Thermoregulation

In Camels and Polar bears

UG SEM 4

By Dr. Subarna Ghosh

What is thermoregulation?

- **Thermoregulation** is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different.
- A thermo-conforming organism, by contrast, simply adopts the surrounding temperature as its own body temperature, thus avoiding the need for internal thermoregulation.
- The internal thermoregulation process is one aspect of **homeostasis:** a state of dynamic stability in an organism's internal conditions, maintained far from **thermal equilibrium** with its environment.
- If the body is unable to maintain a normal temperature and it increases significantly above normal, a condition known as **hyperthermia** occurs. For humans, this occurs when the body is exposed to constant temperatures of approximately 55 °C (131 °F), and with prolonged exposure (longer than a few hours) at this temperature and up to around 75 °C (167 °F) death is almost inevitable.
- The opposite condition, when body temperature decreases below normal levels, is known as **hypothermia**. It results when the homeostatic control mechanisms of heat within the body malfunction, causing the body to lose heat faster than producing it.

- Normal body temperature is around 37 °C (99 °F), and **hypothermia** sets in when the **core body temperature gets lower** than 35 °C (95 °F). Usually caused by prolonged exposure to cold temperatures, hypothermia is usually treated by methods that attempt to raise the body temperature back to a normal range.
- since heat production and heat loss vary considerably in different parts of the body, although the **circulation of the blood tends to bring about a mean temperature of the internal parts.**
- Hence it is important to identify the **parts of the body that most closely reflect the temperature of the internal organs.**
- The **rectum** has traditionally been considered to reflect most accurately the temperature of internal parts, or in some cases of sex or species, the uterus or bladder
- Occasionally the temperature of the **urine** as it leaves the **urethra** may be of use in measuring **body temperature**

Endothermy vs. ectothermy

- Thermoregulation in organisms runs along a spectrum from endothermy to ectothermy.
- Endotherms create most of their heat via metabolic processes, and are colloquially referred to as warm-blooded. When the surrounding temperatures are cold, **endotherms increase metabolic heat production to keep their body temperature constant, thus making the internal body temperature of an endotherm more or less independent of the temperature of the environment.**
- One metabolic activity, in terms of generating heat, that endotherms are able to do is that they possess a **larger number of mitochondria per cell than ectotherms, enabling them to generate more heat by increasing the rate at which they metabolize fats and sugars.**
- Ectotherms use external sources of temperature to regulate their body temperatures. They are colloquially referred to as cold-blooded despite the fact that body temperatures often stay within the same temperature ranges as warm-blooded animals.
- Ectotherms are the opposite of endotherms when it comes to regulating internal temperatures. In ectotherms, the internal physiological sources of heat are of negligible importance; the biggest factor that enables them to maintain adequate body temperatures is due to **environmental influences.**
- Living in areas that maintain a constant temperature throughout the year, like the tropics or the ocean, has enabled ectotherms to develop a wide range of behavioral mechanisms that enable them to respond to external temperatures, such as sun-bathing to increase body temperature, or seeking the cover of shade to lower body temperature.

Vertebrates

By numerous observations upon humans and other animals, John Hunter showed that the essential difference between the so-called warm-blooded and cold-blooded animals lies in observed constancy of the temperature of the former, and the observed variability of the temperature of the latter.
Almost all birds and mammals have a high temperature almost constant and independent of that of the surrounding air (homeothermy). Almost all other animals display a variation of body temperature, dependent on their surroundings (poikilothermy).

In warm environments, mammals employ the following adaptations and strategies to maximize heat loss:

•Evaporative cooling by perspiration and panting

•Storing fat reserves in one place (**e.g., camel's hump**) to avoid its insulating effect

