There was seen on Monday and Tuesday morning playing around the harbor between Eastern Point and Ten Pound Island, a SNAKE with his head and body about eight feet out of the water, his head is in perfect shape as large as the head of a horse, his body is judged to be about FORTY-FIVE or FIFTY FEET IN LENGTH" So read a broadside published in *Boston about a sea monster sighting in Gloucester, MA, in 1817.*

The King of herrings:

- The oarfish!
    - Grow up to 11 meters.
- FOund throughout the world's oceans.
    - Ranges in depths from 20 to 1,000 meters.
- Length is up to 41 feet (12.5 m).
- Weigh up to 272 kg (600lb).
- Is feed on *euphausiids*

Bathynomus giganteus:

- He giant isopod.
- Length: 19 to 36 cm (7.5 and 14 in).
- Weight (1.7 kilograms (3.7 lbs).

Deep-sea gigantism or Abyssal gigantism:

- *The tendency for species of crustaceans, invertebrates, and other deep-sea-dwelling animals to display a larger size than their inland counterparts.*

Why does it happen?

- Not totally know. COuld be because:
    - Adaptation for scarcer food resources.
        - Grow very slow and live very long.
        - Wait for something like a whale fall to eat a lot of food all at once then wait a long time for the next meal to come.
    - Greater pressure?
        - To to the crushing pressure of the depths maybe bodies need to be bigger?
    - Other reasons?
        - Buoyancy.
            - Support of the body.

Japanese spider crab:

- The largest known arthropod.
    - The leg span at full size is 4 m (13 ft).
- Can be found at the bottom of the Pacific Ocean.
- They can live up to 100 years.

Sea Worms?

- In 1555 Olaus Magnus wrote of a marine worm which was apparently 17.76m (58.3ft) long, about the width of a child's arm, and whose touch made the hand swell.
- **Nemertea** is a phylum of invertebrate animals also known as "ribbon worms" or "proboscis worms."

Giant Antarctic Marine Worms:

- Another example of deep-sea gigantism.
- They have a harpoon-like proboscis that can be launch out from their mouth.
    - It can inject digestive toxins into prey.
- Their feeding balls are known as “a rubber band ball of terror”.
- They have a body pH of 3.5.
    - Nothing eats them because it is like eating a bunch of acid.

Polychaetes worms:

- Segmented worms are among the most common marine organisms, and can be found living in the depths of the ocean, floating free near the surface or burrowing in the mud and sand of the beach.
    - They are generally rather small.
    - Then there’s Barry…
- Facebook → Barry the Sea worm.

The Squids / Octopuses:

- RELEASE THE KRAKEN.
- Sketches of “krakens” attacking ships were common in the 1800s.
- Sailors tall tales, or truth?

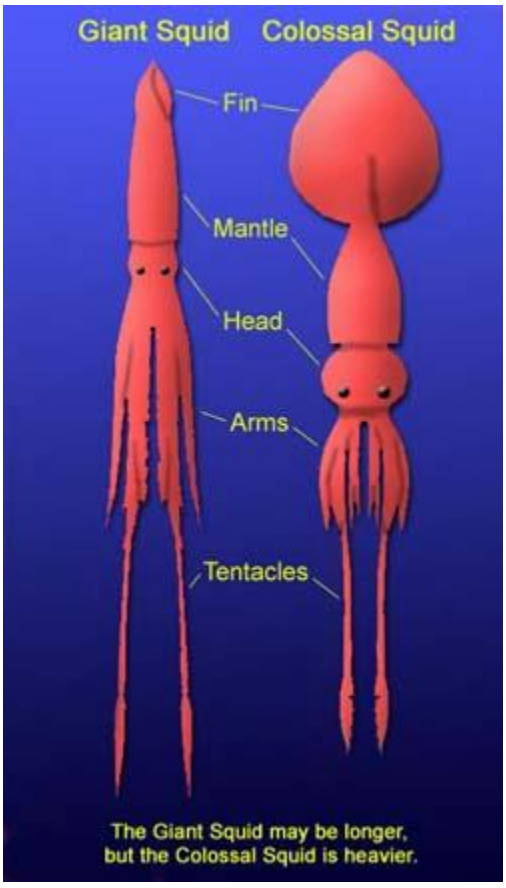
Squids:

- Most squids:
    - 60 cm.
    - Delicious (calamari).
- They are **mollusks.**
    - Includes **gastropods (snails)** and **mollusks (clams).**
- **Mantle:**
    - Highly muscular, forces water through the cavity and out the siphon.
- **8 legs, 2 tentacles.**
- **The Squid Pen:**
    - Squids have an internal shell (like most mollusks).
    - It is internal and shaped like a pen.
        - It was once used to write.
- **Chromatophores:**
    - Pigment-containing and light-reflecting cells.
        - Camouflage and communication.

