Phylum Chordata: Vertebrates
The Fish Classes
Introduction

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

fish are the most diverse and successful group of living vertebrates

→ almost half of all vertebrate species

→ ~28,000 living species

→ ~200 new species described each year

while fish are by far the most abundant and diverse of all vertebrate groups

they remain the least known group of vertebrates

eg. estimates are that we have collected and described only slightly over 1/3rd of fish species in the Amazon river basin

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fish are also the oldest known vertebrates

→ the first true vertebrates appeared in the fossil record 530 MY ago (early Cambrian)

→ a fossil shark species from 310 MY ago was the first vertebrate known to migrate it lived in rivers but swam to the sea to breed

the first fish appeared over 500 MY ago and were small bottom-dwelling animals without jaws, teeth, or paired fins

probably sucked up small particles of food from the bottom sediments

for ~50 M years they were the ONLY vertebrates on earth

they eventually developed primitive **fins** that improved their swimming ability

they also developed heavy bony armor and roamed in this form for over 20 MY

eventually most fish lost the heavy armor, developed more streamlined bodies, jaws and paired fins

this "modern" design produced almost all the varieties of fish we have today

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

fish occupy virtually every kind of freshwater and saltwater habitat 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"

the closest to terrestrial is the "mangrove killifish", normally lives in muddy mangrove swamps but when they dry up the fish can be found stuffed into insect tracks in rotting logs by the 100's

size of fish:

smallest fish (also, smallest living vertebrate)

= stout infantfish, *Schindleria brevipinguis*, (Australia) males 7 mm long (~1/4th "), female 8.4 mm and weighs 1 mg

also, pygmy gobi <1/2"

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

most fish continue to **grow throughout life**

(birds & mammals stop growing at adulthood)

generally **growth is temperature dependent**

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

→ the age can be accurately determined

Skin

consists of two layers:
epidermis
dermis

epidermis usually secretes slimy **mucous**

the slimy skin reduces friction

→ up to 66%

→ improve swimming efficiency

dermis sometimes tough and leathery or relatively thin

dermis produces **scales** in most fish

the scales are *under* the slimy epidermis

the scales are made of enamel and sometimes dentin; the same basic components as our teeth

Skeleton

skeleton begins as **cartilage** framework

in most fish the cartilage is replaced by **bone** by adulthood

bone is a tissue unique to the vertebrates originated as an external protective covering

only later evolved into an internal supporting framework

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

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

most fish have **ribs** but they are not used for "breathing"

→ they support swimming muscles

most fish have bone or cartilage that supports the dorsal, ventral and caudal fins (unpaired fins)

also, most fish have **paired appendages** in the form of **pectoral** and **pelvic** fins

="**appendicular skeleton"**

→ homologous to our arms and legs

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

<u>Movement</u>

most of a fish's body mass is bundles of segmented muscle tissue = **myomeres (=myotomes)** relatively small body cavity for other organs

muscles are **segmented**

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

muscles are mainly for **swimming**

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

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

→ don't need to fight gravity

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

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

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

each myomere extends across several vertebrae

→allows more power and fine control

myomeres produce "S" shaped swimming motion

fish actually "push" on the water

water is relatively dense
non compressible

the fastest 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 are not particularly fast compared to running or flight due to the high density of water

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

the larger the fish the faster it can usually 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 glide above the water 20-40 sec

dorsal and **ventral fins** improve swimming efficiency

Feeding & Digestion

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

most modern fish are carnivores

small, numerous, sharp **teeth** are used to seize prey

most have very flexible jaws to engulf large prey

some can eat prey as large as they are

most fish produce new teeth continuously throughout life

a few fish that scrape algae from hard surfaces have teeth that can bend (rather than break) as they scrape

most fish lack moveable **tongues**

if they do have tongues they are not moveable

fish swallow their food whole; they don't "chew"

chewing would produce pieces that might clog their gills

intestine became longer to provide greater surface area for absorbing a variety of nutrients

Respiration

most fish have **gills** for getting O_2 from water

=thin feathery sheets with lots of blood vessels

some fish can also breath through their skin

a few fish can breath air

one fish (bearded goby) flourishes in a dead zone off the coast of Namibia

can survive in waters where oxygen is <10% and toxic hydrogen sulfide levels are high

→ able to slow their metabolism

they return to surface waters at night

Circulation

the circulation of blood is closely tied to gas exchange through gills

blood is pumped through arteries and veins by simple heart

fish have a **2 chambered heart**

blood flows through a **single circuit**:

heart→ arteries→capillaries→ veins→ back to heart blood is first pumped through gills then out to the rest of the body

