teachers guide

Adaptations 2 Emperor penguins

Components

NAME	DESCRIPTION	AUDIENCE
Emperor penguins teachers guide	Students perform experiments that simulate adaptations of emperor penguins. Laboratory tips and sample data for each experiment are included.	teachers
Investigating penguins procedure sheet	Students conduct experiments that investigate key adaptations of emperor penguins. Three adaptations are featured: insulation (structural), huddling (behavioural), and the diving reflex (physiological).	students
Penguin adaptations worksheet	This is an optional worksheet for students to record data collected in experiments and answer questions about emperor penguin adaptations.	students

Purpose

To conduct experiments that model structural, physiological and behavioural adaptations of emperor penguins. Students **Explore** how different adaptations enable emperor penguins to survive the harsh conditions of the Antarctic.

Outcomes

Students:

- explore adaptations of emperor penguins in relation to the environment they inhabit; and
- identify adaptations as structural, physiological or behavioural.

Activity summary

ACTIVITY	POSSIBLE STRATEGY
Teachers distribute the procedure guide, *Investigating penguins*, that describes three experimental activities. The first activity contains two parts and teachers may choose to complete either or both parts. Activities may be completed over a number of laboratory sessions, as a caucus race, or in a single session with individual activities allocated to different groups.	small groups of 2–4 students
Teachers may instruct students to summarise each experiment in their workbooks, as indicated in the procedure guide. Alternatively distribute the worksheet, *Penguin adaptations*, which includes a structured guide for data recording and analysis.	individual
Student discussion may cover their experimental results; their understanding of emperor penguin adaptations; differences between different types of adaptations; and advantages each adaptation would confer on emperor penguins' survival.	whole class

Technical requirements

The teachers guide, fact sheet, procedure sheet and worksheet require Adobe Reader (version 5 or later), which is a free download from www.adobe.com. The procedure sheet and worksheet are also provided in Microsoft Word format.

Teachers notes

Emperor penguins (*Aptenoytes fosteri*) are the largest of seventeen species of penguin, and well known for breeding during the harsh Antarctic winter. Distributed around the Antarctic continent, they dive for food in waters of the Southern Ocean. Emperor penguins breed on sea ice, and breeding colonies are found around the continent.

Spending a life in one of the coldest environments on Earth requires specialised adaptations. The experiments outlined on the procedure sheet, Investigating penguins, are designed to allow students to explore some of these adaptations, and consider the emperor penguins' survival strategies.

Activity 1: Insulation

Background information for 'blubber glove' experiment

Emperor penguins have a number of adaptations to cope with cold conditions, including: subcutaneous fat, specialised feathers, and adaptations to enable recycling of body heat.

Water temperatures in the Southern Ocean can be as low as –1.9 °C so insulation during foraging dives is important for emperor penguins. A 2 cm layer of subcutaneous fat helps them retain body heat underwater. While this layer of fat aids in thermoregulation in water, it is not as effective as the thick blubber layers of whales, and penguins need to remain active to prevent declining body temperature.

Fat stores have other important functions for emperor penguins. They provide buoyancy in water and an energy store during fasting. Male emperor penguins rely on this fat store to survive the breeding season.

Emperor penguins have four layers of feathers. Outermost feathers are waterproofed with oil produced by the uropygial gland. These feathers lie flat and are unruffled by strong Antarctic winds. Emperor penguins have the densest feathers of any bird on the planet, at 15 feathers per cm^2.

Other adaptations of emperor penguins to cope with cold conditions include: countercurrent heat exchange systems in blood vessels of feet and bill; reduced surface area of feet and bill; and small surface area to body ratio.

Notes on activity 1 (parts A and B)

The 'blubber glove' experiment enables students to understand the importance of insulation in cold water. Students may be encouraged to consider other advantages of fat deposits in emperor penguins.