The Krakens:

- **Giant Squid:**
    - They’re big (giant).
        - (13m) 43 ft for Female (10m) 33 for Male.
    - The feeding tentacles:
        - On the suction cups of the feeding tentacles the edges are serrated with toothy-rings.
    - Sperm Whales:
        - Eat giant squids but the squids don’t go down without a fight.
            - Scarring on sperm whales from battles with the squids.
    - The squids probably found 3,000-5,000 feet below the surface.

        - Used the idea of where sperm whales were diving.
    - The beak:
        - Made from chitin.
        - Used for the killing and tearing of prey.
        - You don't want to get bitten!
        - The beak is hard to digest, so it remains in the stomachs of whales.
    - Eyeball:
        - About the size of a human head.
- **The Colossal Squid (Antarctic or Giant Cranch Squid):**
    - The estimated max size is 12-14 meters (39-46ft) long.
    - Probably the longest invertebrate we know of.
    - Unlike the giant squid with its serrated rings, the colossal squid has shark hooks.
        - These hooks can rotate!
    - Their body is much wider than the giant squid.
    - They have the largest eye, believed, in the animal kingdom.



Octopuses:

- They are **<u>cephalopods!</u>**
    - Bilateral body symmetry.
    - They have a prominent head.
    - The have a set of tentacles or arms or tentacles (muscular hydrostat (a tongue)).
    - Includes the cuttlefish and nautilus.

        - Both of these have **shells (like structures)**!
- **The octopus:**
    - 8 arms.
        - Usually have suction cups.
    - Unlike other cephalopods they have entirely soft bodies.
    - The only hard part of their bodies is their beak.
    - They are incredibly intelligent.
        - Can escape tanks.
        - Navigate mazes.
        - They play with toys.
            - Open jars.
            - Close jars.
            - Throw the jars.
    - **Chromatophores:**
        - Pigment-containing and light-reflecting cells.
            - Camouflage and communication.

The Giant Pacific Octopus or North Pacific Giant Octopus:

- Up to 165 pounds (reports of 600 pounds).

Giant Jellyfish:

- Lion's mane jellyfish (HUGEEEE).

A *Phronima* amphipod:

- It is a mid-water organism.
- They are the size of a human pinky-nail.
- It is mostly transparent.
- It is the inspiration for the movie *Alien.*
- Salp: they are jelly-bodied animals.
    - The *Phronima* will climb inside of the salp's body, eat out the organisms insides, and then lives inside the body.
        - Raises its young inside the body.

Skeleton shrimp:

- Marine crustaceans of the order **Caprellidae.**
    - They will bite you (I hate these things).
- Can be found around Boston in August on lines.

The Tongue-eating louse:

- Eats the tongue of a fish host, becoming the fish's new tongue.
    - It eats little pieces of whatever the fish eats.
    - Also gets the nutrients from the fish's bloodstream.

The definition of a mammal:

- Humans are mammals.
- All mammals have (are):
    - Hair.

    - Females are milk producers.
    - Air breathers.
    - Warm bloodied.
    - Produce live young.
- There are 116 species of marine mammals in the oceans.
    - This is probably accurate.
    - However, there could be more.

The 3 Orders of Marine Mammals:

1. **Carnivore:**
    a. **Pinniped.**
        i. Seals: “Fin-footed”.
2. **Sirenia:**
    a. **Think “mermaid”**
        i. **Aka manatee.**
3. **Cetacea:**
    a. **Odontoceti**
    b. **Mysticeti**

Pinnipeds: Seals, Sea Lions, and Walrus:

- They are **pinnipeds.**
- They are predators, feeding mainly on fish and squid.
- They have thick layers of fat (blubber) to help stay warm in the water and have a high buoyancy.
- **Seals:**
    - The earless (no earflaps, internal ears). 19 representative species.
    - The back flippers are always pointing backward.
    - They have claws and fur on slippers.
    - Short, robust necks.
    - Internal testicles.
- **Seal lions:**
    - Have earflaps (external ears).
    - The back flippers can be rotated forward.
    - They have long, flexible necks.
    - They do not have nails or hair on their flippers.
    - External testicles.
    - Don’t go up and hug them, they will come after you, they can haul (Wally).
    - **California Sea Lion:**
        - Territorial in mating season.
        - Very social → gather in huge groups.
        - Migrate annually.
    - **Harbor Seals:**
        - Shy and quiet.
        - Only social during mating and resting.
        - Haul out in large groups.
        - Globally distributed (they are around Boston).