Body Temperature/Thermoregulation

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

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

some fish maintain a higher temperature in their swimming muscles

→ as much as 20º C warmer than surrounding water

eg. tunas, mako sharks, swordfish

other fish elevate temperature of brains and retinas

eg. marlins

these higher temperatures promote swimming and improved nervous activities

also promote much more precise vision and faster reflexes in predators

→ such fish are some of the fastest in the world

Nervous System

fish brains are relatively small and simple compared to other vertebrates but still considerably more developed than in the invertebrates

brain is made up of several distinct functional areas:

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

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

Sense Organs

in the fishes environment:

light doesn't travel as far in water

also turbidity

sound and pressure waves travel faster and further

1. **lateral line system** = "distance touch"

probably the most important sense in fish

most fish depend mainly on **lateral line system** for sensory information to detect food or danger a set of interconnected tubes and pores along sides of head and body

contains:

mechanoreceptors → water movements
→ sound: can pick up unusually low frequency sounds (.1-200 Hz)

electroreceptors → detect body electricity of other fish and prey

chemoreceptors → equivalent to our sense of smell

2. eyes

paired immoveable eyes

most fish lack eyelids

in the eyes of vertebrates a circle of muscle (=ciliary muscle) focuses the lens for near and far vison

in most fish the muscles of the lens are relaxed 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 the lens to change focus; muscles in fish eyes move lens forward or backwards to focus some variations in eyes of fish:

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 for navigation

in dimmer waters, fish eyes get proportionately larger

in complete darkness they are small or absent (eg. cavefish)

3. Chemoreceptors (smell and taste)

chemicals 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)

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)

fish lack actual 'taste buds' (like we have)

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

→ will expel unwanted items that they eat

5. hearing

we are finding that sound is an important means of communication in fish, especially deepwater fish

fish have an **inner ear** with distinctive bones that vibrate when sound waves pass through and send a signal to the brain

4. touch

barbels in catfish, goatfish, whiting, etc

5. orientation and balance

otolith organ and **semicircular canals**

for detecting orientation and changes in motion

Excretion

kidneys like other vertebrates remove most metabolic wastes (Nitrogen wastes)

they also play a role in salt/water balance

gills also play role in excretion

→ secrete NH_3 and other N wastes

Osmoregulation (salt & water balance)

the body fluids of all animals must either be in balance with their environment or they must have mechanisms that allow them to regulate their own salt and water balance

almost all marine **invertebrates** have body fluids with the same salt concentrations as seawater (3%)

=**Isotonic** to their environment

freshwater fish

have salt content ~100 x's greater than the freshwater they live in

= **Hypertonic**

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

there is a tendency for them to **gain water** and **lose salts**

marine bony fish

most marine fish alive today actually evolved from freshwater fish

so they have salt content about one third that of seawater

= **Hypotonic**

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

scales & mucus make a fish's body almost completely impermeable to water

→ most gain or loss of water and salt is through gills or the lining of the mouth

to maintain salt & water balance:

freshwater fishes:

→must avoid drinking
→urinate often
→absorb salts ions through gill and from food

marine (bony) fishes:
→drink large amounts of seawater
→produce little urine
→while pumping out excess salts from gills

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

only 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

Reproduction & Development

only a few are **hermaphrodites**

only a few reproduce by **parthenogenesis**

most fish are **dioecious**

genders usually cannot be distinguished externally

most with **external fertilization** (oviparous)

a few have internal fertilization

some (eg. guppies) can store sperm for months a few with internal fertilization bear live young

most fish produce large numbers of eggs:

→ 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:

males and females come together in great schools and release millions of egg and sperm

(probably <1/M actually survive)

eggs become part of the plankton through embryonic and larval development

freshwater fish often have elaborate mating behaviors

many make nests

some bear live young

some show parental care

Kinds of Fish:

28,078 species

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

1. jawless fish (Agnatha)

108 species

eg. Hagfish, eg. Lampreys

2. cartilaginous fish (Chondrichthyes)

970 species

sharks, stingrays, manta rays, sawfish

3. bony fish (Osteichthyes)

27,000 species (96% of all fish)

most abundant living group

2 main types: ray finned fish & lobe finned fish

eg. bass, perch, catfish, herring, goldfish, some eels, clownfish, sailfish, etc.

