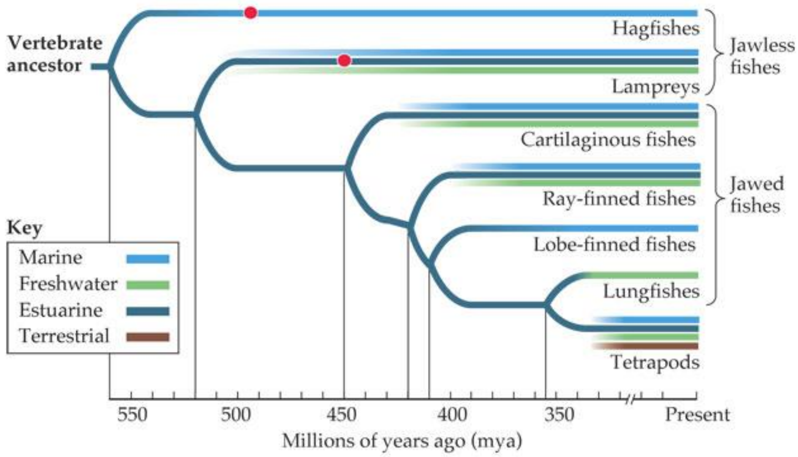
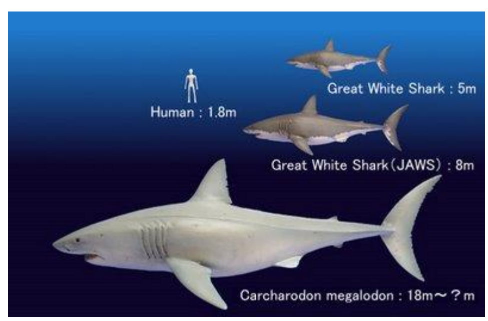
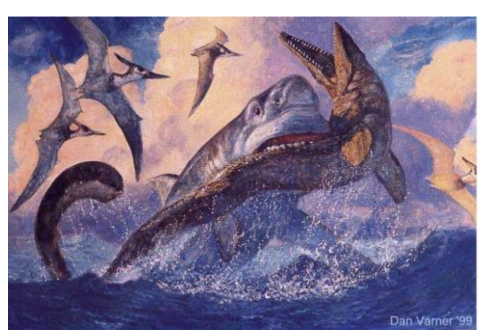
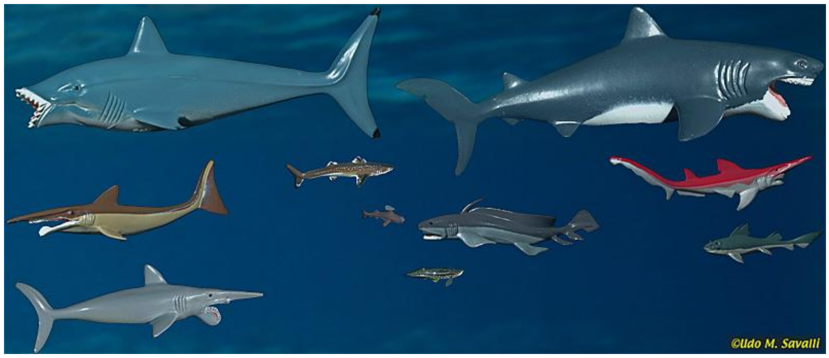


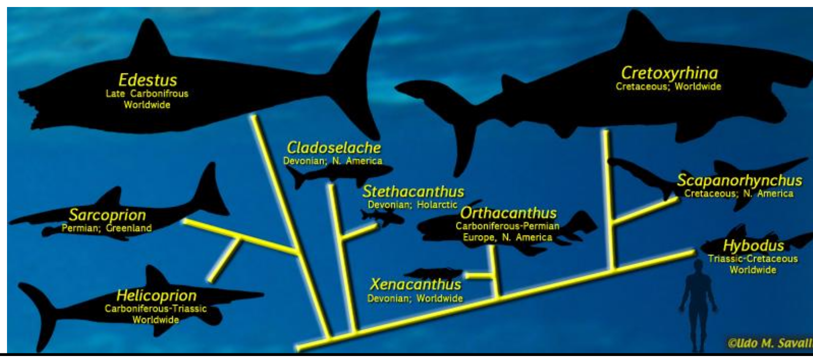
LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 34.8 A Current Phylogeny of the Vertebrates