- **Elephant Seals:**
  - There are 2 species: the Northern and Southern Elephant Seals.
    - The Northern are a little smaller.
      - Found in Pacific Coast, Canada.
    - The Southern are a bigger.
      - Africa.
        - A bull (male) can be 16 ft (5 m) and weigh 6,000 pounds.
        - A cow (female) can be about 10 ft (3 m) and weigh 2,000 pounds.
    - Very territorial.
    - They can dive very deep (1,900 m).
    - They eat skates, rays, squid, octopuses, eels, small sharks, and large fish (basically anything).
- **The Leopard Seal:**
  - They live around Antarctica.
  - They are a **keystone predator:** they are very important for an ecosystem.
    - If removed it would alter the entire ecosystem.
  - They are very fast!
  - They do sometimes kill scientists in Antarctica.
  - Leopard seals can unhinge their jaws (like a snake).
    - Lots of teeth.
- **The Northern Fur Seal:**
  - Found throughout the northern Pacific.
  - It is in the sea lion group (not seal).
  - Solitary, except when mating or nursing.
  - They remain in the water for much of their life except while mating.
  - Long, hind flippers.
  - Eats most types of fish.
- **Walrus:**
  - Walrus are large pinnipeds with a distinctive pair of tusks.
    - Both the males and females have tusks.
    - The tucks can reach 1 meter in length.
  - They are *strictly arctic!*
  - The are benthic-feeder; feeds primarily on clams.
  - A baby walrus will learn its mother's face by squishing it's mustache face against her mustache face.
    - Its super cute.
  - Males get about 3 meter long.
  - They are generally a reddish to brownish color.

Sirenia: Manatees and Dugongs:

- **Manatees:** coastal areas of Tropical Atlantic Ocean.
  - They have a semi-circle spade fluke.

- **Dugongs:** Tropical Indian and Western Pacific Ocean.
    - They have a “whale or dolphin” fluke.
- They are the only vegetarian marine mammal; grazing on shallow water grasses.
    - They are “sea cows”.
    - Usually in shallow areas where vegetation growth is plentiful.
- Some species live in fresh and/or brackish waters.
    - Sometimes found around powerplant estuaries.
- They are severely threatened by motor boat collisions, HABs, pollution, and severe winters.
- **The Stellar Sea Cow:** extinct after 27 years of discovery 1741.
    - It was large and used to be plentiful in the Pacific Ocean.

Carnivoria:

- Prominent canine teeth.
- Skin covered flippers.
- **Sea otters:** no blubber, dense fur, eat various shellfish and crustaceans, kelp beds.
    - Smallest of the marine animals.
        - Their dense fur traps air, which can be heated by their body heat, to keep them warm.
    - They were once hunted for their fur, and almost to extinction, but they are doing much better now.
        - They are believed to have the densest fur of all mammals.
    - They live only in the Pacific Ocean.
    - Live near the shore in the kelp forests.
        - Must eat around 25-30% of their body weight each day. Eat a diet of shellfish and crustaceans.
            - Probably relates to the fat they don’t have any blubber.
    - Another **keystone species (predator).**
        - Without them, the kelp forest change dramatically.
            - The sea otter eats the sea urchins.
            - The sea urchins eat at the roots of the kelp plants.
                - Without the otters eating them, their numbers would swell to huge populations, and they would eat all of the kelp, and graze all of the kelp forest.
- **Polar Bears:** webbed paws, thick and hollow hair, mainly eats seals.
    - They are a semi-aquatic species.
        - Some time swimming, some time on land.
    - They eat seals.
        - A polar bear will stalk a seal through the seal’s breathing holes (in the ice).
    - They are the world’s largest land carnivore.
    - They have thick blubber, with translucent fure, black skin!
        - When they live in non-arctic environments (zoos), sometimes the fur will grow algae in their fur and have a green/brown color.

        - Tales of glowing polar bears → could be accounts of a bioluminescent algae species growing in their fur.
    - They do have 2 layers of fur.
        - Thick undercoat topped by guard hairs.
            - Perfectly adapted for the cold.
    - They are threatened by the loss of arctic sea ice (their environment).
    - The polar bear species is only about 200,000 years old.
        - Evolved from the brown bear.
    - There's 5 polar bear nations.
        - USA.
        - Russia.
        - Greenland.
        - Norway.
        - Canada.
    - Polar bears are found in *The Northern Hemisphere.* In the Arctic.
        - Penguins *ARE NOT* found in the Northern Hemisphere.
            - Penguins live in the Southern Hemisphere. in Antarctica.

Cetacea (Whales):

- They have elongated (telescope) skulls.
    - For hydrodynamics.
- They have blowholes on the top's of their skulls.
    - Mammals → air breathers.
- They have very few hairs.
- Horizontal tail fin (fluke).
- They swim very fast because of their hydrodynamic bodies.
- They can do deep dives.