The Agnatha
(Jawless Fish)

(108 living sp)

remnants of the earliest fish in the fossil record

oldest known vertebrates

not technically “vertebrates” since they have no vertebrae – just a cartilage rod for support

but they are clearly relatives of the other fish groups

most ancient & primitive vertebrate group

→over 500 MY fossils of jawless fish

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

only living vertebrate group with **no jaws**

also lack paired fins

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**

probably for protection against eurypterids and cephalopods

no paired fins

probably stayed close to bottom

probably deposit feeders or filter feeders

may have filtered water for food

but not with cilia & mucus as in cephalochordates

used pumping action of muscular **pharynx**

a few may have even been predators

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

→ greatly improved swimming ability

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

→ similar to todays lampreys

General Characteristics of living Agnatha:

1. all modern surviving relatives of these ancient forms have lost their bony armor

2. can be freshwater or marine

3. long eel-like body form

4. no jaws

5. no paired fins

   generally poor swimmers

6. smooth slimy skin, no scales

7. skeleton is a simple rod of **cartilage** = notochord, no bone

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

   cartilage gill supports hold the gill-slits open spiracle at top of head can draw water in and over gills

9. poor sense organs

10. parasitic or scavengers

two main groups today:

hagfish
lampreys

Hagfish

~65 species

all are marine

about 18” long

largest known is almost 4’ long

found in deep waters

→almost completely blind; eyes have degenerated

Feeding & Digestion

mainly **scavengers**

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

small eyes

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 **keratinized toothed plates** on its tongue

rasps bits of flesh from carcass

recently (2011) found that hagfish can absorb food directly into their body through their skin

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

can secrete enough slime to turn a bucket of water into a gel in a few minutes

→ can clog the gills of predators

→ may be able to extricate themselves from jaws of predator by "knot tying" behavior

Reproduction

breeding habits are still relatively unknown

some are apparently hermaphroditic

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

no larval stage as lampreys have

Conodonts

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

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

their slime has unusual properties since it is reinforced with strong, stretchy, spidersilk-like protein fibers

→ looking at it for potential uses for stopping bloodflow in acidents and surgeries

→ also investigating its use for parachutes, packaging and clothing

→ to make synthetic fabrics similar to nylon and polyester which are petroleum based

some species are in serious decline due to over harvesting

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** (cephalochordate)

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 depleted food

expensive control measures

→ expensive larvicides placed in selected spawning streams

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

Jawed Fish

Origin of Jaws & Paired Fins

oldest known jawed vertebrates appeared 420 MY (Silurian); about 100 MY after the jawless fish first appeared

→ **placoderms** and **acanthodians**

Jaws

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

→ freed from bottom feeding

→ allowed access to a much greater variety of food sources

eg. predators

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:

seaweeds, plants and animals

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

→teeth could be used to seize prey

jaws allowed predation on larger active prey

around the same time that jaws allowed eating larger pieces of food the **stomach** was formed from an expanded pouch of the gut

Paired Fins

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

all living jawed fish (gnathostomes) 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

In addition to moveable jaws and paired fins,

all jawed fish also have **paired nostrils** and **3 semicircular canals** for equilibrium

4 main groups of jawed fish:

A. **Acanthodians** (extinct)
B. **Placoderms** (extinct)
C. **Chondrychthyes**
D. **Osteichthyes**

A. Acanthodians

first group of jawed fish to appear in the fossil record (430-260 MY)

most relatively small; 4-6"

acanthodians had **scales** rather than bony plates

most were covered with small, diamond shaped dermal bony scales

jaws with small sharp teeth

were probably active swimmers

live on today as bony fish

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

→ **Devonian = "age of fishes"**

B. Placoderms

appeared ~20 MY after the first acanthodians

most were medium sized; 1-2′ long

some up to 30′ (10 M) long;

heavily armored fish with dermal bony plates over front 1/3rd to 1/2 of body

the rest of the body with small bony scales or without armor

relatively poor swimmers

were the first vertebrates to have **necks** separating their heads from forelimbs

allowed them to move their heads independently

very diverse group

some were predators

others were bottom dwellers

some had crushing mouthparts

may have eaten shellfish

one species recently found, *Materpiscis attenboroughi*, 380 MY, is the earliest known example of a vertebrate giving live birth. The adult fish was found with bones of a developing fetus inside

placoderms and acanthodians went extinct at end of Devonian

Class Chondrichthyes
(Sharks and Rays)

