Phylum Chordata: Vertebrates
The Fish Classes
Introduction

eg. lampreys, hagfish, salmon, trout, sharks, rays, tuna, sardines, flounder, seahorses, catfish, etc etc

oldest known vertebrates
→ 530 MY (early Cambrian) fossils

all fish are **aquatic** & and highly adapted for aquatic life: freshwater and saltwater habitats

there are no terrestrial fish; although some can survive considerable time outside of water and can often be found crawling on land

eg. walking catfish

fish are the most diverse and successful group of living vertebrates

→ almost half of all vertebrate species
→ 21,000 living species

→ ~100 new species described each year

smallest fish = pygmy gobi <1/2"; smallest living vertebrate

largest fish = whale shark to ~50', rumors to 70' (40 tonnes)

most fish continue to grow throughout adult life

(birds & mammals stop growing at adulthood)

Skin

most with slimy skin and/or **scales** embedded
in skin

the slimy skin reduces friction to improve swimming
efficiency (along with overall shape of fish)

Skeleton

highly flexible "backbone" of cartilage or
bone is main support and framework for swimming
muscles

most fish have **ribs** on which swimming muscle
are attached

also, most fish have **paired appendages**
=appendicular skeleton

paired fins: pectoral and pelvic
→ homologous to our arms and legs

act as rudders, for balance, feelers, weapons, sucking
discs, lures to attract prey

Movement

mainly swimming

although some can walk, crawl, burrow, and "fly"

less energy is required for swimming than most other forms of locomotion

→ water is 800x's denser than air
don't need to also fight gravity as much

most of a fish's body mass is bundles of muscle tissue for swimming = **myomeres (=myotomes)**

relatively small body cavity for other organs

muscles are segmented

→ zig-zag "W"-shaped bands of muscles alond sides of fish

each myotome consist of short muscle fibers connected to tough connective tissue that are also attached to the next myotome

each myotome extends across several vertebrae

→allows more power and fine control

produce "S" shaped swimming motion

fish actually "push" on the water

water is relatively dense
non compressible

fish get most propulsion from hind trunk & tail muscles

dorsal and ventral fins improve swimming efficiency

Respiration

Gills for getting O_2 from water

efficient respiration in water

=thin feathery sheets with lots of blood vessels

some scaleless fish can also breath through their skin

Circulation

blood is pumped through arteries and veins with simple heart

most with **2 chambered heart**;

single circuit:

heart→ arteries→capillaries→ veins

blood is first pumped through gills then out to the rest of the body (ie. single "circuit")

Nervous System & Senses

brains are relatively small and simple but still considerably more developed than in the invertebrates

cerebrum (higher centers) very small
cerebellum (coordination of movement) relatively large
brain stem (automatic activities) also relatively large

sense organs

eyes

paired eyes

in most fish they are set (at rest) for near vision

in sharks (as well as amphibians and snakes and humans) eyes are relaxed for far vision

also, unlike our eyes that stretch lense to change focus; muscles in fish eyes move lens foreward or backwards to focus

lateral line system = "distance touch"

interconnected tubes and pores along sides of body

detects vibrations and current

chemoreceptors

nose

Kinds of Fish:

28,078 species

three different classes of vertebrates are categorized as "fish":

1. jawless fish (Agnatha)

108 species

2. cartilaginous fish (Chondrichthyes)

970 species

3. bony fish (Osteichthyes)

27,000 species (96% of all fish)

most abundant living group

2 main types: ray finned fish

lobe finned fish

The Agnatha
(Jawless Fish)

(108 living sp)

only living vertebrate group with **no jaws**

oldest known vertebrates

most ancient & primitive vertebrate group

→over 500 MY fossils of jawless fish

fossil agnathans are found >500 MY
include extinct conodonts & ostracoderms

three main groups of **agnatha**:

ostracoderms - all extinct

hagfish

lampreys

Ostracoderms

circular or slit -like mouth opening without jaws

some of the earliest vertebrate fossils are in this group (late Cambrian to Ordovician)

recently Chinese fossils pushed date back to 530 MY

flourished for 150 MY

became extinct at end of Devonian

fish armored with heavy dermal bony plates

no paired fins

probably stayed close to bottom

may have filtered water for food but not with cilia & mucus as in cephalochordates

used pumping action of muscular pharynx

some may have even been predators

a later group of ostracoderms had paired **pectoral fins**

→ greatly improved swimming ability

also seemed to have a more sophistocated nervous system and sense organs

→ similar to todays lampreys

probably filtered particles from water

but instead of cilia and mucus, they used muscular pumping of pharynx to take in food

a later group of ostracoderms were even more streamlined (=anapsids)