Toothed whales (Odontoceti):

- Smaller.
- They're social.
- Most are not migratory.
- They activity hunt (chase down) prey.
- They use echolocation to communicate and hunt.

Baleen whales (Mysticeti):

- Larger.
- They are often solitary.
- Long annual migrations.
- The feed on things like krill, small fish, and copepods.
- They were sound only for communication.

Deep Diving:

- Humans:
    - Average breath holding → maybe a minute.
    - Deep divers → about 5 minutes.
    - Herbert Nitsch → 9 minutes.
        - Dove down 702 feet (214 meters).
    - Egypt's Ahmed Gabr assisted scuba (has air tanks):
        - 1090 feet (332 meters).
            - 12 minutes down, 14 hours to come back up.
                - Long ascending trip to avoid the bubbling in the blood.
- Marine Mammals Facing Problems:
    - Pressure:
        - At sea level (Boston) the pressure is 14.7 lbs per square inch.
        - Another 10 atm is added every ten meters down, so a 100 meter dive would be 100x surface pressure.
        - The Bends:
            - Any gas in the lungs will begin to be forced into the bloodstream with greater pressure.
            - If you rise back up too quickly, the transition of gas back into the lungs takes a long time.

        - Too fast, the gas in the blood can come out in the form of bubbles.
    - Oxygen Storage:
        - How do you keep enough oxygen in your body for long period dives?
            - The best human divers only have 5-9 minutes of oxygen in their air supply.
    - Nitrogen narcosis:
        - When there is too much nitrogen gas dissolved in the blood.
            - It causes drunken like conditions, disorientation and would eventually be toxic.
    - Cold:
        - The deep ocean is very cold and body heat would be lost quickly.
            - Water conducts heat away from the body 20x faster than does air.
    - Float:
        - Mammals float easily.
            - Makes it difficult to dive down!

The Sperm Whale:

- The Deep Diving Champion.
- They can dive to around 10,000 feet (3,048 meters).
- They can remain submerged for up to 90 minutes.

How is the Sperm Whale (and other marine mammals) So Awesome?

- Pressure:
    - Many marine animals have evolved to loose the external ears and sinuses.
        - The cavity that we experience pressure in when we dive simply don't exist.
    - Fur seals who do have ears, can fill ears with a bloody fluid when diving.
- Oxygen Storage:
    - They can store more O_2 in their blood.
        - More hemoglobin, more red blood cells and more myoglobin in their muscles.
    - They can also slow their heart rates → the *"mammalian diving reflex."*
        - All mammals when suppressed in cold water, their heart rates drop.
            - Do not do this, but, if you throw a baby into a pool they will close their mouths, open their eyes, and drop their heart rate.
- Decompression Sickness:
    - They exhale before their dive (sperm whales 90% of lung capacity), so no bends.
- Cold:
    - They are large and sausage shaped.
    - They have a low surface to volume ratio, less skin exposed to the cold waters.
    - They also have thick blubber.
- Buoyance:
    - Exhaling air from the lungs, making themselves less buoyant.
        - Allows for diving.

Porpoise vs Dolphin:

- Both odontoceti (toothy).
- Porpoise:
    - Single blowhole.
    - Spade shaped nose.
    - Rounded teeth.
- Dolphin:
    - Single blowhole.
    - Pointed nose.
    - Teeth are more pointed.

The Narwhal (unicorns of the seas):

- Males are about 4.1 meters, females about 3.5 meters.
- They eat greenland halibut, cuttlefish…
- Mainly males have the tusks, but about 15% of females have the tusks.
    - They always spiral to the left.
- The tusk is a big tooth.
- The tusk is covered in small pores which are used to detect chemical changes in the water.
    - Could be used for migration?
- The hard tooth enamel is internal (opposite form human teeth).

The Orca:

- Males 19-26 feet (6-8 tons), females 16-23 feet (4-5 tons).
- Diet:
    - Fish:
        - Salmon, Cod, Herring, Hake and Halibut.
    - Mammals:
        - Seals, sea lions, walruses, baleen whales, other toothed whales.
    - Birds:
        - Penguins, sea birds.
- 500 pounds of food a day.
- Spend 60% of their day hunting and eating.
- **The Residents:**
    - Most commonly sighted of the three populations in the coastal waters of the northeastern Pacific.
        - Fish and Squid eaters.
        - For 300 years, individuals of the same family have returned to the area → why they are residential.
            - Big groups!
    - These are the “nicest” of the three groups.
- **The Transients:**
    - Generally travel in small groups, 2-6, and they have less persistent family bonds.
    - They eat marine mammals (that includes you, you filthy animal).
- **The Offshore:**
    - They are seen in the northeastern Pacific in 1988.