Carcharodon megalodon
10-25 million YA



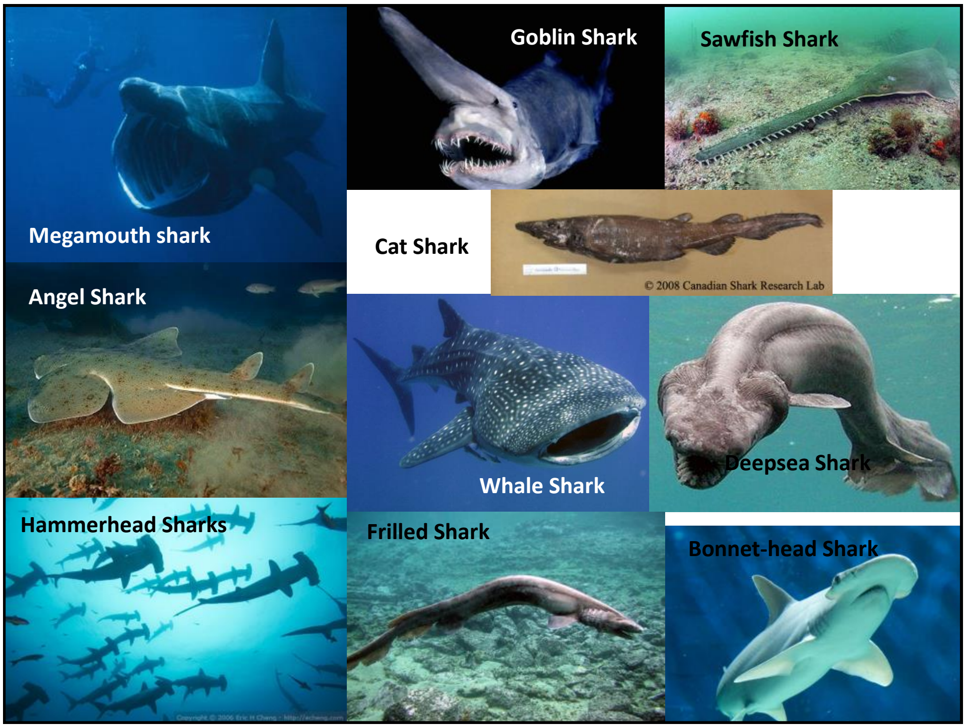


Class Chondrichthyes – fishes with cartilaginous skeletons

- **Sublcass Elasmobranchii – sharks, skates, and ray**
  - **403 shark species and 534 skates and rays living now**
- **Subclass Holocephali – chimaeras**
- **Early sharks date back 400 million years**

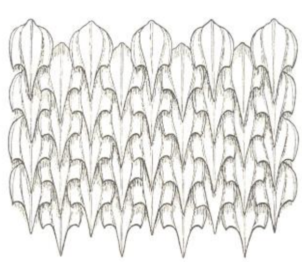


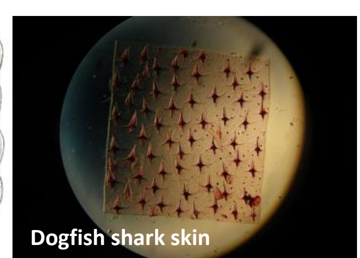


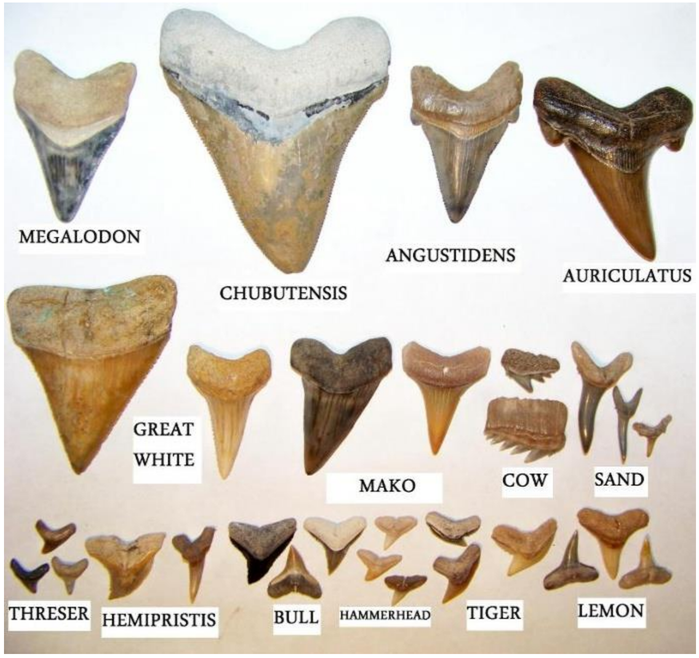


- **There are several types of fish scales:**

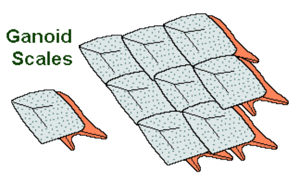
1. **<u>Placoid</u> scales – reinforced with enamel**
   - **<u>Found mostly in Chondrichthyes</u>**
   - **Has a flattened rectangular base with a protruding spine projecting backward**
   - **They are <u>composed of the same material and develop the same way as teeth</u> of sharks and mammals (homologous structures)**