General Characteristics of living Agnatha:

1. can be freshwater or marine

2. long eel-like body form

3. no jaws

4. no paired fins

    generally poor swimmers

5. smooth slimy skin, no scales

6. skeleton is a simple rod of **cartilage**, no bone

7. gills located inside 5-16 prs of pore-like gill openings

    spiracle at top of head can draw water in and over gills

8. poor sense organs

9. parasitic or scavengers

two main forms today:
hagfish
lampreys

Hagfish

70 species

all are marine

found in deep waters

→almost completely blind; eyes have degenerated

Feeding & Digestion

scavengers, predators & omnivores

→eat dead or dying fish, molluscs, annelids, etc

although almost blind they can quickly find food by touch and smell

enters dead or dying animal through an orifice or by actually digging into the animal

has 2 toothed keratinized plates on its tongue

rasps bits of flesh from carcass

Circulation

has unusually low pressure circulatory system

with 1 main **heart** and 3 accessory hearts to boost blood pressure through gills

Excretion

only vertebrate with body fluids the same concentration as salt water (invertebrate trait)

Protection

secrete copious amounts of **slime** (500 ml/min)

→ milky fluid from slime sacs along sides of body

→ on contact with seawater forms a very slippery material making them impossible to hold

→ protection from predators

Reproduction

breeding habits are still relatively unknown

animal has both male and female gonads but only one or other is functional

no larval stage

Human Impacts

bane to some commercial fishermen using gill or set nets

→by the time they pull catch in hagfish have often devoured internal contents of fish

not often a pest with trawl fishing

today hagfish are collected for "leather" to make golf bags and boots

some species are in serious decline due to over harvesting

<u>**Conodonts**</u>

numerous fossils of small tootlike structures have been known for years

common → used as index fossils to date sediments

weren't sure what animal produced them until 1980 when fossils of complete animal were found

was an agnathan, apparently most closely related to hagfish

had toothlike plates in throat area

notochord

swimming muscles as myomeres

paired eyes

similar inner ear structure

Lampreys

38 sp.; 20 sp in North America

most 15 - 60 cm; up to 1 M long

Feeding & Digestion

most are parasitic

others don't feed as adults

parasitic adults attach to prey by sucker like mouth

rasp away flesh with teeth to suck out blood

→inject **anticoagulant**

when finished lamprey releases its hold

host sometimes dies from wound

Reproduction

all spawn in winter or spring
→ in shallow freshwater streams

male builds nest
→ uses oral disc to move stones and make a shallow depression

female joins him

female attaches to rock to hold position in current

male attaches to female and fertilizes eggs as they are released

adults die after spawning

eggs are sticky, covered with sand

in 2 weeks eggs hatch into **ammocetes larvae**

→ close resemblance to **amphioxus**

larvae drift downstream and burrow into sand

larvae are suspension feeders for 3-7 years

feeding on microscopic organisms

then rapidly metamorphose into adults:

larger eyes
oral disc with rasping teeth
nostrils shift to top of head
body shorter and rounder

all lampreys migrate up freshwater streams to breed

eggs and larvae develop in freshwater

→young of marine species then migrate to ocean until sexually mature

→ others remain in freshwaters their entire lives

Human Impacts

Petromyzon first invaded the great lakes in 1913-1918 (bioinvasion)

in 1950's destroyed great lakes fisheries

rainbow trout, whitefish, lake herring, and other species populations were destroyed

their numbers began to decline in early 1960's

due to depleated food

expensive control measures

→ expensive larvacides placed in selected spawning streams

today, some native species have been restocked and are now thriving again

Jawed Fish

Origin of Jaws & Paired Fins

evolution of **jaws** was one of the major events in the history of vertebrates

→ freed from bottom feeding

→could become predators

oldest known jawed vertebrates appeared 420 MY (Silurian)

→ **placoderms** and **acanthodians**

jaws evolved from gill supports (gill arches)

