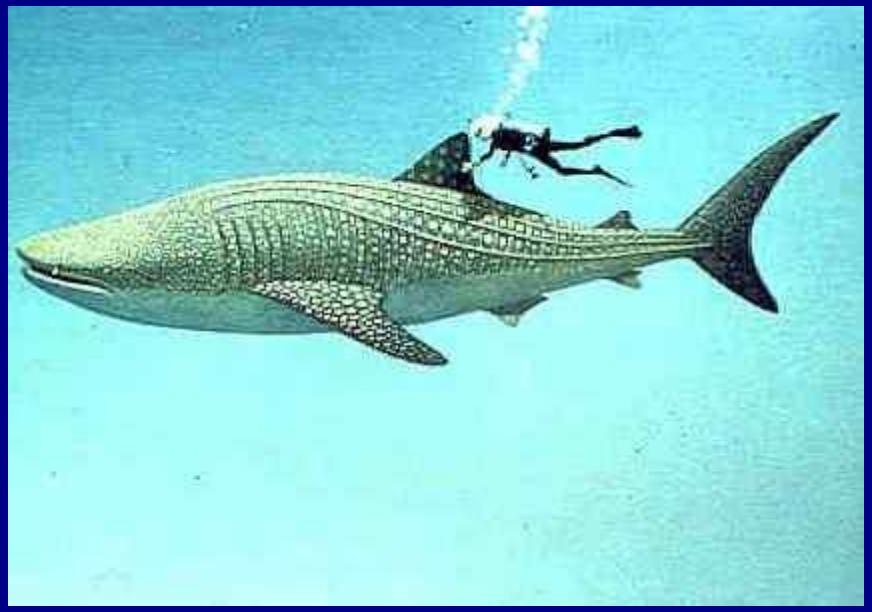






Sharks

- 350+ species
- Smallest: Pygmy shark ~ 25cm



- Largest: Whale shark ~ 15m

- Bottom dwellers, crushing teeth for feeding on shelled organisms (like mollusks)

Nurse Shark

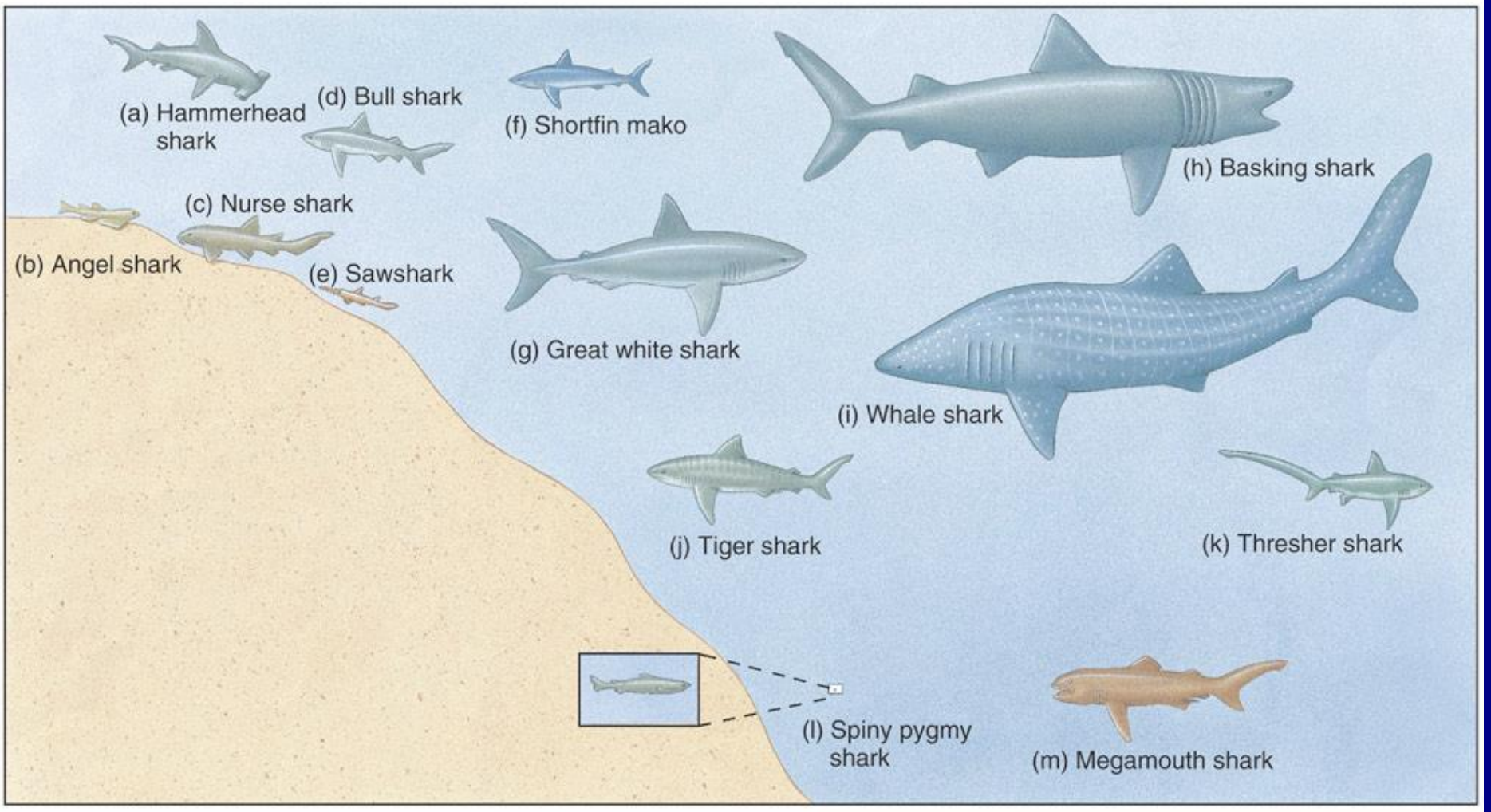
Leopard Shark

- Aggressive predators:
- large, predaceous sharks have large mouths and multiple rows of triangular teeth –lost teeth are replaced from the row of teeth behind it –a tooth conveyer belt