        - Away from land.
    - They have many scars and cuts → their prey could have fought back.
        - Marine mammals?
- **They're endangered:**
    - Vessel disturbance.
    - Quality and quantity of prey have decreased.
    - Pollution → buildup of toxins in their flesh.

Mysticeti Whales:

- No teeth, baleen.
    - Like huge combs.
        - Smell bad → baleen holds onto food stuff.
            - Like if you don't floss but 100X worse.
    - Baleen is made out of keratin.
- The have two blowholes.
- They are the biggest whales in the ocean.

Skimmer:

- Baleen located on the top of the mouths.
- They swim with their mouths open on the surface of the water.
    - Small organisms are trapped in the baleen.
- The whale is able to move their lips around to gather the collected food from the outside and eat it.
    - **Sei whale:**
        - 30 tons.
            - Females a little bigger than males.
        - DIsturbed throughout the oceans except the poles.
    - **Right Whale:**
        - 60 tons 13-18 meters.
            - Females a little bigger than males.
        - "They're the right whales to hunt."
    - **The Blue Whale:**
        - Very elongated, much sausage, wow.
        - Eat 4 tons of food a day → diet of krill.
        - 125 tons, 23-27 meters.

Gulper:

- Have highly extendable "neck pouches".
- They take huge gulps of water.
    - They push out the water, and the small food bites get trapped on the insides of their mouths.
    - **The Humpback:**
        - 12-16 meters.
        - 79,000 pounds.
        - The use bubble netting for hunting.

- A team of whales give off high-pitched calls as they dive under a school of fish.
- The fish panic and rush towards the surface.
- The lead whale goes around the school, making a net of bubbles, the rest of the whales are able to corral the fish into a tight mass near the circle.
    - The fish will not pass the wall of bubbles.
- The leader whale will give the “GO, GO, GO,” signal, and the entire team will rush the fish with mouths open.
    - The team will rise in the same pattern every time.
        - AMAZING.

- Bubble netting requires an incredibly advanced level of intelligence and communication.

Benthic Feeder:

- They vacuumed up the mud on the bottom of the ocean.
    - **The Gray Whale:**
        - Live up to 60 years.
        - Known for making very long migrations.
        - The devil fish?
            - They would attack boats (back in the ol’ whaling days).
            - They would go after the boats.
        - Now:
            - They have learned that human boats are not hunting them (a lot).
                - They are more friendly?
                    - Enjoy human's tongue-scratching.

The Deep Ocean:

- It is cold, dark, and has a deep pressure.
    - 0-3ºC typically.
    - Usually a mud/sandy spread of nothing down there.
    - There is no photosynthesis down here.
        - No light.

Hydrothermal Vents:

- 1977: The Galapagos Rift. WHOI.
    - Discovery of Black Smokers (a type of hydrothermal vent) and 350ºC water found!
        - The hottest chimneys are near 400ºC.
    - There is a flourishing of life around these hydrothermal vents.
    - These vents could provide clues to how early life may have started on earth.
- These environments are completely independent from the surface and sunlight.
- Depending on the location of the vents, the life found at the vents changes.

Early Clues:

- 1964: British *Discovery:*
    - Deep in the Red Sea hot brines were found (44ºC → 111ºF).
        - Very salty, hot water.
- 1965: the R/V Atlantis II:
    - Water temps found of 56ºC (133ºF)
- 1968-1983: Deep Sea Drilling Project, Glomar Challenger.
    - Brought up sediment cores containing metal-rich sediments on top of the volcanic crust.
        - These cores were taken not only in the Red Sea but other oceans where seafloor spreading occurred.
    - To produce these metals some sort of chemical reaction had to be occurring to produce these metals.
- Usually rocks:
    - Most ocean-ridge rocks are black, white and pale green.
    - Found Mid-ocean ridge rocks of brown, orange and dark green.
        - These usually colors and patterns found in the rocks gave clue to the occurrence of some chemical reaction that would allow for the production of these unique metals and minerals in these rock samples.
- Ophiolites:
    - The finding of oceanic crusts on land.
        - Typically brought up from tectonic movement.
    - Copper min in Cyprus.
    - Can examine the metals found through the crust → and how these metals would have been formed and distributed.
- “Missing Heat”:
    - Heat Flow Through the Seafloor:
        - There is a theoretical curve of heat flow in the deep ocean.

        - Warmest directly over the mid-ocean ridge.
        - As you move away it should get colder and colder.
    - BUT:
        - When measurements are really taken, fluctuating uneven distribution of heat is recorded.
            - This unexpected result accounts for a “loss of heat”.
                - This loss is from cold water flowing into the cracks of rocks.
                - The hot water produced near the ridge will be cycled down into the rocks, using up the heat it carries.