→ in certain primitive fish the jaws resemble gill arches

→ in shark embryology jaws do develop from gill arches; can watch it happen

→ cranial nerve branching and placement in jaws and gills of cartilaginous fish resembles each other

initially, jaws just "closed the mouth"

jaws allowed feeding on larger foods:

plants and animals

later jaws became armed with scales that evolved into **teeth**

→teeth could be used to seize prey

jaws allowed predation on larger active prey

acanthodians and placoderms were also 1st fish with **paired fins**

all living jawed fish (gnathostomes) also have paired **pectoral** and **pelvic** fins

pectoral fins appeared before pelvic fins

probably originated as stabilizers for swimming

might have begun as folds in skin along sides of animal

later got muscle attachments and became moveable

Placoderms

heavily armored fish with jaws

some up to 10 M long; very diverse group

Acanthodians

live on today as bony fish

acanthodians had scales rather than bony plates of placoderms

once jaws & fins evolved there was an explosion in fish diversity

→ **Devonian = "age of fishes"**

Placoderms and acanthodians went extinct at end of Devonian

Class Chondrichthyes
(Sharks and Rays)

970 species

ancient group

all but a few are marine

includes the largest fish and second largest of all living vertebrates

whale shark → up to 12 M long

General Characteristics of Sharks

1. mostly predators
2. endoskeleton of cartilage
3. powerful jaws
4. very efficient muscles and shape for swimming
5. well developed sense organs

Body Form

fusiform (spindle shaped)

Skin & Scales

skin is very tough & leathery

→ muscles of shark pull on skin rather than pulling on the skeleton

hard, knife-like (**placoid**) dermal scales are embedded in skin and stick out from skin

made of bony tissue

scales have same structure as tooth including enamel, dentin & pulp cavity

scales are continuously shed and replaced throughout life

Support

skeleton lost bone of ancestors and became completely **cartilaginous**

sharks evolved from fish with bone - neoteny??

but retained mineralization in teeth, scales & spine

paired appendages: **pectoral and pelvic fins**

pectoral fins are rigid, not flexible

powerful dorsal and caudal fins

Muscles & Movement

most of body is muscle mass (**myotomes**) is
for swimming

sharks have excellent swimming ability

sharks are the most graceful and streamlined of all fish

sharks are among some of the fastest fish:

eg mako shark 60mph
eg. blue shark 43 mph

Buoyancy

large liver is rich in fats and oils giving sharks near **neutral buoyancy**

→ don't need to use energy to maintain position in the water column

Feeding & Digestion

most sharks are **predators**

yet, by nature, most tend to be timid & cautious

powerful **jaws**

jaws are suspended from chondrocranium by ligaments
→ free movement

teeth only grasp prey, don't chew

→ the teeth and (dermal) scales of sharks are essentially the same

enamel covered dentin
same structure and composition
both shed regularly

→ teeth are enlarged scales

→ form replaceable rows of teeth

eg. fossil shark teeth

skates and **rays** have broad, blunt, cobblestone-like teeth for crushing clams, oyster, etc

some sharks are **plankton feeders**:

eg. whale shark (>50'); worlds largest fish
eg. basking shark (15-40')

a few are **scavengers**

digestive system is similar to other vertebrates but with **spiral valve** to slow food and increase area of absorption

Respiration

gills used for respiration

rows of separate **gill slits** similar to agnatha

spiracles can take in water when mouth is occupied sharks must be moving or there must be some current to move water over the gills

Circulation

similar to lampreys

two chambered heart with **single circuit** going to gills then rest of body and back to heart

Brain & Sense Organs

small brain but well developed sense organs to locate prey

Senses

a. **lateral line system**

detects vibrations and current

b. **chemoreceptors** esp in olfactory pits on head open through nostrils

widely spaced nostsrils allow shark to more easily localize prey

can detect prey half mile or more distant

c. **eyes** not particularly good but used at close range

d. ampullary organs (of Lorenzini)

electroreceptors in head

senses bioelectric fields around animals

used especially for final stage of attack

Excretion

have 2 long slender **kidneys** for excretion

gills also play role in excretion and osmoregulation

→ secrete NH_3 and other N wastes

retain urea to help maintain internal fluids isosmotic to sea water

also, **rectal gland** assists kidney

secretes excess salts

Reproduction & Development

dioecious

all sharks have internal fertilization

male sharks & rays with **claspers** on pelvic fins

→ used to transfer sperm (NOT for clasping)

usually produce only a few eggs at a time

some skates produce 2 young each time

no member of the group produces >12 at a time

retain eggs in body till hatch

development lasts 6 months to 2 years

some sharks have primitive uterus and placenta and provide "uterine milk" for developing young