970 species

Last of the 4 fish groups to appear in the fossil record

yet retain many primitive fish characteristics

many have changed little from earliest fossils

all but a few are marine

most are 6-15' long

includes the largest fish and second largest of all living vertebrates

whale shark → up to 60' long
→ filter feeder

great white gets up to 30' long

Body Form

either **fusiform** (spindle shaped) = sharks

very streamlined shape → very good swimmers

or **flattened** = rays

spend most time on or gliding near shallow bottoms

Skin & Scales

skin is very tough & leathery

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

bony scales reduced to small, hard, knife-like (**placoid**) dermal scales embedded in skin and stick out from skin

made of bony tissue

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

reduced scales enhance swimming efficiency

scales are continuously shed and replaced throughout life

Support

all members of the group have a skeleton made mostly of **cartilage**

although their ancestors had bony skeletons

but sharks retained mineralization in teeth, scales & spine

the cartilage makes the body lighter and more
bouyant

Muscles & Movement

sharks are the most graceful and streamlined of all fish

sharks have excellent swimming ability

powerful **dorsal** and **caudal fins** for propulsion

paired appendages: **pectoral and pelvic fins**

but **pectoral fins** are rigid, not flexible

hammerhead shark uses its head for steering since pectoral fins are not moveable

sharks are also among some of the fastest fish:

eg mako shark 60mph

eg. blue shark 43 mph

Buoyancy

all fish are slightly heavier than water

to keep from sinking, sharks must keep moving

shape of sharks tail provides lift

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

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

in migrating sharks the liver can enlarge to 25% of the animals weight to provide energy needed for long migrations

Feeding & Digestion

most cartilage fish are **predators**

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

powerful **jaws**

jaws are suspended from chondrocranium by ligaments

→ free movement (somewhat similar to the flexibility in the jaws of some snakes)

teeth only grasp and tear apart prey, don't chew

→ the teeth and (dermal) scales of sharks are essentially identical except for size

-enamel covered dentin
-same structure and composition
-both shed regularly

→ teeth are enlarged scales

→ form replaceable rows of teeth

eg. easily lost, constantly replaced, usually the only part of a shark preserved as fossils: fossil shark teeth

sawfish, a modified ray, flails its toothed snout in schools of fish then sucks up the injured ones

some sharks are **plankton feeders**:

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

a few are **scavengers**

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

food passes from the **mouth**, down the **esophagus** to the large **stomach**

the large esophagus and stomach allow for the passage large, unchewed pieces of food

most digestion occurs in the stomach and the first part of the intestine

the vertebrate **digestive system** has two major accessory digestive organs:

a very large multi-lobed **liver**

→ secretes **bile** which is stored in the **gall bladder** until needed to aid in the digestion of fats and lipids

→ liver also processes and stores nutrients absorbed from the intestine and helps to remove toxins that might have been taken in

→ in sharks the liver also contains huge stores of oil to make the animal more buoyant in the water

a glandular **pancreas**

→ produces dozens of **digestive enzymes** to help break down proteins, carbs and lipids

→ the pancreas also produces important **hormones** that help control sugar levels in the body

most of the remainder of the digestive tract functions in absorption of the food once it is digested

in sharks, part of the small intestine is modified into a **spiral valve** (=valvular intestine) which slows the movement of the food through the system and increases the area available for absorption of these nutrients

undigested materials pass through a short large intestine (**colon**) into the **cloaca** and out of the body

Respiration

gills are inside 5 pairs of **gill slits** similar to agnatha

a pair of **spiracles** behind the eyes can take in water when mouth is occupied with food

sharks must be moving or there must be some current to move water over the gills to extract oxygen from the water

Circulation

all fish have a closed circulatory system with a simple, **2 chambered heart** (1 atrium & 1 ventricle) and a **single circuit** of blood flow

blood is pumped from the heart to the gills to pick up oxygen, then to the rest of the body to deliver nutrients and oxygen and transfer wastes

the blood then returns to the heart

the **spleen** is the main organ that produces blood cells, filters the blood and removes "worn out" cells

Nervous System & Senses

Senses

a. lateral line system

a series of pores running over the surface of the head and down the sides of the body are the **lateral line system**

contain **mechcanoreceptors** and **electroreceptors**

used to detect vibrations and current

and tiny electrical currents produced by nearby animals

especially useful in murky waters

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

widely spaced **nostrils** allow shark to more easily locate prey

can detect prey half mile or more distant

c. eyes not particularly good but used at close range

the hammerhead shark has eyes widely spaced to improve depth perception

→ better for attacking prey

d. ampullary organs (of Lorenzini)

electroreceptors in head

senses bioelectric fields around animals

used especially for final stage of attack

Excretion

sharks have relatively large **kidneys**

sharks retain urea to help maintain internal fluids isosmotic to sea water

also, **rectal gland** assists kidney

secretes excess salts

most sharks, but only a few kinds of other fish posess a **cloaca:**

a single chamber that receives products from the intestine, kidneys and reproductive system

opens to the outside through a single pore

Reproduction & Development

most fish and almost all vertebrates are **dioecious**

while most fish have external fertilization all chondrichthyes 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

many retain eggs in body till hatch

→bear live young! (viviparous)

development lasts 6 months to 2 years

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

others get extra nutrition by eating eggs and siblings in uterus

some sharks and skates have internal fertilization but deposit eggs in horny (keratin) 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