Discovery Cruises:

- In 1977:
    - There was a group of geologists who went out from Woods Hole Oceanographic Institute.
    - They found one of the most exciting biological phenomena ever.
        - The geologists had to call back to the biologists because they did not know what they were looking at.
    - Bob Baller (helped find the *Titanic*).
        - He was one of the people present on the cruise to discover hydrothermal vents.
            - This was his “start off to fame” finding.

How do Hydrothermal Vents Work?

- **Black Smoker:**
    - More hot.
        - The intense heat creates iron and sulfide (the dark color).
- **White Smoker:**
    - Less hot.
        - Produces aluminum and silica (lighter color).

1. Cold seawater (below 2ºC) seeps into the ocean floor cracks.
2. 350-400ºC water reacts with crust.
    a. Oxygen removed.
    b. Becomes acidic.
    c. Picks up dissolved metals (Fe, Cu, Zn).
    d. Picks up hydrogen sulfide (H_2S).
3. The hot liquid rises up (hot substances rise over cold). The metals and H_2S are carried up with the water.
4. Some of the heavier metals settle quickly, building up the chimney surrounding the vent.

Life Without Sunlight:

- **Chemosynthesis:** Uses chemical energy [instead of sunlight].
    - Microscopic Archaea (bacteria-like organisms).
- **$H_2O + CO_2 + H_2S + O_2 \rightarrow CH_2O + H_2SO_4$**
- This reaction is the started base for all life in these environments.

The Life:

- **Tube Worms:**
  - They have a cavity (made out of chiten).
  - Have chemosynthetic bacteria living inside of their guts.
  - The red plum of the tube worm filters the water, bringing nutrients into their body for the bacteria to use.
    The plume is red because the tubeworms have hemoglobin (like us) in their blood.

Life Span of Hydrothermal Vents:

- They have a short life span.
  - Hydrothermal vents are dependent on sporadic volcanic activity of Mid Ocean Ridges.
- How do the vent communities move from one vent to another?
  - When one vent dies, how do the organisms living there get to the other vent.
    - Could it be because of whale falls? (Act like stepping stones).
    - The larva or eggs of the organisms may be thrown into deep ocean currents with the hope they get carried to another healthy vent.
- Estimated by:
  - Heat loss in the rocks.
    - Can estimate decades of existence.
  - Sulphide Radio-Chronology.
    - Dating of the present ions around the vents 15-60 years.
  - Clam ages.
    - Counting the rings present on the clams that are living around the vents.

Cold-Seeps:

- The water temperature here is cold.
  - Not hot → like the water of hydrothermal vents.
- The cold very salty water is what does the chemical reactions.
- **Hypersaline seeps:**
  - Discovered in 1984.
  - Very high salinity.
  - Normal deep sea temperature.
  - Hydrogen Sulfide-rich water seeps.
- **Hydrocarbon deeps:**
  - Discovered in 1984
  - Hydrogen sulfide and methane as energy sources.

Deep Ocean Floor:

- What are you living off of?
  - Whale fall (including any other fall of a large marine organism [tuna, shark, dolphin]→ the flesh and bones of the whale are very important sources of food for deep sea organisms.

        - **Mobile-scavenger stage:** Lasting months to years, during which mobile organisms come to eat on the soft flesh of the whales.
            - Sleeper sharks, hagfish, rat-tails, invertebrate scavengers.
                - They eat the soft tissues at high rates (40-60 kg d1).
        - **Enrichment opportunist stage:** Lasting months to years after soft flesh is gone.
            - Worms and crustaceans feed off of the hard parts of the whale for a long time.
        - **Sulphophilic stage:** Lasts for decades. This is where “vent-like communities” occur.
            - The life living here is dependent on chemosynthetic-type organisms which are independent from any sunlight.
    - Marine snow → the downfall of wastes and small dead organisms.
    - Fish dumps → can be significant depending on where these fish dumps occur.

Chemosynthesis Occurring Not at Depth:

- Since it was discovered, chemosynthesis has been found all over the place in all different environments.
    - Close to the surface → such as in mangroves.

Origin of Life on Earth?

- The “prebiotic soup”.
    - While the earth was under a heavy bombardment from space-stuff and the oceans were just forming.
        - For life to form on the planet, it must have occurred at a place that was protected.
    - This protected place could have been at the bottom of the ocean.
        - Away from bombardment, faulty atmosphere, and UV radiation.
    - Also, the microscopic organisms that dominate in these environments could be some of the first forms of life on earth.
        - Extreme!
        - Could be found on other planets.

Nitrogen:

- Nitrogen is essential for life.
    - C.H.O.N.P.S
        - Nitrogen is one of the essential elements for life.
- Nitrogen makes up amino acids.
    - Protein rich foods contain more nitrogen than other foods.
- Nitrogen makes up the base pairs for DNA (and RNA).
- The human body by weight is 3% nitrogen.
    - Carbon and Oxygen make up more, but Nitrogen is essential.

