

## What is Primary Production?

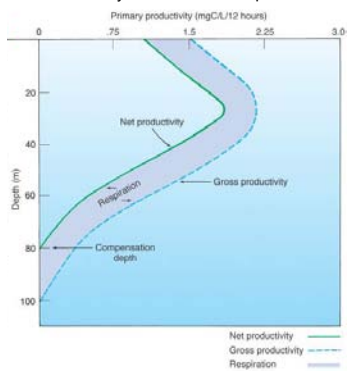
- Photosynthetic autotrophs
  - Phytoplankton
  - Algae
  - Terrestrial plants
- Process where they use sunlight and inorganic compounds to generate organic matter - **photosynthesis**
- Base of the food web



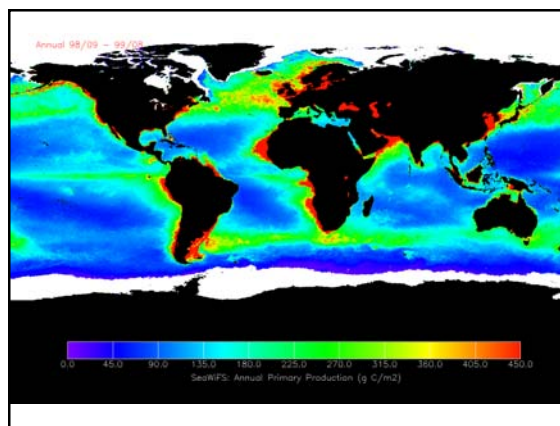
## Photosynthesis

- Series of chemical reactions to generate organic compounds from inorganic precursors
- $6 \text{ CO}_2 + 6 \text{ H}_2\text{O} \xrightarrow[\text{chlorophyll } a]{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$
- Carbon dioxide and water yield sugar and oxygen
- Process of generating organic carbon (sugar) from inorganic carbon ( $\text{CO}_2$ ) = **carbon fixation**

## Gross Primary Production – Respiration = Net Primary Production

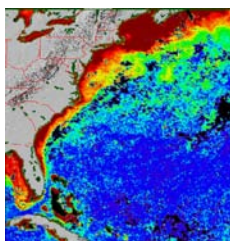


- Gain in organic matter (biomass) available for consumption by heterotrophs
- UNITS?
  - g C/m<sup>2</sup> or g C/m<sup>3</sup>
  - Production
  - g C/m<sup>2</sup>/y
  - Productivity



## What causes these geographic and seasonal patterns?

- Whatever controls primary production
  - Nutrients
  - Light
  - Mixing
  - Grazing
  - Cell Death

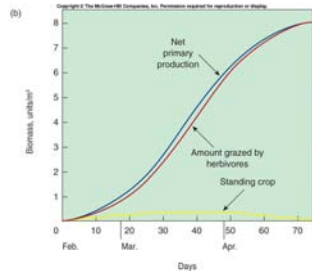


## Nutrients

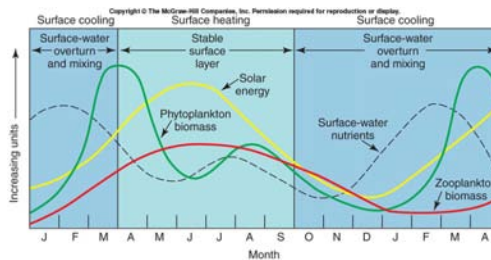
- $6 \text{ CO}_2 + 6 \text{ H}_2\text{O} \xrightarrow[\text{chlorophyll } a]{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$
- Other inorganic chemicals necessary
  - Nitrogen
  - Phosphorus
- Relationship between amount of organic matter produced (mass) and inorganic materials consumed
- $\text{O}_2:\text{C}:\text{N}:\text{P} = 109 : 41 : 7.2 : 1$
- → 10 mg of P produce 410 mg phytoplankton (C)

### Biomass and Standing Crop

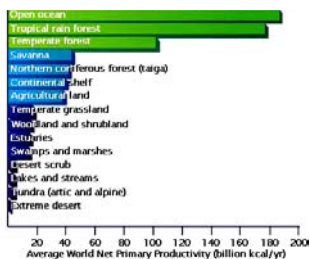
- Total biomass of phytoplankton at any point in time = **standing stock**
- Growth and reproduction – death and grazing