→bear live young! (viviparous)

others get extra nutrition by eating eggs and siblings in uterus

some sharks and skates have internal fertilization but deposit eggs in horny capsule

= **mermaid's purse**

each "purse" may contain several eggs

often has "tendrils" to attach to objects

no parental care after eggs are laid or young are born

eg. <u>Skates and Rays</u>

~ half of all chondrichthyes

mainly bottom dwellers

dorsoventrally flattened

enlarged **pectoral fins** = 'wings'

move in wavelike fashion

gills open on underside but have large **spiracle** on top to take in water

in sting rays caudal and dorsal fins have been lost

tail is slender and whiplike

armed with 1 or more **spines**

teeth adapted for crushing prey (molluscs, crustaceans, small fish)

dioecious

many bear live young

eg. <u>Electric Rays</u>

fish are the only animals that can directly produce an electrical shock the ability to produce electric shocks is confined to only 2 groups of vertebrates:

→electric rays and some bony fish

electric rays are generally slow, sluggish fish that live in shallow waters

have some muscles modified into electric organs to shock prey or stun predators

cells connected parallel
→ high amperage, low voltage

→ high power output – up to several kilowatts

electric rays were used by ancient Egyptians as "electrotherapy" treatment for arthritis and gout

eg. torpedo ray:

contains 400 honeycomb-like prisms filled with clear jelly-like mass

nerves connect organ to lobe of brain = electric lobe

each cell generates .02-.05 volts
→ can generate combined shock of ≤35 Volts

the amount of electricity varies greatly

can only give a few shocks before it has to rest and eat

Ecology

top predators in many ocean food chains

Human Impacts

1. Shark attacks

60 - 70 per year (2000-2006); 1-10 fatalities

especially great white (to 6 M long)
mako
tiger
bull
hammerhead

more casualities reported from Australian region than anywhere else

2. Shark fishing

40 Million/yr are harvested

100,000 killed for "shark fin soup"

sells for up to $100/bowl

"finning" has been outlawed in US

some other countries are setting quotas

3. Medicinal/Pharmaceuticals

electric rays were used by ancient Egyptians as "electrotherapy" treatment for arthritis and gout

chondroitin for joint treatment and health extracts are being tested for anticancer drugs and weight loss

Class Osteichthyes
Bony Fish

27,000 sp; (96% of all fish)

~200 new species are described each year

probably 5-10,000 more undescribed species

most successful vertebrate class

7 mm to 17 M (oarfish) & 4.5 M blue marlin

have adapted to every kind of aquatic habitat

from 8000 M deep to 5200 M in Tibet

some in hot springs (44º C)

others under anarctic ice at -2º C

in totally dark caves

some make excursions onto land

most bony fish are designed for active swimming

but great diversity of size & shape due to differences in lifestyles

→ adaptive radiation

amazing diversity of body form:

eg. streamlined bodies to reduce friction eg. trim, elongated bodies of pelagic predaceous fish with powerful tails → predators

eg. flattened bodies in bottom forms

eg. eellike - wriggling into holes and crevices

eg. grotesque forms cryptic or mimic for protection

actually consists of several distinct groups which probably should be considered separate classes

Skin & Scales

body is covered with mucous secreting **epidermis**

slime is used to reduce friction

→ can reduce it up to 66%

most have thin, overlapping dermal **scales** below epidermis

replaced heavy bony dermal scales of sharks

several types of scales:

eg ganoid → bony, don't overlap

others do overlap

some have completely lost scales

unlike sharks, bony fish do not shed scales

they grow throughout life

→ can be used to age fish

color and bioluminescence

skin of bony fish shows a variety of colors and texture

→used for eg. protection, mimicry, warning, camoflage

skin of fish shows a variety of colors and texture

→used for eg. protection, mimicry, warning, camoflage

eg. concealment:

eg. coral reef fish are highly colored
but on reef cant see them

eg. fw fish shades of green, brown, blue above
and silver or yellow white below

→ from below blends with sky,
from above blends with substrate

eg. often have blotches, spots and bars
→ ~army camoflage

eg. mimicry

another form of camoflage

eg. pipefish, anglerfish, sargassum fish

take coloration, texture and form of seaweed

eg. warning:

many highly colored fish stand out from their surroundings

→ warn potential predators that they are poisonous

most fish can control their color to some degree

due to special skin cells =**chromatophores**

controlled by nervous system

in dermis

can be: silver, yellow, orange, black

blended for other colors

allows fish to change color to blend with substrate

color changing is most highly developed in flounder (flatfish) species

bioluminescence

the skin of some fish also contains **photophores** →light emitting organs or structures

found in many unrelated groups

may be on head; lateral line, sides of belly, on barbels, etc

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Support

cartilaginous skeleton is replaced by bone in adults of most species

a few species retain cartilage skeleton

# of vertebrae on a fish varies from 16 to >400

ribs of fish not used for "breathing"

