## Chapter 24 Fishes 28,000 species

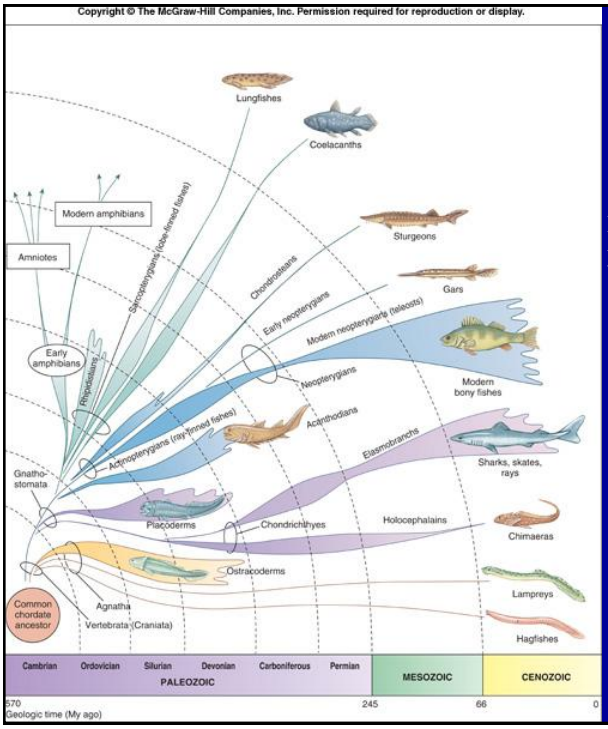
1. Aquatic
   **gills**-efficient at extracting oxygen from water containing 1/20 $O_2$ of air
   **limbs** (if present) in the form of **fins**
   usually with skin covered in **scales** of dermal origin
2. Adapted to live in a medium 800 times denser than air
3. Can adjust to the salt & water balance of their environment
4. Lateral line system detects $H_2O$ currents & vibrations, a sense of "distant touch"
5. Evolution in an aquatic environment both shaped & constrained its evolution
6. "Fish" refers to one or more individuals of one species;
   "fishes" refers to more than one species
7. Fishes do **not** form a **monophyletic group**
8. Common ancestor of fishes: also an ancestor of land vertebrates;
   cladistically → land vertebrates "fish"—(**nontraditional & awkward usage**)
9. Descended from an unknown **free-swimming protochordate ancestor**

## Chapter 24 Fishes

28,000 species

Classification

- Phylum Chordata
  - Subphylum Urochordata
  - Subphylum Cephalochordata
  - **Subphylum Vertebrata (Craniata)**
    - **Superclass Agnatha (jawless)**
      - Class Myxini (hagfish)
      - Class Cephalaspidomorphi (lamprey)
    - **Superclass Gnathostomata (Jaw)**
      - Class Chondrichthyes
        - Subclass Elasmobranchii
        - Subclass Holocephali
      - Class Actinopterygii
        - Subclass Chondrostei
        - Subclass Neopterygii
      - Class Sarcopterygii