### Temperate Areas



### Comparing Net Primary Productivity by Ecosystem



### Learning Objectives

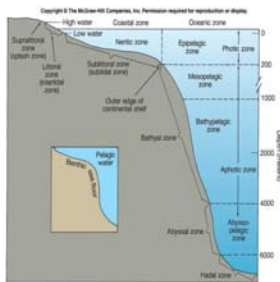
- To study the diversity and life styles of the marine organisms that **swim freely** in the oceans.
- To classify the **one phylum** of invertebrates and **six classes** of vertebrate that make up the nekton.
- To investigate the **commercial fisheries** in the world's oceans to see how endangered many groups of nekton are.

- Definition (from Ch. 12):

*Organisms that are larger than the plankton and can swim faster than the currents.*

- Habitat = Pelagic zone including both neritic and oceanic regions.

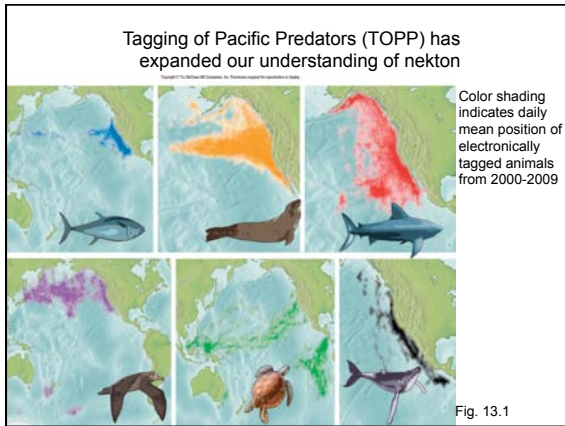
### Nekton



### Nekton Characteristics

- Mostly vertebrates
- Strong Swimmers
- Stream-lined shape
- High muscle to body weight ratio
- Maintain depth in ocean
  - Swim Bladder
  - Active swimming
  - Certain Body Materials
- Active predators or upper level consumers





## Marine Invertebrates

Relatively few invertebrates are nekton

### Phylum Mollusca – molluscs

## Phylum Mollusca

- Class Cephalopoda
  1. Squid: most intelligent, fastest and agile invertebrate
    - 8 arms, 2 tentacles
  - Giant and Colossal squid are nekton
    - Large eyes adapted for seeing predators
    - Generally slow-moving to conserve energy

2. Cuttlefish
  - large brain to body ratio
  - Capable of camouflage
  - has gas filled cuttlebone
  - produce ink like squid, octopi


3. Octopus (benthic)
  - 8 arms
  - hard beak is the animal's hard part, allowing it to fit into small places
  - Defense: ink, camouflage, autotomising limbs
  - Giants ~7 m ; 70 kg
4. Nautilus
  - Up to 90 tentacles
  - Can retreat within shell & "close" it off
  - Longest living cephalopod
  - ~ 20 years

## Phylum Chordata –subphylum Vertebrata

- All possess a backbone
- All possess an internal skeleton
  - protect organs
  - muscles can attach to enhance strength and speed
  - provide housing for the brain, eyes, etc. needed for advanced intelligence
- All but one class have jaws

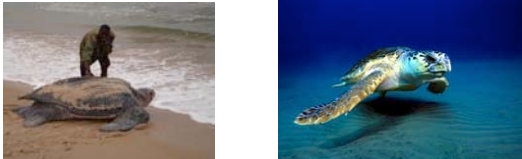
## Phylum Chordata –subphylum Vertebrata

- Class Reptilia
- Class Aves
- Class Agnatha
- Class Chondrichthyes
- Class Osteichthyes
- Class Mammalia




## Class Reptilia

- Family **Cheloniidae**: Sea Turtles
- air breathers
- egg layers, nest on land
- large flattened limbs (oars and rudders)
- nonretractable heads
- migratory (stars, smell, vision, magnetic field)
  - 7 species, most near extinction. All are endangered or threatened
  - 4 large species: Green, Hawksbill, Leatherback, Loggerhead
  - Leatherback is the largest marine reptile
  - Also found in U.S. waters: Olive ridley, Kemp’s ridley turtle (rarest, most endangered turtle)



