COSMOS LESSONS

Biology

Thermoregulation: No sweat

How would you keep cool if you weighed a tonne and had to lumber around under a thick, armoured exoskeleton? Ankylosaurs used their noses. But that's just one of the ways that animals over the ages have managed to stay at the right temperature.

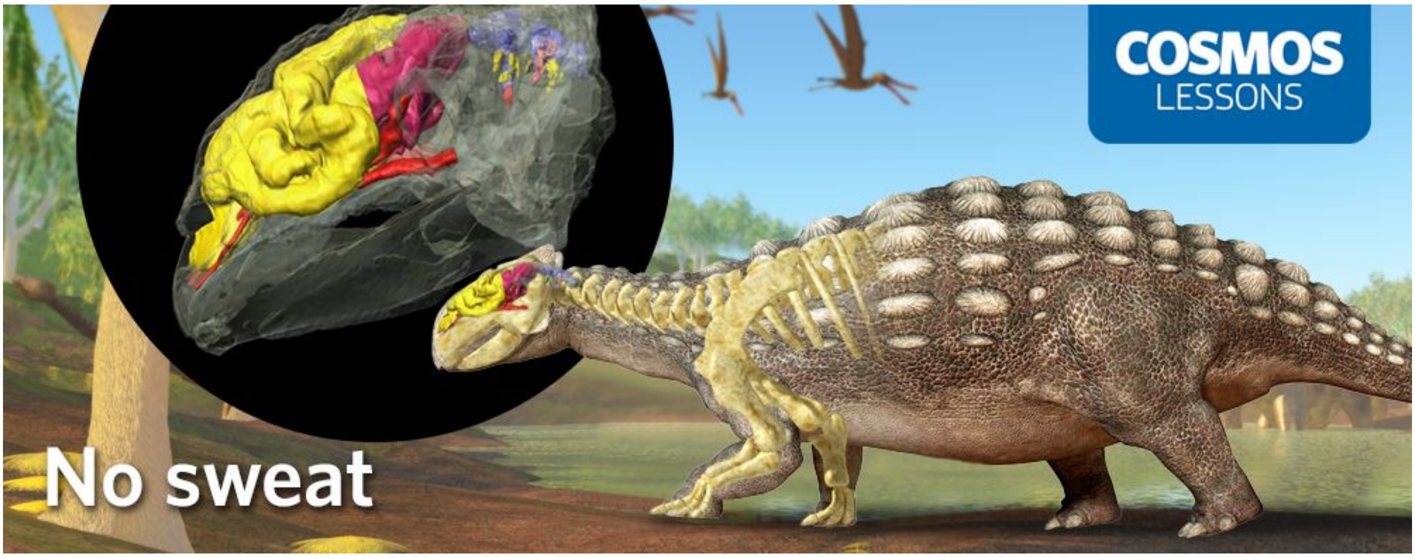
In this lesson you will investigate the following:

- What is thermoregulation?
- What are endotherms and ectotherms?
- What are some of the different methods animals use to avoid getting too hot or too cold?
- What's the best insulator?

Time to heat things up and get into the lesson!

This is a print version of an interactive online lesson. To sign up for the real thing or for curriculum details about the lesson go to **www.cosmosforschools.com**

Introduction: Thermoregulation



Imagine trying to keep cool by walking around with an air-conditioner on your head. That’s almost what the armour-plated dinosaurs – ankylosaurs – used to do. These giant creatures weighed up to four tonnes and their bodies were covered in thick armour to protect them from being eaten by the T-rex, their mortal enemy. Adding to the weight were bony knobs, called scutes, in lines all along their backs and tails. These gave a bit more protection, along with a powerful tail that they probably used for defence.

But underneath all the armour it was hot – very hot. If they hadn't been able to find a way to cool down the ankylosaurs' little brains would have overheated, killing the animals.

Scientists now think that they used their big heads and the long winding passages behind their noses to cool their blood down. The passages there twist around like crazy straws, the scientists say. That gives a large surface area for heat in the blood to be transferred into the animals' breath.

Modern mammals and birds have a different solution to a similar problem. They use curled bones inside their nasal cavities to increase the surface area that their breath flows over. Ankylosaurs just made their nasal tubes longer.

But ankylosaur nostrils are just one of a wide variety of methods that different animals use to keep their temperature in check – either to warm up or cool down.

Read the full *Cosmos Newsblog* post here.