•Elongated, often vascularized extremities to conduct body heat to the air

<u>Life of mammals in deserts</u>

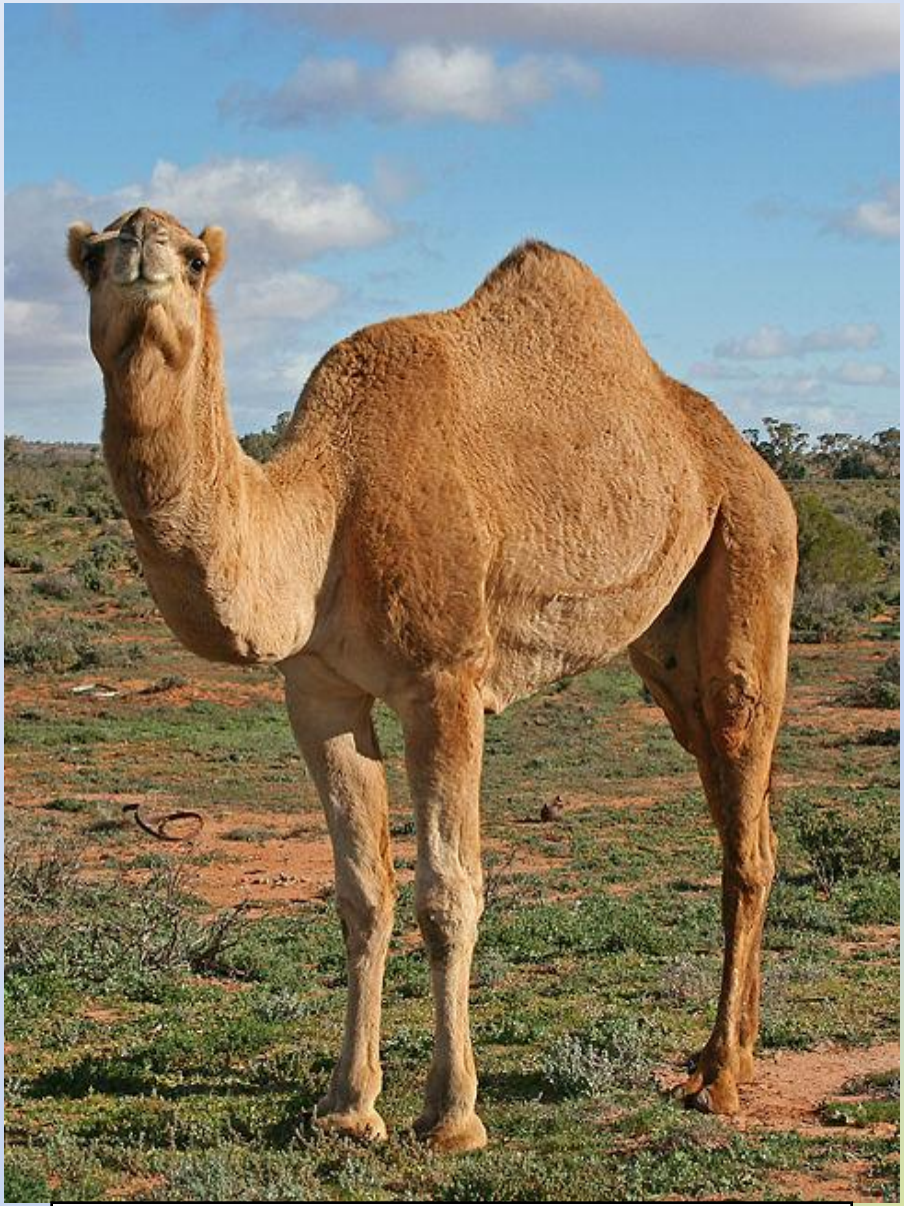
<u>Large mammals in hot deserts:</u>

- ✘ These are **endurers**, their body is too large and they can not hide in burrows or shade thus they are forced to remain exposed to direct sunlight during the day but the advantage is that they can travel for long distances to search for food or water.
- ✘ They use the risk of **evaporative cooling** for heat loss (includes **panting and sweating**).
- ✘ They are **inactive** during the hottest part of the day.

The camel

- One of the best adapted animals to desert conditions. There are two species of camels:

1. The **Arabian camel** (**dromedarian camel**) (*Camelus dromedarius*). Single humped camel in the Middle East and North Africa, it is more adapted to hot conditions.
2. The **Bactrian camel** (*Camelus bactrianus*). Two humped camel in central Asia, it is more adapted to cold conditions.