Results of this experiment should reveal benefits of insulation, as observed in emperor penguins. In part A the unprotected thermometer should reveal a greater reduction in temperature in the ice bath than the protected thermometer.

Students should not extend the time, beyond reasonable limits, of holding their gloved hand underwater— we recommend less than a minute. Extended exposure to very cold water can result in pain and reddening of skin. Skin temperatures below 10 °C will result in dilation of blood vessels to warm the area.

Estimated time to conduct activity: 15–20 minutes

Sample data

room temperature: 20 °C, water temperature: 10 °C

TIME (MINUTES)	GLOVE 1 (BLUBBER) TEMPERATURE (°C)	GLOVE 2 (NO BLUBBER TEMPERATURE (°C)
2	21	14
4	20.5	14

Table 1: temperature observations to illustrate effects of blubber as insulation.

Note: Vegetable shortening may begin to solidify or freeze after extended submersion in iced water.

This activity is based on one presented by Polar Palooza Educator's Corner. (nd) Life in the Cold and Dark: Penguin Adaptation, Retrieved April 19, 2012, from http://passporttoknowledge.com/polar-palooza/pp0901.php

Activity 2: Huddling

Background information for 'huddling' experiment

Breeding during the Antarctic winter exposes emperor penguins to extreme weather conditions such as air temperatures of –40° C and wind speeds of 200 km h^{-1}. Males fast for up to four months as they incubate a single egg.

Emperor penguins have evolved social behaviour that reduces impacts of harsh winter conditions. Huddling occurs throughout the breeding season and involves males grouping together in a tight bunch, with movement of animals on the outside of the group toward the centre. Measurement in the field has shown that huddling increases ambient air temperature significantly, up to 24 °C in tight huddles.

Huddling is a behavioural adaptation that allows emperor penguins to save energy and maintain their long breeding fast (four months) through the Antarctic winter.

Notes on activity 2

Care should be taken when dealing with hot water, and students should follow laboratory protocol. Students are encouraged to allocate tasks to each group member, during the monitoring phase of the experiment, to provide insight into scientific techniques in the field.

Students should take temperature measurements every two minutes.

Collected data may be affected by ambient air temperature, operation of fans, air conditioning or heating. Under warm room conditions temperature of the single test tube may rise. In these instances teachers may decide to turn off cooling or heating appliances.

Results of this experiment should reveal benefits of social huddling, as observed in emperor penguins. The central test tube within the group of test tubes should display a smaller reduction in temperature, compared to the single test tube.

Estimated time to conduct activity: 15-20 minutes.

Sample data

room temperature: 24 °C

TIME (MINUTES)	SINGLE TEST TUBE TEMPERATURE (°C)	GROUPED TEST TUBES TEMPERATURE (°C)
0	59	59
2	48	55
4	41	50
6	36	47
8	33	45
10	31	43
12	30	42
14	28	41
16	27	40
18	26	39
20	25	38
total drop in temperature	34	21

Table 2: temperature values of test tubes to illustrate huddling and non-huddling behaviour

Activity 3: Diving reflex

Background information for 'diving reflex' experiment

The diving reflex is an evolutionary strategy present in all mammals, and some birds and reptiles. The diving reflex is a survival strategy activated by inadequate oxygen in body tissue, known as hypoxic conditions.

The diving reflex triggers:

- apnea — cessation of breathing to prevent water entering the respiratory system;
- bradycardia — decline in heart rate to reduce oxygen use; and
- peripheral vasoconstriction — shunting blood away from non-essential extremities and organs.

The diving reflex is stimulated by cessation of breathing (apnea) and cold water to the facial area, specifically, stimulus of trigeminal nerve receptors.

The diving reflex is strongest in air-breathing diving animals, particularly cetaceans (whales and dolphins) and pinnipeds (walruses and seals). It is variable in humans but results in average reductions in heart rate of 20–30% (approximately 20 bpm). In trained freedivers the diving reflex is stronger and there may be a 40–50% decline in heart rate.