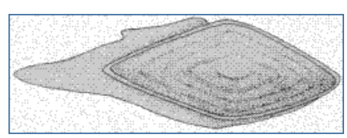


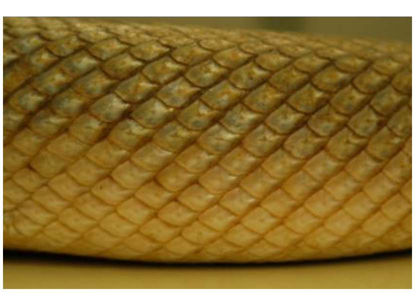




2. **<u>Ganoid</u> – primitive scales of fish of Subclass Chondrostei <u>(sturgeon, paddlefish, gar)</u> and reinforced with <u>ganoine</u>, an inorganic bone salt**
   - **Highly modified into large plates in sturgeon with most of the body scaleless**

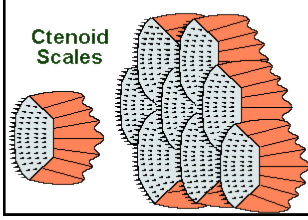


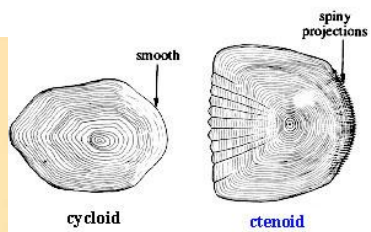




3. <u>Ctenoid and cycloid</u> scales – <u>majority of bony fishes</u>

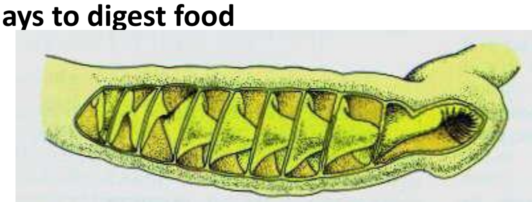
- Very little enamel and no ganoine but impregnated with other bony material, calcium phosphate and calcium carbonate
- Ctenoid scales have teeth, or ctenii, on the posterior surface and cycloid scales lack the teeth, otherwise very similar
- <u>Overlap like shingles</u> on a roof which gives greater flexibility than ganoid scales



Anatomy of Digestive System

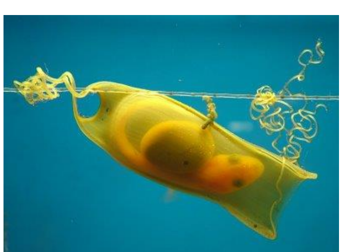
- Chondrichthyes have a <u>spiral valve</u> in their intestines to increase digestive surface area
- Sharks must eat about 0.5 – 3% of its body weight each day
  - They do not have to be selective in food items because whatever they can't digest they spit out later
  - Most are roving predators/scavengers and must eat when they get a chance
  - Takes 2-3 days to digest food

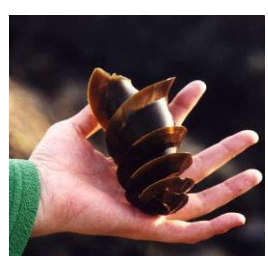


- **Shark teeth vary by species according to their usual diet**
  - **Filter feeding sharks have no teeth but an enormous mouth**
  - **Mollusks and crustaceans: flattened, crushing teeth**
  - **Fish: needle-like piercing teeth for grasping**
  - **Mammals: pointed lower teeth for gripping and triangular, serrated upper teeth for slicing**

Shark Reproduction

- **In Chondrichthyes, eggs leave the ovary and find their way to the oviduct (that transports eggs out of the body) where fertilization takes place near a shell gland or nidamental**
  - **Sharks that lay eggs (oviparous) have tough egg shells made of keratin (below)**
  - **Sharks with live birth (viviparous) have a modified part of the oviduct called the uterus where the embryo develops**