Dromedarian camel

Camelus dromedarius

Bactrian camel

Camelus bactrianus

CAMEL

•The camel (*Camelus dromedarius*) has adapted mechanisms that allow it to withstand prolonged water deprivation, high heat load especially in the absence of readily available water and survive when feed resources are scarce or of poor quality .

•Camels usually maintain a body temperature of 41 Celsius during the day, and almost 34 Celsius over the night.

•Temperature regulation in camels has a lot to do with the water preservation, that is why camels do not sweat till a high temperature is reached (in order to preserve water).

•When they finally sweat, the water evaporates right from their skin, resulting into efficiently cooling their body.

•It is important to say that camels are the only mammals that can withstand a loss of 25% of body weight due to sweating, while others do not survive after 3-4%.

• Moreover, camels have very thick coats. These coats are used for both reflecting the sun light, and therefore the temperature, as well as preventing the camel from the temperature that comes from the sand, that is really hot.

•Furthermore, it is a fact that camels have very long legs, something that is not random, as it is also used to hold their body far from the hot sand, as well as enables air to flow under their body and therefore cool them.

•This is because the camel is anatomically and physiologically equipped with adaptive homeostatic mechanisms enabling it to survive, produce and reproduce, and to support human life in such arid zones.

Thermoregulation in Camel

•In most mammals fat is spread over the body surface just under skin. In camel, the fat is concentrated in the hump which enables sweat to be evaporated easily over the rest of the body surface and this is adaptation to heat transmission.

•The skin is supple, covered with short fine hairs (Waber), which acts as insulating medium and may be longer in cooler climates or during the cool seasons in hot areas. (thermoregulation)

•The poll glands which are situated towards the top of the back of the neck behind the ears and cover an area of about 6 x4 cm in both sexes. It is more active under condition of heat and fatigue and act as modified sweat gland to help in evaporation.

•Also coat is fairly sparse which allows sweat to evaporate at surface of the skin. In mammals with heavy thick coats evaporation occurs at the ends of the hair a less efficient process.

•The body temperature can vary over wide range under condition of dehydration. The large mass of camel acts as a heat buffer.

•The camel can loose 25% of its body weight over a period of time without loosing its appetite and can make up this amount in just 10 min by drinking. While in other animals water loss is drawn from body tissues and the blood plasma.

•As a result blood becomes viscous and heat can no longer pump and explosive heat death occurs ,in camels very little water is drawn from the blood which remain fluid and can thus continue its function of heat transfer.

Physiological adaptations

- **Water conservation:**
- Desert adapted camels have evolved physiological adaptations that reduce the amount of water lost or are able to tolerate significant amounts of water loss .
- the camel may go several months without drinking during winter.
- Under very hot conditions, it may drink only every eight to ten days and lose up to 30 percent of its body weight through dehydration .
- When the mean temperature reach 30-35°C, camels can go 10-15 days without water but when the temperature exceeds 40°C, shorter periods between watering is necessary.
- The digestive and urinary tracts are well specialized in water conservation. Cattle lose 20 to 40 liters of fluid daily through feces, whereas camels lose only 1.3 liters. This is one of the primary methods for resisting water deprivation in the desert. Fluid is absorbed in the end part of the intestines, where the small fecal balls are produced

The rumen helps maintain water balance in two ways.

First, the rumen of hydrated ungulates and the foregut of camels contain a large volume of water, approximately equal to 20% of body weight, and may buffer ungulates against short term water deprivation. During the first few days of dehydration, fluid contained in the rumen is used to maintain water balance of blood and body tissues and represents a large portion (50–70%) of the water lost during dehydration

Second,

after dehydration in some species, the rumen plays a role in the prevention of haemolysis and osmotic tissue shock during rapid rehydration

- The kidney is an important organ involved in the removal of unwanted nitrogenous substances, excess water and relative maintenance of osmotic concentration of the blood . The camel's kidneys play a major role in the process of conserving water through increasing the osmolarity of urine.
- The kidney is characterized by a long loop of henle, and a well-developed medulla (the ratio medulla: cortex is about 4:1) . During dehydration, the kidneys reduce water losses both by decreasing the glomerular filtration rate and by increasing the tubular re-absorption of water

The long loops of henle, which are four to six times longer than in cattle, have the function of both concentrating urine and reducing its flow. A dehydrated camel urinates only drops of concentrated urine being shown by white stripes of salt crystals on the hind legs and tail.

