Adaptations for a marine and land existence

Pinnipeds (including elephant seals, harbor seals, sea lions, and fur seals) are amphibious mammals, necessitating a wide range of adaptions to live in the ocean or on land. In the case of E-seals, how are these warm blooded air breathing animals able to spend 8-10 months in the ocean each year of life? How are they able to tolerate the higher environmental temperatures hauled out on land while not eating or drinking for extended periods of time? How are they able to dive to the great depths for foraging purposes? How do they maintain core body temperatures at the frigid temperature of ocean depths? How well do they see and hear on land and at sea? In the following narrative, I will try to bring some perspective to these questions. Certainly E-seals (elephant seals) among the pinnipeds are the most physiologically interesting mammals as they have made major adaptions to live on land and in the ocean in 2 completely different environments.

Locomotion and Aquatic propulsion

Pinnipeds have overcome some of the difficulties involved in moving efficiently through a dense aquatic medium. Seawater being 800 times denser than air required pinnipeds to develop streamlined bodies that move through water with much less drag. They have done this through appendages such as limbs and feet becoming modified into flippers and fins to propel them through the water. In the case of E-seals sex organs and mammary glands are retracted inside the body within slits beneath the skin. In addition, the blubber promotes a streamlined body shape, their hair coat is sparse, and there are no erector pili muscles in the skin allowing their hair coat to lie flat. It has been suggested that the network of smooth muscle bundles in the skin of pinnipeds may alter the configuration of the skin and reduce drag. Such conformation increases laminar flow which produces little drag on fluid particles closest to the body and the outer fluid layers glide over one another allowing the animals to slip easily through the water.

How do Phocids (elephant seals and harbor seals) swim? Phocids swim by moving their rear flippers and lower body in a lateral, or side to side, sculling motion. The rear flippers may be either held together and spread or used alternatively in a series of strokes. The front flippers are generally held immobile against the body although they can be used for turning and maneuvering at slow speeds.

Size and Shape of body

In general Pinnipeds are relatively large compared with terrestrial animals. Large size helps E-seals conserve warmth; large bodied animals chill less quickly than smaller animals because the surface area where the heat is lost is smaller in comparison with their bulk than it is for a smaller creature.

Blubber

Blubber is the subcutaneous layer of fat beneath the skin covering E-seals which minimizes heat loss in water and thus insulates them from cold. Fat also serves as an energy reservoir providing nourishment in periods of fasting.

Temperature regulation

E-seals must maintain a core body temperature of close to 100 degrees in ocean water that may be only 30-40 degrees. Ocean water has a thermal conductivity 25 times that of air meaning water absorbs heat from the body of an E-seal 25 times more rapidly than air. E-seals have made adaptions as mentioned above, a large size compact body and a thick layer of blubber that help maintain core temperatures.

In addition, countercurrent heat exchange systems preserve heat and address overheating when E-seals haul out on land. To dissipate heat and cool their bodies, as well as to conserve warmth when necessary E-seals have intertwining arteries and veins in their flippers. The veins that carry blood from the flippers back to the heart initially lie beside arteries that circulate blood to the flippers. The arterial blood passes on warmth to the cooler venous blood, so the E-seal retains heat. E-seals also possess this network of arteries and veins in the skin. These intertwining arteries and veins allow blood to flood the skin rapidly and provide rapid heat loss when the E-seal needs to dissipate heat, but the E-seal can also shunt the blood away from the skin to maintain its core body temperature.

Pressure

E-seal bodies are subjected to enormous pressure during dives. There is 1 additional atmosphere for each 33 ft. descended. At a depth of 600 meters the underwater pressure on a seal is equivalent to 60 atmospheres or 60 times the pressure at the surface. One would think that E-seals would be subjected to ill effects from the high pressure experienced on their deep dives i.e., High-Pressure nervous syndrome (HPNS;nerves become hypersensitive, firing too readily and inappropriately) but scientists have not yet solved this puzzle as to why they are not affected.

Scuba divers get the bends because underwater pressure forces nitrogen from a diver's lung air into their blood stream. If a diver surfaces too quickly, nitrogen bubbles out of the blood, collecting in joints and nerves blocking circulation and causing pain/paralysis. Then why don't E-seals get the bends? Before diving E-seals exhale and their lungs completely collapse so that any air carried in the trachea which is cartilaginous, won't absorb the gasses, thus nitrogen cannot accumulate in the blood. In addition, they don't continuously ventilate their lungs as do divers who carry a constant air supply in a pressurized scuba tank.

Oxygen Conservation

How can an E-seal not breathe for such long periods of time without asphyxiating? A diving E-seal is able to reduce oxygen consumption by shunting blood to only essential organs thereby decreasing metabolic rate. The heart beat slows to 1/10 of its surface rate. A slow heart beat and channeling of blood to critical organs saves oxygen. Muscles are deprived of their usual supply of blood but they compensate by containing large amounts of myoglobin, a compound related to hemoglobin that stores oxygen. The oxygen in the myoglobin is recharged along with the hemoglobin during the brief period on the surface. Myoglobin helps the E-seal tolerate the large accumulation of carbon dioxide that prompts breathing during periods of prolonged breath holding. An E-seal's muscles are also able to handle the high amount of lactic acid that accumulates during diving, which causes muscle exhaustion in land mammals. This lactic acid accumulates as the E-seal's muscle function moves from aerobic to anaerobic metabolism when oxygen supplies are depleted by prolonged submergence. Finally, an E-seal's oxygen transporting circulatory system is very large. An E-seal's total blood volume in relation to its body weight is 1.5-2 times greater than that of other mammals. E-seals blood has a greater capacity than the blood of land mammals to store oxygen because they have larger red blood cells with a higher concentration of hemoglobin. And despite its high viscosity E-seal blood has a high rate of flow.