Other Kinds of Cartilaginous Fish:

eg. Skates and Rays

~ 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 like sharks

eg. Electric Rays

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

eg. Sawfish

were once common predators in coastal bays and lagoons

they like murky water and can tolerate low salinities

Aztecs refered it as an "earth monster"

grow to about 20' long

use their "saw" to slash and flail about to kill or stun prey,

then as a ladel to orient and swallow their prey

bear live young, 6-12 at a time, each ~1' long already with "saw"

for milennia the fish was considered a nuisance to fishermen

caught unintentionally as bycatch in tangled and torn nets

they virtually disappeared by the 70's

now a protected species

teeth of snouts still sold for artificial spurs for
fighting cocks

fins sold for up to $3000 in asian markets for an
alternative kind of "shark fin soup"

Ecology

1. sharks are top predators in many ocean food chains

2. **Symbioses: Mutualism**

   eg. Shark Suckers (remoras)

   an example of **commensalism**, although some species may be more mutualistic by removing parasites and pathogens from their host's skin

   shark suckers are bony fish with one of the dorsal fins modified into a suction disc

   up to 3' long

   use large "suction cup" like disc on the top of their heads to attach to sharks

   they spend most of their lives attached to the shark and feed on debris produced from the shark's feeding activities

   some also feed on parasites on skin of shark

   some feed mainly on the hosts feces rather than pieces of dropped food while common to sharks, some are also found in rays, whales, turtles and other marine creatures

some species are host specific

eg. Pilot Fish

about 2’ long with dark blue stripes

act as cleaner fish

keep the sharks healthy

they will eat anything; including parasites and bodily wastes off the shark

not attached to sharks but swim along side them for sometimes long distances

are territorial about the shark they travel with

don’t allow others to ‘horn in’

3. Symbioses: Parasitism

parasitic flatworms, annelids, roundworms and several different kinds of Arthropods are known to parasitize Sharks and rays.

only one species of shark is actually a parasite itself

= **Cookiecutter Shark**

they parasitize fish and sea mammals

eg. marlins, whales, larger sharks

after finding a host they fasten their highly specialized mouth equipped with a pair of suction-cup like lips onto their flanks

it closes its spiracles to form a tight seal

the uses its teeth to bite down and wheels in a circle to dislodge a plug of flesh from its host

the scars left by these fish are common in large sea animals

there are some reports reports of human “hosts”:

underwater photographers

ship wreck victims

usually night time attacks

Examples of Cartilaginous Fish

Nektonic fish
sharks
swordfish

Benthic Fish
skates & rays
guitar fish

Hammerhead Shark
loners
slower than most sharks
use head for maneuvering
eyes far apart improve depth perception
often basks near surface of water

Guitarfish
all are tropical and warm temperate waters
sluggish bottom dwellers
eats shellfish, worms and small fish

Skates & Rays
benthic fish

Human Impacts

1. Shark attacks

60 - 70 per year (2000-2011); 1-12 fatalities

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

more casualities reported from Australian region than anywhere else

in 2008 in US 4 people were killed in shark attacks; 108 were killed by cows (blunt force trauma)

2. Shark fishing

~40 Million/yr (26-73 M 2011) are harvested worldwide

recent estimates (2012) are that shark populations at inshore reefs worldwide have declined by 90%

harvested for their skeletons that is dried and powdered and used as an "herbal remedy" to 'cure cancer'

the primary cause is China's growing appetite for **shark fin soup** sells for up to $100/bowl

eg. Dubai alone exports 500 tonnes of shark fins and other shark products/ yr to Hong Kong (~ half the world shark fin production)

its generally a legal harvest but increasingly being banned

eg. "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

extracts are being tested for anticancer drugs and weight loss

Class Osteichthyes
Bony Fish

most successful vertebrate class

more species than all other kinds of vertebrates combined

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

~200 new species are described each year

probably 5-10,000 more undescribed species

bony fish range in size from the tiniest of all vertebrtates to over 15’