The Two Categories of Nitrogen:

- Biologically usable.
    - AKA Reactive Nitrogen (Nr).
        - Nitrite, Nitrate, Ammonia (NH_4^+).
        - The dissolved inorganic nitrogen forms.
- Biologically Un-usable.
    - AKA Unreactive Nitrogen.
        - N_2 (atmospheric nitrogen).
    - *1% of the organisms on earth can use the atmospheric nitrogen.*
        - Fix N_2 into ammonia → **nitrogen fixation.**
            - Only specific forms of bacteria can do this.

An Essay on the Principle of Population or the "*Malthusian catastrophe,"*

- The population of mankind is growing, and will grow too large for the available resources on our planet to provide for.
    - Not enough food.
- *A Christmas Carol,* 1843*,* Charles Dickens:
    - *"If they would rather die they had better do it, and decrease the surplus populations…"*

Justus von Liebig *"Father of Fertilizer Industry":*

- 1855: Liebig's Law of Limitation.

Where did mankind get fertilizer form before we could make it?

- Unable to fix nitrogen, we needed to find nitrogen (ammonia):
    - Feces:
        - "Guano [bird/bat poop], though no saint, works many miracles." –Peruvian proverb.
- 1824 two caskets to The American Farmer in Baltimore.
- 1840 first shipment from Lima to England.
    - Wars were fought over the available guano.
        - Very quickly depleted.

"The Wheat Problem":

- Sir William Crookes:
    - "We are drawing on the earth's capital and our drafts will not be perpetually honored." -Crookes 1898.
        - Mankind was taking all of the guano at a rate that would completely deplete the supplies the earth had to offer.

- [Like today, with oil? Coal?]

The Greatest Invention of the last 150 years or so?:

- **Haber-Bosch process:**
  - Under high temperatures and very high pressure, with an iron catalysts, the atmospheric nitrogen could be fixed into ammonia.
    - Allowed for unlimited fertilizer!
- Without this process, 50% of the human population today would not exist.

Human Driven Reactive Nitrogen Change:

- Before Haber-Bosch:
  - 1860 total: about 15 Tg N per year.
- After Haber-Bosch:
  - 2010 total: 210 Tg N per year.
- A 1300% increase.

However: too much N causes many negative consequence and N gets around through the environment by promiscuous means.

- N Fertilizer produces: 100 units.
  - 6 units lost.
- N Fertilizer is consumed by plants: 94 units.
  - 47 units lost.
- The N left in the crop (consumed): 47 units.
  - 16 units lost.
- N left in harvest: 31 units.
  - 5 units lost.
- N in processed food: 26 units.
  - 12 units lost.
- N used by the body: 14 units.
- Only 14% of the Nitrogen produced in the Haber-Bosch process enter the human mouth (if you're a vegetarian).

Eutrophication:

- The process of an increased supply of organic matter into a system.
  - Most cases it deals with the increase of Nitrogen into a system.
- **Causes:**
  - Increase in phytoplankton productivity.
  - Increase HABs.
  - Formation of nuisance algal mats.
    - Could lead to the loss of submerged aquatic vegetation.
      - Blocks out the sunlight.
  - Low Oxygen Conditions.
    - When these huge algal populations die and decompose, the oxygen in the water is consumed by decomposing bacteria.
      - These conditions have been increasing globally since the 1960s.
        - However, we have only been paying global attention to this since the 1960s.
          - Changes were occurring *before* the 1960s.

        - Where people are (coastal) these increases have been bigger.
    - Fish kills.
        - Shellfish → Can't move.
        - Fin fish → Disorientation, end up in places they should not.
            - Hypoxic environments → little oxygen, suffocation.
    - Loss of biodiversity.
        - Killing off of "non-favored" organisms in this changed environment.
            - Fish kills.
            - Loss of aquatic vegetation.
    - Significant Economic cost in terms of any relying on the productivity or leisure use of the ocean.
- Nitrous Oxide:
    - The #1 greenhouse gas that is leading to the depletion of the ozone.

The Grand Challenge: How do we feed an ever growing population and protect our environment from excess Nitrogen?

- Learn how to increase fertilizer efficiency in farmer practices.
- Someone increase plant nitrogen use efficiency.
- Increase the natural process of denitrification.
- Increase Waste Water Treatment Plant (WWTP) N removal.

But What can I do?

