Chondrichthyes: Cartilaginous Fishes

I. Chondrichthian characteristics & groups
II. Holocephali
III. Elasmobranchii
   A. Evolution of elasmobranchs
   B. Elasmobranch basic characteristics
   C. Elasmobranch basic adaptive patterns
   D. Taxonomy of elasmobranchs

Review

Superclass Gnathostomata - Jawed fishes

- Class Placodermi (plate-skinned) extinct
- Class Acanthodii (spiny sharks) extinct
- Class **Chondrichthyes** living
- Class Sarcopterygii living
- Class Actinopterygii living

Jawed vertebrates

Classes:

Superclass **Gnathostomata**

Placodermi {extinct}

Chondrichthyes
cartilaginous fishes

Acanthodii {extinct}

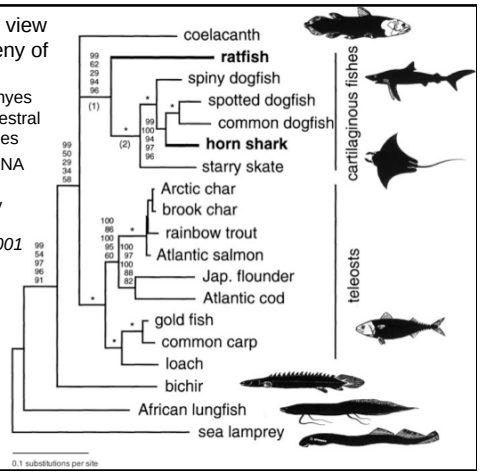
Sarcopterygii
lobe-finned fishes, tetrapods

Actinopterygii
ray-finned fishes

An alternative view of the phylogeny of fishes

- Chondrichthyes are not ancestral to bony fishes
- based on DNA instead of morphology

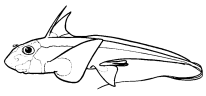
Arnason et al. 2001



Class Chondrichthyes, two major groups:

Subclass Elasmobranchii (sharks & rays)

Subclass Holocephali (chimaeras)



Subclass Elasmobranchii (sharks & rays, "strap gills") ≈ 930 living spp.

Infraclass Cladoselachimorpha (1 extinct order)

Infraclass Xenacanthimorpha (1 extinct order)

Infraclass Euselachii (2 extinct orders; 13 living orders in 2 subdivisions)

Subclass Holocephali (chimaeras, "whole heads") ≈ 35 living spp.

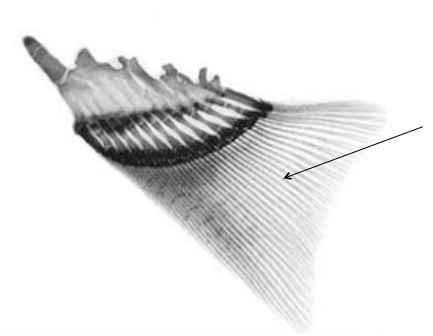
Superorder Paraselachimorpha (6 extinct orders)

Superorder Holocephalimorpha

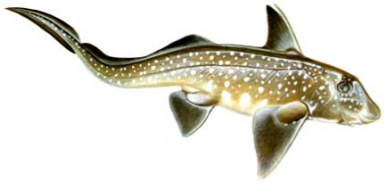
- 6 extinct orders
- Chimaeriformes (1 living order)

Characteristics of Chondrichthyes:

- cartilaginous skeleton (w/ endoskeletal calcification)
- male intromittent organs ("claspers")
- placoid scales
- teeth not fused to jaws (only to connective tissue)
- lipid (squalene) filled livers
- fin rays soft and unsegmented (*ceratotrichia*)
- swim bladder and lung absent
- high concentrations of urea and trimethylamine oxide (TMAO) in blood (for osmoregualtion)



Subclass **Holocephali** ("whole head")
Superorder **Holocephalimorpha**
Order **Chimaeriformes**
- chimaeras (ratfishes)

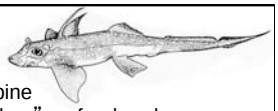


Order Chimaeriformes: 3 families, ≈ 35 spp.