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

some fossil forms may have reached up to 100’ long

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

<u>Body Form</u>

most bony fish are designed for active swimming but with an amazing diversity of body form:

fusiform shape (eg. tuna)

powerful tail

fastest fish, often live in open ocean

streamlined bodies to reduce friction

rod shaped (eg. barracuda)

elongated, arrow-like fish with powerful tails, pelagic predaceous fish

flattened/depressed (eg. flounder)

flattened bodies in bottom forms

spherical shape (eg. puffer fish)

when threatened, can inflate body so they can't be swallowed

ribbon shape (eg. wolffish, eels)

slow swimmers, secretive, move easily wriggle into cracks and crevices for protection or to ambush prey

laterally compressed (eg angelfish)

camoflage; viewed head on are almost invisible; also allows quick, sharp turns

grotesque forms (eg. anglerfish)

many deepwater forms; cryptic or mimic for protection

unusual shape of seahorse head is perfectly suited for attacking its tiny crustacean prey

Skin & Scales

most bony fish have thin, overlapping dermal **scales** in dermis

replaced heavy bony dermal scales of extinct groups

light and flexible to enhance swimming ability

several types of scales:

eg ganoid → bony, don't overlap (more primitive)

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

skin color

skin of fish shows a variety of colors and texture most bony fish can control their color to some degree due to special skin cells in dermis

=**chromatophores**

controlled by nervous system

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

skin color serves a variety of functions:

eg. countershading

most open ocean fish have dark backs and light bellies making it more difficult for predators to spot them in open water

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. concealment:

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

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. distraction:

eg. false eyespots

draw a predator to the back of the animal allowing fish to escape in other direction

eg. butterfly fish

eg. advertising:

attract attention for a special service

eg. cleaner fish help remove skin parasite

their distinctive color is recognized by their "customers" and they are not harmed by them

eg. warning:

many highly colored fish stand out from their surroundings

→ warn potential predators that they are poisonous

eg. lionfish

bioluminescence

the skin of some fish also contains light emitting organs

= photophores

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

found in many unrelated groups

Support

cartilaginous skeleton is laid down in embryo

it is then replaced by well ossified **bony skeleton** in fetus and adults of most species

a few species retain cartilage skeleton

all **fins** contain bony or cartilage rods = **rays** connected by thin membranes

→ makes them stronger

→ they can also be folded down for more maneuverability

pectoral and **pelvic fins** are both moveable and controlled by muscles for more precise control

dorsal fin is moveable and sometimes becomes highly specialized for:

camoflage

venomous spines (eg. scorpion fish)

lures (eg. anglerfish)

sucker (shark suckers)

Movement

most of body mass is segmented **myotomes**

even more so than in cartilaginous fish

(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"

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

pectoral fins used to steer and swim

Buoyancy

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

swim bladder arose from **lungs** of some primitive air breathing bony fish lungs evolved 1st in fish → then swim bladders!

most early bony fish evolved and diversified in freshwaters

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

alternating wet and dry temps made lungs essential for survival

called a **lung** if used mainly for respiration;

called **swimbladder** if used to control buoyancy

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

bony fish diversified into a variety of feeding types:

a. plankton feeders

most common feeding type

most pelagic species and commerical fish 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

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

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

eg. Piranhas are known as viscious predators - mainly through movies and TV

several dozen species of carnivores; 6-10" long

found in South American Rivers of the Amazon Basin

jaws bristle with unique, sharp, densly packed teeth

bad rap; can be very aggressive but are only rarely known to bite and injure humans

but are considered a nuisance to commercial and sport fishers

sold for aquaria but illegal in most states in US

occasionally found in US rivers but generally can't survive cold winters

c. herbivores

many freshwater fish eat plants, grasses, algae, etc

eg mollys, some cichlids, head standers, etc

d. omnivores

eg. angelfish, goldfish, guppies

e. scavengers & detritivores

eg. catfish, suckers & minnows

f. parasites

eg. 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 orifice;

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

Respiration

most bony fish get oxygen through **gills**

the gills of bony fish are much more efficient at extracting oxygen from water

gills are located inside **pharyngeal cavity**

gills are highly vascularized filaments of soft feathery 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 by a 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

Nervous System & Senses

bony fish have a simple nervous system and the sense organs as described for fish in general

however, bony fish make much more use of **sound** than the other two fish groups

at least 1000 fish species make and use sounds

clicks, grunts, thumps

we have an outer ear that collects sound waves, a middle ear with an ear drum and ear ossicles that vibrate and transmit the sound waves to the inner ear for processing

fish have no "outer ear" or ear drum

sound travels further and faster in water than it does in air

there is a great variation in fishes ability to produce and detect sound in water

The Hearing Ranges of Fish (humans ~20-20,000 Hz)

Common Name	Hearing Range in Hz
Atlantic Salmon	40 to 350
Bonito/Tuna	100 to 900
Red Piranha	80 to 1,500
Goldfish	40 to 3,200
Brown Bullhead	100, to 4,000