→ support swimming muscles

fins contain bony or cartilage rods

= rays connected by thin membranes

pectoral and **pelvic fins** are controlled by muscles for more precise movements

dorsal fin is moveable and sometimes becomes highly specialized for:

camoflage

venomous spines (eg. scorpion fish)

lures (eg. anglerfish)

Movement

most of body mass is segmented **myotomes**

(2/5^{ths} of body volume in most; 3/4^{ths} in tuna)

movement is mainly swimming,

but some can walk, crawl, burrow, or "fly" less energy is required for swimming than most other forms of locomotion

→ don't need to fight gravity

→"S" shaped swimming motion

Energy Consumption/kg body wt/km:
swimming: 0.39 kcal (salmon)
flying: 1.45 kcal (gull)
walking: 5.43 kcal (squirrel)

get most propulsion from hind trunk & tail muscles

fish actually "push" on the water

water is relatively dense

non compressible

the most rapid fish exchange the snake-like motion for more rigid position where most of the flexing is toward the tail only

eg. tuna doesn't flex body at all; all thrust is from the tail

overall, swimming speeds not particularly fast compared to running or flight

→ water is 800x's denser than air

eg. 1 ft trout → 6.5 mph
eg. 2ft salmon → 14mph

the larger the fish the faster it can swim barracuda is fastest fish → 27 mph

usually cruising speed is much slower

most speeds reported for fish are speeds as they jump out of water so they appear to be much faster

Maximum Speeds	
sailfish	68mph
swordfish	40-60mph
marlin	50mph
bluefin tuna	30-44mph
bonito	50mph
wahoo	40-49
salmon	25mph
mackerel	20mph

flying fish can achieve launch speeds of 35mph and glide above the water 20-40 seconds

very flexible and moveable **pectoral** and **pelvic fins**

pectoral fins used to steer and swim

Buoyancy

all fish are slightly heavier than water

to keep from sinking, sharks must keep moving

shape of sharks tail provides lift

most bony fish have **swim bladder** to control buoyancy

swim bladder arose from "lung" of some primitive bony fish

they lived in swamp waters with low O_2 levels needed accessory oxygen source

(called a **lung** if used mainly for respiration; called **swimbladder** if used to control buoyancy)

most early bony fish evolved and diversified in freshwaters

alternating wet and dry temps made lungs essential in some forms

by adjusting the volume of gas (O_2)in the swim bladder a fish can achieve neutral buoyancy and remain suspended indefinitely with no muscular exertion

control of buoyancy probably coevolved with fin modifications to improve and refine locomotion

most pelagic fish have swim bladders (except tuna)

bottom fish generally lack swim bladders (eg. flounder)

in fish that migrate to & from great depths have the additional problem of the gasses being forced into blood

eg. humans suffer the bends when returning to surface as gas comes out of solution and forms bubbles in the blood fish are able to prevent gasses from entering body fluids at great depths and keep body fluids at equilibrium with oxygen in surface waters

their swim bladders can resist pressures >240 atm (up to 8000' depth) (=pressure inside compressed gas cylinders) and still keep oxygen in blood at 0.2 atm (~sea level pressure)

Feeding & Digestion

after the evolution of jaws, fish were freed from deposit feeding and filter feeding

they diversified into a variety of feeding types:

most fish are **carnivores**

most lack tongues

also chewing would produce pieces that might clog gills

→ must swallow their food whole

a. plankton feeders

most common feeding type

most pelagic species are plankton feeders (zooplankton)

eg. herring, anchovies, menhaden

travel in large schools

plankton are strained with sieve like gill rakers

b. predators

teeth used to seize prey

a few have molar-like teeth behind gills to grind food

gill arches of some fish are modified into "**pharyngeal jaws**" for chewing, grinding & crushing