## Why will they soon be extinct?

- **Habitat destruction** - egg laying. 80% of U.S. turtles nest in Florida
- **Pollution**
- **Hunting** - Turtle eggs and turtle meat eaten by most Pacific nations. Shells used for jewelry, etc.
- **By-catch** - Killed in longlines & nets. TED’s are only used in U.S. shrimp boats



## Class Reptilia

**Diagnostic characters:**  
 Breathe air  
 Lay eggs with shells  
 Secrete excess salt with nasal glands  
 Poikilotherms  
 Skin permeable to gases

**Family Hydrophiidae: Sea Snakes**

- Very poisonous venom
- Not aggressive
- Give birth to live young
- Can dive down to 100m, stay submerged for 2 hours
- Indian and Pacific oceans

**Galapagos Iguana (only marine lizard)**

- 3 ft long, 15 to 20 lb
- spends a lot of time on land
- feeds on algae

**Crocodiles** - estuarine

- Asia & Australia

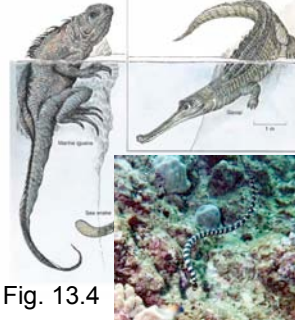



Fig. 13.4


## Class Aves

- Birds
  - specialized and perfected reptile
- Marine Species (3 % of all birds)
  - Some only come ashore to reproduce
  - Most nest on shore, feed in the ocean
  - Most have specific breeding sites (rookeries) and seasons
- **Characteristics**
  - Don’t need freshwater
  - Salt Glands located near eyes, salt is removed through nasal passages
- Homeotherms
  - Feathers
  - Preen oil acts as waterproofer
- Highly developed eyesight
  - Must locate food in the water
- Less developed hearing, smell
- Poorly developed taste




## Class Aves

- Large appetites
  - High metabolic rate
- Larger and stronger than land birds
- Some are Long-distance flyers
  - Light weight bones
  - Excellent navigators
  - Long-narrow pointed wings




**• Marine Birds**

- Bird species often share habitat
  - Niche separation allows them to co-exist
- Four orders, or groups
  1. Albatross, petrels, fulmars, shearwaters
  2. Penguins
  3. Pelicans, cormorants, boobies frigate birds
  4. Gulls, terns, alcids (auks)




## Albatross

- Largest wingspan (~3.5 m)
- Most oceanic of the marine birds
- Spend ~5 years at sea, return to nest



## Magellanic Penguins


- 17 species
- Most live in Antarctic, Sub-Antarctic. All in Southern Hemisphere, one at the equator (Galapagos Penguin)
- Flightless
- Swim at ~ 5 m/s in pursuit of prey



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## Pelicans & Cormorants


- Large fishing birds
- Large beaks
- Strong fliers
- Brown pelicans - dive from air after prey
- White pelicans - groups herd schools of fish into shallow water where they are scooped up
- Cormorants - dive from ocean surface after prey



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## Terns & Gulls

- Found everywhere except South Pacific
- Gulls are excellent foragers. Will feed off land or ocean surface. Will eat almost anything
- Terns are plunge-divers, so they are more slender and streamlined




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## Puffins, Murres & Auks




- Heavy, short wings, short legs
- Dive for prey
- Nest on isolated cliffs & islands
- All in North Hemisphere
- The largest, the Great Auk was hunted to extinction ~ 1850



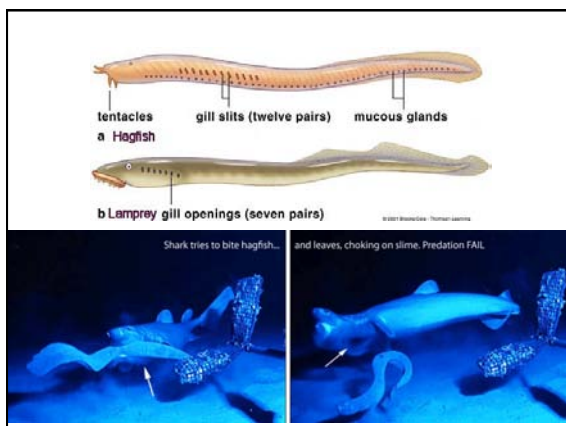
## Fishes are Earth's Most Successful Vertebrates