This concentrated urine not only serves to conserve water, but also allows camels to drink water which is more concentrated than sea water (above 3% NaCl), and to eat salty plants (halophytes) that would otherwise be toxic.

Anti-diuretic hormone (ADH) is important in regulating the volume of urine excreted and its concentration. ADH is produced in the hypothalamus and is released into the blood stream in response to increased blood osmolarity . Larger release of ADH leads to a fast renal response that causes increased re-absorption of water. This leads to a smaller volume of more concentrated urine being excreted.

The body of camels can tolerate loss of water over 30% of body weight whereas most mammals die if they lose half of this value. Rehydration following a period of water deprivation is important for animal survival. A camel may drink more than one third of its body weight as it rehydrates. In terms of actual water of 110 liters in 10 minutes. In other animals rehydration at these levels would lead to over hydration and possibly death. The camel is able to do this as large amounts of water can be stored for up to 24 hours in the gut to avoid a rapid dilution of the blood

Unique features of blood

- **The camel can dehydrate without compromising blood viscosity. The camel's blood plays a principal role in adaptive mechanisms to high heat load and dehydration. Blood composition and volume remains relatively constant and haemoglobin function remains normal**.
- **The erythrocytes of the camel are oval shaped and non-nucleated which resist osmotic variation without rupturing; these cells can swell to twice their initial volume following rehydration.**
- **The oval red blood cells in dromedary camels can easily flow quicker in a dehydrated state of the animal as compared to the round shaped red blood cells in other mammals.**

These red blood cells are also enormously expansible . Because of the shorter and less saturated fatty acid chains that they identified, the dromedary **red cell membranes are more fluid** than those of human red cells thus explains the remarkable stretching ability in camels.

The ellipsoid shape of camel erythrocytes is very stable and that the cytoskeleton differs from that of human red cells and they may expand with distilled water to 400% before they rupture.

Another unique feature of the erythrocytes is their **long life span when the camel is dehydrated**. The life span of the erythrocytes of hydrated camels is 90 to 120 days. When camels are **chronically dehydrated during summer (40°C mean during day; 20°C mean at night) the life span of erythrocytes extends to 150 days. Erythrocyte turnover is water and energy expensive. Therefore extending the life span of erythrocytes reduces energy and water expenditure**

•Animals living in the Arabian desert are subjected to extremely high temperatures during the day in summer and very cold nights in winter. They have developed various adaptive mechanisms in order to cope with these severe heat conditions.

• The camel (*Camelus dromedarius*), like many other land animals, resorts to **selective brain cooling** when it is subjected to heat stress.

• This **mechanism protects the heat-sensitive brain tissue from heat stress and at the same time increases the animals' tolerance to high temperatures.**

•The **blood cooled in the nasal cavity by evaporative heat loss is diverted to the brain sinuses via the nasal and angular veins.**

•In the **cavernous sinus**, the arterial blood in the carotid rete is cooled by the cold venous blood before entering the brain. This will lead to significant cooling of the brain tissue.

• Active **myogenic tone** was mainly observed in the facial, nasal and angular oculi veins of the camels head. This tone was found to be sensitive to small changes in temperature in the range 33–45°C.

•The facial veins constricted, while the nasal and angular oculi veins relaxed to increasing temperatures. This leads to a coursing of cold venous return to the brain's sinuses for selective brain cooling.

•It is concluded that this **myogenic vasoactive mechanism** is a major factor in the control of blood flow in the facial area of the camel during heat stress.

