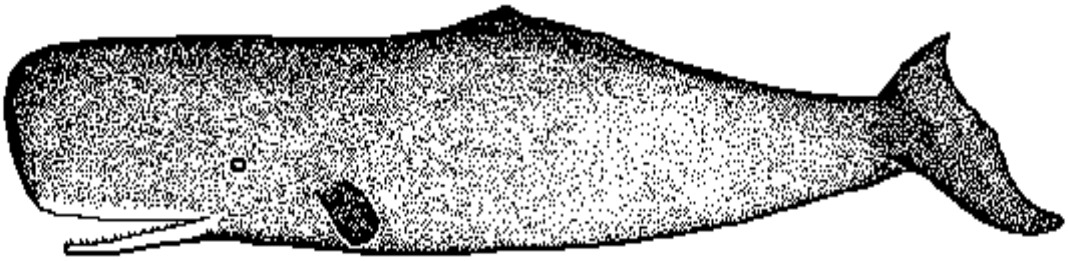
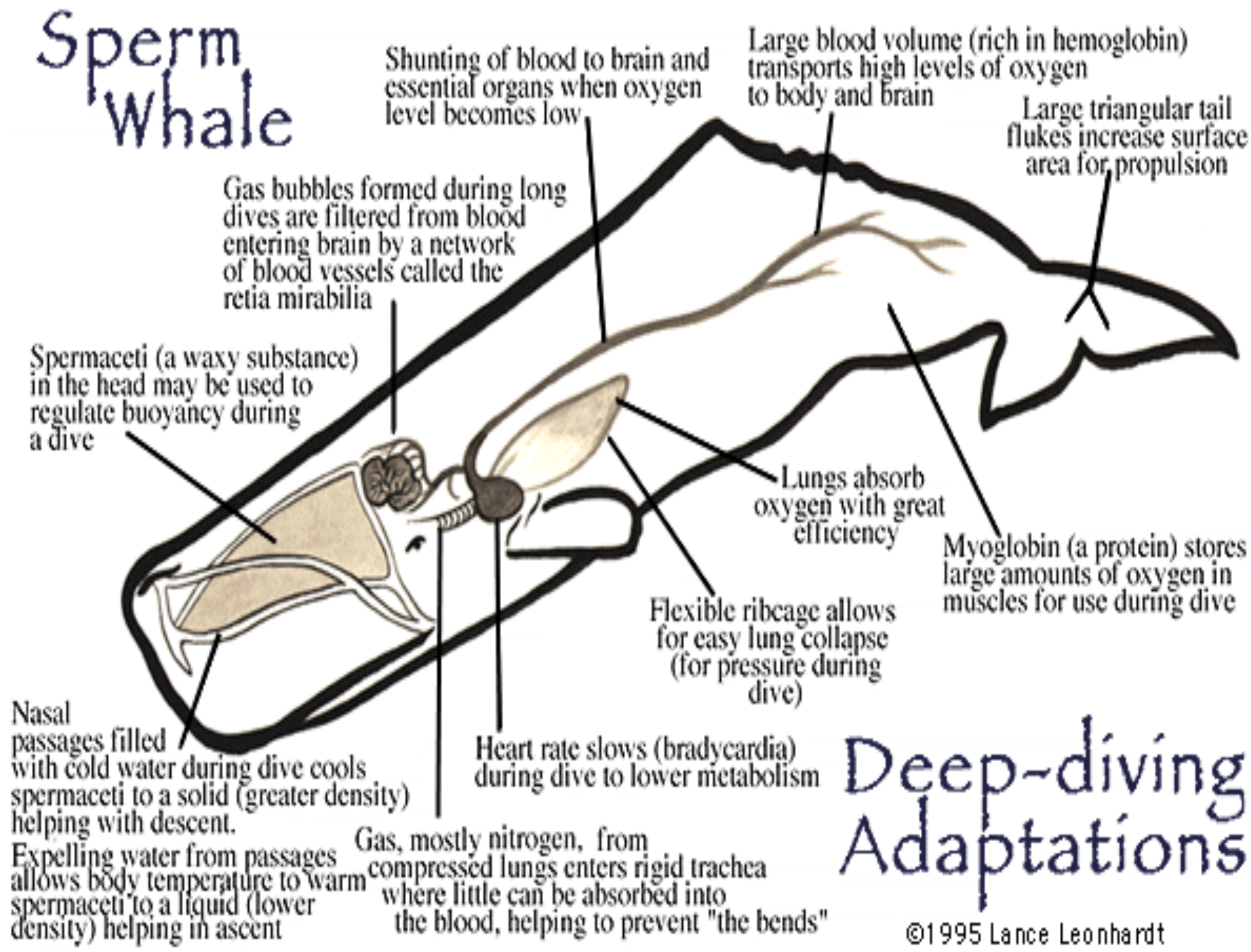
ADAPTATION SPERM WHALE DIVING