- More species and more individuals of fishes, than species and individuals of all other vertebrates **combined**
- 60% of species are marine
- First evolved around 500 m.y.a
- Numbers & types rapidly increased 410m.y.a. (410 - 360 mya *The Age of Fishes*) and they have dominated aquatic and marine habitats ever since.
- 3 very different classes

- **Class Agnatha:**
  - Jawless fish, primitive
  - No paired appendages
  - Cartilage skeleton

- **Hagfish**
  - Feed on dead vertebrates
  - Prefer inner flesh & organs

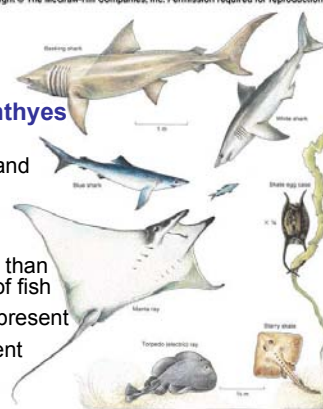
- **Lamprey**
  - Suction onto other fish, use toothed tongue to cut, then feeds on blood
  - Usually detaches before it kills the host



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## Class Chondrichthyes

- Sharks, Skates and Rays
- cartilaginous
- Bone is absent
- tend to be larger than other 2 classes of fish
- Jaws with teeth present
- Paired fins present
- ~ 750-850 living species



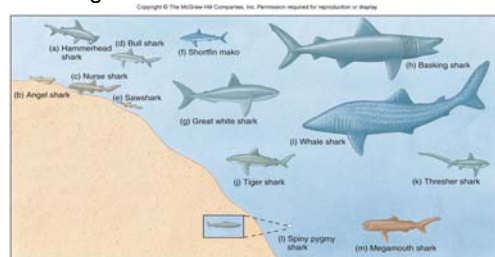
## Sharks

- Appeared 450 mill. y.a., before mammals
- Teeth are modified scales
- 80% of species < 2 m long
- Largest: Whale Shark, 18 m long, 41,000 kg
- Great White: 7 m long, 1,400 kg
- Excellent:
  - **Eyesight** -even in dim conditions
  - **Smell** - 2 nasal sacs with many receptors
  - **Chemical sense** - pit-organs distributed on its body with sensory cells
  - **Electrical sense** - receptors on its body to lead it to prey



## Chondrichthyes: Sharks

- Many body sizes, all have streamlined shape and use tail for propulsion and fins for turning.



## Sharks

- ~ 350 species
- ~ 50 species near S. C.
  - Dogfish, sand sharks most common inshore
  - Offshore: Tiger, Bull, Blacktip, Hammerheads
- Most populations are rapidly declining
- 65 species endangered



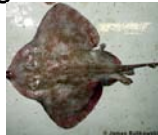
## Shark Attack (Not!)

- Globally, sharks are responsible for 6 human fatalities per year
- In 2012, there were 72 reported incidents of shark – human interactions
- More people in the U.S. are killed by dogs **each year**, than were killed by sharks **last century**
- For each human killed by a shark humans kill 18 million sharks



## Skates & Rays

- Live near the sea floor
- Undulate side fins to move
- Most are carnivorous preferring benthic organisms but also fish
- Some have shock producing organs in their tails (skates) or on their wings (rays)



Stingray Barb

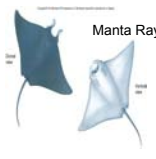


## Body form for Rays

Southern stingray



Cownose ray



Manta Ray

"Wings" = pectoral fins

## Class Osteichthyes:

- Bony, modern fish
- >27,000 species
- Most at 0-200m depth, but some are demersal
- Most ectotherms
- Many commercial species

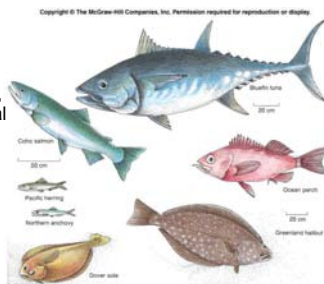
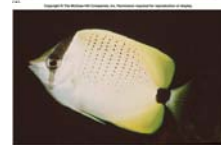