<u>Characteristics that separate them from Elasmobranchs:</u>

- upper jaws attached to braincase (*autostylic suspension*)
- single opercular opening, covering 4 gill openings
- all are oviparous
- separate anal and urogenital opening - no cloaca
- mostly scaleless

Other cool things about chimaeras:



- first dorsal has venomous spine
- some males have a "tenaculum" on forehead
- tend to live very deep and are rare

3 orders of Chimaeras:

ploughnose
Callorhynchidae

shortnose (ratfishes) Chimaeridae

Subclass Elasmobranchii (sharks & rays)

Evolution of Elasmobranchs

- arose in early Devonian (400 mya)
- modern forms in place by early Cretaceous (144 mya)
- three major radiations:

(1) *Infraclass:* Cladoselachimorpha

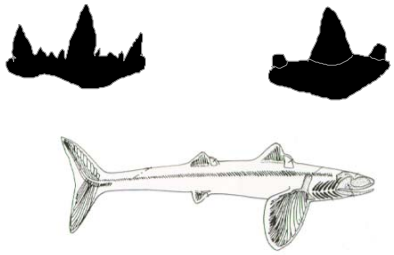
Infraclass : Euselachii

(2) Hybodonts

(3) modern elasmobranchs

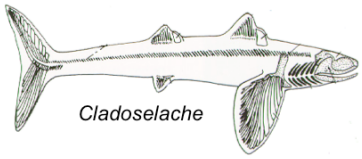
1st elasmobranch radiation:
Infraclass Cladoselachimorpha (cladoselachid sharks)

Cladodont ("branched tooth"): all had a three-cusped tooth



Characteristics:

1. terminal mouth
2. fins broad-based and stiff, long radial elements
3. no anal fin
4. homocercal caudal fin
5. body supported by notochord only
6. spines often in front of dorsal, pectoral, pelvics



Stethacanthus

Symmorium

Cladoselache

- pelagic predators of placoderms, acanthodians, and bony fishes
- fed by engulfing or slashing

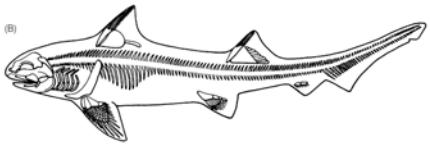
2nd elasmobranch radiation:
Infraclass Euselachii: Hybodonts
early Mesozoic (250 mya)

Hybodont = "humpback" tooth

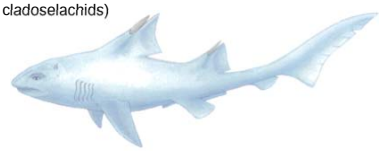
Front teeth grasping

Back teeth crushing

Hybodus



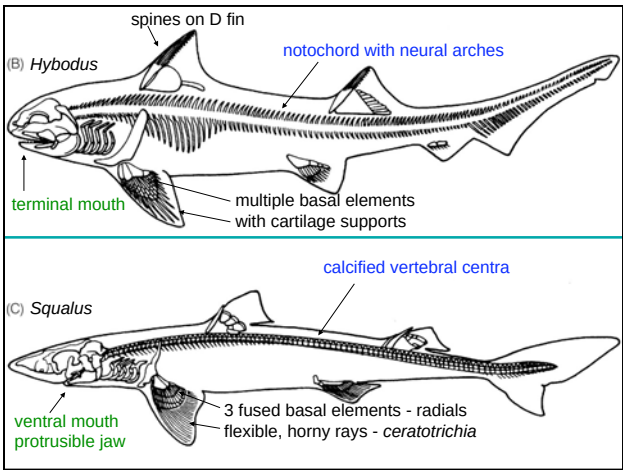
1. terminal mouth (same as cladoselachids)
2. fins flexible and mobile
3. anal fin
4. caudal fin heterocercal



