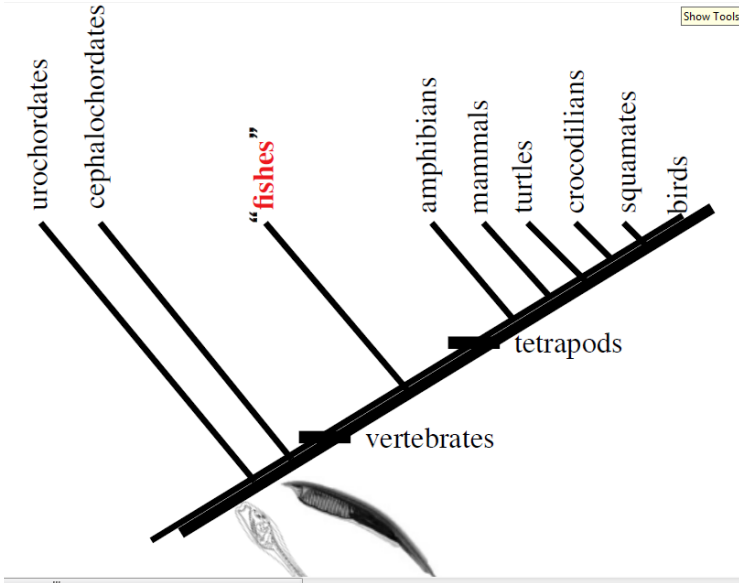
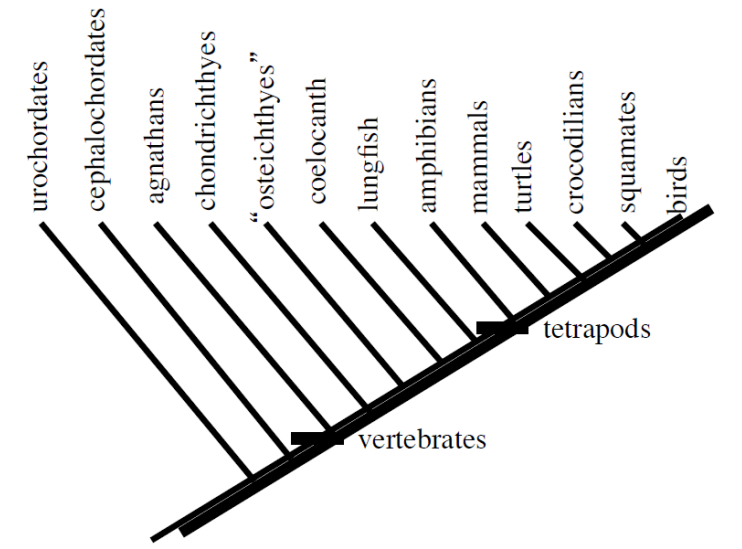
Fishes

1) Ichthyology the study of fishes
   a) Fish = one species
   b) Fishes = more than one species
2) Much of the fascination with fishes comes from the "exceptions" to general rules. This should give you insight into the selective pressures faced by fishes and how they have responded over time.
3) What is a fish?





   a) Fishes are an incredible divers group. The term fish does not denote an actual taxonomic group.

4) So What are fishes?
   a) Aquatic
      i) Exceptions mudskippers
      ii) Catfish *Clarias* and eel

b) "cold blooded"
    i) **Poikilotherm =** does not maintain a constant body temp
    ii) **Ectotherm =** derives body temp from environment
    iii) Exceptions to this is the tuna, billfish, white and Mako shark.
        (1) Some of these fish use behavioral thermoregulation to maintain a constant body temp because warm muscles contract better
        (2) Others are a constant swimmers (white shark) produce heat internally and maintain it with specialized blood vessels that can direct blood flow toward the skin (to cool) or away from skin (to warm).
        (3) Typical blood serum freezes at -0.7^{o}C, Some fish in artic waters can survive temperatures at -2.2^{o} C (salt water freezes at -1.9^{o}C at sea level it goes down with increased pressure) as long as they don't actually touch ice .

c) Have fins
    i) Median fins= located medially along body (dorsal and anal fin for stabilization and caudal for movement)
        (1) **Heterocercal** caudal fins have unequal lobes. This is seen in fish without swim bladders and helps them get off the bottom and swim
        (2) **Homocercal** caudal fins have equal lobes. This is found in most advanced fishes.
    ii) Paired fins = located laterally/ on side of body (pelvic and pectoral for steering and stopping)
    iii) Exception is eels
d) Respire by gills
    i) Exceptions is air-breathing catfish, gobies, lungfish, and others
e) Have dermal armor
    i) Scales derived from bony coverings of ancient fishes
    ii) Can be used to age fish
    iii) **Placoid** scales in sharks/rays/ skates/ ratfish
    iv) **Cosmoid** scales in lung fish
    v) **Ganoid** scales in sturgeon and gar
    vi) **Cycloid** scales in more primitive fishes (minnows, pike, mullet, ect…)
    vii) **Ctenoid** scales in more derived fishes (sunfish, bass, darters)
    viii) Exceptions is scale-less fish (Sculpins, catfish, adult swordfish)
f) Have lateral line
    i) Senses vibration
g) Bioelectric
    i) Unique to fishes
    ii) Can sense electric signals from prey
h) Can produce light
    i) Unique to fishes among the vertebrates
    ii) Can be autogenic (made by the fish) or symbiotic (bacteria living in fish)