Fig. 13.9



## Adaptations

- **Coloration**
  - Camouflage
  - Mating
- **Schooling**
  - Defense
  - Mating
- **Body Shape**
  - Speed -minimize friction
  - Long distance
  - Catching prey

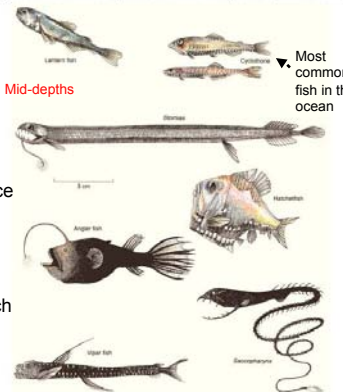


## Adaptations

- **Buoyancy**
  - Some have gas filled swim bladders
  - Fastest swimmers just use muscle power
  - Chondrichthyes must swim
- **Defense**
  - Plating (sea horse)
  - Spines (puffers)
  - Countershading
  - Schooling

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**Mid-depths**


- **Deep-Sea Fish**
  - Small size: high pressure and scarce food
  - Bioluminescent
  - Large, unhinged jaws
  - Expansible stomach

Most common fish in the ocean

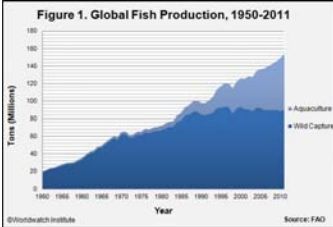
## Commercial Fisheries

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- Decline despite increase in catch effort
  - Overfishing
  - Max. Sustainable Yield
- **Largest:**
  1. Pelagic: herring, sardine, anchovy
  2. Demersal: haddock, sole, flounder
  3. Large pelagic: tuna, swordfish, mahi
- Cod - crashed
- Sharks - decimated



### Figure 1. Global Fish Production, 1950-2011




- ~33% of fish catch ends up as livestock feed
- Between 1950- 2000 catch increased 5X
- Aquaculture has doubled in 10 years, now 40% of total harvest

## Today's Fisheries are not Sustainable

- Max. Sustainable yield is estimated to be 100-135 mill. tons
- Huge factory ships using huge trawl nets can process, can or freeze the fish on board
- **Bykill** - animals killed while collected targeted species is enormous. Estimates are ~ 30 million tons 2010:
  - 57 percent of fisheries were estimated to be fully exploited—meaning current catches were at or close to their max. sus. yield, with no room for further expansion.
  - 30 percent were deemed overexploited.
  - Only 13 percent were considered to be not fully exploited
- **Estimated that all major fish stocks will be extinct (<90% of their historic levels) by 2050**
  - Science 2006

## Class Mammalia

- Homeotherms
- Air breathers
- Bear live young
- Evolved from land mammals 50 to 60 mill y.a.
  - Well-insulated – blubber, fur
  - Deep divers
  - No freshwater requirement
- Order **Cetacea**
- Order **Carnivora**
- Order **Sirenia**





### Threatened vs. Endangered?

- Most marine mammals are either threatened or endangered
- These are legal terms.
- **Threatened**: A species that is likely to become endangered in the future
- **Endangered**: A species is endangered if it is in danger of extinction throughout all or a significant portion of its range
- US: Marine Mammal Protection Act (1972), Endangered Species Act (1973)


### Order Carnivora

- **Fissipedia (split footed)**
  - Polar Bears (1 species)
  - Translucent fur – reflects color of snow/ice; black skin to absorb sunlight
  - Streamlined for swimming, webbing between toes, blubber
  - Threatened by pollution and habitat changes



### Order Carnivora


- Sub-order **Fissipedia**
- **Sea otters** (1 species)
  - Have thick fur: traps layer of air
  - No blubber
  - Reproduce on land
  - Smallest marine mammal
  - Use tools to break open shellfish prey, eats ~ 33% of body weight per day
  - Live in kelp beds, feed on urchins



### Sub-order Pinnipedia

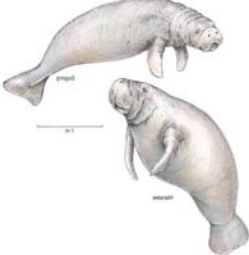
4 swimming flippers

- **Sea Lions**
  - Ear Flaps
  - Independent hind limbs
  - Breed in rookeries
  - Territorial
- **Seals**
  - Most have no ear flaps
  - Immobile hind limbs
- **Walrus**
  - No external ear flaps
  - Independent hind limbs
  - Tusks
  - Air Sacs around face for flotation
  - Live in Arctic