Earliest fish-like vertebrates: paraphyletic group **agnathan fishes**

1) extinct ostracoderms → jawed **gnathostomes**

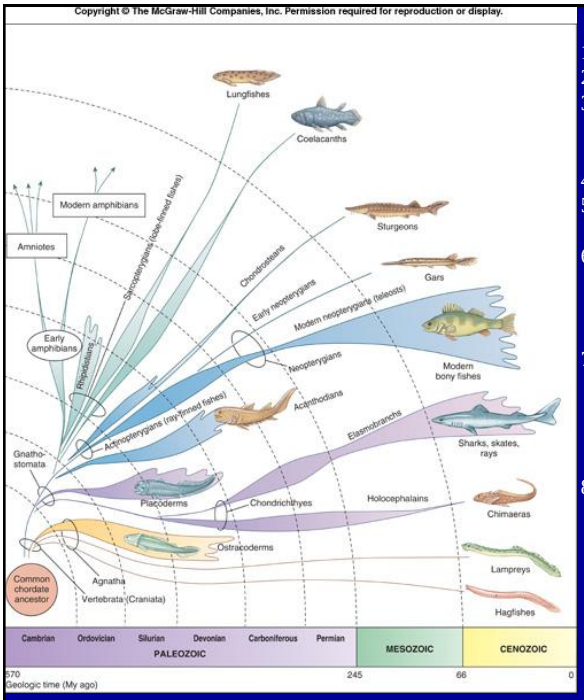
2) living hagfishes lack vertebrae

3) living lampreys rudimentary vertebrae

4) included subphylum Vertebrata cranium & other features

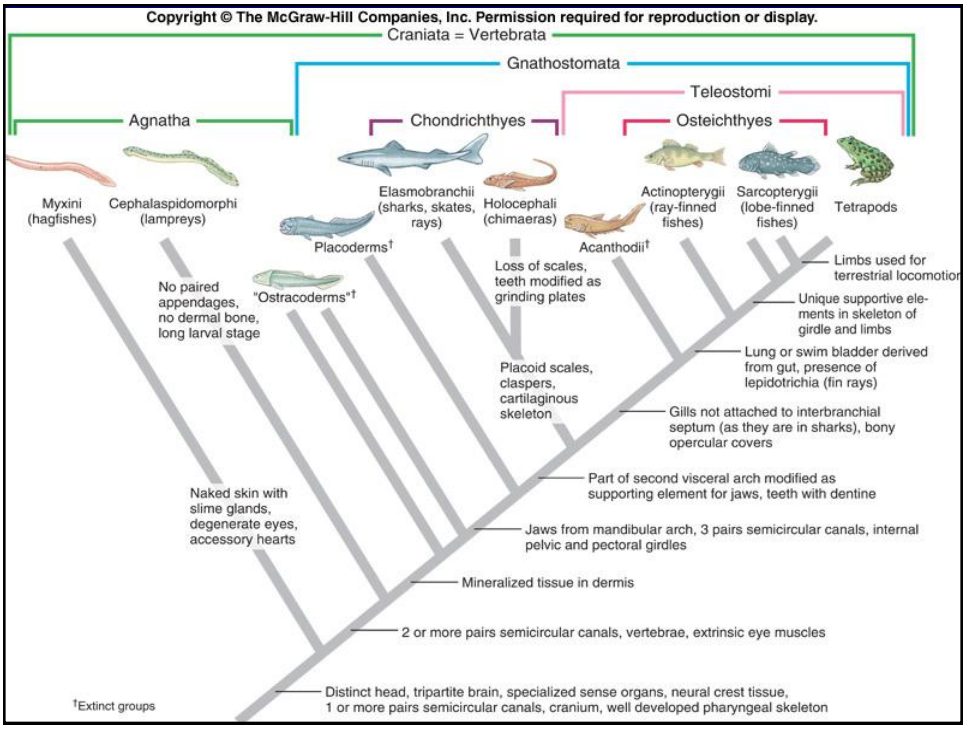
5) unique assigned in separate classes



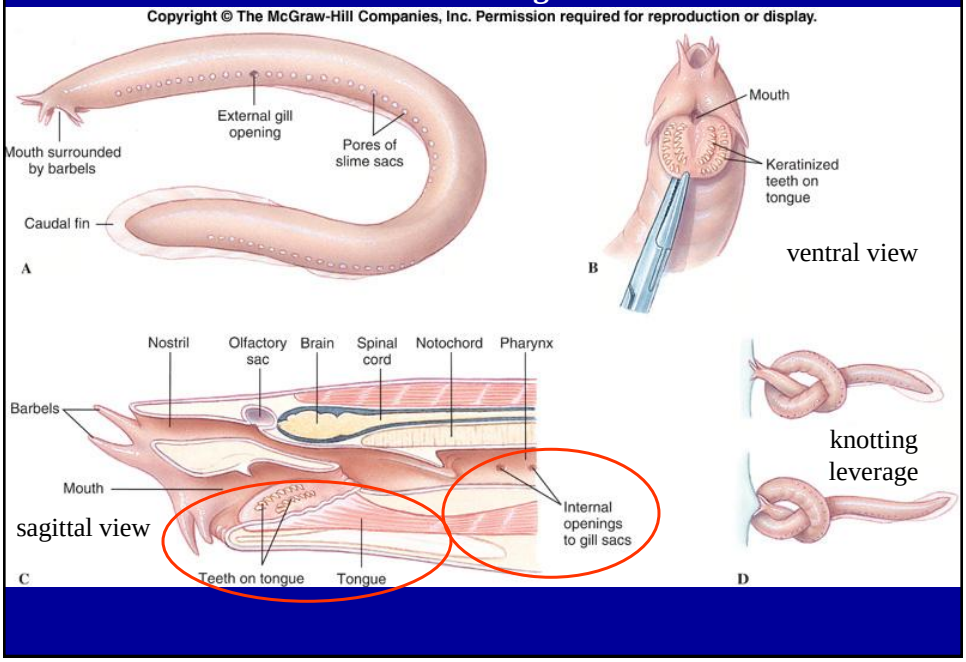



## Gnathostomes

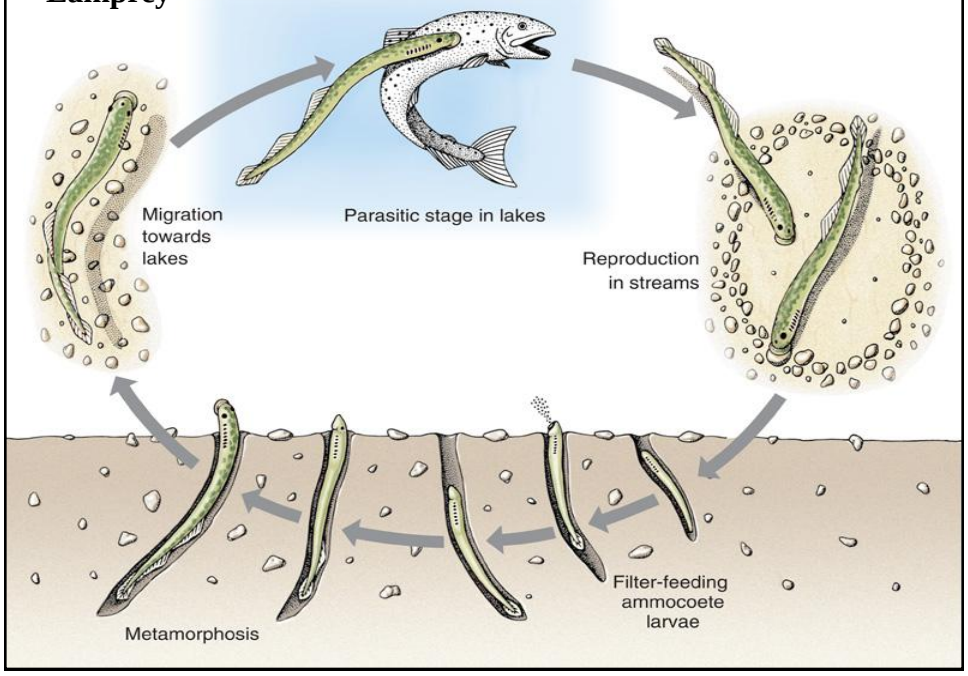
1) paired appendages
2) monophyletic lineage (tetrapods)
3) appear in Silurian fossil record
   a. with fully formed jaws
   b. no intermediates are known
4) Devonian called Age of Fishes
5) **Placoderms**: extinct Carboniferous
   a. left no direct descendants
6) **Cartilaginous Fishes** (sharks/rays)
   a. lost heavy dermal armor
   b. adopted **cartilage** as skeleton
   c. most predators
7) **Acanthodians**
   a. Devonian:extinct by lower Permian
   b. resemble bony fish/but have heavy spines on all fins except caudal fin
   c. ? sister group of bony fishes
8) **Bony Fishes**
   a. dominant fishes today
   b. two distinct lineages:
      1. **ray-fined fishes** radiated to form modern bony fishes
      2. **lobe-finned fishes** lungfishes/coelacanth sister group to tetrapods