Great White Shark

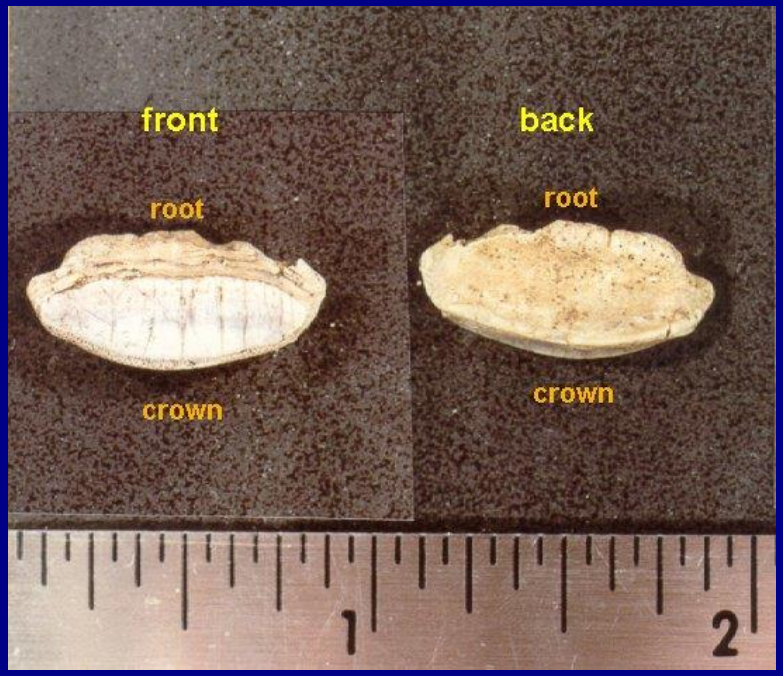
Tiger Shark

Hammerhead Shark



Teeth Structure

- Bottom feeders – crushing teeth
- Predatory sharks – sharp serrated teeth



Sharks

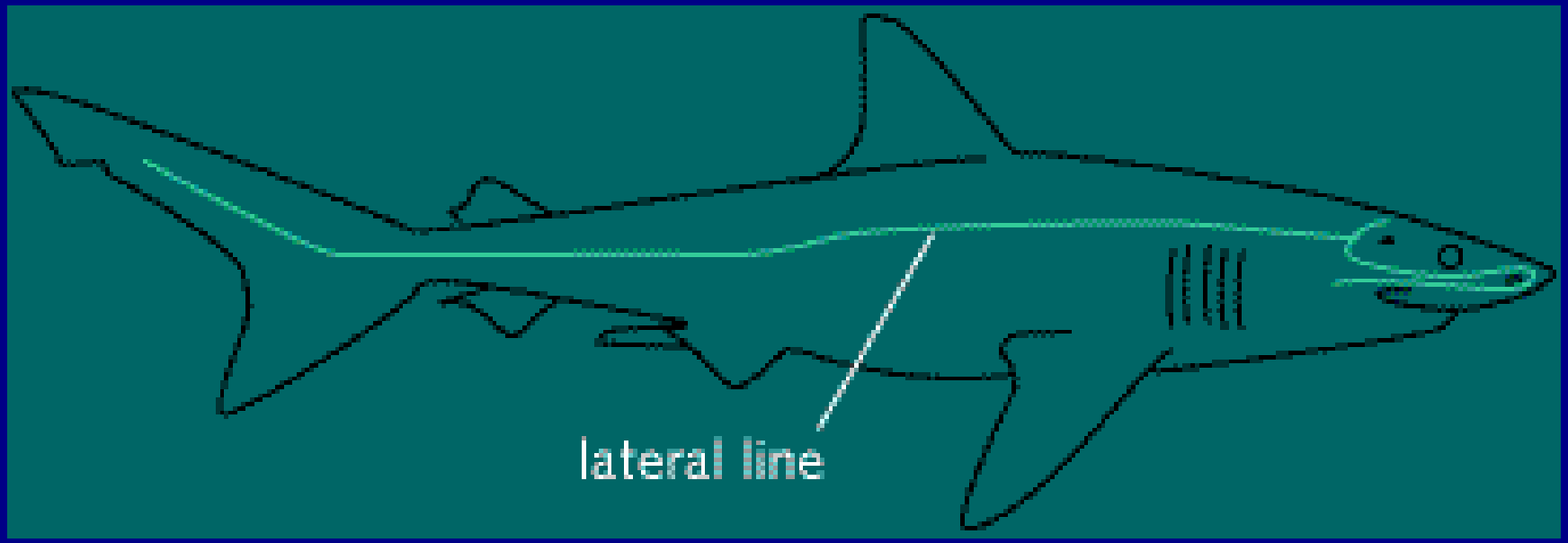
- Larger shark species such as the whale shark and the basking sharks are **filter feeders**, straining plankton from the water for food.
- Most sharks are marine, the majority of species are tropical; bull sharks may have become established in lakes and rivers which communicate with the ocean in tropical regions.

Gas Exchange

- five to seven gill slits on each side of the body
- most sharks swim continuously with an open mouth, water is forced through the mouth and over the gills and out through the gill slits
- as a result, when the shark can't swim (i.e. caught in a gill net), they suffocate and "drown"
- some larger benthic species, such as nurse sharks, can extract enough oxygen from the water through their gills and can rest on the bottom