c. herbivores

eat plants, grasses, algae, etc

d. omnivores

e. scavengers & detritivores

suckers & minnows

f. parasites

intestine long to provide greater surface area

- no spiral valve

Respiration

fish get oxygen mainly through **gills**

gills are located inside **pharyngeal cavity**

gills are highly vascularized filaments of soft tissues covered with a thin epidermis

often have **"gill rakers"** that filter water before passing over gills

→to remove food and bits of debris that might clog the gills

gills are covered bony flap = **operculum**

→offers protection and reduces friction when swimming

→ operculum can also actively pump water across gills

fish can still "breath" even if not moving

Body Temperature/Thermoregulation

fish are cold-blooded; ie **poikilotherms**

→the body temperature of most fish is the same as their environment

some fish eg. tunas, mako sharks, maintain a higher temperature in their swimming muscles

→ as much as 10º C warmer than surrounding water

other fish; eg. marlins, elevate temperature of brains and retinas

elevated temperatures promote swimming and enhance nervous activities

→ such fish are some of the fastest in the world

Nervous System & Senses

simple brains as described for Fishes in general

fish do **sleep**

→ stay motionless for several hours

some marine species (eg. wrasses, Labridae) may bury themselves in sand or spin "sleeping bags" → cocoons of mucus each night to sleep

Senses

the fishes environment:

light doesn't travel as far in water

also turbidity

sound and pressure waves travel faster and further

a. eyes

most fish lack eyelids

one eye of flounders migrates to same side as other eye during embryonic development

a few freshwater fish have “bifocal” lenses to see above and below the water at the same time

can enhance prey perception

fish can see in color

can also detect polarized light → navigation

b. lateral line system

bony fish also depend mainly on **lateral line system** for sensory information to detect food or danger

contains:

mechanoreceptors → water movements
electroreceptors
chemoreceptors

can also pick up unusually low frequency sounds (.1-200 Hz)

c. Chemoreceptors (smell and taste)

chemicals also travel well in water

for fish there is no clear distinction between smell and taste

chemoreceptors are located in:
- mouth
- around head
- in some over entire body
- catfish and loaches on barbels around mouth (barbels also for touch)

fish lack taste buds

but can apparently discriminate between bits of food and trash that they take in

→ will expel unwanted items that they eat

olfactory sacs (=nose)

fish don't "breath" through their nose

→ nostrils are just sensory pits

most fish have a good sense of smell

prey detection

communication (with pheromones)

d. touch

barbells in catfish, goatfish, whiting, etc

e. hearing

swim bladder has secondary function in hearing

swim bladder is connected to inner ear by set of bones = **Weberian ossicles**

sound vibrations are picked up by swim bladder and transferred to ear through ossicles

acts kind of like an eardrum and ear ossicles in humans

helps to amplify even very faint sounds in water

f. balance

otolith organ and semicircular canals

swim bladder is close to inner ear
→ acts as a receiver and transmitter

transmits vibrations to inner ear

inner ear can pick up frequencies up to 8000 Hz

no outer ear or eardrum

Water Balance & Excretion

scales & mucus make body almost completely impermeable to water

→ most gain & loss is through gills

all modern bony fishes are believed to have descended from ancestors that evolved in freshwaters.

→ **marine bony fish** (returned to oceans from freshwater) have salt content about one third that of seawater

→ **freshwater fish** have salt content ~100 times greater than freshwater they live in

[fw salt conc=.001-.005 Moles; freshwater fish = .2-.3 M]

"Water follows Salt"

marine fishes has a tendency to **lose water** and

freshwater fishes has a tendency to **take on water**

most of this exchange occurs through the **gills** and **mouth**

marine fish urinate little and drink large amounts of seawater while pumping out excess salts from gills

freshwater fishes must avoid drinking and urinate often while getting ions through food and gill uptake

because of these osmotic limitations 90% of all fish are restricted to either freshwaters or salt water

10% of fish are able to easily move between freshwater and salt water = **euryhaline fish**

→ can actively regulate to maintain salt/water balance in their internal fluids

Defenses

color and shape can be used for camoflage

some fish are highly venomous; eg scorpionfish

Electric Fish

water conducts electricity

the ability to produce electric shocks is confined to only 2 groups of vertebrates: electric rays and some bony fish bony fish: electric eel & electric catfish

eg. electric eel

in rivers in South America

grows to 3 - 7 ft long

electric organ is modified muscle tissue

→ up to 40% of body weight

most powerful electric organ of all fish
→can produce 600 volts to stun or kill prey