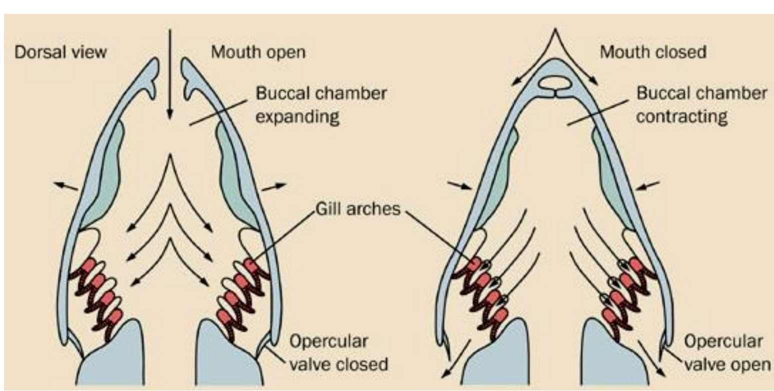


- But, young born live get no nutrition from mother (other than yolk)
- Fetuses may consume other eggs or fetuses in the womb
- Typically, larger sharks have live birth and smaller ones lay eggs

Respiration

- The only way that gills will function is to have water continuously flowing across their surface, and this is done in 2 ways:

1. <u>Pumping water</u> – most fish pump water across gills by increasing and decreasing the volume within the <u>buccal chamber</u>



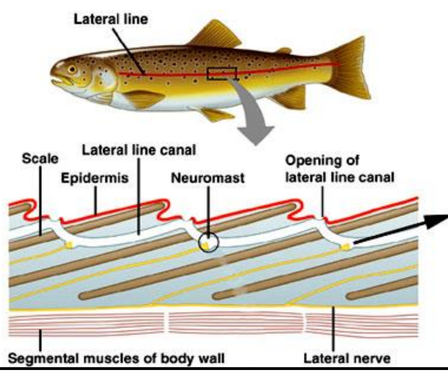
2. Ram ventilation – some keep their mouth slightly open while swimming
   - Efficient energetically because the swimming muscles are doing the work
   - Only fish that move the majority of their life and swim quickly can do this, but only some use this exclusively and they will die if they stop moving (tuna and large sharks)
   - Most fish that use this method can switch to pumping when they are stationary or moving slowly (sharks)

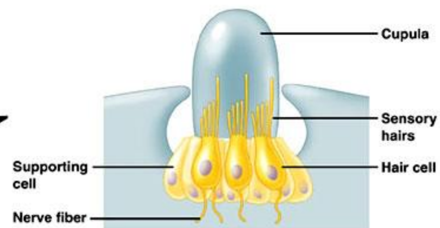

Nurse shark resting on bottom

Mechanoreception

- In fishes, this involves detection of movement or vibrations in the water involving 2 main systems: lateral line system and inner ear
  - Both rely on sensory hair cells to detect movement
- Lateral line system
  - Detects movements in the water so aids fish by
  1. Detecting currents
  2. Capturing prey
  3. Avoiding obstacles and predators

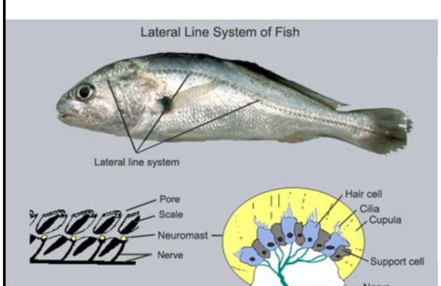
– The hair cells of this system are organized into neuromasts which are clusters of cells with a gelatinous cover or cupula
  - The cupula is easily displaced by water and its movement causes the hairs beneath to move
  - The cupula also screens out background noise by not allowing tiny vibrations to move the tiny hairs

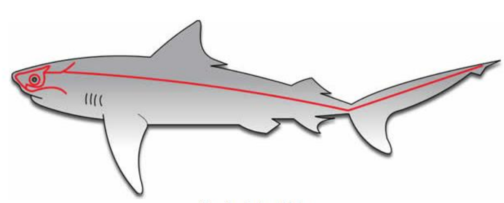




– Many fish also have neuromasts along dermal bones of the head (cephalic lateral lines)

– Studies have shown that neuromasts can compensate for lack of sight due to low light and allow fish to hunt in the dark





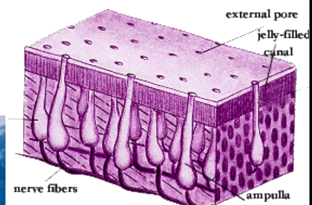
- Lake trout will follow hydrodynamic trails of prey fish in total darkness and have little success catching prey if the lateral line system is rendered ineffective
- Many artificial baits are designed to elicit a predatory feeding response in fish by producing a lot of vibration

Electroreception

- Most groups of non-teleost fishes (sharks, rays, sturgeon, paddlefish) and some teleosts can detect electrical fields
- There are 2 types of receptors and both evolved from mechanoreceptors of the lateral line system