Stone Moroko	100 to 8,000
Atlantic Cod	20 to 38,000
American Shad	200 to 180,000
Gulf Menhaden	200 to 180,000

used mainly to attract mates or ward off predators

in fish, the **swim bladder** has secondary function in hearing

swim bladder is connected to inner ear by a 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

Defenses

1. color and shape can be used for camoflage

2. puffer, blowfish and porcupine fish

fill their elastic stomach with water or air until it's large and spherical in shape

predators may die from choking

3. venomous fish

some fish (including puffers) are highly venomous

eg.Puffer

contain high concentrations of potent toxin concentrated in internal organs

if a puffer is swallowed they can sicken or kill its predator

In Japan some eat puffer (fugu) as a delicacy specially prepared by trained chefs

eg scorpionfish lionfish:

dorsal spine can inject venom

produce painful would, rarely fatal

4. 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 up to 600 volts @ 1 ampere to stun or kill prey

the eel is well insulated and does not get shocked

→ 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 bony 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)

unlike sharks & rays, most bony 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

A few fish make nests and show fairly elaborate mating behaviors and parental care

→and its most often the **male** who puts in the "extra effort"

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

eg. Seahorses

seahorses are only vertebrates in which the male actually becomes pregnant
male contains a brood pouch, completely sealed except for a tiny hole
female lays eggs in males pouch
male squirts sperm directly into pouch to fertilze eggs
males nurture their young, provide food and oxygen and get rid of waste products
young remain there for ~ 10 days till hatching
male convulses (as if in labor pains) and muscular contractions eventually force all the seahorses out of the pouch
almost immediately, the female shows up, an new courtship ritual and the male may again become pregnant by the next day

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

eg. Some other Catfish species

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

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

→ the age can be accurately determined

Migrations

A. Catadromous ("down running") fish

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

= **catadromous**

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

B. **anadromous** ("up running") **fish**

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

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

all other vertebrate classes are primarily terrestrial and evolved from fish ancestor

(NOT 'in preparation' for moving onto land, but adaptations that made the transition possible)

a. Air Breathers

many fish can survive out of water for a short time by breathing air in a variety of ways:

lungs, skin, gulping air, rectum, air chambers in head, etc

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 also absorb 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

eg. a species living in African streams and ponds that often dry up during dry season. fish burrow down into mud and secrete copius amounts of slime and mix it with mud to form a hard "coccoon" until next rainy season

b. some fish can walk on land with their strong fins

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

only climb in wet weather

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

eg. walking catfish

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

Fish Ecology and Symbioses

1. Fish occupy almost every conceivable aquatic habitat

   in most they play a significant role in several levels of the food chain; predators, herbivores, scavengers, etc

   especially abundant in coastal areas

2. Symbioses: Mutualism

   eg. cleaner fish

   ~50 species of cleaner fish

   esp along coasts and coral reefs

   generally remove dead skin and parasites

   cleaner fish advertise their services with conspicuous coloration

   eg. Hippo cleaner fish

   several species of fish clean Hippos

   some feed on vegetable matter in feces of hippo

   some clean cracks in the bottom of feet

   some clean hippo tail bristles

   Hippos visit cleaning sites where these fish gather and invite fish to clean them

eg. remora

attaches to shark

eats excess foods, removes skin parasites, etc

eg. clown fish

sea anemones

eg. Pistol shrimp and goby fish

pistol shrimp dig holes in sediment looking for food

they are almost blind and when they bring a load of sand out of their burrow they are highly susceptible to predation

gobys live in the tunnels made by the shrimp for protection

goby actively protects the shrimp from harm

they communicate through antennae of shrimp and tail of fish

when predator comes both rush into the tunnel

at night they both go into the burrow and shrimp closes the opening

3. Symbioses: Parasitism

eg. some fish mimic the bright colors of cleaner fish to actually feed on the skin and scales of their host

eg. candiru (toothpick fish)

Examples of Bony Fish

Fish of the Nekton

- squirrelfish
- jacks
- butterfish
- triggerfish
- cowfish
- filefish
- tuna
- sailfish
- anchovies
- menhaden
- lookdowns
- sheepshead
- drum
- redfish

Benthic Fish

- founder
- moray eels
- snake eels
- batfish
- seahorses
- pipefish
- sea robins
- soles
- tongue fish
- stargazers

Sharksucker (Remora)

- flat oval sucker on head
- attach to hosts by suction
- up to 2 feet long
- hitchhikers: free ride and eat food scraps
- also remove parasites and clean damaged skin