→ can give several 100 shocks up to 300 V each/second

doesn't need to actually touch victim
→electric field extends several feet around fish

eg. electric catfish

found in the Nile river

organ seems to have evolved from the skin rather than from muscle tissue (?)

consists of a uniform layer of gelatinous tissue

Reproduction & Development

most fish are **dioecious**

only a few are hermaphrodites

genders cannot be distinguished externally most with **external fertilization** (oviparous)

a few bear live young (eg. guppies)

→generaly little or no parental care

most fish produce large numbers of eggs:

eg. herring → 25,000
eg. lunpfish → 155,000 - 1M
eg. halibut → 3.5 M
eg. sturgeon → 635,500
eg. cod → 4 - 6 M

→ less than 1/million will survive to maturity

most fish spawn at certain times of the year

→ spawning is temperature dependent

→ temperature is critical for survival of eggs and young

in most marine fish: eggs are released and become part of the plankton through embryonic and larval development

some fw fish make nests and have fairly elaborate mating and nesting behaviors

eg. Stickleback
male constructs very elaborate nest of grass and weeds bound by mucous threads
(only example of "case building" in a vertebrate animal)
then looks for a mate to entice inside
if gentle persuasion doesn't work, he may drive 1 or 2

females into nest until enough eggs are laid
then he jealously guards them for many days until they hatch

eg. Tilapia

starting in late spring they begin to spawn
males build circular nests in streambed
females choose mate based on nest
both spawn over nest
after eggs hatch mother will carry the young in her mouth for a few weeks then they are on their own

A few fish show rather elaborate parental care

eg. some Catfish species

females attach eggs to underside and she carries them around till they hatch

eg. pipefish & seahorses

male contains a brood pouch
female lays fertilized eggs in males pouch
they remain there for ~ 10 days till hatching

eg. some marine catfish

eggs are incubated in males mouth
young continue to be carried an protected in males mouth after they hatch
male doesn't eat for ≥ 1 month

some fish show absolutely no parental care or interest

eg. Gambusia

in an aquarium will eat all their young as soon as they are born

fish continue to **grow throughout life**

generally **growth is temperature dependent**

annual rings are produced in scales, otoliths and other bony parts

→ the age can be accurately determined

Migrations

some fish spend most of their lives in freshwater but return to sea to spawn

= **catadromous** ("down running")

eg. some eels

each fall large #'s of female eels are seen swimming down rivers toward the sea

when adults leave rivers in Europe and N America they reach ocean and swim at great depths to Sargasso Sea

takes several months to reach this area; here they spawn and die

they tiny larvae begin their return trips to the coastal rivers
→ takes up to 3 yrs in Europe

each spring large #'s of young eels appear in coastal rivers swimming upstream

males remain in brackish waters near mouth
→ female continue 100's of mile upriver

by 8-15 years females >1 M long; return to sea to rejoin males and spawn

other spend most of adult life in the sea, and return to freshwater to spawn

= **anadromous**

eg. Atlantic species (eg. salmon & steelhead trout)

make spawning runs year after year

eg. pacific species (sockeye, sliver, humpback & chum salmon)

make one spawning run then die

adults spend 4 yrs at sea yet can unerringly return to parent stream
→ only a few stray go to wrong stream

when salmon return to site where they were hatched, they spawn and die

the following spring the newly hatched fry "**imprint**" on the stream as they drift downstream to the sea

How do they find the mouth of the river when they are returning to spawn?

apparently can navigate by orienting to sun's position

but they can also navigate on cloudy days

may also be able to use earth's magnetic field

probably also use ocean currents, temperature gradients, food availability to reach general area annual run of wild salmon today is ~3% of the 10-16 Million fish that ran 150 yrs ago

Salmon runs in Pacific NW have been devastated by stream degradation:

eg. logging, dam construction (50 dams)