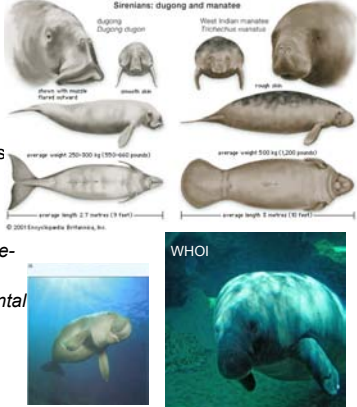
### Order Sirenia

- Coastal
- Tropical
- Only herbivore marine mammals
- **Sea Cows**
- **Manatees**
  - Amazon, Caribbean, SW Africa, Florida
- **Dugongs**
  - Indo Pacific
  - Indian Ocean





### Sirenians: dugong and manatee

- **Manatees** (3 species and **Dugongs** (1 species))
  - No pelvic limbs
  - **Manatees**: paddle-like tails
  - **Dugongs**: horizontal flukes





## Order Cetacea

- **Whales and Dolphins**
  - No pelvic limbs as adults
  - Use broad tail flukes for propulsion
  - Spend their entire lives in the water
  - Blubber
  - Blow-holes for breathing

## Order Cetacea

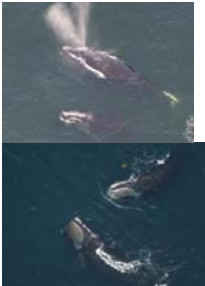
- Suborder **Mysticeti**: **Baleen Whales**
  - Largest mammals – great whales
  - Blue Whale is 100 ft long and 90 tons
  - Two blowholes
  - Use Baleen to strain out their food
  - Very high brain: body weight ratio (smart)
  - Vocalize: Songs
- Bowhead
- Finback
- Sei
- Minke
- Gray
- Right
- Blue
- Humpback
- Bryde's

## Order Cetacea

**North Atlantic Right Whale**


- Endangered (~350 living adults).
- Populations severely depleted by commercial whaling (~ early 1900s)
- Baleen whales that eat zooplankton (copepods, euphausiids); feed in coastal waters and may be seen off SC coast.
- Calve and raise young in coastal waters.
  - **Winter**: Mate and birth young in the tropics (warm water; use less energy)
  - **Summer**: Arctic – more food

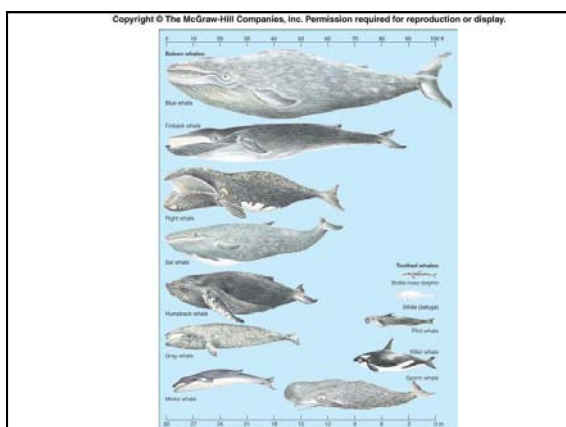


## Order Cetacea

- Suborder **Odontoceti**: **Toothed Whales**
- Pursue and catch prey
- One blowhole
- Lifespan ~ 50 yrs
  - Highest brain to body weight ratio
  - Use sonar
  - Vocalization

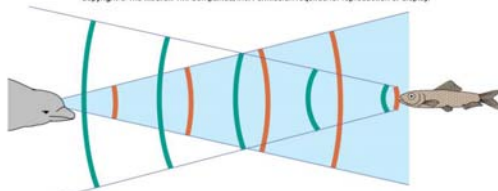
- Sperm Orca
- Pilot Beaked
- Beluga Narwhal
- Dolphins Porpoises





## Echolocation

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- Use clicks and whistles to picture their environment
- Clicks reflect off target, cetacean learns the speed, distance and direction of target
- All toothed whales, a few baleen whales, Weddell seal, Cal. sea lion, walrus