Body temperature regulation:

- A fully hydrated camel has a diurnal body temperature range of 36 to 38°C. However when dehydrated and exposed to high environmental heat load body temperature may fluctuate by 6 to 7°C, from approximately 34 to 41°C.
- The increase in body temperature of camels exposed to high heat load, especially following a 2°C reduction below the normal minimum, is advantageous because it allows a considerable amount of heat to be stored during the day and dissipated at night (by radiation) without the expenditure of water.
- **Selective brain cooling:** Selective brain cooling has been postulated as a mechanism for animals to maintain brain temperature below thermal critical values when body temperature increases.
- The carotidrete, an area of the carotid artery divided into a series of small blood vessels posterior to the brain, contacts a network of small veinules returning blood from the nasal passages.
- Heat is transferred from the warmer arterial blood to venous blood cooled by respiratory evaporation in the nasal passage.
- Blood entering the brain is 3.98°C cooler than core body temperatures. This observation conclude that selective brain cooling is an adaptation to protect the brain when core body temperature increases. By cooling the brain the animal is able to tolerate higher temperatures

- The camel has a bi-phasic air flow pattern, i.e. the inspiratory and expiratory flow rates through the nasal turbinates are similar. The biphasic breathing pattern also reduces water use.
- Camels, like most other animals, need to maintain a constant brain temperature.
- To assist this, camels have a **"rete mirabile**”, it is a complex of arteries and veins lying very close to each other which utilizes countercurrent blood flow to cool the blood flowing to the brain. Doing so helps camels to maintain a stable brain temperature essential for survival.
- Under normal conditions the cool venous blood, after having passed over the nasal cavity, travels via a general circulation.
- However, when temperature increases in the body the nasal and the angular veins (1 and 2) (figure 1) become wider while the facial vein (3) (figure 1) is constricted. When this situation occurs the cool venous blood can only go in one direction through the ophthalmic veins to the cavernous sinus which then cools the arterial blood through heat exchange in the carotid artery