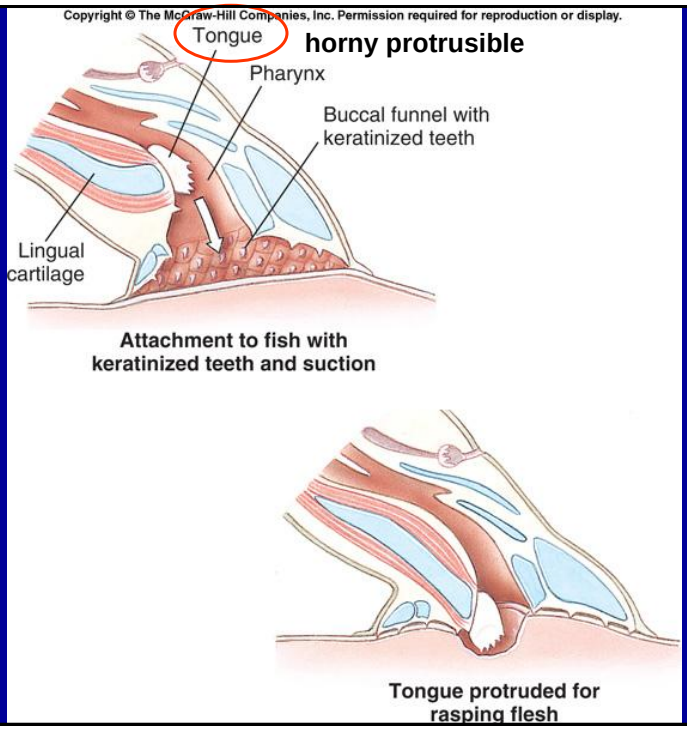

## Atlantic Hagfish



## Lamprey



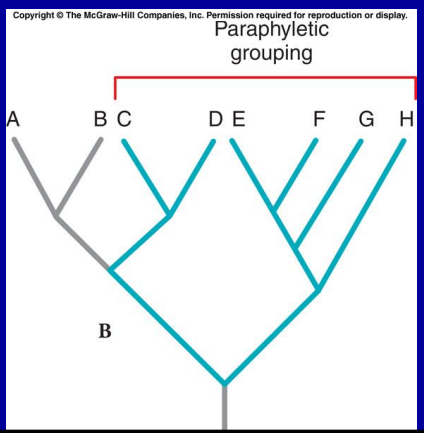


## Living Jawless Fishes

hagfishes (~ 65 species) & lampreys (~ 41 species)

1. lack jaws, internal ossification, scales or paired fins
2. pore-like gill openings & eel-like body
3. hagfishes least derived; lampreys much closer to gnathostomes
4. grouping Agnatha: **paraphyletic assemblage** of jawless fishes




## Class Myxini: Hagfishes

1. entirely marine.
2. scavengers & predators of annelids, molluscs, dead/ dying fishes
3. 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
4. nearly blind but can locate food by
   an acute sense of smell & touch
5. provide leverage, ties a knot in its tail & passes it forward
   to press against the prey
6. special glands along the body secrete fluid
   that becomes slimy in contact with seawater
7. body fluids are in osmotic equilibrium with seawater
8. circulatory system: three accessory hearts & heart behind the gills
9. reproduction
   a. Females: small numbers of surprisingly large, yolky eggs
      2-7 centimeters in diameter
   b. both male & female gonads in each animal; only 1 functional gonad
c. direct growth, no larval stage

## Class Cephalaspidomorphi (Petromyzontes): Lampreys

1. **Diversity**
   a. 41 described species
   b. marine lamprey *Petromyzon marinus* occurs on both Atlantic coastlines & grows to a length of 1 m
   c. 22 species in North America; half belong to nonparasitic brook-dwelling species
   d. *Petromyzon* means sucking, grasp stones with their mouths to withstand currents

2. **Reproduction and Development**
   a. all ascend freshwater streams to breed
   b. marine forms anadromous, leaving the sea where they were adults to spawn upstream
   c. in North America, all spawn in winter or spring
   d. males build a nest by lifting stones with oral discs & using body vibrations
   e. as eggs are shed into the nest, male fertilizes them; adults die soon thereafter
   f. eggs hatch in two week into unique larvae **(ammocoetes)**
   g. larva feeds on invertebrates, detritus, & other particulate matter
   h. larva grow for 3 to 7 years before until metamorphosizing into adults

## Class Cephalaspidomorphi (Petromyzontes): Lampreys

3. **Parasitic Lampreys**
   a. marine, parasitic lampreys migrate to the sea; other species remain in freshwater
   b. attach to a fish by a sucker-like mouth; sharp teeth rasp away flesh & suck fluids
   c. inject anticoagulant into wounds to promote blood flow
   d. when engorged, they drop off & wound may be fatal to fish
   e. parasitic freshwater adults live 1-2 yrs before spawning & dying; **anadromous** forms live 2-3 years
   f. nonparasitic lampreys do not feed; their alimentary canal degenerates as an adult, & they spawn & die


4. **Sea Lamprey Invasion of the Great Lakes**
   a. no lampreys in U.S. Great Lakes west of Niagara Falls until Welland Ship Canal built 1829
   b. 100 yrs later, sea lamprey first seen in Lake Erie, spread to all U.S. Great Lakes in 1940s
   c. preferred lake trout & destroyed this commercial species
   d. then turned to rainbow trout, whitefish, burbot, yellow perch & lake herring
   e. populations declined both from depletion of food & from control measures
   f. chemical larvicides used in spawning streams; lake trout populations are recovering

## Class Chondrichthyes: Cartilaginous Fishes

~ 850 living species

**A. Overview**

1. although a smaller & more ancient group, survived through
   a. **well-developed sense organs**
   b. **powerful jaws**
   c. **predaceous habits**

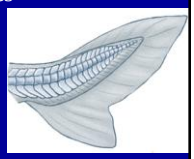


2. some limited calcification, but bone entirely absent throughout class even though derived from ancestors with well-developed bone

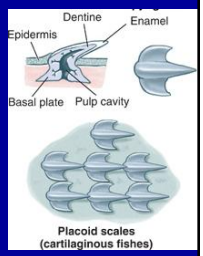
**Cartilage**: translucent elastic connective tissue

**Subclass Elasmobranchii: Sharks, Skates & Rays** ~815 total species

1. 9 orders of elasmobranchs with
2. plankton shark, a plankton feeder, may reach a length of 15 m
3. **Dogfish sharks** order Squaliforme studied in comparative anatomy classes
4. Form & Function
   a. Sharks among most gracefully streamlined of fishes; body **fusiform**



      1) Sharks heavier than water & will sink if not swimming
      2) front of the ventral mouth is the pointed rostrum
      3) tail longer upper lobe; this pattern is called **heterocercal**
      4) fins include paired pectoral & pelvic fins,
         one or two median dorsal fins, median caudal fin & sometimes median anal fin




      5) tough, leathery skin: **placoid scales** that reduce water turbulence
      6) placoid scales modified to form teeth in jaws; consist of dentine
         in an enamel-like substance
   b. sharks track prey using an orderly sequence of sensitive senses
      1) detect prey at a distance by large olfactory organs sensitive to one part/10 billion
      2) prey may also be located from long distances sensing
         low frequency vibrations in **lateral line system**
      3) lateral line consists of **neuromasts** in interconnected tubes and pores on side of body