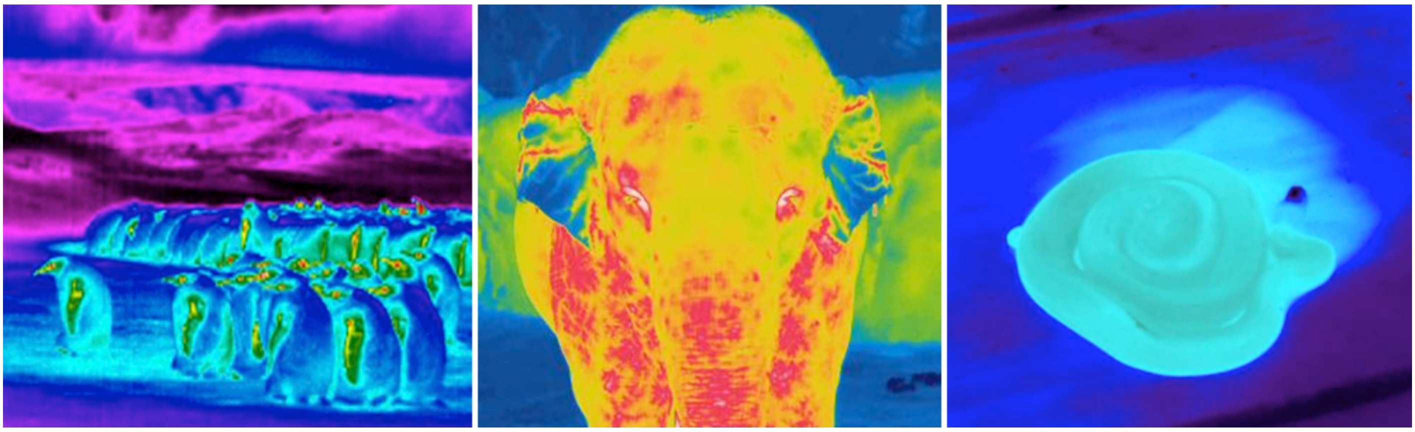
Question 1

Describe: We don't have air conditioner noses like ankylosaurs. What do you do to keep cool, or warm up?

In the table below, describe two times you felt hot and two times you felt cold. Explain what you did to cool down or warm up.

I remember feeling	when	I	by
hot		cooled down	
hot		cooled down	
cold		warmed up	
cold		warmed up	

Gather: Thermoregulation



These infrared images, of penguins, an elephant, and a snake, show the heat, in yellow and red, escaping from their bodies.

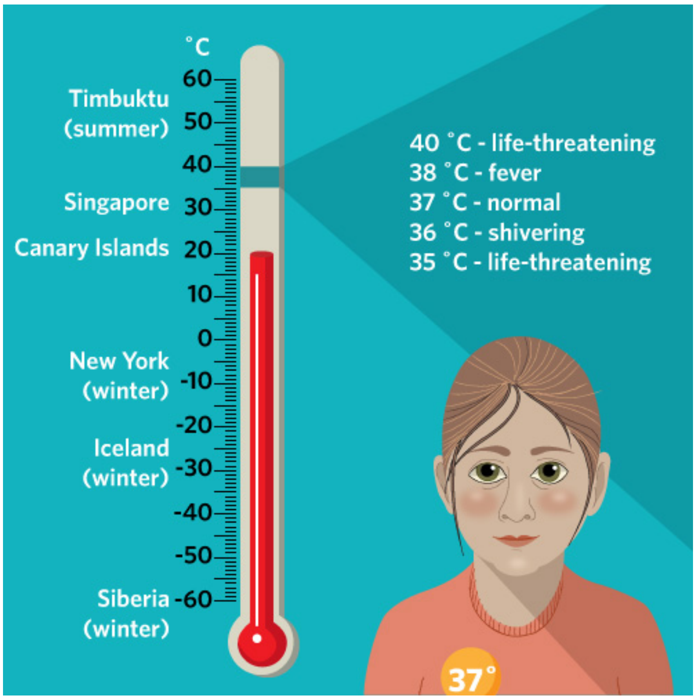
Minus 60° Celsius – that's cold. And positive 55° C – that's hot. Yet humans live in parts of the world where these temperatures occur fairly regularly every year. And they live at places with every temperature in between. It adds up to a range of 115°, so it's amazing that our bodies have to stay within a five degree range or else we die!

The range where our bodies work well is even smaller – half a degree for most people, somewhere between 36.5° C and 37.5° C. Thirty seven degrees is usually considered normal.