No living animals have captured our imaginations as have the great whales... They fire our imaginations and stab at our emotions. They inspire our art, literature, and music. And so they should. The indescribable blend of grace, power, and beauty of a whale as it glides underwater, leaps toward the sky, or simply lifts its flukes and slides into the sea symbolises a vanishing poetry of the wild.
- Dr James Darling, With The Whales



- The Sperm Whale, *Physeter macrocephalus*, was so named by Linnaeus because this whale exhibits a characteristically forceful singular spout, *Physeter*, and an extremely large head that can sometimes take up 1/3 of its length, *macrocephalus*.
- There is some discrepancy about the name though, because some scholars insist that the correct name of this whale should be *Physeter catodon*, with *catodon* referring to the fact that the whale has teeth only in the lower jaw.
- These whales are some of the largest members of the Order *Cetacea* which consist of water-dwelling animals that generally have spindle shaped bodies, forelimbs transformed into flippers with nearly completely degenerated hindlimbs.
- In *Cetacea,* the skin at the end of the tail has evolved into a highly efficient, and horizontally positioned swimming apparatus known as a fluke.
- These animals also have a waxy skin surface and underneath the epidermis, contain a thich layer of fat and dermis called blubber that functions in thermoregulation, as well as a well developed skull, flexible backbones, and 10-20 ribs depending on the species.
- The Order *Cetacea,* includes animals such as whales, dolphins, and porpoises, including the Blue Whale, Sperm Whale, Humpback whale, Bottlenose Dolphin, and Dall's Porpoise.
- The Sperm Whale belongs to the Suborder *Odontoceti,* which consists of cetaceans that have a single nostril opening, teeth, no baleen, a concave upper skull, and a larger sternum, and the Family *Physeteridae*, of which they are the only member. (http://www.cetacea.org/whales.htm, and Ridgway, 1972).

Adaptations: pressure and nitrogen absorption



When SCUBA diving, we as humans are able to experience the wonders of the upper 20-30 meters of the ocean. We explore this region using a sophisticated breathing apparatus that allows us to stay down for usually more than an hour, but at great risk to our personal health. Sperm Whales and other diving cetaceans are able to accomplish this feat with great ease and in fact dive to nearly 100 times these depths on a regular basis. The sperm whale is the undisputed king of deep diving, able to make dives of up to 3000m and remain submerged without breathing for more than an hour. When ascending, the whale moves toward the surface with such speed that to a human would cause death due to severe decompression sickness. The whale does not exhibit the least bit of decompression sickness. This ability is incredible and is due to one specific adaptation common to nearly all cetaceans.

Upon ascending to the surface, the decrease in pressure of the water poses a range of perils to the animal, including decompression sickness, commonly known as "The Bends," and "shallow-water blackout," a probable result of a sharp drop in the concentration of oxygen in the arteries, ultimately reducing the amount of oxygen that gets to the brain (Kooyman). The sperm whale is primarily able to avoid decompression sickness because it has the ability to collapse its thoracic cavity, lungs and alveolar sacs as a passive response to increasing pressure (Kooyman, Mitchell). This passive response is due to the whale's weak and flexible rib cage that collapses under pressure, forcing atmospheric pressure air (which has decreased in volume due to the increased ambient pressure outside the whale) into the bronchioles, bronchi, and trachea (Mitchell). Due to the large proportion of cartilage in these sections of the lungs, the air cannot be absorbed into the bloodstream, limiting the amount of nitrogen that can dissove into the tissues because it is no longer in the alveolar sacs, the usual site of absorption. Lung compression also limits the amount of blood that flows through the alveolar sacs (Mitchell). This adaptation serves as a check of the other processes. Because blood is unable to pass through the alveoli, the air that may have remained in the lungs is unable to be aborbed by the blood and is trapped until the pressure decreases upon ascent and gas exchange is again able to occur. The other difference between whales and SCUBA divers is that humans breathe compressed air at depth which increases the nitrogen absorption into the lungs, whereas whales exchange atmospheric pressure air in the beginning of their dive and thereby decrease the amount of nitrogen absorption that can occur.