1. Eat Less meat.
    a. You do not need to become a vegetarian.
        i. One day a week makes a difference!
    b. It takes 220 pounds of N placed into corn to produce 11 pounds of beef.
    c. 170 million metric tons of N used yearly on cropland (to produce livestock).
2. Reduce Fossil Fuel Use:
    a. Fossil Fuels increased the amount of N_2 in the atmosphere.
        i. Greenhouse gas.
        ii. Depleting the ozone.

What's the difference between weather and climate?

- Weather: day to day variation in the atmosphere.
- Climate: A long term conditional change of the atmosphere.
    - Includes both year to year change and the extremes.
    - 30 years of time (the interval).

Intergovernmental Panel on Climate Change (IPCC):

- *"Formed in 1988 by 2 United Nations organizations, the United Nations Environmental Programme and the World Meteorological Organization…"*

Why do People Make Fun of Scientists?

- Difficult to give a definitive yes/no answer.
- The IPCC uses terms that are on the "Likelihood Scale":
    - Virtually certain.
    - Very likely.
    - Likely.
    - About as likely as not.
    - Unlikely.
    - Very unlikely.
    - Exceptionally unlikely.
- When asked the idea "the planet is warming" they would reply "very likely."
- *"You only have 100-150 years of data…"*
    - Yeah, but, there was not a good way to measure stuff before then?
        - *"But it's only 100-150 years!"* –The Non-believers.

Global Warming ≠ Climate Change:

- Yes, some places on the earth will get warmer.
    - Other places will get colder.
- Some places (like New England) will be more wet.
    - Other places will become more dry.
- Climate Change is more of the increasing in extremes and the timing of events, than anything else.

Warming of the Planet:

- The 3 best data sets on global average temperature anomaly (1850-2015):
    - NOAA, NASA, and Met Office HAdley Center and Climate Research Unit (MOHCCRU?)
        - The data is does vary (there is never any data that has no variability).
        - The overall trend is an **increase** in global temperature.
            - Began with the industrial revolution.
            - Further increase after WW2.
                - Baby boomers.

Where Does this Heat Go?

- Most of the heat is being absorbed into the ocean.
    - In the last decade, about 30% of the warming is occurring below 700 meters.
- Again, there is a little variability in gathered data, but the overall trend shows an increase in temperature.
- How?

    - It gets into the ocean [at depth] through **thermohaline circulation.**
        - Downwelling takes down the “warmer” water.
            - Yes, downwelling water is cold, but this “cold” water is getting warmer and warmer.
    - The capacity to hold more heat in the deep ocean is greater than the surface water.
- 93.4% of the heat is going into the ocean.
    - WOW.
- We know the *all* of the ocean basins have been warming for the last 50 years.
- The temperature of the water is also increasing coastally (not just out in the middle of the ocean).
    - The biggest increase is shown to be in the winter.

“Human influence has been detected in warming of the atmosphere and the ocean, in changes in to global water cycle, in reduction in snow and ice, in global mean sea level rise, and in charge in some climate extremes…” (IPCC).

Why is it a Climate Change a Controversy?

- Scientists are just as certain about Climate Change as the ideas:
    - Cigarettes kill.
    - The age of the universe.
    - That vitamins make you healthy.
    - That dioxin in Superfund sites is dangerous.

The Future?

- It is likely will will exceed 1.5ºC by the end of the 21st century.
    - Similar to the increase seen in the 1850-1900 trends.
- Sea level will rise.

Sea Level RIse:

- Sea level refers to the height of the sea in relation to a surface reference point. Sea level goes through periodic cycles of change throughout geologic change.
    - **Eustatic:** the global change (driven by climate).
        - 3.5 mm rise since the 1990s.
    - **Isostatic:** the local change.
        - Alaska: sea level going down.
            - This entire area is actually rising up due to tectonic movement.
        - Louisiana (Gulf States): sea level is rising.
            - These places are sinking!
        - East Coast: sea level rising.

Why does sea level change?

- **Thermal Expansion:**
    - Adding heat into the ocean causes the water in the oceans to expand.
        - This expanding ocean will just take up more space than colder water.
    - Could be accounting for 30-55% of sea level rise. (Controversial Still).
- **Melting of glaciers and ice caps (ON LAND):**
    - Ice melt from the land.
        - Adding more water into the oceans.

Sea Ice:

- When sea ice melts… THE SEA LEVEL RISE DOESN'T INCREASE.
    - The sea ice is already floating around in the sea.
        - It is taking up space already → like ice cubes in a glass.
- It can cause other problems (increase in fresh water).

What can you do about Climate Change?

1. Decrease your use of personal vehicles.
    a. Bike, public transport.
2. Decrease the use of electricity.
3. Eat locally.
    a. Decrease the need to transport food.
4. Recycle.
5. Consume less.
6. Compost.
7. Use less water.
8. Spread the Word.
    a. BU will not make any future investments in fossil fuel industries… Let's make it none.