4) at close range, sharks switch to vision;
most sharks have excellent vision even in dimly lighted waters
5) up close, sharks guided by bioelectric fields that surround all animals
6) **Electroreceptors** = **ampullae of Lorenzini,** located on shark's head

c. upper & lower jaws are equipped with sharp, triangular teeth constantly replaced
d. mouth opens into large pharynx, which contains openings to **gill slits** & **spiracles**
e. short esophagus runs to the stomach
f. liver & pancreas open into the short, straight intestine
g. **spiral valve** in intestine slows passage of food & increases absorptive area
h. **rectal gland** secretes sodium chloride and assists the **opisthonephric** kidney
i. heart chambers provide standard circulatory flow through gills & body
j. retain nitrogenous compounds (**urea**) in blood to raise blood solute concentrations & eliminate the osmotic inequality between blood & seawater

8. **Reproduction and Development**
a. all chondrichtheans internal fertilization; maternal support of embryo variable
b. in male, medial part of the pelvic fin modified to form a **clasper** used in copulation
c. those that lay large, yolky eggs immediately after fertilization **oviparous**
d. embryo nourished from yolk for up to two years before hatching as a miniature adult
e. sharks retain embryos in reproductive tract = **ovoviviparous** if embryo is nourished by yolk
f. true **viviparous** reproduction occurs where embryos receive nourishment from maternal bloodstream from nutritive secretions of the mother
g. prolonged retention contributes to success of this group but after no further parental care

**Oviparity**: eggs developed after leaving female body

**Ovoviviparity**: young hatch from eggs retained in mother's uterus

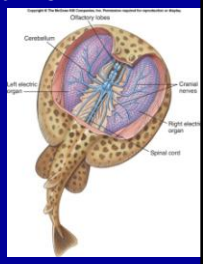
**Viviparity**: eggs develop within mother's body & young born free-living

viviparity in rainbow surf fish

male banded jawfish brooding eggs

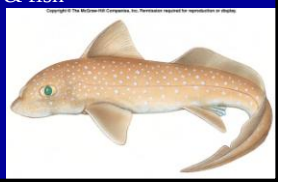
**9. Form and Function of Rays**

a. >50% of all elasmobranchs are rays; most are specialized for benthic life
b. dorsoventrally flattened body & enlarged pectoral fins used as wings in swimming
c. water for respiration taken in through large spiracles on top of head
d. teeth adapted for crushing prey: molluscs, crustaceans & sometimes small fish
e. stingrays have whip-like tails with spines
f. electric rays have large electric organs on each side of head

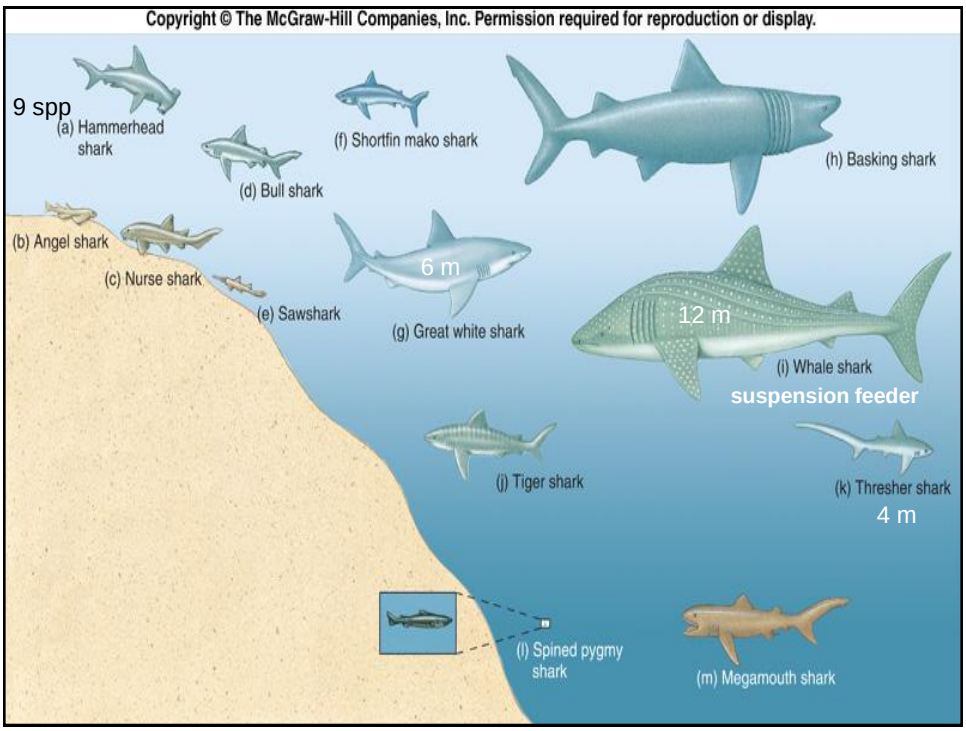


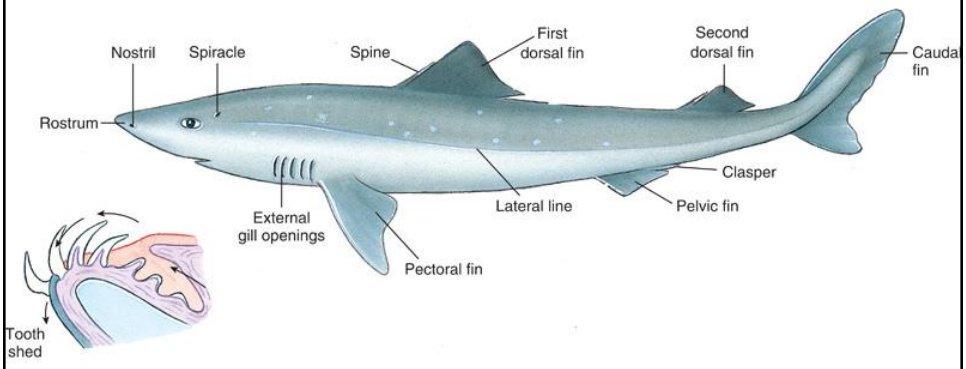

**C. Subclass Holocephali: Chimaeras**

1. members of this small subclass remnants of a line that diverged from earliest shark lineage
2. 35 extant (living) species
3. fossil chimaeras first appeared in Jurassic & reached zenith in the Cretaceous & early Tertiary & then declined
4. wide range food: seaweed, molluscs, echinoderms, crustaceans & fish
5. anatomically linked to elasmobranches
6. bizarre shape contrasts with pearly iridescence

