

Emperor penguins (*Aptenodytes fosteri*), largest of all 17 penguin species, live in one of the toughest environments on Earth, Antarctica. Emperor penguins are distributed around the Antarctic continent, feeding in waters of the Southern Ocean.

To survive this harsh environment emperor penguins need structural, physiological and behavioural adaptations.



Emperor penguin courtship involves trumpeting and bonding of pairs. They breed on sea-ice and most eggs are laid in May-June after which males take responsibility for the entire 62-66 days of incubation while females are at sea finding food. Photograph by Glenn Grant, National Science Foundation.

Activity 1: Insulation (part A)

Emperor penguins are one of the top predators in the Antarctic food chain. They hunt squid, fish and krill in the Southern Ocean, where water temperatures can be as low as -1.9°C . For emperor penguins, having the ability to stay warm in extremely cold temperatures is essential.

Emperor penguins have a layer of fat below the surface of their skin, around 2 cm thick. During summer months, prior to breeding, this fat layer is at its thickest in preparation for winter.

Aim

To investigate effects of insulation on body temperature.

Equipment

- 4 plastic or zip-lock bags
- masking tape
- vegetable shortening (softened)
- basin/bucket of cold water
- ice cubes
- two thermometers
- stopwatch

Method

1. Fill 1 plastic bag with 1 cup softened vegetable shortening.
2. Insert a second plastic bag inside bag containing shortening. Shortening should be sandwiched evenly between the two bags.
3. Take other two bags and place one inside the other with no shortening.
4. Record room temperature.
5. Fill basin with cold water. Place thermometer in water. Add ice until temperature is around 10°C . Record water temperature, and remove thermometer.
6. Place a thermometer inside each pair of bags. Thermometers should not touch the bottom of bags.
7. Secure each pair of bags with masking tape or using zip-lock feature. It is important that water does not enter bags.
8. Suspend both in water basin.
9. Record temperatures inside the bags at 2 minutes, and at 4 minutes. Ensure thermometers remain as far down in bags as possible, when reading temperature.

Record your experimental results in an appropriate format.

Summarise results, making sure to address the following points:

- changes in temperature between the two pairs of bags;
- effects of vegetable shortening on temperature; and
- advantages of a thick fat layer for emperor penguins.

Activity 1: Insulation (part B)

Emperor penguins have a layer of fat below the surface of their skin, around 2 cm thick. During summer months, prior to breeding, this fat layer is very thick in preparation for winter.



Photograph by
Glenn Grant,
National Science
Foundation

Aim

To investigate effects of insulation on body temperature.

Equipment

- two plastic or zip-lock bags
- masking tape
- vegetable shortening (softened)
- basin/bucket of cold water
- ice cubes
- 2 disposable gloves
- stopwatch
- thermometer

Method

1. Put on pair of disposable plastic gloves.
2. Add 1 cup of vegetable shortening to first plastic bag. Second plastic bag has no vegetable shortening.
3. Record room temperature.
4. Fill basin with cold water. Place thermometer in water. Add ice until temperature is around 10 °C. Record water temperature.
5. Place a gloved hand inside plastic bag with shortening. Place other gloved hand into second plastic bag. Secure bags so no water leaks into them. (Make sure shortening is evenly distributed around hand in plastic bag.) Start timer.
6. Submerge both hands into water. Note, for each hand, how long it takes for cold to become intense. Remove hand immediately. Record immersion time, for each hand.

Safety note

Water temperature should not be below 10 °C. Immersion in cold water for extended periods can be hazardous and painful. Less than one minute is recommended for the hand inside second plastic bag, and a maximum of two minutes for the hand in vegetable shortening.

Record your experimental results in an appropriate format.

Summarise results, making sure to address the following points:

- observed differences in temperature between the two bags;
- effects of vegetable shortening on temperature; and
- advantages of a thick fat layer for emperor penguins.

Activity 2: Huddling

Emperor penguins breed on sea ice during the Antarctic winter. Males incubate the single egg, fasting for up to four months. They must withstand extreme weather conditions: air temperatures as low as -40°C , wind speeds of 200 km h^{-1} , and up to 20 hours of darkness per day.



Male emperor penguins huddle together in large groups to withstand harsh winter conditions. Photo by Frederique Olivier © Australian Antarctic Division.

Aim

To investigate effects of huddling behaviour on temperature.

Equipment

- 8 test tubes
- rubber bands
- 2 thermometers
- 2 stands
- 2 clamps
- stopwatch
- source of hot water

Method

1. Fasten 7 test tubes together using rubber bands.
2. Attach group of test tubes to a stand using clamp.
3. Attach remaining test tube to separate stand using clamp.
4. Record room temperature.
5. Fill all test tubes with hot water. Take care handling hot water.
6. Place 1 thermometer in central tube of group of test tubes.
7. Place second thermometer in single test tube.
8. Record initial temperature of each test tube.
9. Take readings of both test tubes at 2-minute intervals over ten-minute period. Record temperatures.

Record your experimental results in an appropriate format.

Summarise results making sure to address the following points:

- changes in temperature between the single test tube and group of test tubes;
- advantages of huddling behaviour for male emperor penguins; and
- effects fans, air-conditioners or heating appliances in the room might have on this experiment.

Activity 3: Diving reflex

Emperor penguins are air-breathing animals that dive for food, holding their breath. During a dive emperor penguins display a number of physiological changes to their bodies. Collectively these changes are known as 'the diving reflex'.



Emperor penguins dive beneath dive holes in Antarctica. Photo by Kathi Ponganis, Scripps Institution of Oceanography at UCSD.

The diving reflex is an adaptation common to all mammals, along with some birds and reptiles. In humans, the diving reflex is evident during immersion. It is stimulated by breath-hold and cold water to the upper portion of the face.

Aim

To investigate the dive reflex in humans.

Equipment

- large basin filled with cold water (approximately 10° C)
- ice cubes
- thermometer
- heart monitor
- stopwatch
- towel or paper towel

Method

Student participation in this experiment is optional, and students must only breath-hold to the limits of their own comfort; a 30 second breath-hold is sufficient for the experiment.

Part 1: Resting heart rate

1. Select one member of group to be test subject. Other team members will be responsible for monitoring stopwatch and recording heart rate.
2. Attach heart monitor using manufacturer's instructions.
3. Seat test subject on chair/stool at laboratory bench. Subjects lean forward with forearms placed flat against bench top and heads down.
4. Activate stopwatch and record resting heart rate of subject at 0, 15 and 30 seconds.

Part 2: Breath-hold without immersion

1. Instruct subject to hold breath and activate stopwatch.
2. Record heart rate at 0, 15 and 30 seconds.
3. Call out each time increment for test subject.
4. Allow subject to rest until resting heart rate is restored.

Part 3: Breath-hold with immersion

1. Fill basin with cold water and place in front of subject. Add ice cubes to water until temperature is approximately 10 °C. Record water temperature.
2. Instruct subject to hold breath and immerse face in basin of water. Start stopwatch. Record heart rate at 0, 15 and 30 seconds. It is important forehead is underwater.
3. Call out each time increment for test subject.

Safety note: Very low water temperatures are painful and hazardous, do not conduct experiment if water temperatures are less than 10 °C.

Record your experimental results in an appropriate format.

Summarise results, making sure to address the following points:

- changes to heart rate during breath-hold without immersion;
- changes to heart rate during breath-hold with immersion;
- comparison of breath-hold results (with and without immersion);
- reasons for the presence of diving reflex in humans; and
- advantages of diving reflex (especially a decline in heart rate) to emperor penguins.