1. <u>Ampullary receptors</u> – in recesses of the skin and connected to the surface by a canal filled with conductive gel (for low frequency electric fields)
2. <u>Tuberous receptors</u> – for detecting higher frequency electrical fields and found in fish that produce their own electric field

- Ampullary receptors (Ampullae of Lorenzini)
  - Most widespread type and found in lampreys, sharks and rays, lungfish, coelacanth, sturgeons, paddlefish, and a few teleosts
  - For <u>passive electroreception</u> or detecting electrical fields produced from a source outside of the fishes body



- Sensory hair cells release a neurotransmitter when there is a difference in electrical potential between its apex (top) and base
- <u>Most species are marine</u> where higher ion (salts) concentrations make sea water a good electricity conductor
- The <u>main use is for prey detection</u> so in sharks they are concentrated on the head
  - The broad head of the hammerhead shark allows it to sample a wider area

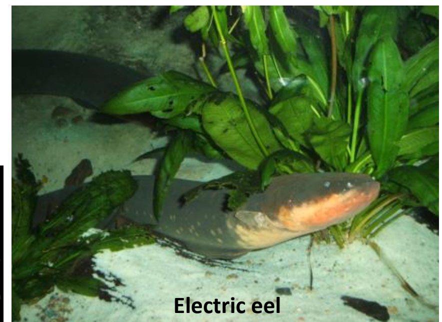
- Skates and rays have ampullae concentrated on their pectoral fins ("wings") to detect buried prey
- Paddlefish are filter feeders and can detect concentrations of zooplankton with their snout



- Other uses:
  - Young sharks and rays and those developing in egg cases can detect when a possible predator is near and will stop tail and respiratory movements
  - Some male stingrays can locate females buried in the sand during mating season by detecting movement of her respiratory muscles
- Tuberous receptors
  - Only fish that produce their own electric field, or electric organ discharge (OED), have these

– Found in only a few freshwater species because sea water is too conductive and the electrical field cannot be maintained near the body

– Some examples are elephant fishes and African knifefish in Africa and the electric eel in South America



– The fish is constantly emitting a weak electric charge that generates a field and they can sense when an object moves into the field

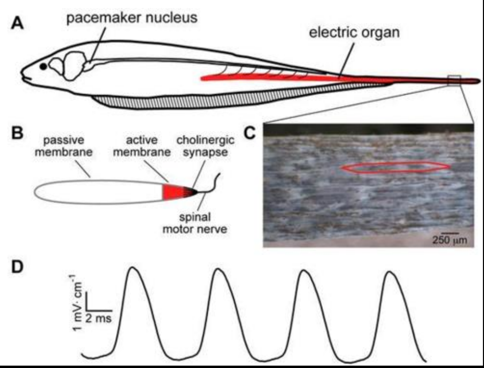
- Most can discern size and distance of the object and whether or not it is living

- Most of them are active at night and use their vision very little to sense their surroundings

– The most important function for many species is electrical communication

- They can exchange info such as species, sex, size, maturation state, and possibly individual ID

- The electrical organs that generate the field are composed of electric-generating cells called <u>electrocytes</u>
  - When stimulated, ions (Na, K) flux and a small current results
  - Cells are arranged in a column so the effect is additive when many are discharged at the same time, like many small batteries linked together



- Most of the "electric" fish only produce weak fields for communication and prey detection but a few can stun prey for food or stun an attacker
  - An <u>electric ray can generate about 20-50 volts</u> and can stun prey about 15 cm away
  - The <u>electric eel can produce 400 volts</u> to stun predators (or humans)


Lesser electric ray

Buoyancy Methods

1. <u>Swim/gas bladders</u> – sharks do not have them

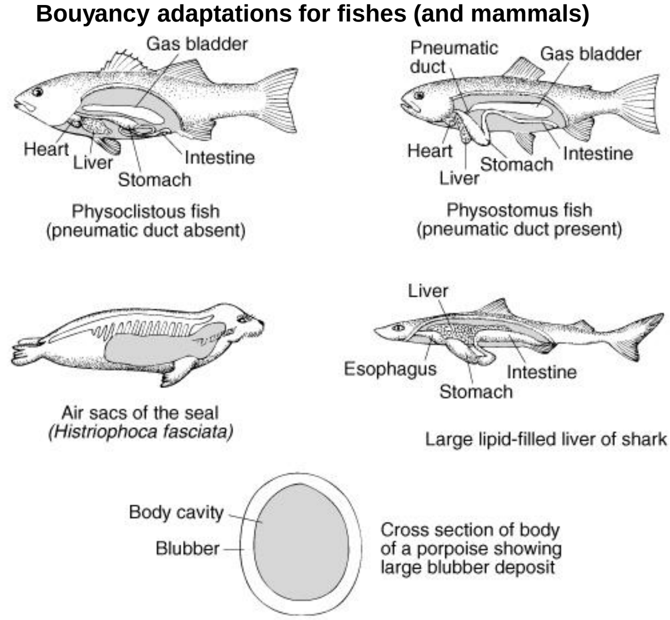
2. Fast moving fishes do not have gas bladders due to difficulty in equalizing pressures quickly so they <u>create lift with pectoral fins during rapid locomotion</u> (sharks)