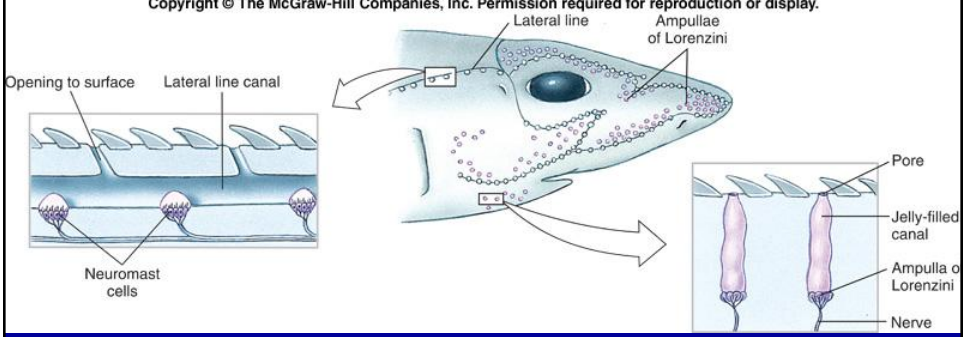


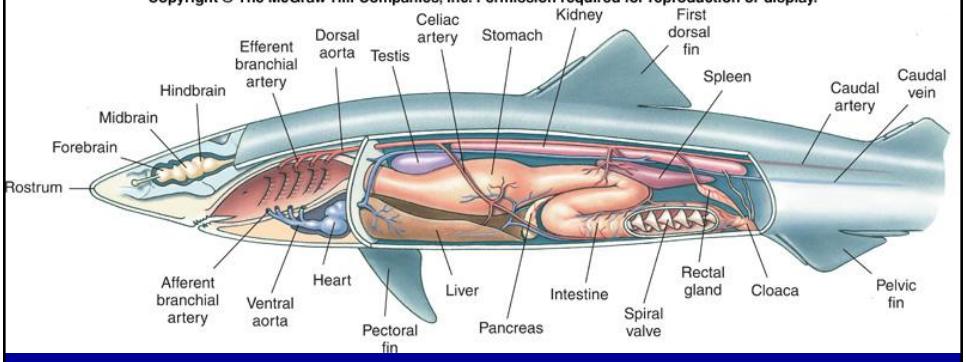








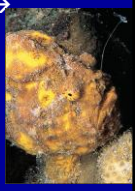



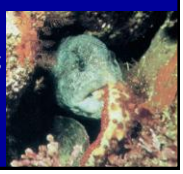



## Osteichthyes: Bony Fishes

**A. Origin, Evolution & Diversity**

1. in early to middle Silurian, a lineage of fishes with **bony endoskeletons** → to a clade 96% of living fishes & all living tetrapods
2. other early fishes now known to also have had bone
3. 3 features unite **bony fishes** & **tetrapod** descendants
   a. endochondral bone present replaces cartilage developmentally
   b. lung or swim bladder present evolved as an extension of gut
   c. several cranial & dental characters unique to this clade
4. **"Osteichthyes"** not define natural group & term convenience rather than valid taxon
5. Bony fishes & acanthodians probably descended from a unique common ancestor
6. By middle of Devonian, bony fishes developed into two major lineages
   a. **Ray-finned fishes, class Actinopterygii**, radiated to form modern bony fishes
   b. 7 species of **lobe-finned fishes**, **class Sarcopterygii,** include **lungfishes & coelacanth**
7. operculum increased respiratory efficiency; outward rotation helped draw water across gills
8. gas-filled pouch branched from esophagus in early bony fishes.
9. pouches helped in buoyancy and in gas exchange in hypoxic waters; they became **lungs** or **swim bladders**
10. specialization of jaw musculature improved feeding

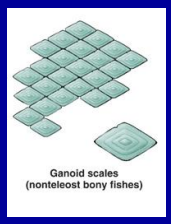




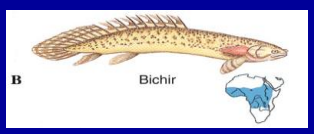
## Ray-finned Fishes: Class Actinopterygii

**A. Diversity**

1. > 27,000 species constitute most familiar bony fishes
2. **Palaeoniscids**: rise to 2 major ray-finned groups: **chondrosteons** & **neopterygians**
3. **Chondrosteons**
   a. most primitive characteristics
      1) **heterocercal tail**
      2) **ganoid scutes** or **scales**




   b. living species include the sturgeons, paddlefishes & bichirs
   c. bichir of African waters: relict with lungs, & resembles palaeoniscids

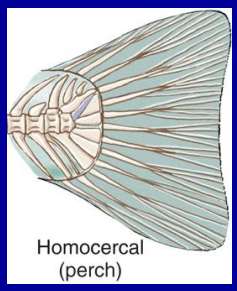



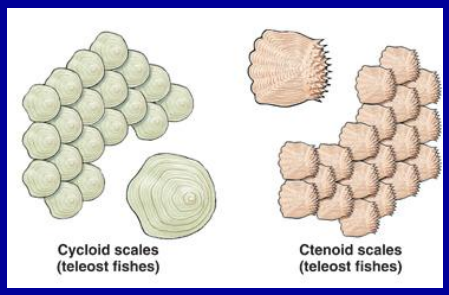


4. **Neopterygians**
   a. appeared in late Permian & radiated extensively during Mesozoic
   b. during Mesozoic, one lineage gave rise to modern bony fishes, teleosts
   c. 2 surviving early neopterygians, **bowfin** & **gars**
   d. bowfin & gars gulp air, vascularized swim bladder to supplement gills
   e. gars ambush prey using needle-sharp teeth


**B. Morphological Trends**

1. heavy dermal armor replaced by light, thin, flexible **cycloid** & **ctenoid scales**
2. increased mobility from shedding armor helps avoid predators & obtaining food
3. fins changed to provide greater mobility & serve for braking, streamlining, social communication, camouflage, protection & attachment
4. **homocercal tail** allowed greater speed & buoyancy
5. **swim bladder** shifted from primarily respiratory to **buoyancy** in function
6. jaw changed to increase suctioning & protrusion to secure food