Lookdown

- prefer to stay near bottom
- scrounge around for small shrimp, worms, etc
- thin sharp turns, lots of maneuverability

Sheepshead

- especially in brackish coastal waters, around mangrove roots and pilings
- crush shells of barnacles, stone crabs and fiddler crabs, mole crabs, coquinas in surf

Stargazer

- live on sand and mud bottoms
- eyes protrude above
- have electric organs

Sea Robin

bottom dwellers
to one foot long
use free pectoral rays as tiny legs

Pipefish

males brood young
live in submerged grass beds nearshore
hidden predatory

Sea Horse

in ancient religious writings it was believed that everything seen on land was also represented in the ocean; eg grape fish, sword fish, sawfish, sea horse, also sea bulls, sea goats, sea lions; only some were true beings of the sea
very slow swimmers; use mainly small pair of pectoral fins for locomotion
male broods young
well camoflaged
prefer grassy areas of estuaries and nearshore

Moray Eel

lives in burrows and crevices
predator
elusive, sly, powerful, viscious

Toadfish

sedentary; poor swimmers
well camoflaged
feed on fish and shellfish, some scavenging
prefer oyster reefs and shelly habitats around pilings; quiet areas
large gills can thrive in low oxygen waters

Human Impacts of Fish

1. As Food: Commercial Fisheries

we have harvested fish throughout all of human history

piles of fish remains have been found in archaeological sites 90,000 years old

A. 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 billion people worldwide depend on fish for protein (2002)

60% of all fish consumption is by the developing world (2008)

main fish taken commercially:

- anchovies
- pollock
- mackerel
- herring

location of largest fishing grounds:

- China
- Peru
- Chile
- Japan

United States

main uses of commercial fish are as food for humans and livestock

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

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

additionally, about 20% ($10 – 20 Billion) of fish catch is illegally caught

an evolutionary consequence of overfishing: fish are adapting by growing slower and staying smaller in size

a few of the problems:

a. subsidies have encouraged overfishing which makes it a nonsustainable resource

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

the difference was paid for by taxpayers

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

c. 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

d. a recent study estimates that about 20% of commercial fish are illegally caught at a cost of $10-20 Billion in lost profits

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

examples:

eg. shrimpers typically discard 5 to 8 times as many creatures than they keep

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

eg. open ocean fishermen use large drift nets (25'deep & 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

e. there has been an increase in **biomass fishing**:

→collecting all life in an area and grinding it up for meal, to use as animal feed & for fish farming

decimates communities in an area

estimates are that at least **half** of the world's continental shelves are scoured by trawlers at least **once every year**

B. 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

C. Aquaculture (fish farms)

global production from aquaculture (2012) = 69 million tons

in 2013, for the first time ever, the world is producing more farmed fish than farmed beef

if the current trend continues humans will consume more farmed fish than wild-caught fish by 2015

fastest growing animal protein sector

especially in developing countries

aquaculture produces more than 220 species

carp are the largest group

China and other Asian countries are the largest producers least environmentally damaging since they farm scavenger species

salmon and other carnivorous fish favored by the west require much heavier food and energy inputs and create huge amounts of pollution

2. Pets

15-30 Million fish of up to 1000 species are sold globally each year

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

marine animals only $200 M - 300 M sales annually

Outdoor fish ponds have been around for at least 2000 years

The Romans were the first to bring fish indoors - for fresh food

10^{th} century Chinese kept bowls of goldfish

in Victorian England marine aquariums became the rage

3. Commercial Uses

eg. fish scales used for decorative beads

eg. fish meal: made from fish heads, fish offal and trimmings

also converted into liquid form and used as additions to animal feed.

eg. unsold or surplus fish are composted to produce high nitrogen fertilizer

4. Pharmaceuticals

eg. oil extracted from fish livers are good source of Vitamin D

eg. fish oil especially rich in omega-3 fatty acids

eg. puffer fish → tetrodotoxin as pain releiver

1 fish can produce 600 doses

5. Research

3.5 - 7 M fish used for research in us each yr

6. "Herbal" uses of fish

eg. ancient greek writings and herbals from China and other countries have touted the healing properties of seahorses for 1000's of years

pulverized and made into a tea used to calm bladder, treat asthma, soothe boils, pustules and ulcers, and as an aphrodisiac

today seahorse powders and tablets are taken to treat throat infections, high cholesterol, kidney and liver disease

today, at least 70 tons (25 Million) seahorses are harvested worldwide, each year, to be roasted, crushed and dissolved to make traditional medicines; whole ones are used as talismen to improve luck in fishing

→ none of the uses have been shown to have any scientifically valid value