3rd elasmobranch radiation:
coming of the modern sharks
mid-Mesozoic (200 mya)

- **Jaws**: subterminal mouth with protrusible upper jaw
- **Dentition**: tooth replacement system
- **Fins**: *ceratotrichia* supporting the fin
- **Vertebrae**: calcified vertebrae instead of notochord

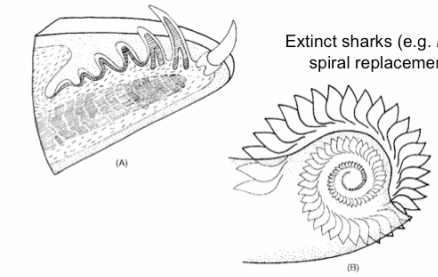
⇒ *improved feeding and locomotion*
(parallel changes were occurring in bony fishes)



Teeth replaced differently in modern sharks

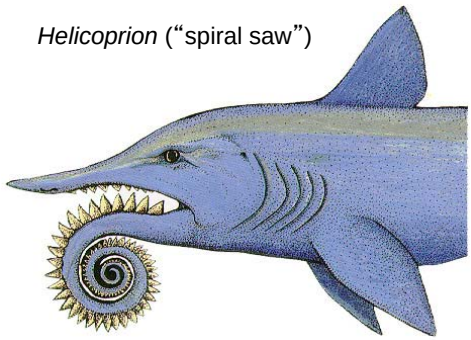
Modern sharks:
rows of replacement teeth

Extinct sharks (e.g. *Helicoprion*):
spiral replacement of teeth



Spiral tooth replacement

Helicoprion ("spiral saw")



Living Elasmobranchs ("strap gills")

2 subdivisions:

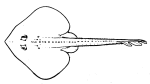
- **Selachii** (sharks)

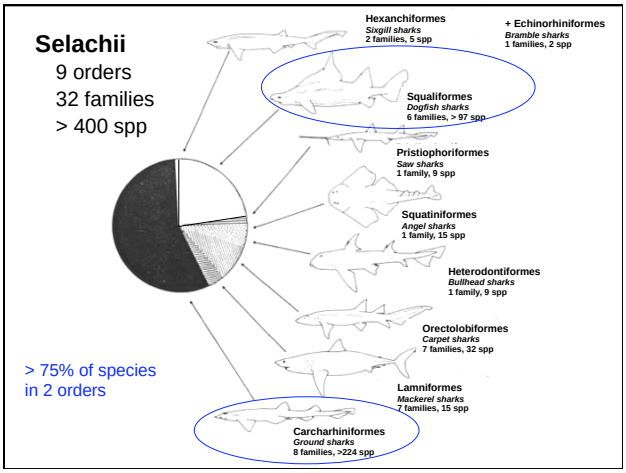
2 superorders

- Galeomorphi (4 orders) ("shark form")

- Squalomorphi (5 orders) ("dogfish form")

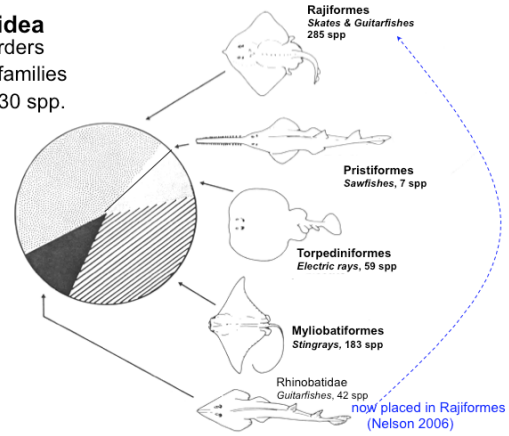
- **Batoidea** (skates & rays) **(4 orders)**





Batoidea

4 orders
17 families
> 530 spp.