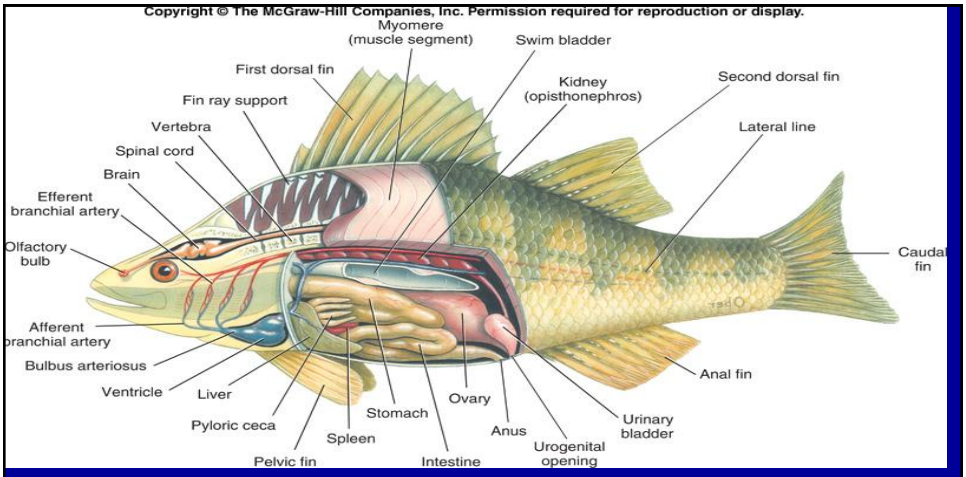

## Diversity of Teleost Fish

blue marlin

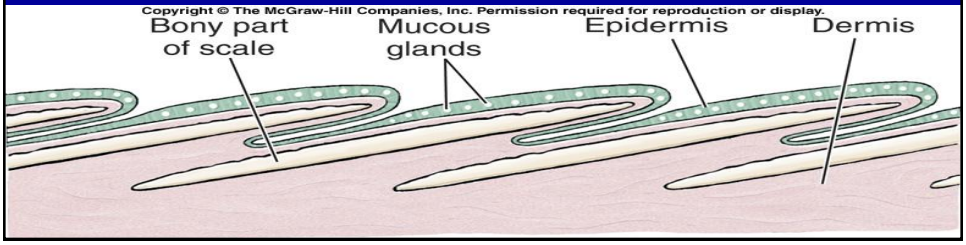

mudskipper

lionfish with venomous dorsal spines


sharksucker



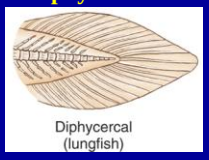



## Lobe-finned Fishes: Class Sarcopterygii

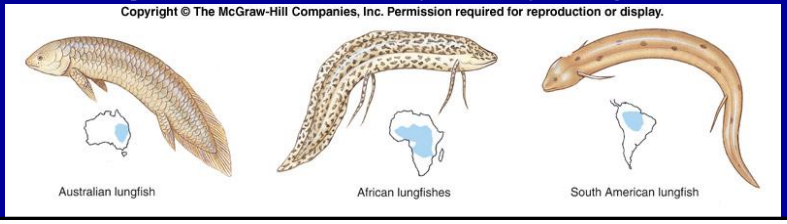
**A. Diversity**

1. only 8 species alive today; 6 species of lungfishes & 2 species of coelacanths
2. Rhipidistians flourished in late Paleozoic, became extinct; include ancestors of tetrapods
3. early sarcopterygians: lungs as well as gills & a heterocercal tail
4. during the Paleozoic, tail became symmetrical with a continuous fin = **diphycercal**

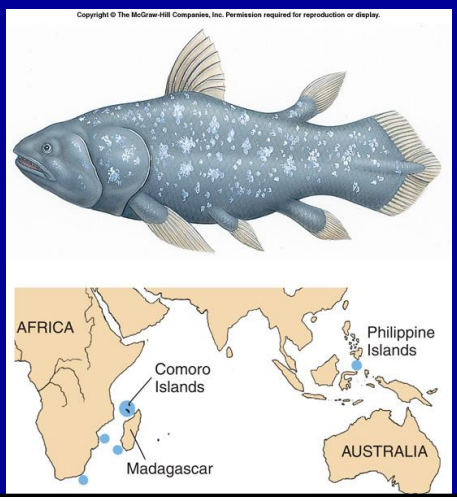

Diphycercal
(lungfish)

5. fleshy, paired lobes appear for scuttling along bottom
6. Australian **lungfishes**, unlike close relatives, rely on gill respiration & cannot survive long out of water
7. South American & African lungfish can live out of water for long periods of time
8. African *Protopterus* burrows into mud in dry seasons by forming a hard cocoon with slime





9. **Coelacanth (living fossil)**
   a. arose in Devonian, radiated, reached peak in Mesozoic & dramatically declined
   b. thought to be extinct 70 million years, specimen dredged up in 1938
   c. More caught off coast of Comoro Islands & in 1998 Indonesia
   d. living coelacanth a descendant of Devonian freshwater stock.
   e. tail **diphycercal** with a small lobe between the upper and lower caudal lobe
   f. young coelacanths born fully formed after hatching from eggs up to 9 cm diam




**Poikilothermic:** body temperatures fluctuate with ambient temperatures

**ectothermic:** rely on external heat source

e.g. invertebrates, aquatic organisms, fish, amphibian, reptiles

ranges: generally limited to lower latitudes (tropics)

benefit: reduce energy needs

1) low feeding rates

2) low metabolism for low internal heat production

cost: enzyme activity less efficient low temperatures

**Homeothermic:** constant body temperatures

**endothermic:** production of internal heat

e.g. birds & mammals

ranges: lower latitudes (tropics) to higher latitudes (polar)

benefit: enzyme activity efficient high temperatures

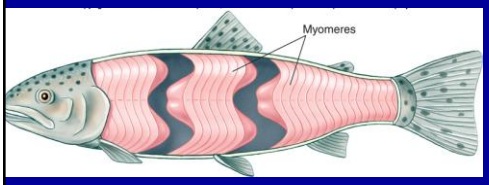
cost: high energy needs

1) constant feeding

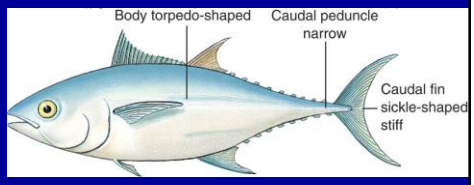
2) high metabolism for internal heat production