   – If sharks quit moving forward they sink

3. <u>Large quantities of fats in the body</u>

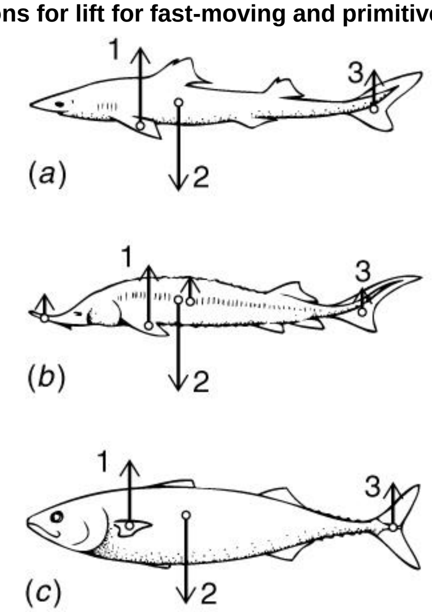
   – Fast swimmers need some aid since they lack swim bladders: sharks, mackerels, bluefish, tuna

Bouyancy adaptations for fishes (and mammals)



- **Anatomical adaptations for buoyancy**:
  - **Lifting surfaces at anterior part of body act as pectoral fins or flippers**
  - **Heterocercal tail - upper lobe larger and better developed**
- **Generally, more advanced forms (bass, carp) have passive means for buoyancy (swim bladders) and primitive forms (shark, sturgeon) have active means requiring continuous motion**
  - **One big advantage is that much less energy is required for passive**

Adaptations for lift for fast-moving and primitive fishes



Shark Attack Statistics: How dangerous are they?

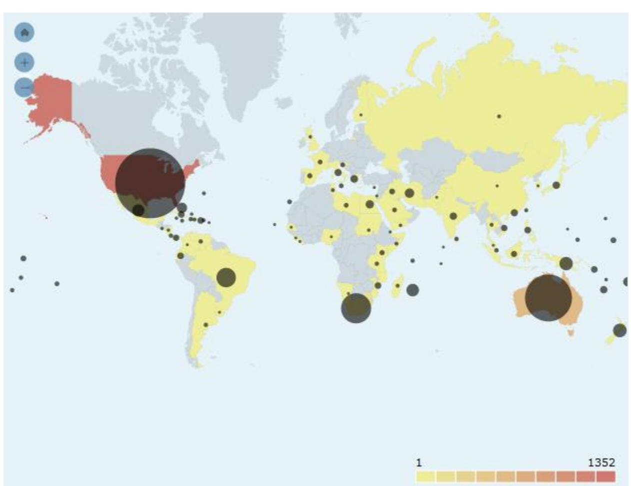
- International Shark Attack File (ISAF) compiles all known shark attacks
  - Administered by the American Elasmobranch Society
  - Covers from mid-1500's to present
  - Initiated by U.S. Navy in 1958
  - About 2,700 cases on file

International Shark Attack File

The International Shark Attack File (ISAF), the longest running database on shark attacks, has a long-term scientifically documented database containing information on all known shark attacks, and is the only globally-comprehensive, scientific shark attack database in the world.

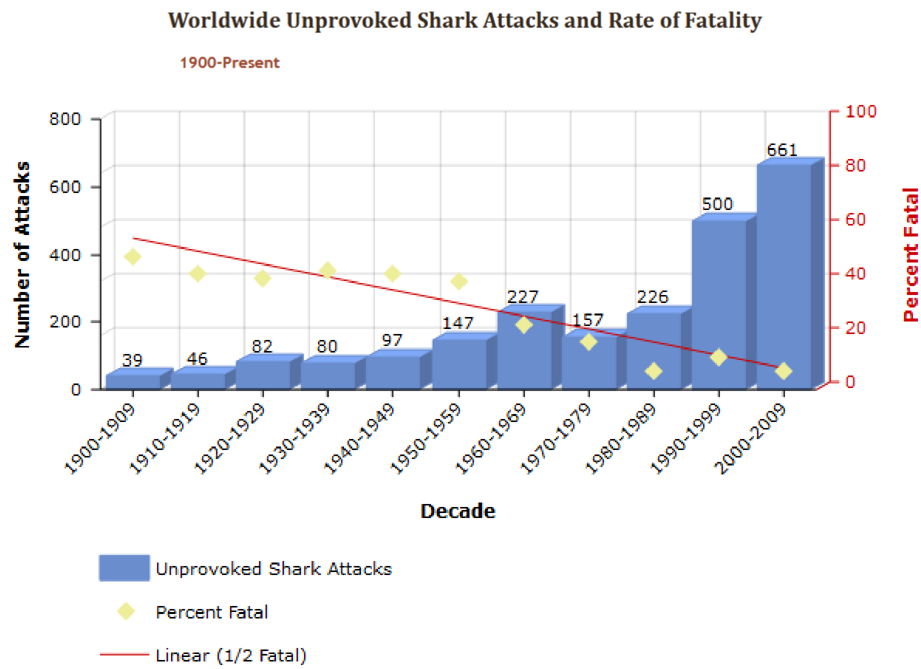
Map of World's Confirmed Unprovoked Shark Attacks