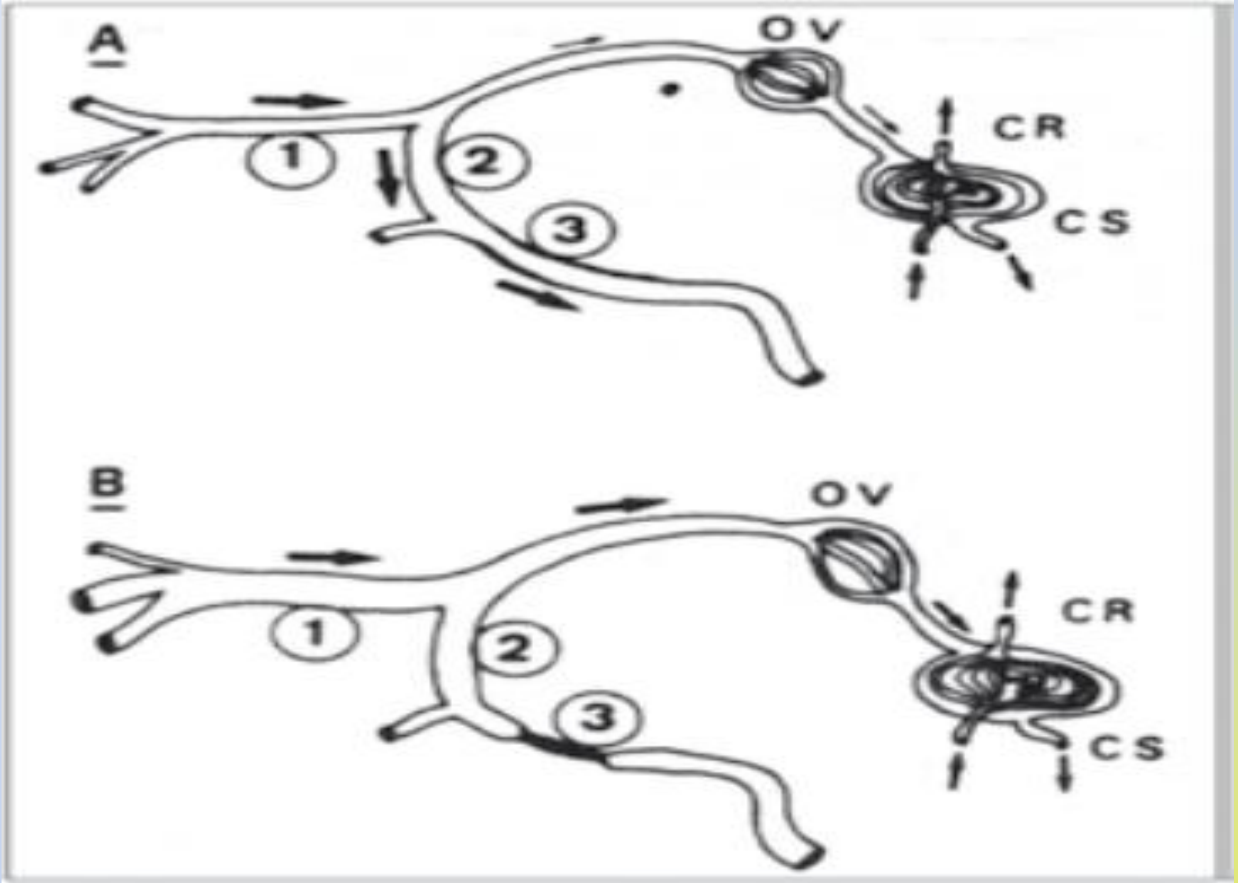


Figure 1: Superficial veins of the camel head under normal conditions (A) and hot conditions (B).

Digestion and metabolism

Gastric digestion: The pre-stomachs of the camel are characterized by the presence of only three compartments in comparison with true ruminants. The great digestive capacity of cellulose by camels is due to a specific and differentiated motility, a very active micro flora and better microbial digestion and more significant food mixing in prestomachs

Lipid metabolism: The proverbial capacity of the dromedary to resist thirst and lack of food is related to remarkable adaptive mechanisms, including the mobilization of the body reserves of lipids (fatty tissue) during malnutrition and the storage of fat during favorable periods

The cholesterol concentration increases in the dehydrated dromedary as a consequence of the hypothyroidism. In dehydrated dromedaries, liver lipids decrease from 13 to 2.5%, indicating a strong mobilization of hepatic lipids. On the contrary, concentrations of triglycerides and free fatty acids remain unchanged.
However; a severe water deprivation during 14 days would induce a lipolysis revealed by the increase in concentrations of triglycerides, free fatty acids, phospholipids and cholesterol

Nitrogen metabolism: The **nitrogen recycling** in Camelids increases in the case of lower proteins in diet and/or dehydration.

This great aptitude of urea recycling is due to very powerful mechanisms whose effectiveness does not deteriorate in the case of dehydration.

It has very particular anatomical structures in the kidney, which limit considerably the urea elimination by the urine. The urea appears to play a significant role during dehydration.

Indeed, by its **osmotic effects**, the urea attracts the water of other mediums towards the plasma. The tubular re-absorption of urea would be under the hormonal influence of the anti-diuretic hormone (ADH).

So the water **re-absorption** in the collecting tube is accompanied by that of the urea. Camelids are, therefore, particularly well adapted to lower nitrogen diets by limiting the urinary rejection of urea.

The animal can also produce urine with extremely low concentration of urea, when fed a diet low in proteins. Thus the camel can conserve urea for protein synthesis when food is low in protein or when growing or pregnant

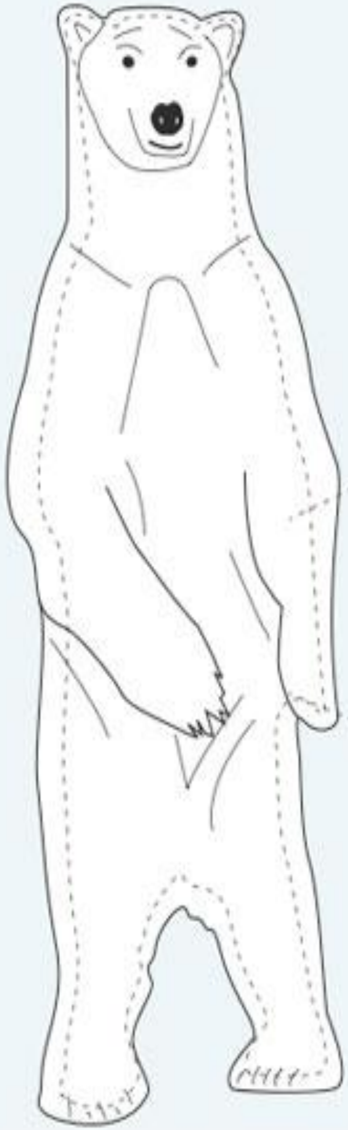
Polar bear

snout: long snout acts as a heat and moisture exchanger. Cold, dry air is warmed and moistend before reaching the lungs.