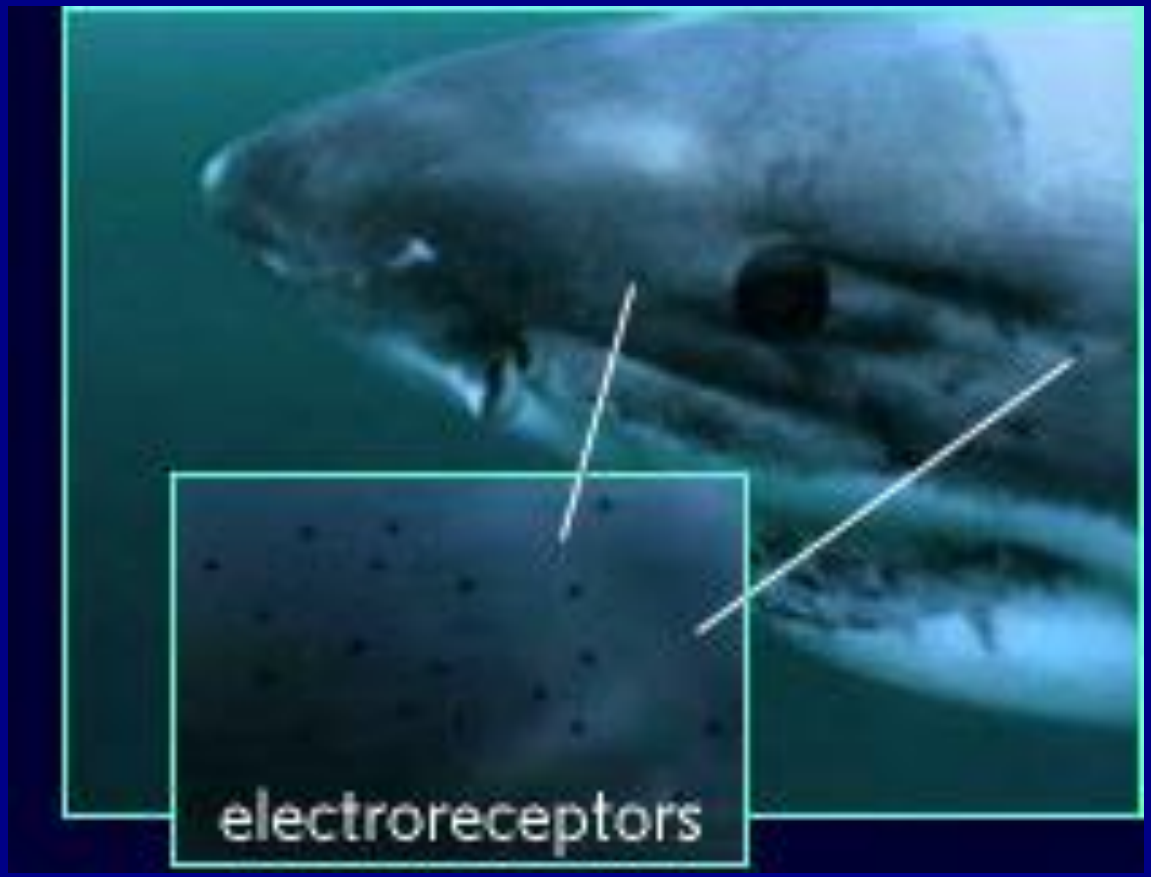
Shark Behavior

- Lateral Line system - pick up sound/water vibrations over long distances



- Sense of smell
  - 2/3 of brain devoted to smell
  - many times stronger than a human's
  - can detect the scent of prey that is ½ a kilometer away
  - some sharks can smell as few as 10 drops of liquid tuna in the volume of water it takes to fill an average swimming pool!

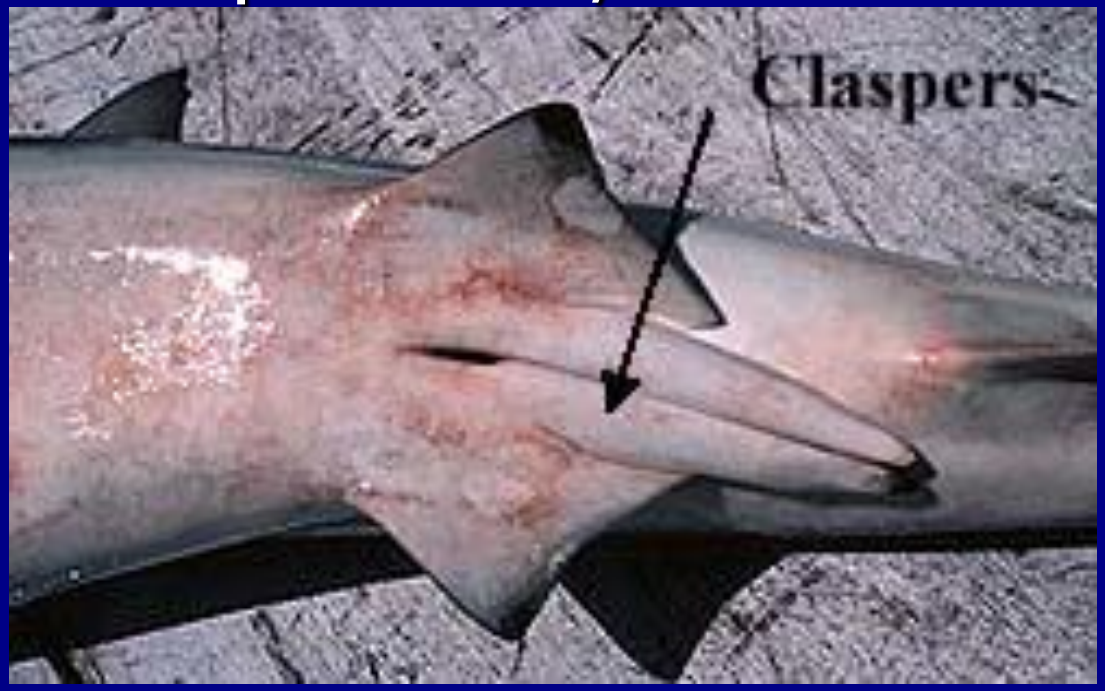
- Electric fields
  - Can detect weak electric fields given off by muscle action of prey
  - Ampullae of Lorenzini – tiny pores in snout



- Body Structure
  - Fusiform torpedo shape
  - Powerful lateral muscles and caudal fin
  - Wing-like pectoral fins provide lift (as well as oily liver to provide buoyancy)
  - Rapid acceleration
  - Constant motion
    - Tendency to sink
    - Oxygenated water to gills

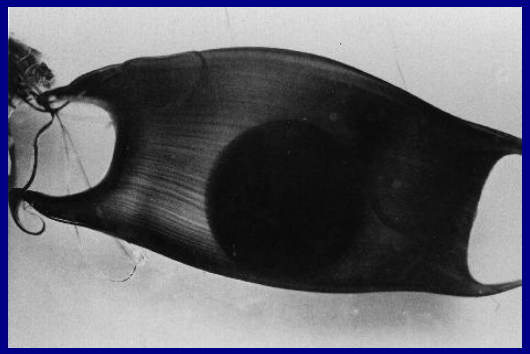
Reproduction

- Internal fertilization
- Male has 2 claspers between pelvic fins
- Claspers transfer sperm to female cloaca
- Some develop internal, some external



- Internal – dogfish shark develop in mother up to two years

- External – leathery egg cases ("mermaid's cup")



- over-harvesting of sharks has become a major issue—used for steaks, shark-fin soup, and ground shark cartilage is sold in pill form (anti-cancer?)