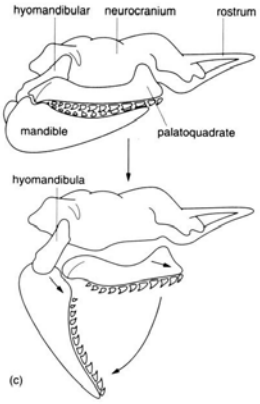


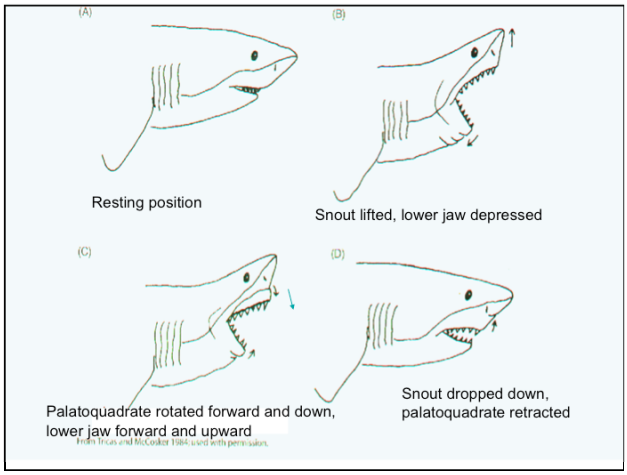
Characteristics of living Elasmobranchs:

1. cartilaginous skeleton
2. gill slits (usually 5-7) not covered by an operculum
3. paired ventral nostrils
4. subterminal mouth (usually)
5. protrusible upper jaw (usually) (*hyostylic suspension*)
6. fin rays are unsegmented, soft, epidermal = ceratotrichia
7. placoid scales
8. enlarged liver for buoyancy
9. spiral valve intestine
10. electrical field receptors: Ampullae of Lorenzini
11. cloaca (shared urogenital and anal opening)
12. internal fertilization (males have claspers)

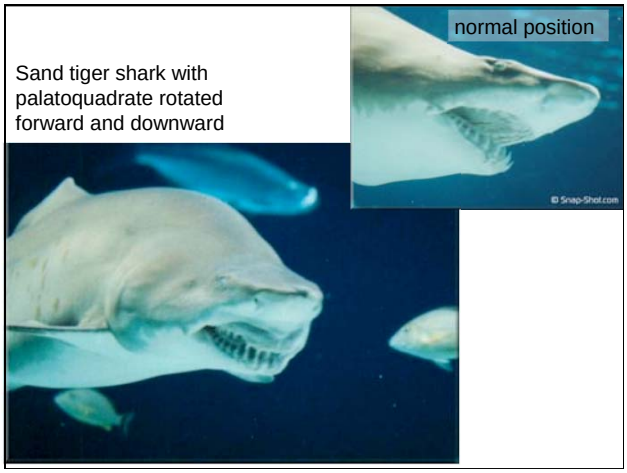
Hyostylic suspension –

allows protrusion of the upper jaw

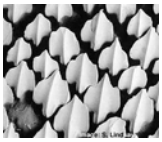


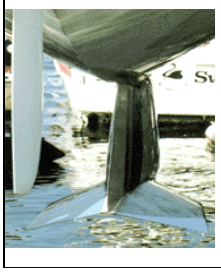


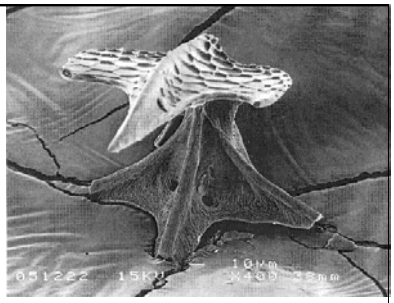
Sand tiger shark with palatoquadrate rotated forward and downward



Placoid scales



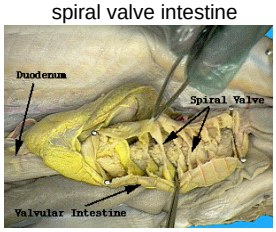




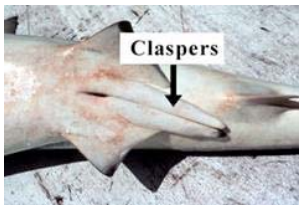
large, lipid-filled liver

ampullae of Lorenzini

spiral valve intestine



intromittent organs: claspers



female male

Biological Attributes:

1. distribution: mostly marine

2. generally adapted for movement at low energy costs:
   - heterocercal tails
   - placoid scales
   - cartilaginous skeletons
   - static buoyancy mechanism - enlarged liver with squalene

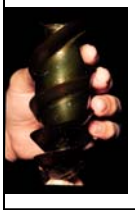
3. feeding: most are predators, carnivorous, and tend to be large

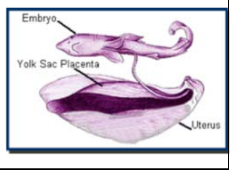
Biological Attributes:

4. Reproduction:

   a) in general:
      - mature late (6 - 35 yrs)
      - produce few relatively large young
      - internal fertilization (male claspers)

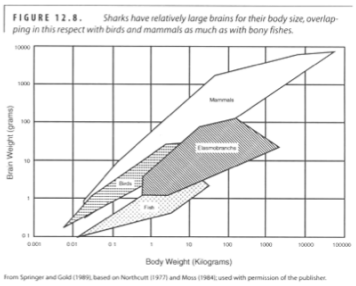
   b) Modes:
      1. Oviparous: lay eggs externally
      2. Viviparous: live-bearing





Biological Attributes:

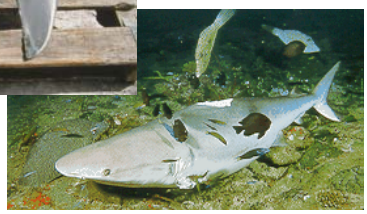
5. Sensory physiology: non-visual senses are extremely acute



6. Vital statistics:
   - low fecundity
   - slow growing
   - long-lived

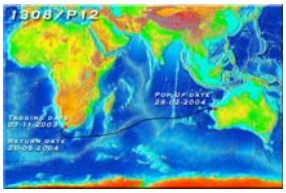
… thus very susceptible to overfishing

Threats to sharks: finning



Biological Attributes:

7. Tend to be highly mobile



- Nicole, 12.5 ft female great white shark
- tagged off S. Africa
- showed up 99 days later off W. Australia, 11,000 km away.
- 6 months later, she was back in S. Africa!

Living Orders of Elasmobranchs:

Subdivsion Selachii

Galeomorphi

1. Heterodontiformes (8 species)
2. Orectolobiformes (32 species)
3. Lamniformes (15 species)
4. Carcharhiniformes (224 species)

Squalomorphi

5. Hexanchiforrmes (5 species)
6. Echinorhiniformes (2 species)
7. Squaliformes (97 species)
8. Squatiniformes (15 species)
9. Pristiophoriformes (5 species)

Subdivision Batoidea

1. Torpediniformes (59 species)
2. Pristiformes (7 species)
3. Rajiformes (285 species)
4. Myliobatiformes (183 species)

Class Chondrichthyes
Subclass Elasmobranchii
Subdivision Euselachii
Order Heterodontiformes

- 1 family, 8 species

- examples: bullhead shark, horn shark

Order Heterodontiformes

- 2 dorsal fins, each with a spine
- anal fin
- 5 gill slits
- large pectorals
- two types of teeth
  - — grasping
  - — crushing
- benthic, smallish (max. size 165 cm)

Sleeping Horn shark

Horn shark egg

Order Orectolobiformes "carpet sharks"

- 7 families, 32 spp.
- examples: whale shark, nurse shark, wobbegong

Epaulette shark

Wobbegong

Order Orectolobiformes

- 2 dorsal fins, no spines
- anal fin
- 5 gill slits
- small teeth, terminal mouths
- mouth usually with barbels
- tropical shelf fishes

Whale shark: the largest living fish

nurse shark

Order Lamniformes
(mackerel sharks)

- 7 families, 15 spp.