5) Size

a) Largest 12m and 34,000kg whale shark (cartilaginous fish), >8m Oar fish (bony fish)
b) Smallest fish is in the carp family and is about 7.5mm long and lives in acid.

6) Where to they live?
   a) From 0-8000m depth
   b) 5200m above sea level (high altitude lakes)
   c) Arctic ice
   d) Desert hot springs
   e) Hyper saline (a lot of salt)/acidic (low pH)/ alkaline (high pH)/ anoxic (low oxygen)
   f) Most diverse in tropics
   g) 58% live in salt water
   h) 41% live in less than 1% of available habitat
   i) Marine species have ~7500x more water available to them
      i) Most marine species however live in shallow near shore areas, why?
7) How many are there?
   a) To date there are 27,977+ species known
      i) 108 **agnathans** (jawless), 870 **chondrichthyes** (sharks/ rays and relatives), 26,000+ "bony fish"
      ii) There are more fish on earth (physical number and number of species) than all other vertebrates combined!
   b) In Georgia
      i) 325 species of freshwater fish
         (1) 8 federally listed endangered
         (2) 57 state listed endangered
         (3) 15 invasive
         (4) 8 endemic (only found in Georgia)
      ii) Georgia is ranked 3rd in fish species diversity in the U.S. (Alabama is #1 and Tennessee is #2)
8) Age
   a) Fish vary greatly in how long they live
      i) Pygmy goby only lives 56 days from fertilization to death
      ii) While the Rougheye Rockfish can live more than 205 years!
      iii) Koi have been recorded as living 226 years
9) Basic morphology
   a) Swim bladder
      i) Controls buoyancy in most fishes (only bony fishes not sharks, skates, rays etc…)
      ii) Reduces cost of locomotion
      iii) Used by some for respiration
         (1) **Obligate air breathers** (have to gulp air to survive, example goldfish, gars)
         (2) **Non-obligate air breathers** (can gulp air to supplement O2 intake but it is not required, example beta fish)
      iv) They have recently been shown to be used at a sound producer and receiver
         (1) Direct connections to inner ear and swim bladder allow for hearing

(2) Drumming on swim bladder, grinding teeth and using swim bladder as amplifier, and squeezing air from bladder and out anus are all mechanisms observed for fish to produce sound

v) Species who don't have a swim bladder are either benthic (spend their lives on the bottom) or have an enlarged liver (livers are very oily so they float) and a heterocercal tail.

b) Muscle
   i) White
      (1) Fast muscle
      (2) Poorly vascularized
      (3) Burst behavior
   ii) Red
      (1) Slow
      (2) Aerobic
      (3) Endurance behavior
   iii) Pink
      (1) Intermediate
      (2) Aerobic

c) Digestive system
   i) Varies with diet
      (1) Species that eat low nutrient diets have longer small intestine and smaller stomachs
      (2) Species that predate have smaller small intestine and larger stomach
         (a) Why?

d) Reproduction
   i) All sexual, males have testis females have ovaries
   ii) Fertilization can be internal or external

e) Respiration
   i) Fish all have gills
      (1) Fish gills are the most effective means for getting oxygen into the body in all the animal kingdom
         (a) They have to be this way because water has $1/20^{th}$ the amount of oxygen than air
      (2) Fish have to get water across their gills either by ramming (swimming with mouth open), using a muscular adapted **spiracle** (modified gill slit above gills to bring in water), or by an **Operculum**.
      (3) Fish use **a counter current** exchange to allow continuous diffusion of oxygen into the blood

f) Cardiovascular system
   i) Blood is pumped from the heart to the gills then to the body and back to the heart
      (1) This means the heart is the last organ to get oxygen, so if a fish is constantly stimulated (say by tapping on the aquarium glass) then it's muscles will suck up all the oxygen and leave none for the heart killing the fish.
         (a) This is why you see "please don't tap on glass" signs at pet stores/aquariums
   ii) All non-sharks have two chambers and two non-muscular pouches

(1) Blood goes into the **sinus venosus** then **atrium** then **ventricle** (the large muscle part of the heart) and out through the **bulbus arteriosus** (this chamber dampens pressure so blood is flowing continuously and not in pulses)

iii) Sharks and its closest relatives have a **conus arteriosus** instead of the bulbus arteriosus. The conus arteriosus is muscular and helps circulate blood quicker for faster nutrient usage and a more mobile life style.

g) Osmoregulation

i) Fish have kidneys

ii) Do fish drink water?

