Cold Science: Thermoregulation

How often do you go outside and say it is cold? It usually depends on the time of the year, right? Well, in Antarctica, it's cold all the time. Antarctica is the coldest place on earth, with the coldest measured temperature ever recorded (-128.6°F). Even in the summer the highest temperature generally only reaches 26.6°F. Being that cold, you would think there would not be many animals; however, there are a wide variety of birds, mammals, fish, and invertebrates. How are all those animals able to survive with it being that cold? Well, the answer is ***thermoregulation*** (see def.).

Southern elephant seals (Photo: Cool Aantarctica.com/gallery/seals).

Thermoregulation is the process a body uses to maintain its core internal temperature. Animals need to maintain a certain internal temperature in order to maintain normal body functions. For humans, our internal temperature must be kept between 98°F and 100°F. When our internal temperature falls below 95°F, the human body does not function properly and we fall into hypothermia. The required internal temperature varies for different animals, but they all have developed mechanisms to maintain their optimal temperature. These mechanisms for heating or cooling include hair, large ears, bumps on the skin, and water-proof coats).

Killer whale preying upon a Weddell seal (Photo: R. Pitman, NOAA).

Fun Fact

Blubber is a special layer of fatty tissue that animals living in especially cold environments have developed over time as a way of keeping warm. Animals don't just build up blubber by eating to gain thicker and heavier than normal body fat. Blubber is a physical characteristic that animals either develop or they don't. For example, sea otters don't develop blubber; they rely on their dense fur to stay warm.

Fun Fact

Roughly 30–40% of a Weddell seal's body is fat (blubber)! Blubber traps heat inside their bodies, keeping their core temperature very warm – even if they are lying (also "hauled out") on the ice. In fact, Weddells are rarely cold because their core temperature stays around 100°F. Think of this: when we get cold, the first thing we do is grab a jacket or blanket to warm up. So we use an external insulator. Seals have an internal insulator that keeps their organs warm. When seals are hauled out on a sunny day, they are more likely to be hot than cold, and their warm bodies will actually melt the ice or snow they are laying on.

Weddell seal (Photo: KQED TV, kqued.org).

In Antarctica, for most animals to survive, their bodies had to change. These changes helped them adapt to the cold temperatures and maintain their internal temperatures. Some adaptations include small tight feathers, production of a natural antifreeze-type substance pumped into the blood stream, and thick, water-proof fur coats. Seals are a good example of the body type required in order to thrive in very cold Antarctica, and they have developed a few key adaptations that help regulate their body temperature. First, since the right type of skin is the most important asset in staying warm, and because any cut or scrap lets warmth escape, seals shed their old skin every year and grow healthy new skin. Second, young seals have a thick layer of water-repellent fur that helps them stay warm. And finally, seals rely on a thick layer of ***blubber*** (see def.) that insulates their bodies from the frigid water and air temperatures. Blubber is a thick layer of lipid-rich tissue, or what we commonly think of as fat. Not only does blubber help seals stay warm, it functions as an energy/food reserve, and it helps them remain buoyant while swimming.

How does blubber do that? First, the layers of the fatty material can impede heat generated deep in the body from leaving. Second, fat prevents cold water from entering the body because it can exclude (or repel) water molecules. Substances that can exclude water molecules are usually **nonpolar** and are called ***hydrophobic*** (see def.).

Why Won't Oil and Water Mix?

The geometry of atoms **in polar molecules** is such that one end of the molecule has a positive electrical charge and the other end has a negative charge. In a water molecule, which is a polar molecule, the atoms bind so that there are excess electrons on the oxygen side and a lack or excess of positive charges on the hydrogen side of the molecule.

In a **nonpolar molecule**, the electrons are distributed more symmetrically and thus the molecule does not have an abundance of charges at the opposite sides. The charges cancel out each other. Non-polar molecules do not have charges at their ends.

Mixing molecules of the same polarity usually results in formation of a solution. Thus, the rule for determining if a mixture will become a solution is that polar molecules will combine with other polar molecules to form solutions and non-polar molecules will combine with other non-polar molecules to form solutions, but a polar and non-polar combination will not form a solution. Water is a polar molecule and oil is a non-polar molecule. Therefore, they won't form a solution.

Don't Forget to Put on a Coat

The human body has not adapted to extreme cold temperatures like the bodies of penguins, seals, and whales. So how are humans able to survive in the cold without thick fur coats, small tight feathers, or even blubber? Well, in addition to creating shelters for protection and building fires for warmth, humans have been able to use some of the adaptations that animals have, like thick fur coats, by developing heavy clothing to protect themselves from extreme cold. For example, much like indigenous peoples in the farthest northern regions, early explorers to northern regions like the North Pole used coats made of reindeer fur to protect them from the cold. Early Antarctic explorers generally used little fur, opting for layered wool coats and clothing and wore boots made of reindeer fur. Sealskin mitts were also used by some.