- examples:
  - sand tiger
  - thresher
  - megamouth
  - basking
  - great white
  - mako
  - salmon

Order Lamniformes

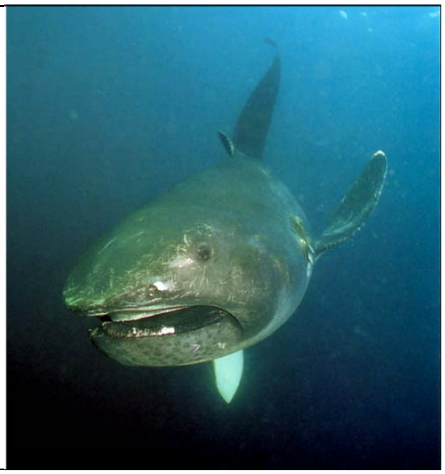
- 2 dorsal fins w/o spines
- anal fin
- 5 gill slits
- no nictitating membrane
- mouth extends well beyond eyes
- epipelagic, often coastal
- generally large, active sharks

White shark

Carcharodon megalodon, extinct lamniform, estimated to 16 m in length

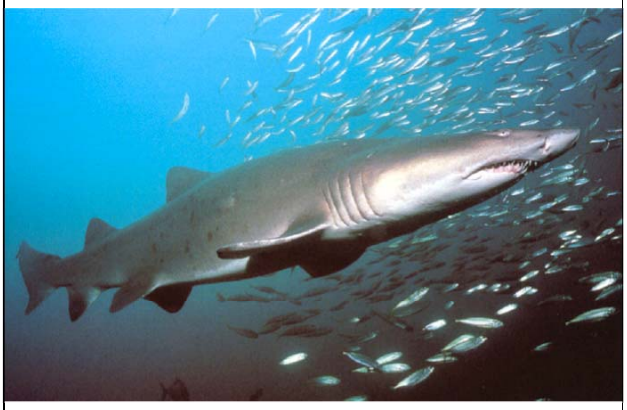
Basking shark

Megamouth shark



mako sharks

sand tiger



Order **Carcharhiniformes** (ground sharks or requiem sharks)

- 7 families, 224 spp.

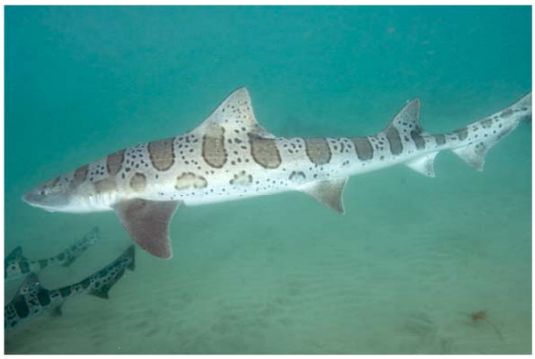
examples: tiger, bull, hammerhead, blue, leopard, smoothhound

Order Carcharhiniformes

- 2 dorsal fins w/o spines
- anal fin
- 5 gill slits
- nictitating membrane
- dominant in tropics (90% of all sharks there)
- pelagic and coastal