Shark Attacks

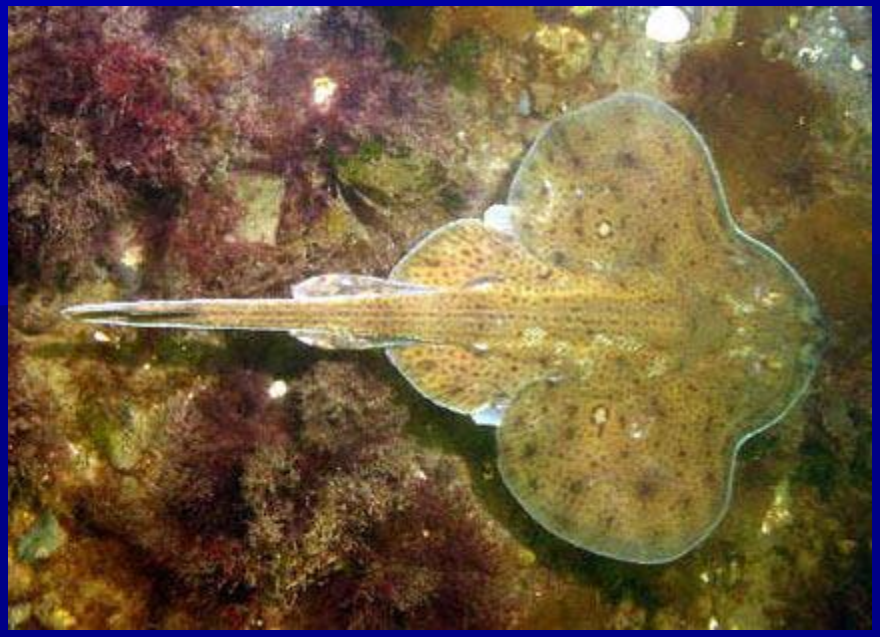
- In warmer temperate and tropical coastal areas, most human attacks are attributed to bull and tiger sharks; usually the shark mistakes a human for food. Bites occur when the shark "tests" the food (human).
- Your chances of an encounter with a shark are good in coastal areas, but generally, you will not see the shark.
- Your chances of an accidental shark bite increase when you swim (1) near a fishing pier, (2) in an area where sharks are actively feeding and/or breeding, and (3) around sunrise and sunset in muddy or murky water.

Skates & Rays

- flattened cartilaginous fishes, benthic
- skates and rays have their gill slits on the underside of the body, spiracles on dorsal side
- pectoral fins are greatly extended giving a "wing-like" appearance
- stingrays have spines in the tail which are attached to poison glands –the poison can cause serious injury, particularly if the "sting" is abdominal
- electric rays have special organs on each side of the head that can produce and electric current of up to 200 volts.
- skates are similar to rays in appearance but lack the tail and the stinging spines.

Manta Ray

Sting Ray – sharp spine at base of tail



Rays & skates eat crustaceans and mollusks in the subtidal zone

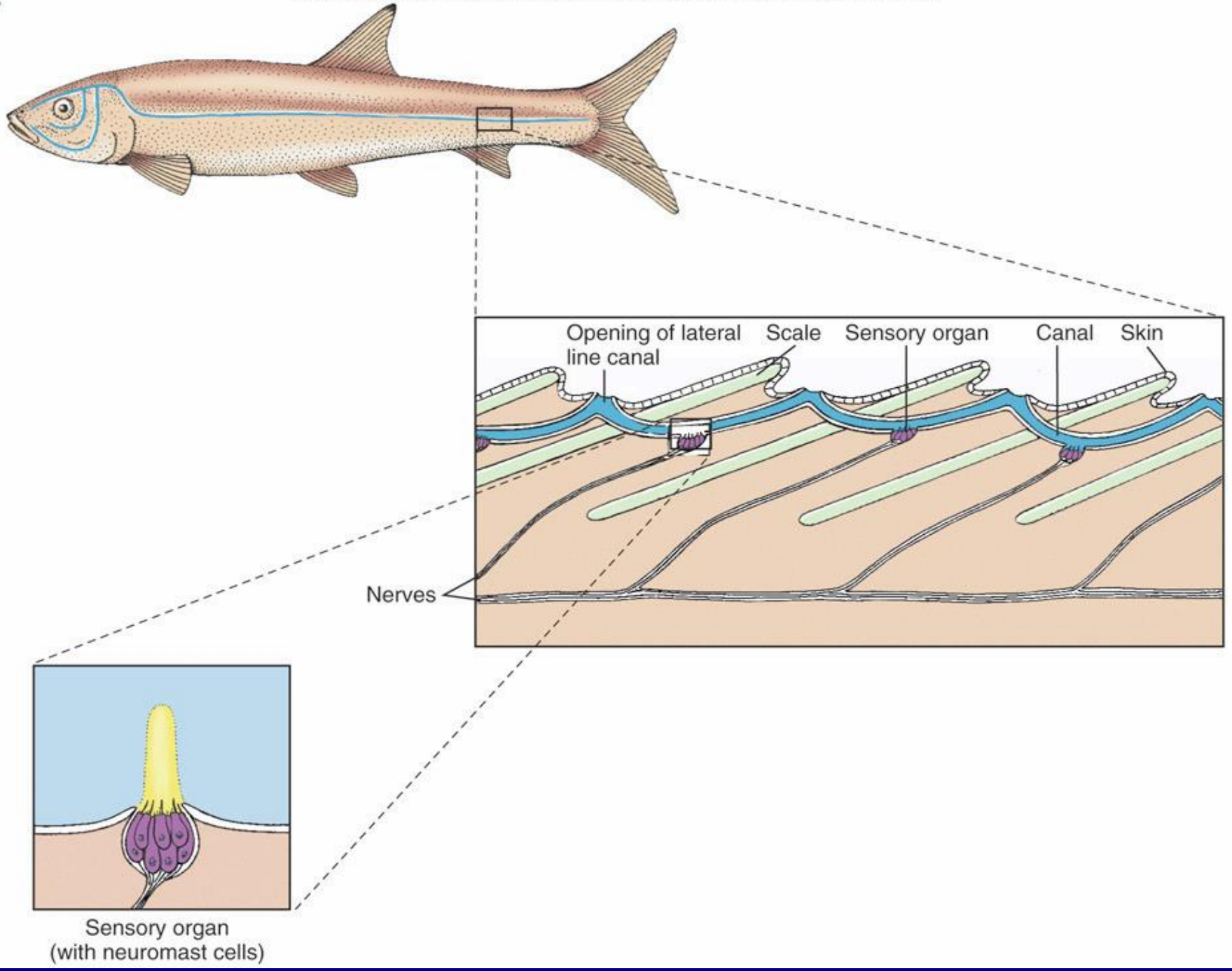
Why are the sharks, skates, and rays placed in their own class?

In what kind of habitat are skates and rays found? What do they usually eat?

What special receptors does the shark have for detecting prey?