> **Fun Fact**
> Seals and sea lions are one of the few groups of marine mammals that live in the Antarctic. There are two natural groups of seals: (1) true (earless) seals and (2) fur seals, which have small flaps over their ears and are related to sea lions.
> Six different seal species live in Antarctic waters: Ross, Weddell, crabeater, leopard, fur and elephant seals. Fur seals are the smallest, with adult females weighing only 150 kg, while male elephant seals can weigh 4,000 kg.
> Four of these species are ice-habitat specialists, breeding on the sea ice in spring. Leopard and Ross seals tend to be solitary, whereas Weddell and crabeater seals form breeding groups or colonies. The other two species—Antarctic fur seals and elephant seals—are both found north of the pack-ice zone (an area of free-floating, broken ice) and breed in dense colonies on beaches.

Robert E. Peary in the fur clothing he wore when he explored the North Pole (photo: Google images).

Early explorers often lost their lives or faced amputations as a result of over-exposure to cold. But today, with modern materials, we are able to design outerwear that can protect humans in very extreme conditions. Clothes made with synthetic material such as Gore-Tex® and Polartec® fabric, down-filled materials, and wind-stopping materials have allowed manufacturers to make specific clothes for survival in extreme environments.

The party of five (note the clothing), led by Robert F. Scott, Royal Navy (British) officer and explorer, which reached the South Pole on January 17, 1912, only to find that their efforts to be the first humans to reach the South Pole were preceded (by 1 month) by Roald Amundsen's Norwegian expedition. On their return journey, Scott and his four comrades all died from a combination of exhaustion, starvation, and extreme cold (photo: Wikipedia).

Fun Fact

Do crabeater seals eat crabs? Nope. There are no crabs in Antarctic waters. Crabeater seals, which are the most abundant seal species on earth, likely received their name because of a mistake by the early sailors. These seals actually eat krill—tiny shrimp that are rich in oil and perfect for supporting stores of blubber. Crabeater seals are unique amongst seals in that their teeth are adapted to form a sieve. Crabeaters take a mouthful of seawater and krill and expel the water through gaps in their teeth while the parts that overlap prevent the krill from escaping.

A pair of crabeater seals at ice edge (Photo: travelwild.com).

Activity – Blubber Mitts

Let's use some "blubber" to find out if it works the way scientists say it does. First, what is blubber? Well, blubber is fat. In this activity we will use some type of fat to make a blubber glove that we can use to see if our bare hand will stay warm inside when dipped into cold water.

Materials:

- Two zip-lock bags (quart size will work well)
- 2 cups of Crisco, or some other type of shortening or lard
- Duct tape
- One large bucket
- Liquid water
- Ice

Method:

1. Take one zip-lock bag and fill it with the 2 cups of Crisco. With a clean hand, place the second zip-lock bag centrally inside the first bag, and then use your free hand on the outside to make sure the Crisco coats the inside of the first bag and the outside of the second bag.
2. Fold the top of the inner bag over the top of the outer bag, keeping the Crisco between the two bags. Duct tape the fold in place so that the Crisco doesn't escape. Your blubber glove should be complete.
3. Fill the bucket with water and ice, creating an ice bath. Your ice bath should be very cold, so add ice as necessary.
4. Place a bare hand into the ice bath. Is it cold?
5. Place your other hand into your blubber glove and insert it a few inches into the ice bath, covering most of the hand, but avoiding submerging the glove and filling it with water. Now, assess the experience. Is the gloved hand cold? Is there a difference in the sensation of cold between your two hands? How significant is the protection provided by the blubber glove?

Questions:

- Do you think that other materials would work the same as the Crisco? Try using different materials (i.e., butter, cotton balls, peanut butter, sand, etc.) inside a glove. Which one works the best?
- Why do you think blubber is able to help maintain body temperature?
- When your hand is wet, why do you think it is colder than when it is dry?

Fun Fact

Blubber is effective at keeping animals warm partially because it is thick and dense—so thick, in fact, that it can account for a substantial portion of an animal's body mass. Some aquatic mammals have a body mass that is as much as 50% blubber. In addition to providing insulation, blubber actually manipulates a mammal's blood vessels to help the animal stay warm. Blubber is more densely packed with blood vessels than a typical layer of fat, and when the temperature drops, those blood vessels constrict to reduce blood flow in the animal. By doing that, the animal spends less energy heating its own body, ultimately keeping it warmer without burning energy as quickly.

Food for Thought… Or Maybe Fat for Thought

Before there were wetsuits, many long-distances swimmers smothered themselves in lard. The swimmers said the lard helped them stay warm while swimming in cold water, and it helped them stay afloat. The only problem was that the lard blocked the swimmers pores and didn't allow them to sweat properly, which is important to keep our bodies cool and healthy. Now, with the advent of wetsuits that help insulate swimmers, the practice of using lard in swimming isn't followed as much.

Emperor penquins (Photo: G. Grant, U.S. Antarctic Program, National Science Foundation).

Definitions

Thermoregulation. The process a body uses to maintain its core internal temperature.

Blubber. A thick layer of lipid-rich tissue or fat that animals use for thermoregulation and to help them remain buoyant.

Hydrophobic. A non-polar substance that can exclude water molecules.