The diving reflex involves circulatory changes. Blood is diverted away from extremities and some organs, reducing cardiac output and oxygen demands. Blood supply is always maintained to oxygen-sensitive organs such as the brain and heart.

Notes on activity 3

Heart rate monitors are recommended for this experiment and are available through the Regional loan pool. If they are not available, radial pulse measurements can be made manually.

Results from this experiment, in the classroom, are often highly variable. Controlling as many factors as possible is recommended, including test posture, water temperature, and maintaining quiet conditions.

Individual variation will be evident when conducting the experiment, as the dive reflex is more pronounced in some individuals. Pooling class data can provide clearer evidence of it.

An initial period of tachycardia (increased heart rate) is often observed during facial immersion, due to the shock of cold water or anticipatory excitement/anxiety. Increased activity or boisterous behaviour prior to breath-hold may obscure the dive reflex.

Student participation in this experiment is optional. Students must only breath-hold to the limits of their comfort.

Water temperatures less than 10 °C are not recommended, as they may cause pain and skin reddening. Skin temperatures below 10 °C can result in dilation of blood vessels to warm the area and cause reddening of skin.

Sample data have been provided for those teachers who do not wish to engage their class in this activity. Students can interpret these data to investigate the dive reflex.

Excellent videos are available on the dive reflex to complement the experiment. Wonders of the Human Body (BBC, http://www.youtube.com/watch?v=oemp6TTtFQQ) is recommended.

Adaptations 5: Diving adaptations and *Adaptations 6: The risks of diving to depth* explore the diving reflex in greater detail.

Estimated time to conduct activity: 30 minutes

Sample data

Water temperature for subject 1 was 9 °C and for subject 2 was 12 °C.

Average resting heart rate for subject 1 was 73 bpm and for subject 2 was 89 bpm.

TIME (SECONDS)	RESTING HEART RATE (BPM)		BREATH-HOLD HEART RATE (BPM)		IMMERSION HEART RATE (BPM)	
	SUBJECT 1	SUBJECT 2	SUBJECT 1	SUBJECT 2	SUBJECT 1	SUBJECT 2
0	73	94	75	94	80	94
15	72	82	70	118	73	82
30	74	92	69	105	48	67

Table 3: heart rate measurements for two subjects.

This activity is based on material presented in Hiebert, S. M. and Burch, E. (2003). Simulated Human Diving and Heart Rate: Making the most of the diving response as a laboratory exercise. *Advances in Physiology Education, 27*(3), 130–145.

Associated SPICE resources

Adaptations 2: Emperor penguins may be used in conjunction with related SPICE resources to study structural, physiological and behavioural adaptations.

DESCRIPTION	LEARNING PURPOSE
Adaptations (overview) This learning pathway shows how a number of SPICE resources can be combined to teach the concept of adaptations in plants and animals.	
Adaptations 1: Defining adaptations An interactive quiz encourages students to differentiate between different types of adaptation: structural, behavioural or physiological.	**Engage**
Adaptations 2: Emperor penguins Students conduct experiments to model structural, physiological and behavioural adaptations of emperor penguins.	**Explore**
Adaptations 3: Barrow Island marsupials Students use a learning object to investigate adaptations of four marsupials that live on Barrow Island.	**Explain**
Adaptations 4: Samphires A profile diagram of a lake provides students with an opportunity to determine which species of samphire would be mostly likely to survive in particular locations.	**Explain**
Adaptations 5: Diving adaptations Students use a learning object to compare and contrast physiological, structural and behavioural adaptations of air-breathing diving animals.	**Explain**
Adaptations 6: Freediving Students watch a video of a human freediver and consider differences between acclimatisation and adaptation. Students review risks of diving associated with pressure.	**Elaborate**

SPICE resources and copyright

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banner image: 'An emperor penguin swims under the sea ice of McMurdo Sound' by Emily Stone, Courtesy: National Science Foundation.

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