Preadaptations to terrestrial environment

a. Air Breathers

many fish can survive out of water for a short time by breathing air

eg. some fish (eg. Anabantoids) can breath air via labyrinthine chamber in head behind gills

eg. lungs of lungfish & gars

eg. bowfin (*Amia*) at low temp use mostly gills, at higher temperature use mostly lungs

eg. some *Corydoras* Catfishes can process air in the hind part of the gut

eg. freshwater eels commonly make excursions onto land in rainy weather

do gas exchange through moist skin

eg. electric eel has degenerate gills and must get most of its oxygen by gulping air

eg. Indian climbing perch (*Anabas*) spends most of its time on land near water's edge

has special chamber above much reduced gills for respiration can alsoabsorb oxygen from air if skin is moist

eg. mudskipper can be out of water for long periods but prefers to keep tail in water to absorb oxygen from water through its skin

b. supporting fins

climbing perch

only climb in wet weather

Fish Life Histories

eels, Anguilla sp

hatch in spring
begin life in larval form, ribbonlike
larvae enter estuaries and bays turn into "glass eels" transparent but resembling adult
move to freshwaters and live 8-15 years
stay hidden in weed beds ledges ormud during daylight
eat whatever is available
can come ashore searching for food: worms and grubs
can breath through skin
slime layer protects from salinity changes
highly developed sense of smell
light sensitive skin also responds to low frequency sounds
after 10 years in freshwaters, gonads enlarge, fish change shape and become a bronze or silver eel
eyes enlarge and become more sensitive to light
body fat increases
begin migration to sea to Sargasso sea
need fairly high water temperatures to reach sexual maturity
large eel can produce 2.5 Million eggs

Toothpick fish (Candiru)

parasitic freshwater catfish in Amazon river

eel shaped, translucent → impossible to see in water

up to 6" (15 cm) long

most feared fish in these waters, more than piranha

they can detect respiratory currents and swim toward gill openings of other fish where they feed on prey's blood

some species lie in wait in murkey bottom mud sample water for nitrogen wastes from gills of fish

eg. ammonia, urea

once detected they dart towards the gill cavity with a burst of speed

once inside gills they lodge themselves in place with its spines

gnaws a hole toward a major blood vessel and gorges itself for a few minutes only

it then dislodges itself and sinks back to bottom of river to digest its food

victim usually bleeds to death

is known to attack people and swims into an orificea;

vagina, anus, penis

locates its target when people urinate near the fish

has been known (and videotaped) swimming up a urine stream into penis of victim

almost impossible to remove without surgery

Human Impacts of Fish

Pets

20 million fish are sold each year as pets in US alone

Commercial Fisheries

marine fisheries

marine food sources (including fish) provide about 25% (directly and indirectly) of animal protein

commercial fishing employs 200 Million people worldwide

2.6 bilion people worldwide depend on fish for protein (2002)

60% of all fish comsumption is by the developin world (2008)

estimates suggest that seafood production from wild fish stocks will not be sufficient to meet growing world demand in the next century

global production from fishing and aquaculture

1999-2001 →93 million tonnes

2002 →133 million tonnes

total marine fish catch has peaked at about 100

Million tons and remained stable, in spite of increased efforts to catch fish

most commercial fisheries are near shore where most pollution and damage occurs

open ocean catch has been increasing

~ 11% of total (2002)

per capita (per person) fish catch is decreasing as population expands

11 of worlds 17 major fisheries are overfished and in decline

estimates that ~ half of all commerical fisheries stocks are "fully exploited" and another quarter are overexploited, depleted or slowly recovering

→most conclude that global marine fish production is not sustainable at the current levels

subsidies encourage overfishing:

world spent $124 billion to catch $70 billion worth of fish, the

difference was paid for by taxpayers

of the world fish catch only two thirds are used **directly** for human consumption,

the rest is converted to fish meal and oil,

and pet and livestock food

much of what is collected is wasted as "**bycatch**", especially in industrial countries,

examples:

shrimpers typically discard 1 to 8 times as many creatures than they keep

gulf of mexico shrimpers killed 34 million red snapper and over 3000 sharks in one year

open ocean fishermen use large drift nets (25'deep and 50 miles long), set out 30,000 miles of net a night worldwide;

18 miles of net is lost per night,

1000 miles per year become 'ghost nets' and trap and entangle fish for decades as they float in the ocean

these nets killed 42 million seabirds, marine mammals and other nontarget animals increase in **biomass fishing**:

→collecting all life in an area and grinding it up for meal, used as feed
for fish farming
decimates communities in an area

freshwater fisheries

fish from inland waters accounted for 10% of total catch (2002)

many river basins, especially in developing countries support intensive fisheries

inland fish are considered to be the most threatened group among all vertebrates used by humans

<u>Aquaculture</u>

fastest growing animal protein sector

especially in developing countries

contributes almost 1/3rd world supply of fish products

China and other Asian countries are the largest producers

aquaculture produces more than 220 species carp are the largest group