The Order of Cetaceans
(Again, Latin names italicized; Genus name capitalized, species not)
- Great variety of cetaceans! Over 80 species, w/varied habitats, foods, body sizes, social systems, etc.
  - Cognition studied in 1, behavior in ~10, so “the cetacean mind” is a great mis-representation…
- Key cognitive features that characterize the more studied species…
  - Highly Social, Large brains, Acoustic, Few long-dependent young, Playful, Collaborative

Mammals – Warm-blooded, breathe air (so must come to surface regularly – no gills), nurse young
- Completely aquatic (unlike other marine mammals like seals that sometimes come on land)
- Can see vestigial hairs (whiskers) in fetus and infants of some species
Development – Have only 1 offspring; Nurse for 2-5 years, depending on species
  - Long dependent young, some species not reach sexual maturity until 10-12 years old
  - Raised in school, much to learn!

Brains – Largest brains on planet, although significant variation across species
- Bottlenose dolphin = 1.5X vol of Human; Largest brain: 60ft Sperm Whale = 7.5X Human, 15lbs
- Huge cerebellum; Expansive convoluted cortex; Well developed social areas; Wired for sound!
- Buoyancy in aquatic environment supports gigantic body, and corresponding large brain size

Evolution – From land animals!? Two-toed, hoofed predators: Artiodactyls?, returned to sea ~55 MYA
- Earliest forms: Archaeoceti; Still had pelvis, hind limbs, poor acoustic sense;
  - Early forms: large teeth, small brains. Eventually large brains, small (or no) teeth, especially…
- Odontocetes: Complex sound system (social & echoloc) type beats out large teeth, small brain type
- Mysticetes: Probably branched off early from Odont’s (35MYA?), since Mysticet fetus has, then loses teeth

- Mysticeti = Mysticetes, Baleen Whales, filter feeders, 11 species
  - Baleen, or “whale bone” = long keratinous plates with fringed edges
    - Hang down from upper palate (along elongated arched upper jaw) on both sides of mouth
  - Strain seawater, catch small crustaceans (e.g. krill, copepods), small fish, squid, etc.
    - Very large bodies - Compare: Male Elephant: 6 tons; Female Blue Whale: 100 tons
    - Smallest (Pygmy Right Whale) = 6.4M (21ft) Largest (Blue Whale) = 30M (~100ft)
    - Blue Whale’s heart is the size of a Volkswagen bug!
  - All Marine, various species found from topics to poles
    - Some make epic global migrations; Others roam a particular zone
    - Have two nares (nostrils) each with its own “nasal plug” which rapidly open/close when breathe
    - Variable feeding strategies
      - e.g. Roquals (e.g. Minke, Brydes, Sei, Fin, Blue, Humpback Whales) are “Gulpers”
        - i.e. Come up from below prey, gulp huge mouthful
        - Have expanding throat grooves
        - Some (e.g. Humpbacks) form bubble net around prey school, then engulf
      - e.g. Right & Bowhead Whales are “Skimmers”- Open mouth slightly as swim along, “grazing”
        - Have highly-arched upper jaw and very long baleen
      - e.g. Grey Whale, (often seen off our coast as migrate to southern mating/calving grounds)
        - “Bottom feeders”: Stir up bottom and sift out water & sand
      - Do not have same specialized system for sound production/reception that Odontocetes have
        - Although do vocalize and may have rudimentary echolocation abilities
      - Brains huge, but proportionally smaller than Odontocetes
* We will be most interested in only one Mysticete: The Humpback Whale (Megaptera novaenglia)
  - Produces elaborate “songs” that change each season, and all males learn new version

- Odontoceti – Odontocetes, Toothed Whales, ~70 species
  - Generally smaller than Mysticetes; Vary from <2M (Vaquita) to >18M (Sperm Whale);
    -NOTE: Sperm Whale (“Moby Dick”) – the only gigantic Odontocete; Most are <6M
  - Mostly Marine
    - Single blowhole (not doubled like Mysticetes); doubled nares inside head
  - Some Riverine (fresh water!) species (e.g. in India, SE Asia, China, Amazon) - Endangered!
    - Tend to be small, long-snout, “primitive”, relatively smaller brained than marine
    - Water often clouded so depend on echolocation, some have very poor eyesight
  - All oceans, including Arctic - e.g. Belugas: Slow, blubbery “White Whale” AKA “Sea Canary”
    - e.g. Narwhals: Only tooth is elongated tusk in males, for sparring? sensing?
  - All have evolved complex acoustic (vocalization and hearing) anatomy for Echolocation (see below)
- **Hunters**: Larger prey, capture one at a time, swallow whole, simple conical teeth for grabbing
  - Eat mainly fish, & squid, sometimes shrimp, reef creatures
- Many **opportunistic feeders**; i.e. varied and idiosyncratic techniques
- Some **hunt cooperatively**, herding school of fish & sharing access
- Some (Bottlenose, Orca) will beach themselves to get prey (fish, seals respectively)
- Some Orca also eat other marine mammals (large baleens, small dolphins, seals, sealions)