1580-Present



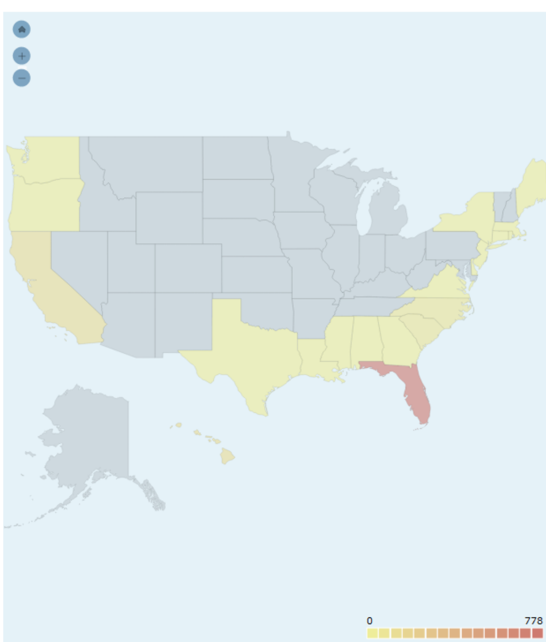
Last updated: January 23, 2017

Country	Total Attacks
USA	1352
Australia	607
Republic of South Africa	250
Brazil	103
New Zealand	50
Papua New Guinea	48
Mascarene Islands (Reunion Island)	42
Mexico	40
Bahama Islands	28
Iran	23