Class Osteichthyes: Bony Fishes

- 23,700 species, approximately 98% of all fishes and 50% of all vertebrates belong to this group
- skeletons composed of osseous tissue (bone with high calcium content)
- thin and flexible scales which overlap and cover the body surface
- scales covered by a thin layer of tissue and mucous to protect the skin



Class Osteichthyes: Bony Fishes

- upper and lower lobes of the caudal fin (tail) are always of equal size
- bony spines, **fin rays**, prevalent in fins –the fins are more flexible and adapted for a variety of movements than the stiff, cartilaginous fins found in sharks and rays.
- the mouth is anterior, not ventral as in cartilaginous fishes
- teeth are fused to the jawbone
- swim bladder present in many bony fish
- **Ichthyology**: science of the study of fishes

Spanish mackerel, bay anchovy, & lookdown

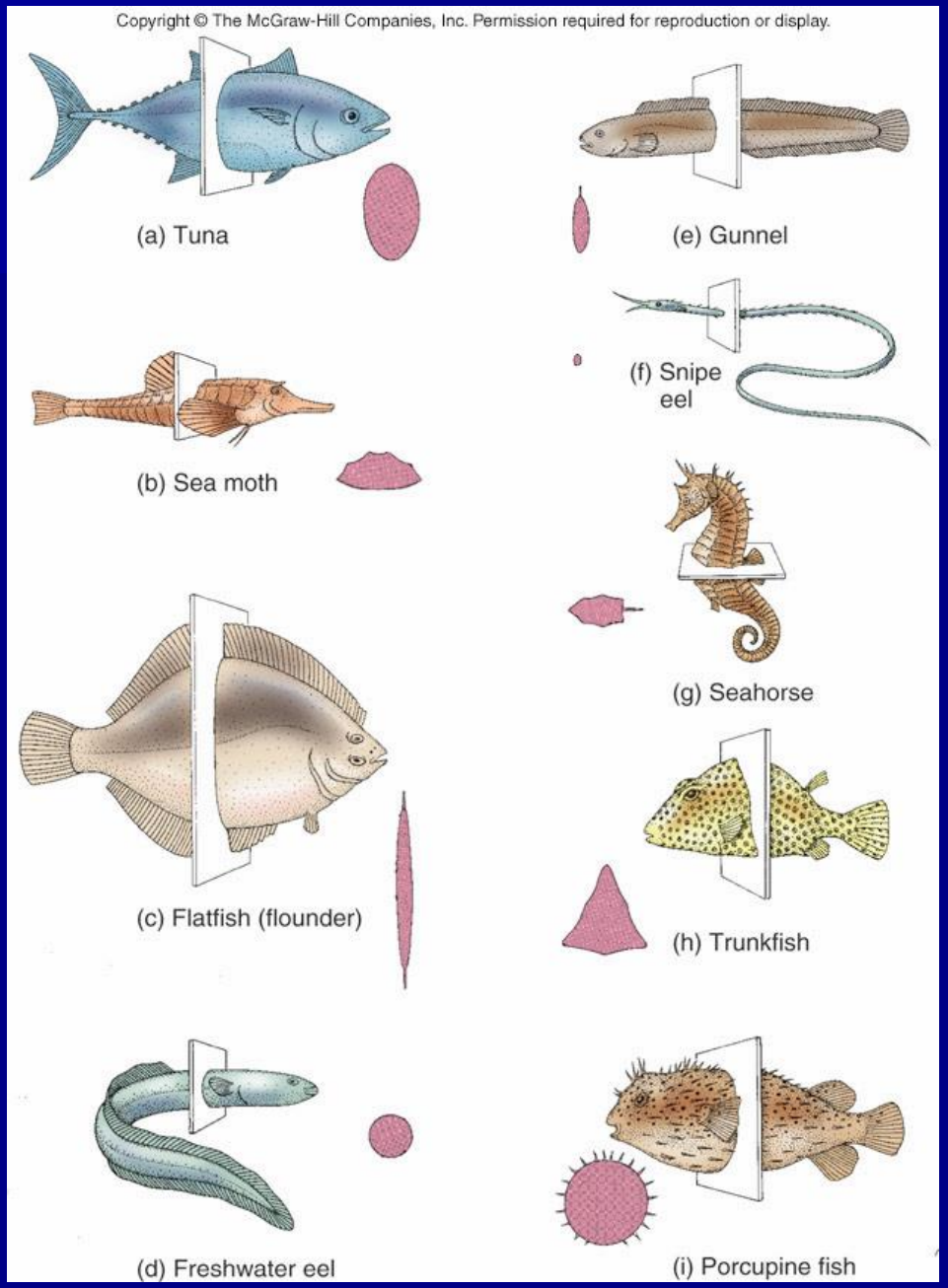
Gills for breathing?

- Gills covered by a flap of tissue called the **operculum**, underneath are the gills
- Water enters the mouth and passes over the gills (oxygen diffuses into the gills/blood, carbon dioxide goes into the water), exits through gills slits

Fish Biology--Nekton

- body shape is related to swimming style, and hence the "lifestyle" of the fish
  - 1.fast swimmers have streamlined, torpedo-shaped bodies
  - 2.laterally compressed bodies (tall and thin) are good for slow, steady swimming but also allow for quick bursts of swimming –many inshore species exhibit this body form
  - **3.demersals** (benthic fish) are dorsal-ventrally flattened (examples: rays, skates, flounder) –both eyes migrate to the upper surface
  - 4.distinctly elongated bodies are characteristic of fishes that live in rock/coral crevices such as moray eels

- Which fish is a fast swimmer?
- Which fish lives on the bottom (benthic)?
- Which fish is a slow swimmer?
- Which fish lives in vegetation?



Fish Biology

- body color pattern can give clues to where the fish lives –camouflage!
- pipefish live in elongated sea grass beds where they blend in with the vegetation
- stonefish –looks like a rock, but very poisonous
- **chromatophores**: pigment-bearing cells found in bony fishes

- Emperor Angel fish, chromatophores give the fish its bright blue, white, and yellow stripes.