*We will be most interested in the following Odontocetes:*

- **Killer Whale** (Orca): *Orcinus Orca*
- **Bottlenose dolphin**: *Tursiops truncatus* (Atlantic) and *T. aduncus* (Indian Ocean)
- **Beluga Whale**: *Delphinapterus leucas*
- **Sperm Whale**: *Physeter catodon*

**Perceptual & Motor Constraints on Cognition**

- **AUDITION** = Primary sensory modality (i.e. Most refined reception, largest dedicated “wetware”)
  - **Hearing** in Odontocetes = External ear opening vestigial
    - Elongated (telescoped) jaw bone, very thin at rear beside mammal-typical inner-ear
    - Sound enters throat & lower jaw, travels through fat channels to inner ear at rear of jaw
      - Fat is ~ same density as water = **impedance match**, so little sound energy lost
    - **Exquisite discrimination** abilities, brain a massive acoustic processor
      - e.g. Discriminate ball bearings differ ¼” @ 50 M !!
    - Odont’s hear up to **150KHz** (Humans to 20KHz); Many most sensitive to “ultra-sonic”
  - **NOTE**: Mysticetes produce/are sensitive to lower frequencies, which travel farther in sea

- **Echolocation** in Odontocetes = via Bilateral structures in forehead
  - Sound produced in nasal passages; Air recycled between air sacs, to phonate underwater
    - Vibrations of “**dorsal bursae**” (“monkey lips”, probably derived from nasal plugs)
    - Nasal sacs reflect sound (because of tissue/air **impedance mismatch**), direct it forward
    - Vibrations pass into fatty “**melon**” in forehead = lens to focus outgoing **beam of sound**
    - Produces series of clicks (bursts of broadband sound) that bounce back from targets in environment
    - Can produce slow to very rapid **click-trains**: faster for better focus & higher acuity
  - **So, perceive/represent world acoustically!**
    - “**X-Ray Vision**” Get separate set of echos from bones, muscles, air sacs in other’s bodies
    - Tell shape, material, distance, size of targets
    - More detail on this to come!

Other perceptual/motor constraints include…

- **Somatosensory** (tactile) can be very **sensitive**, especially around **genitals**, also **face** in Odontocetes
  - Tactile sensitivity in face probably involved in sensing acoustic vibrations

- **Tacto-Acoustics**: Acoustic output can have **tactile impact** – from “tickle buzz” to “punch”
  - So note, “meaning” of at least some vocalizations may include their tactile qualities!

- **Vision** quite good (comparable to cat), esp. sensitive to **motion & high contrast**, no color (monochromat)
  - **No fovea**, but sufficient acuity to distinguish…
    - Human faces, although ID better if moving
    - Trained dolphins can leap and grab fish from trainer 20 feet above water
    - Many species “**spy hop**” (raise vertically out of water) to look around
    - Eyes placed **laterally** (prey-like); Vision mainly **monocular**, either side of head, totals up to 360°
      - No visual access immediately above&ahead (echolocation site); Small binocular field below&ahead
      - Can “pooch” eyes out to look behind&above or behind&below; use e.g. during **social interaction**

- **Olfaction absent** (cannot smell, unlike many fish), no Olfactory Bulbs (see Brain lecture)
  - Do have minimal **Taste** receptors, but swallow food whole; Possibly taste **pheromones** in water??

- **No Hands**, limited manipulatory abilities, grab w/mouth only, can tow seaweed etc on flipper, tail
  - Fore limbs & hands contracted into paddle-like flippers, skeletal hands still **pentadactyl** (5 fingered!)

- **No malleable facial features**: Facial expression limited by hydrodynamic-streamlining, no pinna
  - Some **body language** (Gesture) - e.g. Can expose teeth/not; Can tilt exposing light underside
  - Dolphins can do aggressive “**S-Posture**” with body, jaw-snap
  - Most “wiggle” when play