(1) Yes and no

(a) If you are a freshwater fish you never drink water because your body has more ions than the surrounding water so water is constantly being absorbed into the body, so you must constantly be urinating.

(b) If you are a freshwater fish you are constantly drinking water to replace the water that is being pulled out of your body by osmosis, and you almost never urinate

10) Major groups of fishes

a) **Agnathans**

i) These were the first of the vertebrates appearing in the Cambrian about 530million years ago.

ii) All the ancient extinct groups were well preserved in early geologic sediments but this group is only represented by two modern groups: hag fish and lamprey

(1) Both these groups arise in the carboniferous era ~350 million years ago but there is a gap in the fossil record that tells us what group these modern species have arisen from

iii) Hag fish

(1) About 43 species

(2) No scales

(3) No paired fins

(4) No bone

(5) No lateral line

(6) Isotonic with environment

(7) Invertible mouth with hard teeth

(8) Poor vision uses smell primarily to hunt

(9) Found in high densities

(10) Create a slime on its body in high amounts (50cm hag fish can fill a 5 gal bucket with slime in a minute)

(11) Knotting behavior for feeding

iv) Lamprey

(1) Both marine and freshwater

(2) Well developed eyes

(3) Well developed lateral line

(4) Adults have oral disk for scraping flesh

(5) Have both parasitic and non parasitic adults

(6) Can migrate great distances for mating
(7) Creates nests for mating
(8) Sea lamprey are becoming a problem for great lakes killing many important commercial and game species

b) **Gnathostomes** (jaws!!)
i) Jaws formed from the anterior (front) most set of pharyngeal arches
(1) Jaws provide better manipulation of food, a greater diet, and some protection
ii) Gnathostomes also have paired fins (pectoral and pelvic fins)
(1) Where these evolved from is still debated by ichthyologist
iii) These evolved during the Devonian era (age of fishes)
iv) Origionally there were 2 groups
(1) One that was heavily armored with bone on head and body
(2) The other was covered with spines on body (these were called spiny sharks)
v) Both of those groups are now extinct and have been replaced with **chondrichthyes, lobe fin fish, and ray-fin fish**
vi) **Chondrichthyes**
(1) These are sharks, rays, skates, and ratfishes
(2) They have pelvic claspers for reproduction
(3) Calcified cartilage for a skeleton (no ossification)
(4) Skull lacks sutures
(5) Soft fin rays
(6) Teeth not fused to jaw and replaced frequently
(7) Placoid scales
(8) Lack swim bladders
vii) Sharks
(1) Gills on side of body
(2) Pectoral fin not attached to head
(3) 8 different classes
(4) Some sharks
(a) Frill sharks
(i) May gestate 3.5 years!!
(ii) Rarely seen in wild because they live a great depths
(b) Dogfish
(i) What you dissected in class
(ii) Deep water species that schools in same size and sex groups
(c) Saw sharks
(i) **Rostrum** elongated and serrated with teeth to stun or kill prey
(d) Angel sharks
(i) Eyes dorsal
(ii) They sit on bottom and ambush predators
(e) Whale sharks
(i) Largest of fishes

(ii) Filter feeds

(f) Thresher sharks

(i) Uses long tail to stun prey

(g) Mako shark

(i) Fastest animal on earth (that can maintain its speed at least many other animals exceed its speed but only very briefly)

(h) Mackerel sharks

(i) These include the sand tiger (or snaggle tooth if your Australian) , great whites, megamouth, goblin shark, and Megaladon

1. They all lack spiracles so they must continually swim
2. Their jaws are protruding to capture prey
3. Megaladon is now extinct but would have been huge!! A great white tooth is at most 2 inches long, megaladon teeth have been found over 9 inches!!!