body structure: low surface to volume ratio minimizes heat loss. The head is the warmest part of the body.

claws: sharp curved claws help grip icey surfaces and enable bears to dig for seals.

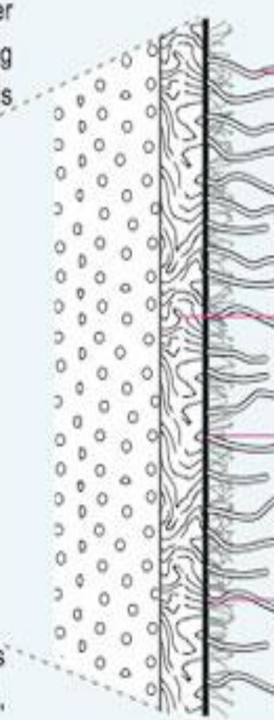
feet: soft fat pads with rough texture keep the bear from slipping. Long thick fur insulates between these pads. Feet are large for stability, balance and swimming.



skin: black skin absorbs the heat of the sun.

blubber: bears can have over 10cm of fat, important during the summer when there is little food.

hair: white fur camouflages them in their environment, hiding them from their prey. They have two layers to their fur, long guard hairs and short wooly hairs.



hollow transparent hair takes on water when swimming, acting like a wet suit. Also directs UV light down to the black skin

white wooly fur traps heat close to the body

dark skin maximizes the absorption of solar radiation

11 cm fat layer insulates bear from low temperatures

muscles layer striated and highly vascularized

Physiological adaptations to cold environmental temperatures:

- Thick fur (although not as insulating as we might expect!)
- Blubber (up to 11 cm thick)
- Low surface area to volume ratio