3) insulation: fur, hair, feathers, blubber, fat, oil for heat retention

## musculature & swimming in fish

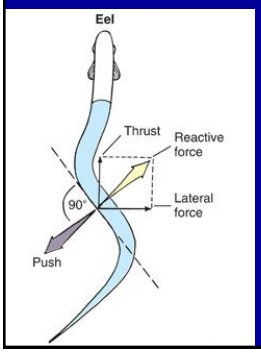


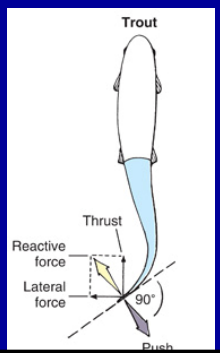

myomeres (musculature) of teleost fish




bluefin tuna: fast swimming
body does not bend; thurst from tail

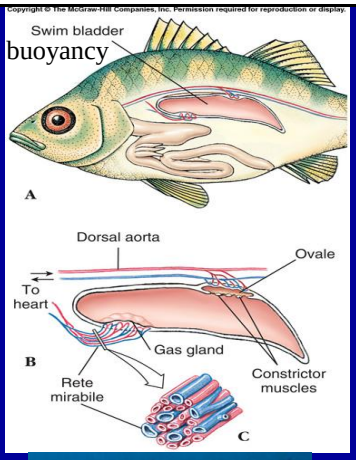
**Homeothermic:** regional production of internal heat through countercurrent exchange of heat from deep inner core muscles to raise blood temperature to provide heat for contracting swimming muscles

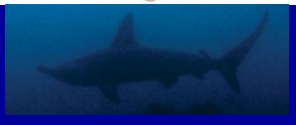



**red muscle**: maintenance swimming
highly vascularized: aerobic

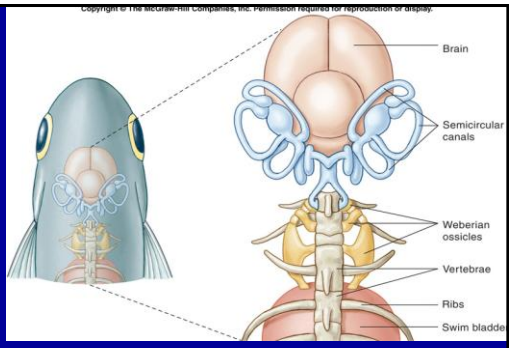
**white muscle**: burst swimming
not highly vascularized→anaerobic

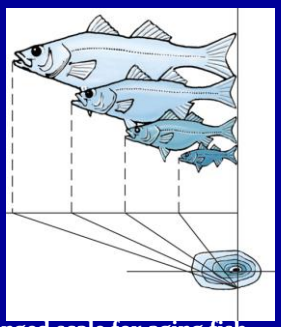


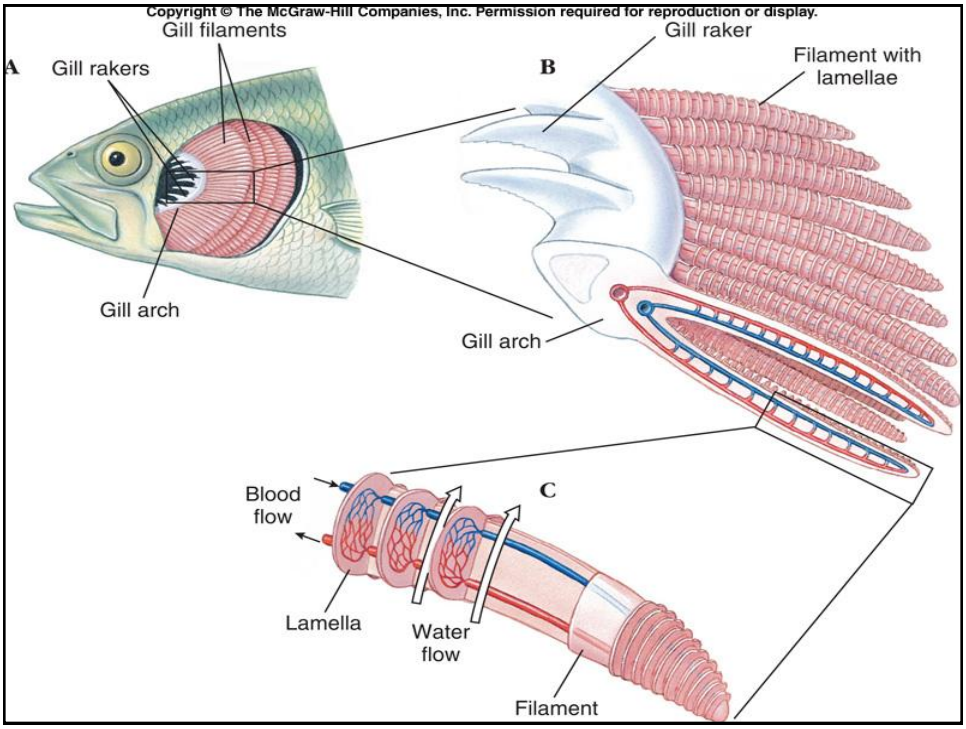
Buoyancy in sharks

1) constant swimming
2) heterocercal tail
3) broad head & flat pectoral fins
4) large liver contains oil-like squalene



**ringed scale for aging fish**
**also otoliths (ear stones) for aging**




## Osmoregulation

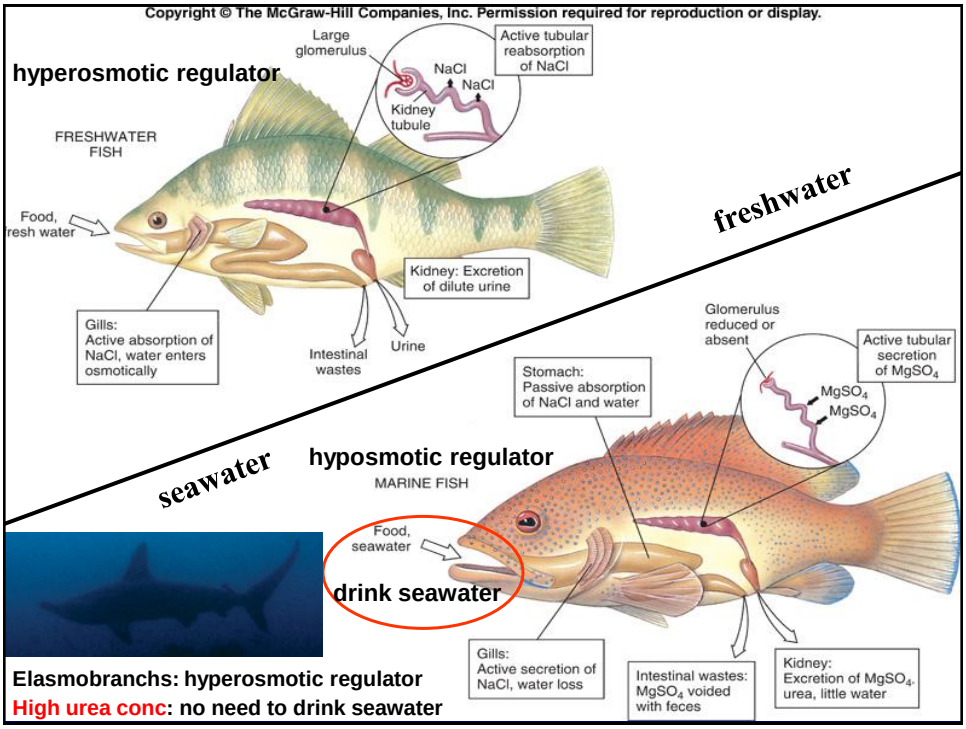
1) **regulation of $H_2O$**
2) **regulation of internal solutes'**
3) **regulation of nitrogenous end products**