For most of the time, at most of the places humans live, the air temperature is below 37 degrees, so you might think that we need to find sources of heat to bring our temperatures up. But we provide most of our own heat with trillions of chemical reactions in our bodies, called our *metabolism*. These reactions include digestion and "burning" chemical energy in our muscles.

With air temperature and sunlight always changing and people going between hard work, light work, and doing nothing at all, the body has a tool kit of different ways to warm up and cool down, so it stays in the half-degree range where it is healthy. These different methods are called *thermoregulation* (*thermo* means heat).

But it's not only humans that do this. Answer the questions below and then watch the video to see how some other animals handle thermoregulation.



Question 1

Recall: If your body is at 38° C you are probably:

- ☐ in a fever
- ☐ shivering
- ☐ feeling fine
- ☐ dead

Question 2

Recall: If your body is at 30° C you are probably:

- ☐ dead
- ☐ feeling fine
- ☐ in a fever
- ☐ shivering

Question 3

Review: *Metabolism* is:

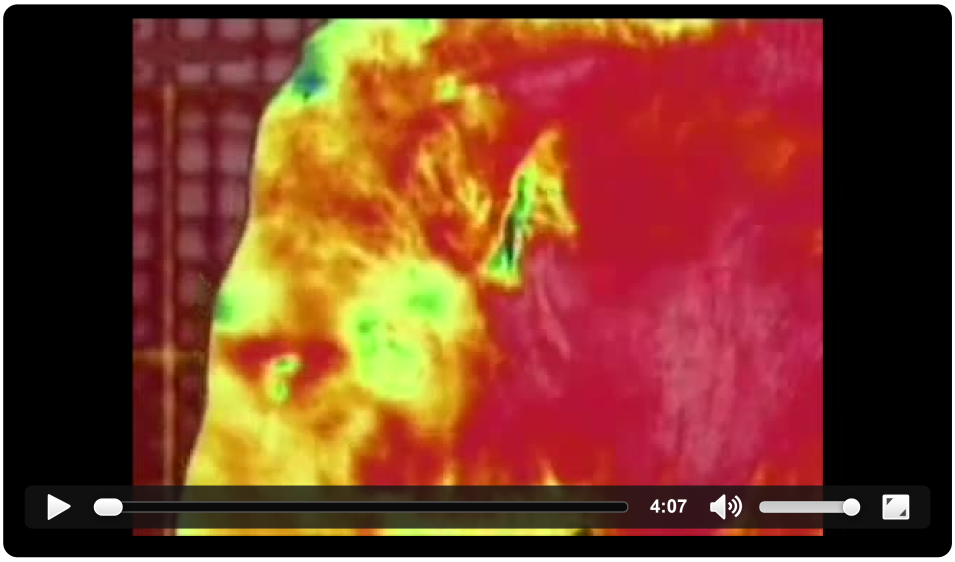
Hint: There may be more than one correct answer.

- ☐ the main source of heat in the body.
- ☐ when you exercise your muscles.
- ☐ all the chemical processes that occur in our cells, but not digestion.
- ☐ all the chemical processes that occur in our bodies.