Map of United States Confirmed Unprovoked Shark Attacks

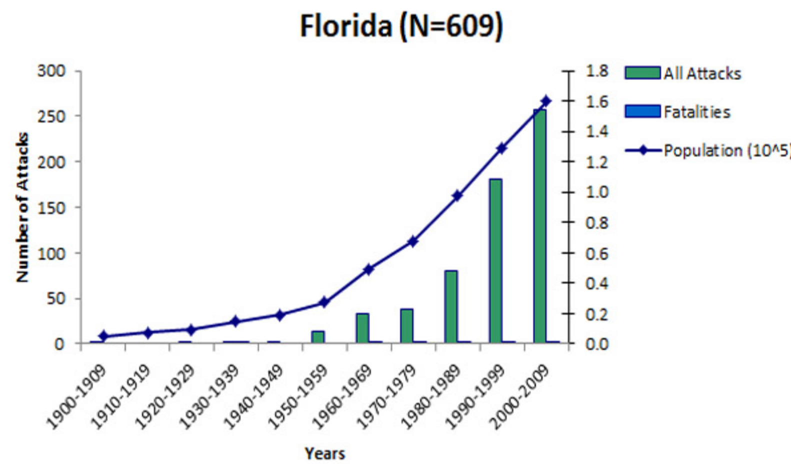
1837-Present



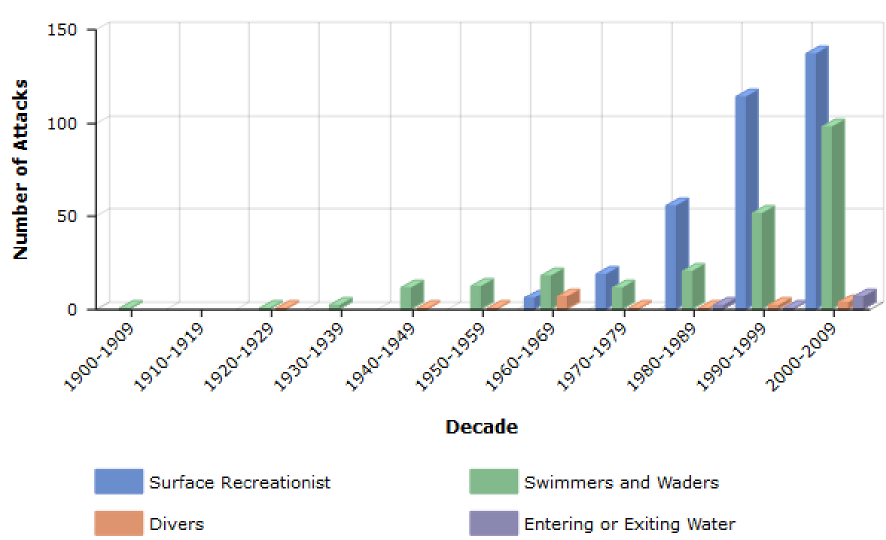
Last updated: January 23, 2017

State	Total Attacks
Florida	778
Hawaii	153
California	120
South Carolina	92
North Carolina	63
Texas	42
Oregon	27
New Jersey	15
Georgia	13
New York	10

Shark attacks vs. population growth over the decades in Florida



Victim Activity During Unprovoked Shark Attacks in Florida by Decade



Shark vs. Lightening Fatalities

A Comparison of Unprovoked Shark Attacks with the Number of Lightning Fatalities in Coastal United States: 1959-2010

State	Number of Lightning Fatalities	Number of Shark Attacks	Number of Shark Attack Fatalities
Alabama	109	5	0
California	30	89	7
Connecticut	17	1	0
Delaware	15	3	0
Florida	459	603	9
Georgia	111	10	0
Hawaii	0	97	6
Louisiana	139	1	0
Maine	27	1	0
Maryland	126	0	0
Massachusetts	30	2	0
Mississippi	104	1	0
New Hampshire	8	0	0
New Jersey	68	8	0
New York	139	3	0
North Carolina	193	39	1
Oregon	8	22	1
Rhode Island	5	0	0
South Carolina	98	51	0
Texas	213	32	1
Virginia	66	5	1
Washington	5	1	0
TOTALS	**1,970**	**974**	**26**
Number per Year (average)	**37.9**	**18.7**	**0.5**

Shark vs. Dog Attack Fatalities

A Comparison of Shark Attack Fatalities with Dog Attack Fatalities in the U.S.: 2001-2010

Year	Number of Dog Attack Fatalities	Number of Shark Attack Fatalities
2001	23	3
2002	15	0
2003	25	1
2004	22	2
2005	28	1
2006	31	0
2007	31	0
2008	23	1
2009	32	0
2010	33	2
2011	31	0
2012	38	1
2013	32	0
Total	**364**	**11**

Source of fatal dog attack statistics: National Canine Research Foundation www.dogbitelaw.com and www.dogsbite.org

Which species attack?

- **3 large species are the primary offenders:**
  - **White shark (*Carcharodon carcharias*) 20' and 5,000 lbs**
  - **Tiger shark (*Galeocerdo cuvier*) 20' and 2,000 lbs**
  - **Bull shark (*Carcharhinus leucas*) 13' and 1,300 lbs**
  - **All are large, widespread, and eat large prey such as marine mammals, sea turtles, and fishes**



- **Others:**
  - **Great hammerhead (*Sphyrna mokarran*)**
  - **Shortfin mako (*Isurus oxyrhynchus*)**
  - **Oceanic whitetip (*Carcharhinus longimanus*)**
  - **Galapagos (*Carcharhinus galapagensis*)**
  - **Some reef sharks such as the Caribbean reef shark (*Carcharhinus perezi*)**

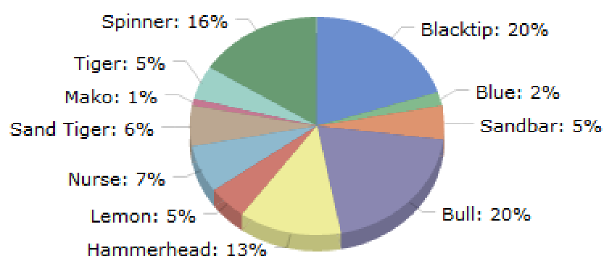




Species Involved with Unprovoked Shark Attacks in Florida

1926-Present

Of 97 cases (N=97)



- **Shark attack is a hazard that must be considered by anyone entering the marine domain. As in any recreational activity, a participant must acknowledge that risks are part of the sport:**
  - **Jogging offers shin splints**
  - **Camping brings ticks and mosquitoes**
  - **Tennis may result in sprained ankles**
- **Beach recreation has its inherent risks as well, and shark attack is simply one of many that must be considered before entering the water. Most people agree, however, that the extremely slim chance of even encountering a shark - much less being bitten - does not weigh heavy in their decision-making.**