**nitrogenous end products:**
**produced during catabolism of proteins & amino acids for energy**

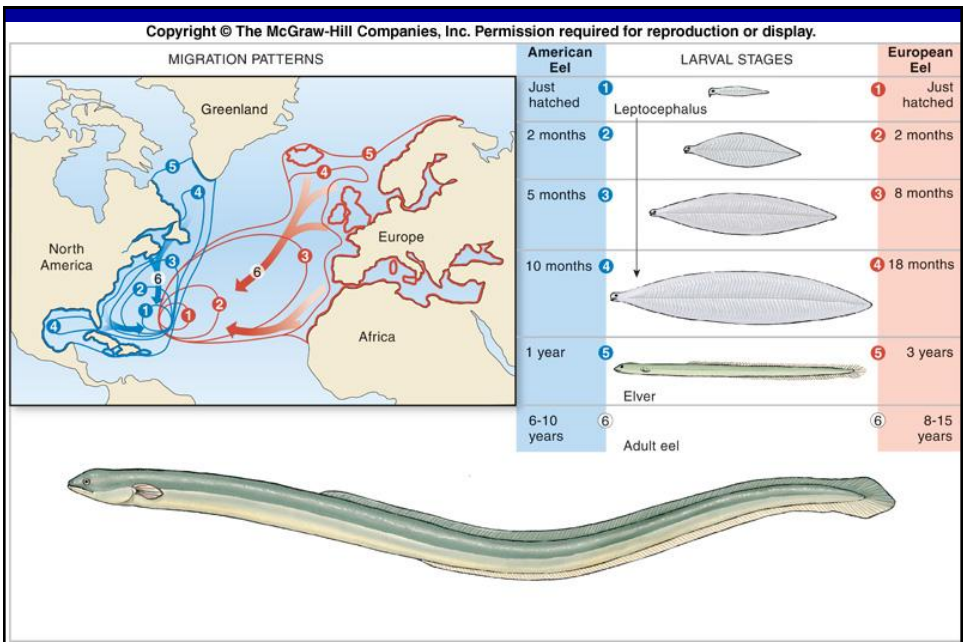
1) **$NH_3/NH_4^+$** (toxic)
aquatic organisms, invertebrates, fish

2) **Urea** (less toxic than $NH_3/NH_4^+$)
elasmobranchs, mammals

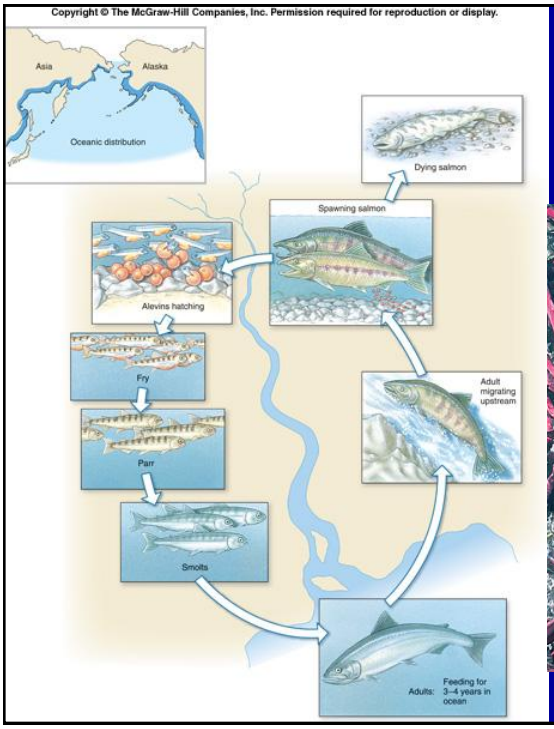
3) **Uric acid** (least toxic)
birds & terrestrial reptiles & insects




**Elasmobranchs: hyperosmotic regulator**
**High urea conc: no need to drink seawater**

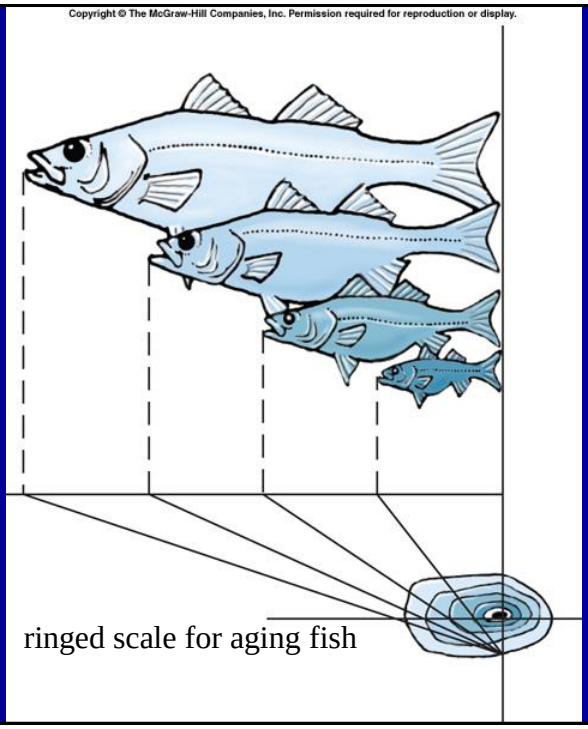



**Catadromous:** majority of life history in fresh water & migrate to sea for spawning




**anadromous:** majority of life history in seawater & migrate to fresh water to spawn

**migrating Pacific sockeye salmon**




ringed scale for aging fish

## Summary

- >50% of all vertebrates: fishes
- **Characteristics**
  - vertebral column
  - jaws (410 mya) & paired appendages
  - gills
  - single-loop blood circulation