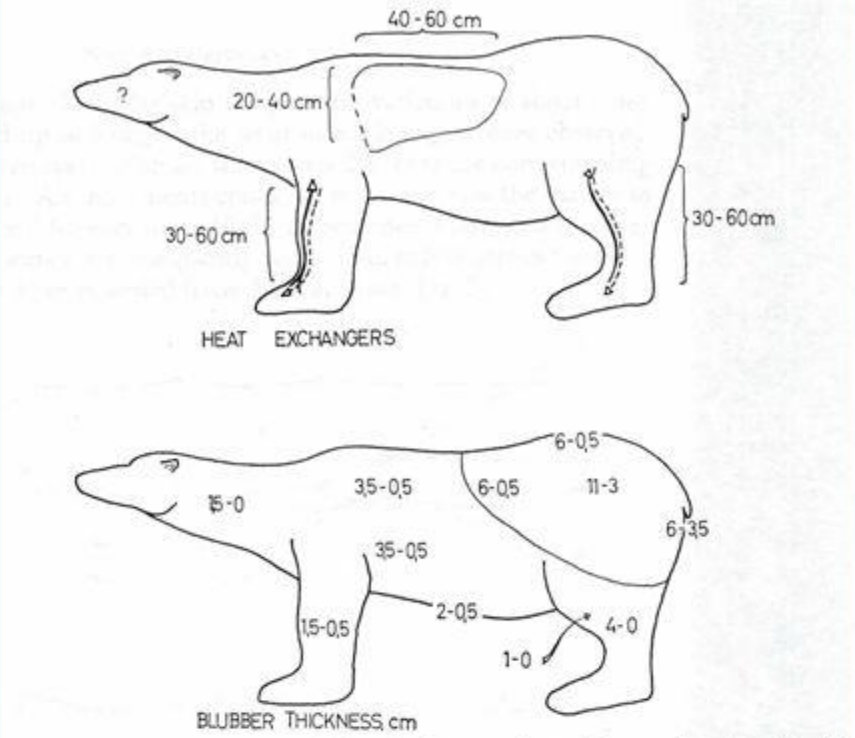


FIG. 1. Anatomical features of the polar bear as observed on twelve animals 1–25 years old. Main arteries and veins circulating the legs are running in close contact over a length of 30 to 60 cm. Pairs of 2 mm thick muscle sheets were found as indicated with solid and broken line. The sheets are placed 0·5–3 mm beneath the skin and covers up to 4 cm thick layers of blubber. Blubber thickness was the same on the inside as on the outside of the fore legs. A blubber pad as indicated with solid line was found on all bears examined. The pad's area showed a proportionality with total blubber weight.

Heat of Metabolism

- Main energetic problem for the polar bear is dissipating metabolic heat (Body-to-air temp. differentials of 100 C)
- Why do polar bears have this problem?

Swimming

Polar bears are strong swimmers; they swim across bays or wide leads without hesitation.

They can swim for several hours at a time over long distances. They've been tracked swimming continuously for 100 km (62 mi.).

A polar bear's front paws propel them through the water dog-paddle style. The hind feet and legs are held flat and are used as rudders.

A thick layer of fat, up to 11 cm (4.3 in.) thick, keeps the polar bear warm while swimming in cold water.

Polar bears can obtain a swimming speed of 10 kph (6.2 mph).

A polar bear's nostrils close when under water.

Diving

Polar bears make shallow dives when stalking prey, navigating ice floes, or searching for kelp.

Polar bears usually swim under water at depths of only about 3-4.5 m (9.8-14.8 ft.).

They can remain submerged for more than one minute.

Maximum dive duration is unknown; however the longest polar bear dive observed to date lasted a total of 3 minutes and 10 seconds covering a distance of 45 to 50 m (148–164 ft.) without surfacing. No one knows how deep a polar bear can dive.

Thermoregulation
Body temperature, which is normally 37°C (98.6°F), is maintained through a thick layer of fur, a tough hide, and an insulating fat layer (up to 11 cm or 4.5 in. thick). This excellent insulation keeps a polar bear warm even when air temperatures drop to -37°C (-34°F).

Overheating

- Polar bears are so well insulated they tend to overheat.
- Polar bears move slowly and rest often to avoid overheating.
- Excess heat is released from the body through areas where fur is absent or blood vessels are close to the skin. These areas include the muzzle, nose, ears, footpads, inner thighs, and shoulders.
- Polar bears also swim to cool down on warm days or after physical activity.

The Polar Bear and its “body action”

The polar bear is the biggest carnivore animal in the earth. Polar bears are excellent swimmers and are found basically in the Arctic sea. Their major habitat is on Arctic sea ice. The sea ice is an entire ecosystem for polar bears, in which they can live, create maternal dens, and hunt. Their scientific name is “Ursus Maritus” it is Latin and means sea bear. The biome that live these animals is called polar ice cap, it is a high latitude region that is covered by ice most of the year, and includes large portions of the Arctic and Antarctic. The reason that there is so much ice is because the region cannot receive energy from the sun through solar radiation. Analyzing the ice cap biome is important to mention that the climate experiences very cold temperature (10º C in the summer and -30º C during winter) and the humidity levels are too low. The search of food for these animals is the basic factor that makes them to withstand the low temperatures.

Polar bear’s temperature is normally 37º C and it is maintaining through a layer of fur in the outside and a layer of fat that is 11cm thick.

In order to keep their temperature stable bears have to move slowly.

The important thing about their coat is that it is made up of water repellent hairs that conserve heat.

Also their skin is black (dense fur) something that helps them to absorb the rays of the sun.

Based on a source that I found on the internet “heat can be released from their bodies where there is no fur and where blood vessels are close to the skin such as the nose, ears, bottoms of their feet and inner things”.

Additionally, in warm days they have to swim in order to sustain their body temperature

the animal needs to have a certain performance which is directly affected by temperature regulation, thing that is crucial for them in order to survive in such low temperature.