(i) Ground sharks

(i) Most common type of shark

(ii) Includes tiger sharks, bull sharks

(5) Sharks are the ultimate predators

(a) Great vision

(b) Great sense of smell

(i) A blue shark can smell one drop of blood from 25 miles away

(c) Well developed lateral line

(d) Ampullae of lorenzini

(e) Nictitating eye lids

(6) "I am a shark, not a mindless eating machine" –Bruce the shark

(a) On average there are 55 unprovoked attacks each year world wide

(i) 54% on surfers

(ii) 38% on swimmers and waders

(iii) 6% on divers

1. Obesity kill 30,000 people annually (at least)
2. Lightning kills 10,000
3. Texting kills 6,000
4. Airplanes 1,200
5. Volcanos 845
6. Autoerotic asphyxiation 600
7. Falling out of bed 440
8. Deer kill 130
9. Ice sickles 100
10. Hotdogs 70 children
11. Tornados 60
12. Shopping on black Friday 50
13. Dogs 30
14. Ants 30

15. High school football 20
16. Vending machines 13
17. **SHARKS kill 5**

viii) Rays and skates
   (1) Extended pec fins
   (2) Ventral gills
   (3) No anal fin
   (4) Large spiracles
   (5) Teeth are small and in a plate for grinding
   (6) Sting rays
      (a) Whip tail with spine on end and venom
   (7) Skates
      (a) Similar to rays but no spine
      (b) Most common of non-bony fishes

ix) Rat fishes
   (1) Deep sea benthic fish
   (2) Have claspers on face of males

c) Ray fin fish
   i) This group makes up the majority of vertebrates that are currently or have ever lived on earth
   ii) They have ossified bones
   iii) Fins end in thin rays with no bone
   iv) Two main groups: **teleost** and **non-teleost**
   v) Teleost are more modern fish while most non-teleost are ancient lineages.
   vi) Non- teleost
      (1) These include bechirs, sturgeon, paddle fish, gars, bow fin
      (2) They all have strong scales (except paddlefish) that protect the body.
         (a) Alligator gar scales are so strong they can withstand a direct blow with an axe.
      (3) All are long lived (over 100 years)
      (4) They maintain sexual maturity slowly (many not for 60 years) but they produce a lot of eggs (a 200kg sturgeon produces 1.6million eggs)
      (5) Many are obligate air breathers
      (6) Paddle fish have long rostrums that detect food and help guide it into its mouth
         (a) There are two species of paddle fish still existent however the Chinese paddle fish hasn't been seen since 2003…
      (7) All but the gars are used in caviar production (gar eggs are incredibly toxic)
   vii) Teleost fish
      (1) They are similar to non-teleost except they have evolved lighterweight and more mobile scales
      (2) They make up the vast majority of ray-finned fish
      (3) Jaws are not attached to head (used to suck food in)

viii) Reproduction
    (1) All of these are sexual reproducers
    (2) Some have elaborate reproduction traits
        (a) In sun fishes they will clear out a circular area to lay the eggs, when a male come by the female will chase him away if he is not worthy , if he is then she will allow him to fertilize her eggs. She then remains near to fan the eggs and protect them.
            (i) This has led to an adaptation called **sneaker males**. Females will chase other lesser males away, but typically leave juvenile females alone. So some males have evolved to look like juvenile females and when the real female is not looking he sneaks in and fertilizes her eggs.
        (b) Pencil fish spray their eggs on terrestrial plants and stay nearby to splash water on them to keep them moist.
        (c) Some species show advanced care for young
            (i) Mouth brooders
            (ii) Bowfin/ snakeheads
        (d) Some have very complex life cycles
            (i) Trout/salmon
            (ii) American eels
        (e) Some display specialized mating rituals
            (i) Tubercles in minnows/suckers
            (ii) Darters
ix) Behavior
    (1) In order to avoid predators fish have evolved many useful traits
        (a) Jumping out of the water is a great way to avoid a predator
            (i) Flying fish take this to the extreme
        (b) Many minnows produce alarm chemicals to warm others that a predator is near by
        (c) Camouflage
        (d) climbing catfish
        (e) mud skipper
        (f) lionfish
        (g) puffer fish
x) feeding
    (1) fish span every niche in feeding from herbivores to predators to parasites
        (a) candiru

d) **lobe fin fish**
    i) have ossified bones
    ii) fins are heavily bony
    iii) share a common ancestor with terrestrial vertebrates
    iv) **coelacanths**

(1) once thought to be extinct but have recently been rediscovered off Madagascar and in the pacific in 1997
(2) live bearers of young
(3) fleshy limbs, closely related to the species that gave rise to modern tetrapods and probably shares many traits with it.

v) Lung fish
(1) 3 species; one in Australia, one in Africa, one in South America
(2) Fossils have been found on all 7 continents including Antarctica.
(3) Australian species
(a) Has one lung but is not reliant on it. One supplements oxygen needs with lung when water conditions are bad.
(b) Fins are flipper like
(4) African and south American
(a) Fins are filamentous without rays
(b) Has two lungs on dorsal side
(c) Can **Aestivate**
(i) When water runs out they can form a moist cacoon with a small air tunnel
(ii) Their heart rate slows tremendously, they retain urea and other wastes, they gain energy from metabolizing their own body
(iii) Can last 7-8 months in the wilds like this, the longest recorded aestivation was in the lab for 4 years (university of southern Illinois)