Decompression Sickness, is popularly and mistakenly referred to as "The Bends"

Decompression sickness, commonly but mistakenly referred to as "The Bends" is a phenomenon that commonly occurs in SCUBA divers that dive too deeply for too long and then return to the surface at too quickly of a rate. The U.S. Navy developed dive tables in the 1960s that described the appropriate rate of ascent for a diver based on the depth of dive, time of dive, and upon the age and weight of the diver. This table describes a safe rate of ascent that will adequately allow dissolved gases to escape the body without causing physiological damage to the individual. There are two types of Decompression Sickness, appropriately numbered Types I, and II. Type I refers to the sypmtoms we generally refer to as "The Bends" and skin manifestations. Type II includes pulmonary, central nervous system, and cardiovascular problems (Martin). "The Bends" usually refers to the severe leg and lower back spasmodic pains that cause one with this condition to walk in a bent over position-- with a stoop.   Decompression Sickness was originally discovered in the 19th century among bridge-building caisson workers, and was originally referred to as Caisson Sickness. The workers who experienced this sickness, often referred to its symptoms as "The Bends" because the posture of the men with this condition resembled that of the fashionable women of the time who exhibited the "Grecian Bend" due to the bustles and full-length skirts they wore (Martin).

DCS is generally caused when nitrogen bubbles form in the blood stream and tissues of the body as a result of the rapid changes in pressure that occur when one repidly descends from deep within the ocean to the surface. "If the rate of ascent exceeds the rate at which nitrogen can be released (from the body) it forms bubbles in the blood and tissues- similar to opening a bottle of fizzy drink too quickly" (Easmon).

The explanation of why we can experience decompression sickness when SCUBA diving is given primarily by Dalton's Law of Partial Pressures and Henry's Law. Dalton said that in a mixture of gases, the total pressure of gases is equal to the sum of the individual pressures of each gas in the mixture. In the case of air, which contains 78% Nitrogen and approximately 21% Oxygen, this equation is written in the form:

$$P_{(total)} = P_{(oxygen)} + P_{(nitrogen)}$$

78% of the pressure comes from nitrogen and 21% comes from oxygen. Henry's Law states that the concentration of a solute gas in a solution is directly proportional to the partial pressure of that gas above the solution.   As depth increases, the total pressure of the water increases because the column of water directly above a point at depth weighs more, and the partial pressures of each gas in solution must increase to compensate for this overall pressure increase. Thus, because the partial pressure of a gas increases with depth, Henry's law predicts that at increased depth, the concentration of that gas dissolved in the solution will increase proportionately. At increased depth, more of the compressed air that a diver breathes will diffuse into his blood. Because the air we breathe is composed of 70% nitrogen, a substance that humans cannot metabolize, when humans breathe compressed air, they breathe much more nitrogen than oxygen, and at increased depth, more nitrogen diffuses into the tissues. The amount of oxygen diffusing into tissues causes no problem because this substance can be metabolized in the process of aerobic respiration. Nitrogen will build up in the tissues and can only be released when the pressure decreases and it passively flows from the tissues. The longer and the deeper the dive, the greater the amount of nitrogen that builds up in the tissues. If the rate of pressure change when ascending is adequately slow, the nitrogen remains dissolved in bodily fluids and diffuses out in this relatively harmless form. DCS arises when the pressure gradient for nitrogen leaving the tissues is so great that large bubbles form within tissues causing the blockage of blood flow to joints which causes "the Bends" symptoms, or to nervous tissue, causing paralysis or stroke (Easmon).

SYMPTOMS

The symptoms caused by the formation of nitrogen bubbles within body fluids and tissues include:

TYPE I

- Severe Pain around the knees, legs, and lower back
- Abdominal pain
- Vomiting
- Tenderness to touch
- Patient may walk with a stiff gait
- Dizziness and Headache
- Skin mottling
- Itching

TYPE II - these symptoms are especially common because nitrogen is particularly soluble in the fatty myelin sheath that surrounds neurons.

- Paralysis of motion and sensation - usually paraplegia, but can be general (usually goes away in several days)
- Lung Edema
- Shock
- Apoplexy - patient rapidly becomes comatose and death can follow within hours.

Patients usually experience symptoms within the first 24 hours after a dive, 50% within the 1st hour and 90% within the first 6 hours (Easmon).

TREATMENT OF DCS: Onsite treatment includes

- Step-by-step first aid if diver is unconscious
- 100% oxygen by mask at 10-15 liters/minute
- Plenty of Fluid
- Do not allow exertion
- Keep patient warm

In the hospital

- Treatment in a hyperbaric chamber - pressure within corresponds to pressure at 18 meters underwater. Diver breathes pure oxygen (this process occurs as a way of forcing nitrogen from tissues) and gradually is weaned to regular air. The pressure is gradually decreased to that of normal sea level pressure over a period of about 5-6 hours.

- Kept for 24 hours of observation