Hammerhead

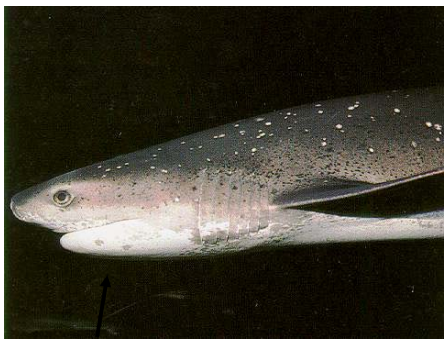
Leopard shark



Blue shark

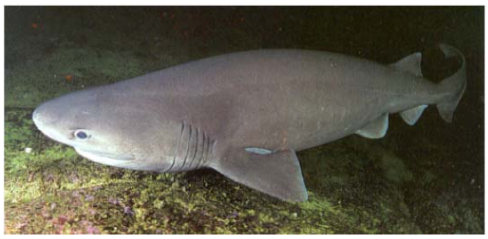
Order Hexanchiformes

2 families, 5 spp.
examples: frilled, sixgill, & sevengill sharks



Order Hexanchiformes

- single dorsal fin, far back, without spine
- anal fin
- six or seven gill slits
- cone-like teeth (eat sharks, rays, bony fishes)
- patchy distribution, wide ranging
- deepwater or cold areas (usually)



Order Echinorhiniformes (bramble sharks)

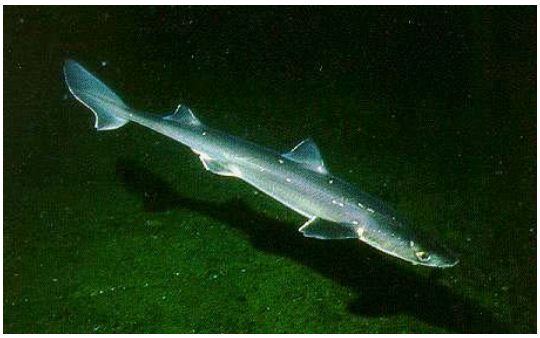
1 family, 2 spp.
examples: bramble shark, prickly shark

Order Echinorhiniformes

- 2 dorsal fins without spines
- anal fin
- 5 gill slits
- denticles few and large (brambles or prickles)
- deepwater (usually)
- large (3-4 m)

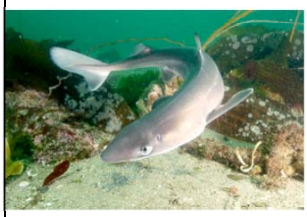
Order Squaliformes

1 family, 97 spp.
examples: dogfish, sleepers, cookie cutter



Order Squaliformes

- 2 dorsal fins w/ or w/o spines
- no anal fin
- 5 gill openings
- nictating lower eyelid absent
- mostly deep sea



cookie cutter shark

Order Pristiophoriformes

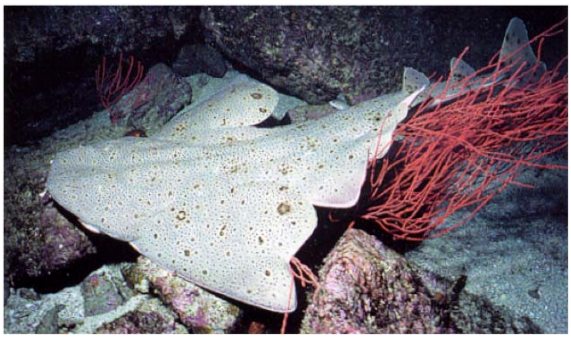
1 family, 5 spp.
saw sharks

Order Pristiophoriformes

- 2 dorsal fins
- no anal fin
- 5-6 gill openings (lateral)
- rostral barbels (taste sensors)
- toothed, elongated rostrum (saw)

Squatiniformes (angel sharks)

1 family, 15 spp.
example: Pacific angel shark



Order Squatiniformes

- intermediate between sharks and rays in appearance
  - dorso-ventrally compressed (= depressed)
- 2 dorsal fins w/o spines
- no anal fin
- 5 gill openings, *lateral*
- pectorals *not* attached to head
- large spiracles on top of head
- lie-in-wait predator

Subdivision Batoidea

- Torpediniformes
- Pristiformes
- Rajiformes
- Myliobatiformes

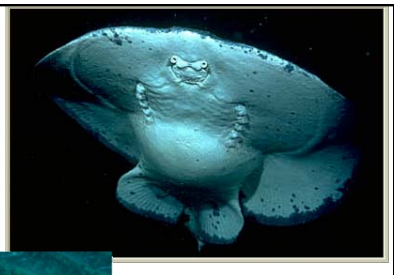
Batoids

- ventral gill openings
- enlarged pectorals, attached to side of head
- no anal fin
- eyes and spiracles on top of head
- pavement-like teeth
- bottom feeders (except torpedo rays, mantas)