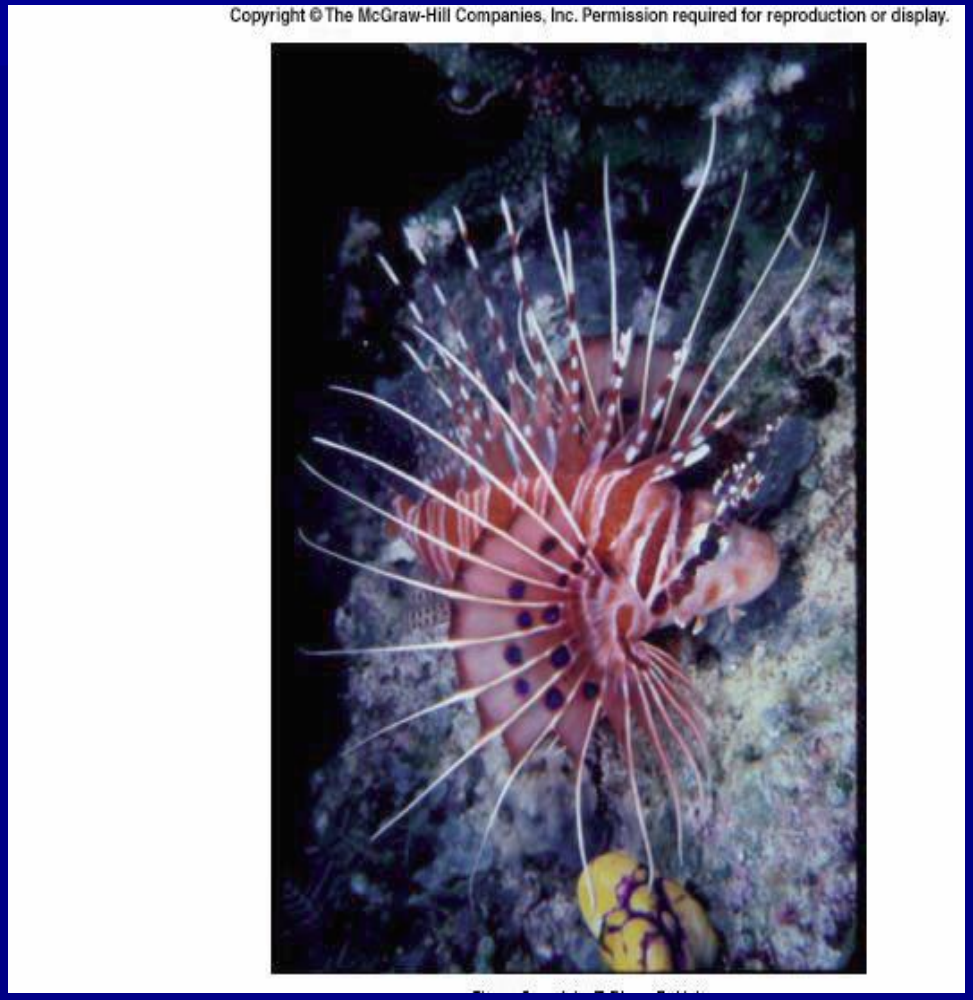
- Red snapper, chromatophores give the fish its characteristic “red” color.

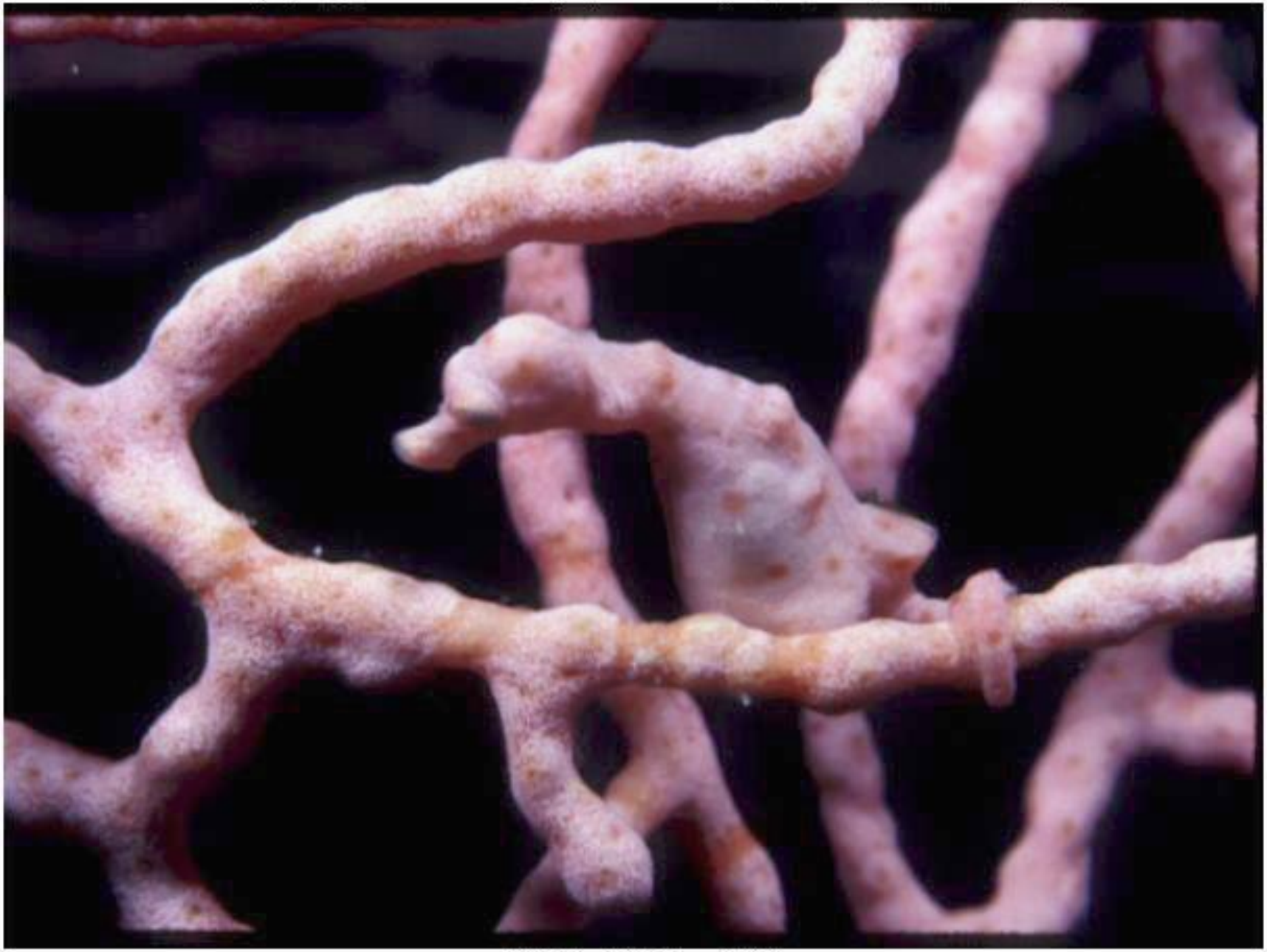
Fish Biology

- **warning coloration**: brightly colored or irregularly patterned colored fish warn potential predators that they taste bad or that they are poisonous –Lion fish (venom in dorsal fin/spines)
- **cryptic coloration**: color blends in with the environment –camouflage