Elimination of Salt

Living in salt water poses some osmoregulatory problems for pinnipeds. Most pinnipeds are hypo-osmotic that is, they are constantly in danger of losing water to the more concentrated or salty ocean water. Pinnipeds conserve water and maintain proper water balance in several ways. The heavily lobulated kidneys of pinnipeds are extremely efficient at concentrating urine; they absorb and eliminate excess salt through urine that has a salt concentration equal to or greater than seawater. Pinnipeds that drink a liter of seawater, after excreting the salts, end up with a slight gain of pure water but at the expense of energy. However, many phocids appear to restrict their intake of seawater and derive fluids from the foods they consume. In addition, they produce water metabolically by the oxidation of stored fat and conserve water using their nasal turbinates.

Fasting; conserving water and burning fat

E-seals fast for long periods of time during their breeding seasons. Adult males may go without food and water for up to 3 months while females do not eat or drink while expending tremendous amounts of energy nursing their pups. These E-seals depend on metabolically produced water yielded by oxidation of stored fat. E-Seals have unique abilities to assist them while fasting. For instance, they have the unique ability to use mainly fat stores rather than protein during their long fasts. In addition, weaned E-seal pups have demonstrated a long term positive water balance which means all forms of water loss must be less than or equivalent to metabolic water production. Furthermore E-seals minimize water loss by producing only a small amount of concentrated urine. Finally E-seals have the ability to synthesize protein from a fixed store of amino acids during long fasts by recycling them.

Female E-seals conserve water while nursing their young by producing milk that is extremely high in protein and fat with a minimal expenditure of water. Additionally the water content of the milk decreases during lactation. E-Seals also conserve water using their complex nasal turbinates. Inhaled air cools the nasal turbinates by evaporation. Then water is condensed from the air by the lungs during expiration of which about 70% is recovered by the turbinate system.

Hearing underwater and in the air

Pinnipeds must be able to distinguish important sounds (locate prey) from the considerable amount of noise in the ocean. In fact, pinnipeds hear better underwater than in the air. In water, sound waves cannot enter the ear the usual way – through the auditory canal to the inner ear. Instead water borne sound waves reach the inner ear through the skull from all directions at once. The pinniped ear has been modified to improve hearing sensitivity and directional hearing underwater, with the inner ear located so that it does not touch most other bones of the skull, thus diminishing the non-directional sounds waves pelting it through the skull.

On land pinnipeds hear slightly less well than land mammals. Because pinnipeds lack a large external ear their hearing sensitivity is reduced. Moreover, the heavy wax coating in their auditory canal probably inhibits sound perception to some degree. Pinnipeds have good directional hearing on land which is an important aid for a mother searching for her pup, a breeding bull in locating the competition, and all pinnipeds in detecting predators.

Chemoreceptive senses

On one hand, underwater pinnipeds have virtually no sense of smell (their nostrils are closed tightly anyway) and a limited sense of taste. On the other hand, pinnipeds appear to have an acute sense of smell out of water. For example, during the breeding season, E-seal adult males often investigate a female's anogenital area to determine, presumably, whether she is in estrus. The frequent practice of nose to nose nuzzling of E-seal mothers and their pups is also an important means of mutual recognition.

Tactile senses

Tactile sensory abilities are well developed in pinnipeds. The most obvious sensory structure is the skin. E-Seal group together densely on land – a tendency called thigmotaxis. Burney Le Boeuf calls such aggregations the downtown area of an E-seal rookery. Pinnipeds have an abundance of vibrissae or whiskers that contain many sensitive nerve fibers and are probably most important underwater for detecting prey. Like other carnivores pinnipeds on land may use their whiskers when socially interacting with other animals. Some pinnipeds have whiskers over their eyes and near their nose. The position of the pinniped's whiskers---held back or stiffly forward conveys such states as attentiveness or aggression.

Vision

E-seals are able to see well both on land and underwater. E-seals need to see in conditions of extremely variable light intensities—while foraging in deep dimly lit waters or breeding along bright sandy beaches. E-seals have greatly enlarged orbits and eyes that are large in relation to body size. Most E-seals under low light conditions are able to dilate their pupils to let in more light using well developed ciliary muscles for dilating the pupil. The E-seal's eye contains a high number of rods (cells that respond to low light) which help them to see at night or at great depths where light penetrates poorly. In addition, E-seals have a well developed tapetum lucidum, a specialized layer behind the retina that reflects light like a mirror. The tapetum functions to send the light that passes through the retina back through a second time, essentially doubling the light gathering work of the rod cells. The E-seals eye is protected on land and underwater by the strongly keratinized corneal epithelium. A thick sclera (the white portion of the eyeball) also forms a protective coating that safeguards the eye against the underwater pressure experienced by an E-seal submerged at great depths. The lacrimal glands steadily lubricate the E-seals eye with tears to help protect it from the salty seawater and sand. An E-seal's eye is also protected by a nictitating membrane which is like an inner eyelid that effectively wipes away sand and debris.

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