Torpediniformes
electric rays

2 families, 59 spp.

example: Pacific torpedo ray



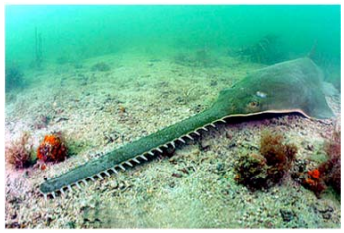
Order Torpediniformes

- two dorsal fins
- caudal fin well developed
- thick disc
- electric organs

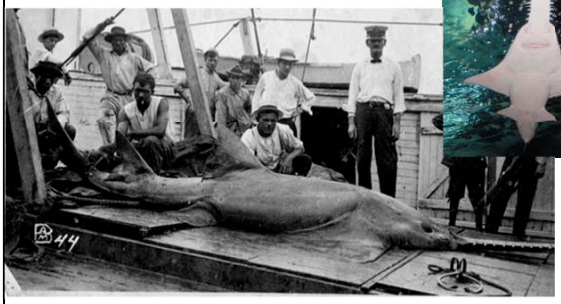
Pristiformes (sawfishes)

one family, 7 spp.

- toothed, elongated rostrum (saw)
- barbels absent
- two dorsal fins and strong caudal fin
- gill slits ventral
- big: to > 6 m!



Pristiformes



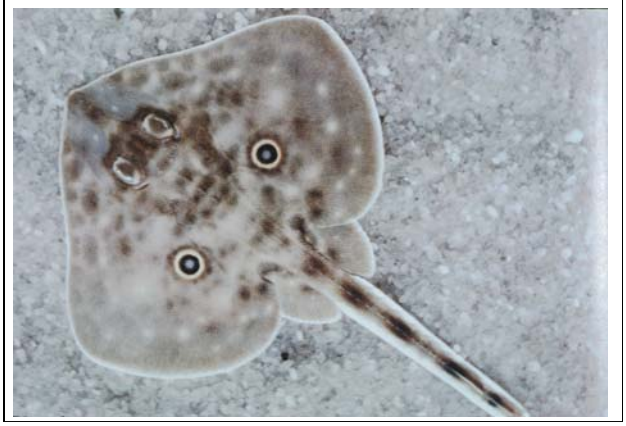
Bigtooth and smalltooth sawfish are endangered, due to bycatch

Rajiformes (skates, guitarfishes, etc.)

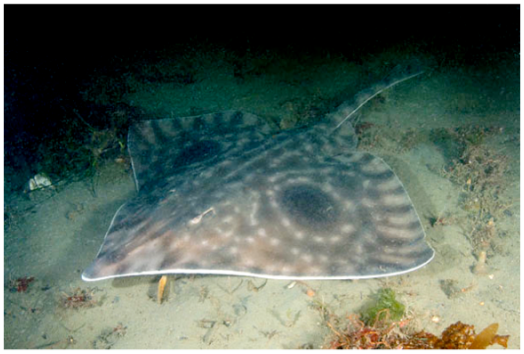
4 families, 285 spp.
examples: shovelnose guitarfish, big skate

- two dorsal fins
- no strong electric organs
- egg layers

Rajiformes: Rajidae



Rajiformes: Rajidae



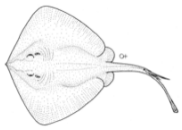
Myliobatiformes
stingrays, mantas, etc.

10 families, 183 spp.

examples: southern stingray, round stingray, manta ray, bat ray

Myliobatiformes

- spine near tail
- small or no caudal fin
- 1 or no dorsal fin
- viviparous



bat ray

Myliobatiformes: Dasyatidae

freshwater stingray in Cambodia: 2 m across

Manta

•plankton feeder

•up to 20 feet and 2,000 pounds!