Lion Fish

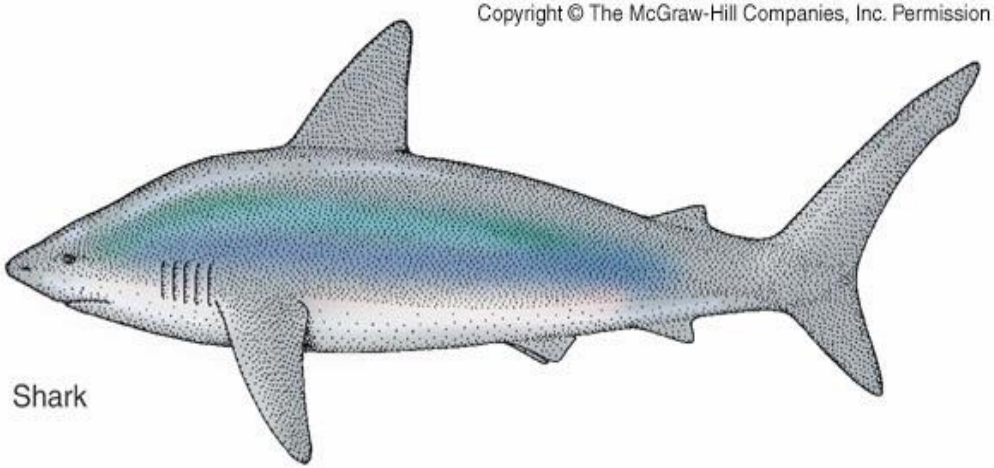
- The lion fish (*Pterois radiata*), red color advertises the fact that the spines contain a strong venom. The venom is so potent that it will make a human sick, and the venom is potentially lethal in large enough doses. Don't touch!



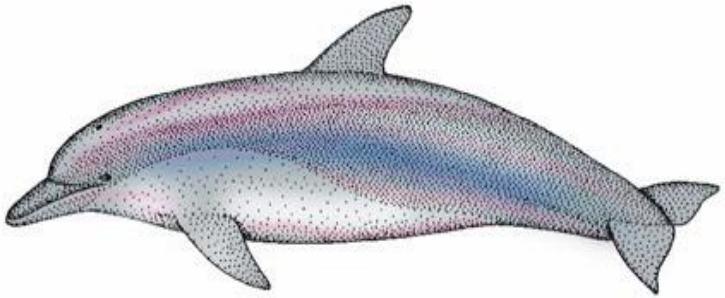


Fish Biology

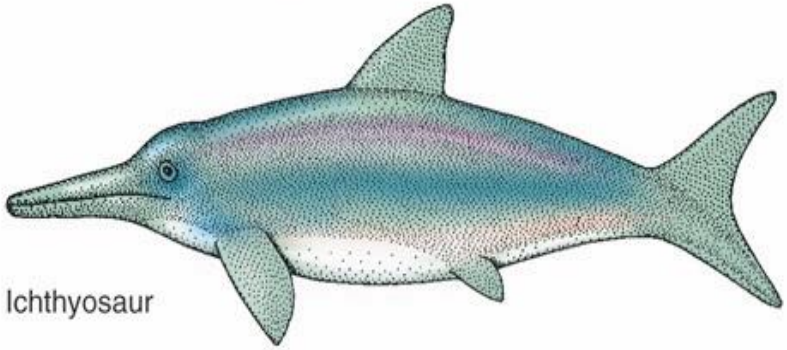
- **disruptive coloration**: color patterns break up the outline of the fish so that it is difficult to see –this tactic is used in many coral reef fishes
- **counter-shading**: white or silver underbellies and dark backs –look like the water from above, look like the surface from below