Question 4

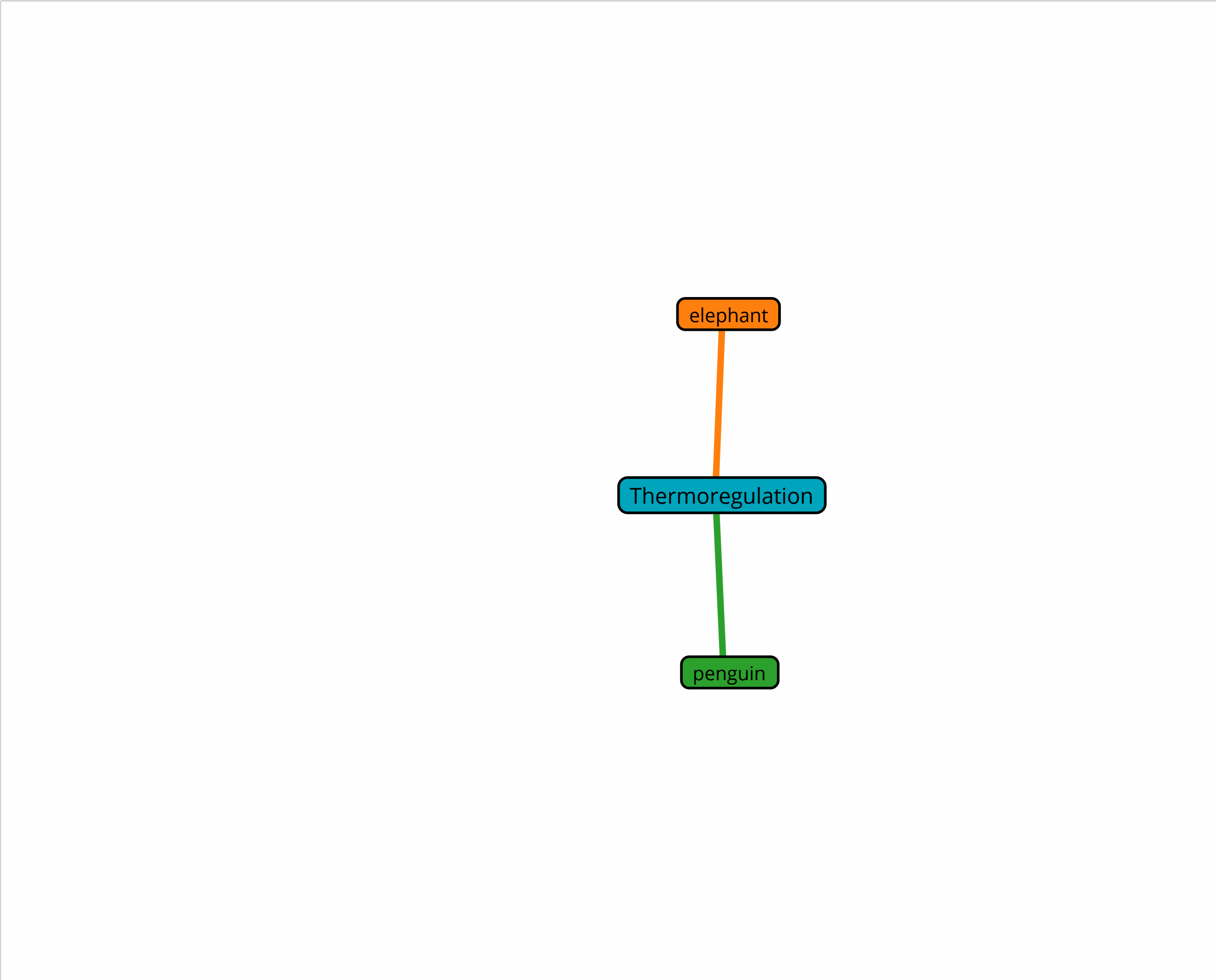
Review: *Thermoregulation* is:

- ☐ all the methods our bodies use to stay at the right temperature.
- ☐ a chemical reaction that keeps our bodies warm.
- ☐ all the methods our bodies use to warm up, but not cool down.
- ☐ all the methods our bodies use to cool down, but not warm up.



Question 5

Remember: Using the mind map below, identify as many examples of thermoregulation in elephants and penguins as you can. Find at least 3 for each.



Structure and behaviour

Some of the ways that animals thermoregulate are *structural*, meaning they rely on the way the animals' bodies are built. For example, elephants' large thin ears are structural features.

Other ways of thermoregulating are *behavioural*, meaning that they are things that animals do. When elephants flap their ears, that is a behaviour.

Question 6

Tabulate: Pick two examples each of elephant and penguin thermoregulation and:

1. say if it is to lose heat or retain heat,
2. explain briefly how it works, and
3. classify it as structural, behavioural, or both.

An example of human thermoregulation has been put in to help you get started.

Animal	Example	To lose or keep heat?	How does it work?	Structural or behavioural
Human	*putting on extra clothes*	*keep heat*	*The clothes form a layer around the body that holds heat in.*	*behavioural*
Elephant				
Elephant				
Penguin				
Penguin				

Did you know?

One of the easiest ways to stay cool on a hot day is to stay in the shade. That's what the sooty tern chicks are doing in the photo to the right, using a handy, and much bigger, black-footed albatross chick as their shade sail.

On the other hand, if you want to warm up, sit in the sun. Your cat probably knows this trick.

Endotherms and ectotherms

Elephants, penguins and humans – in fact all birds and mammals – are *endotherms*, or "warm-blooded" animals. Their bodies use thermoregulation to stay at a near-constant, warm, temperature. This keeps their bodies operating optimally day and night, summer and winter.

But it takes a lot of energy to keep your temperature up, and that means you have to eat a lot. So many animals use a different strategy. Reptiles, like crocodiles and lizards; amphibians, like frogs and salamanders; invertebrates, like insects and sea slugs; and fish – do not use their metabolisms for heat but instead allow their body temperatures to vary. These are *ectotherms*, or "cold-blooded" animals.