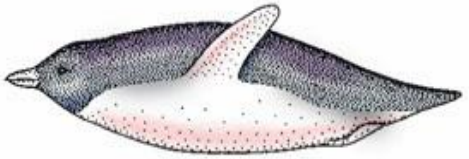
Shark



Dolphin



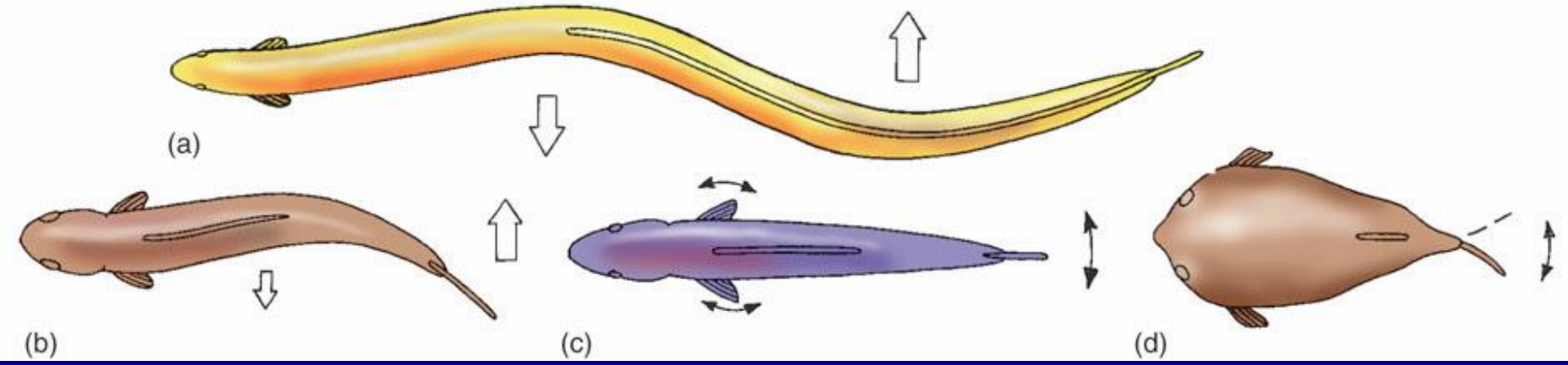
Ichthyosaur

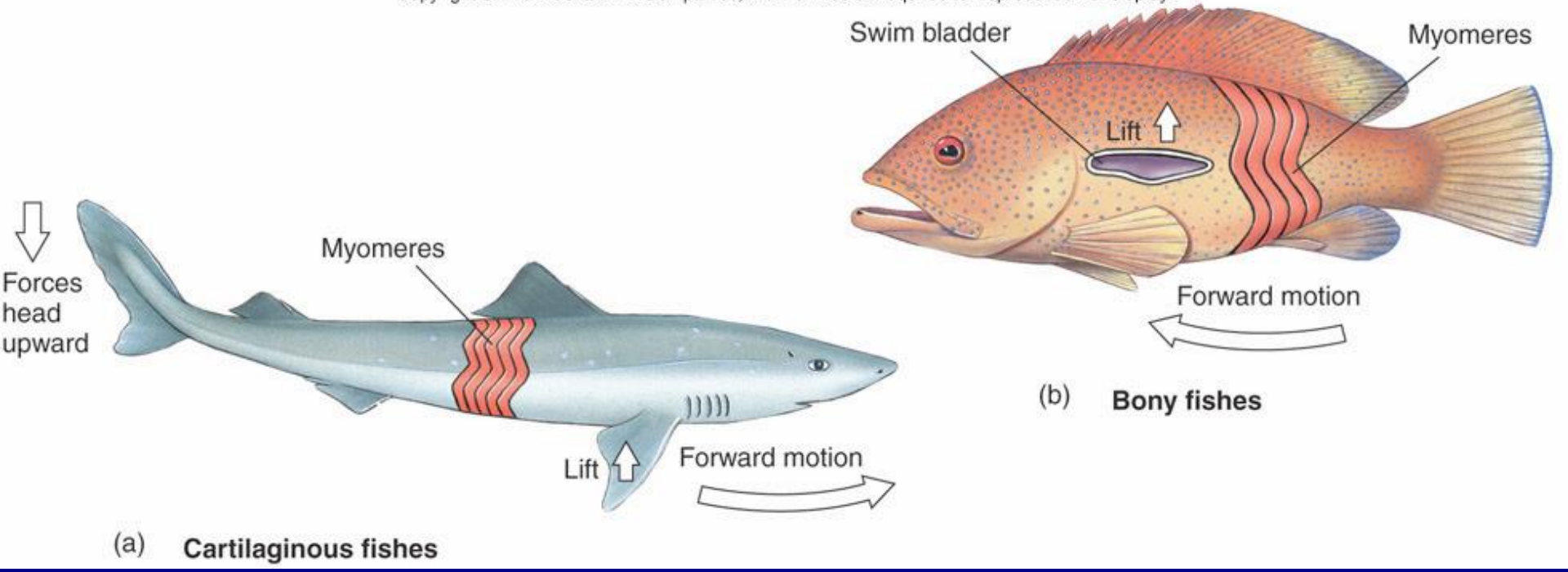


Penguin

Locomotion in Fishes

- swim in rhythmic side-to-side motion –producing "S" wave of muscular contractions from head to tail pushing the fish forward through the water
- **myomeres** (*myo*-muscle, *mere*-subunit)--bands of muscle on running perpendicular to the length of the fish
- muscle may comprise the majority of the fish –75% in tuna and sharks
- rays, skates, sharks –large pectoral fins give the fish lift –oil and fatty livers provide buoyancy
- bony fishes with swim bladders do not need large pectoral fins for lift as the bladders provide buoyancy





Adaptive Behaviors

- territoriality –establish boundaries in habit and defend the boundaries against any intruders
  - 1.for feeding and mating
  - 2.common in crowded habitats such as kelp beds or coral reefs
- aggressive behaviors may be used to defend territories –increase in the appearance of size –raising fins, blowing up –puffer fish, making sounds –like the red drum or black drum

Adaptive Behaviors

- schooling: adaptive behavior that may serve as a predator defense mechanism
  - 1.may increase swimming efficiency by reducing drag –drafting in another fishes wake
  - 2.vision plays a critical role in schooling behavior –most schooling fishes maintain constant distance from one another

Adaptive Behaviors

- **In some fishes, males and females look different!**
- **The males are brightly colored while the females are drab.**
- **Why do you think that this happens?**
- Scientific term for sexual differences: ***sexual dimorphism***

Adaptive Behaviors

- **In some fishes, the fish changes its sex as it gets older.**
- *Example: Black Sea Bass -protogynous hermaphroditism*
  - *It is female first. This means that there are lots of small females to lay a lot of eggs. This means more bass!*
  - *It becomes male toward the end of its life. The males are larger. Fewer males are needed because one male can fertilize a lot of eggs!*

Do all fishes have scales?

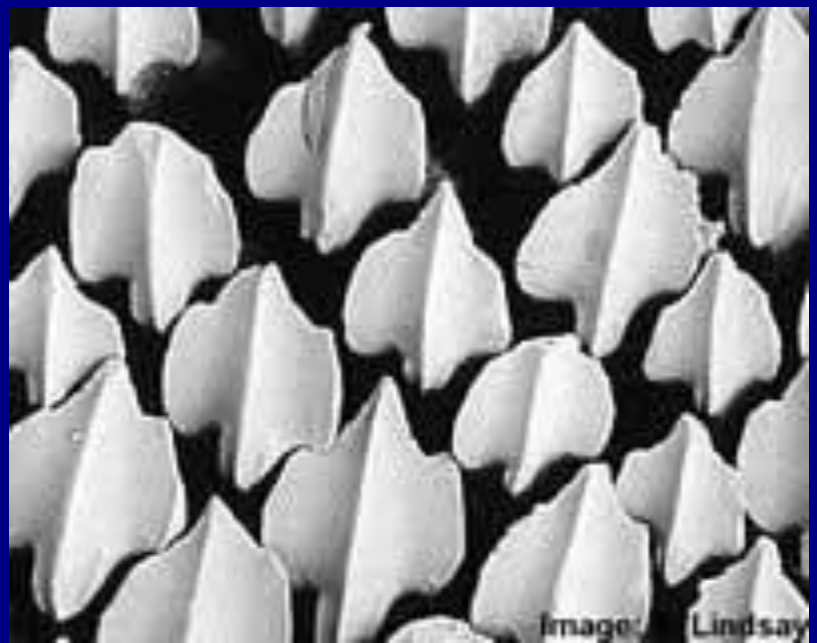
- No. Many species of fishes lack scales.

Why do fish have scales?

- The primary purpose of scales is to give the fish external protection.

Placoid Scales

- Placoid scales are found in sharks and rays, and can vary greatly in external appearance. They do not increase in size as the fish grows, instead new scales are added. Placoid scales are often referred to as denticles.



Placoid Scales

- Placoid scales consist of a flattened rectangular base plate which is embedded in the fish, and variously developed structures, such as spines, which project posteriorly on the surface. The spines give many species a rough texture. There are large differences in the development of these spines between different species.

Cosmoid scales

- Cosmoid scales are found in the lungfishes (family Ceratodidae) and some fossil fishes. Cosmoid scales are similar to placoid scales and probably evolved from the fusion of placoid scales. They consist of two basal layers of bone, a layer of dentine-like cosmine, and an outer layer of vitrodentine.

Ganoid scales

- Ganoid scales are usually rhomboid in shape and have articulating peg and socket joints between them. They are modified cosmoid scales which consist of a bony basal layer, a layer of dentine, and an outer layer of ganoine (an inorganic bone salt).
- Bowfin
- Gars
- Paddlefish
- Sturgeons

Cycloid scales

- Cycloid and ctenoid scales are found in the majority of bony fishes (the Teleostei). The anterior part of each scale is usually overlapped by the posterior portion of the scale in front. This arrangement of imbricate (overlapping) scales gives the fish greater flexibility than in those species with cosmoid and ganoid scales.

Ctenoid Scales

- Ctenoid scales have a variously developed spiny posterior margin (the word "ctenoid" comes from the Greek "cteno", meaning comb, and refers to the comb-like ctenii on the margin of the scale).