Still, most ectotherms have structural features and behaviours that they use to keep their temperatures as close as possible to an optimum level – they also thermoregulate.

Question 7

Recall: Black-throated monitors can go for long periods without eating because they do not need food to generate body heat.

- True
- False

Question 8

Recall: River turtles avoid the sun because they are ectotherms.

- True
- False

Question 9

Recall: The big ears of white-tailed deer are designed to catch the sunlight and warm the animals.

- True
- False

Question 10

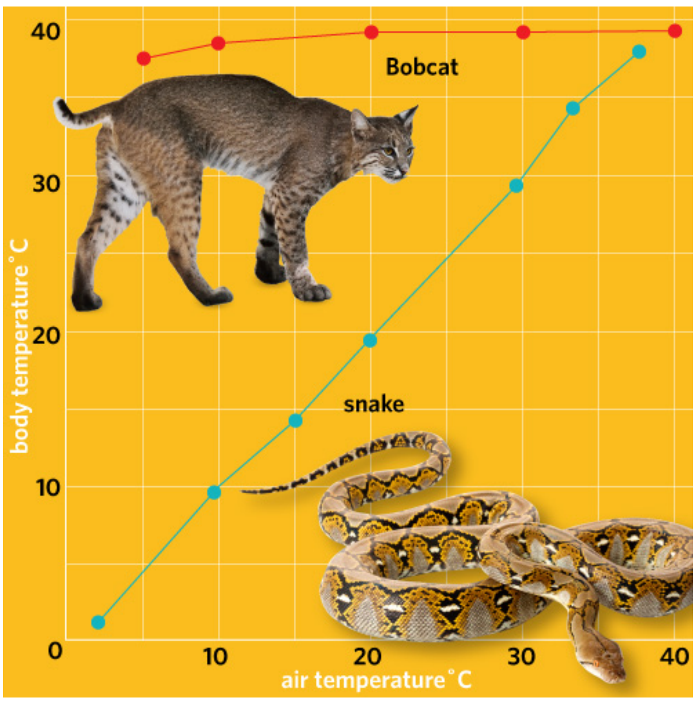
Recall: American alligators use their scutes to help warm up and to cool down.

- True
- False

Question 11

Compare: The graph on the right shows the body temperatures of a bobcat and a snake at different air temperatures .

1. What are the body temperatures of the snake and bobcat when the air temperature is 15° C?
2. What are their body temperatures when the air temperature is 30° C?
3. Are the animals endotherms or ectotherms? Explain your answer.



Process: Thermoregulation

Left: An anhinga, from central America, spreads its wings to catch the sun and warm up. Right: A puppy curls up to keep warm while it is sleeping.

Common themes

There are some common themes in the different methods of thermoregulation we have looked at.

- Evaporation: when moisture on a surface of an animal moves into the air it takes heat energy with it and cools the animal down.
- Insulation: when an animal has some form of covering around it it stops heat leaving the animal.
- Surface area: special areas of animals are made as large or as small as possible depending on what form of thermoregulation the surface is used for.

Question 1

Categorize: Some of the methods of thermoregulation that we have looked at are listed in the table below.

1. Type "Yes" in the appropriate column if the method uses evaporation or insulation.
2. Type "Large" or "Small" in the surface area column if having a large or small surface area is important to the method. Briefly state why.

Note: Some table cells will remain empty.

Animal	Method of thermoregulation	Evaporation	Insulation	Surface area
Elephant	Ears			
Elephant	Mud bathing			
Penguin	Huddling			
Penguin	Standing on heels			
River turtle	Sun bathing			
Otter	Thick coat			
Alligator	Opening mouth			

Did you know?

Fans are a good way to keep cool.

If there's no breeze the air close to your skin gets warmed up by your body, and stays there. If there is evaporation this air becomes full of moisture as well. So you become surrounded by a layer of warm, possibly moist air. That means you don't cool down much.

Blow the warm air away with cooler air that your body hasn't warmed, and you feel cooler.

Garrett knew it was important to keep his brain from overheating during big tests.

Cosmos Student: Thermoregulation specialist

Now that you are an expert in thermoregulation some of your scientist colleagues – who aren't up in the field – are asking for your help. They've discovered some structural features and behaviours in humans and koalas and they're not sure whether they are involved with thermoregulation or not. Can you help them?

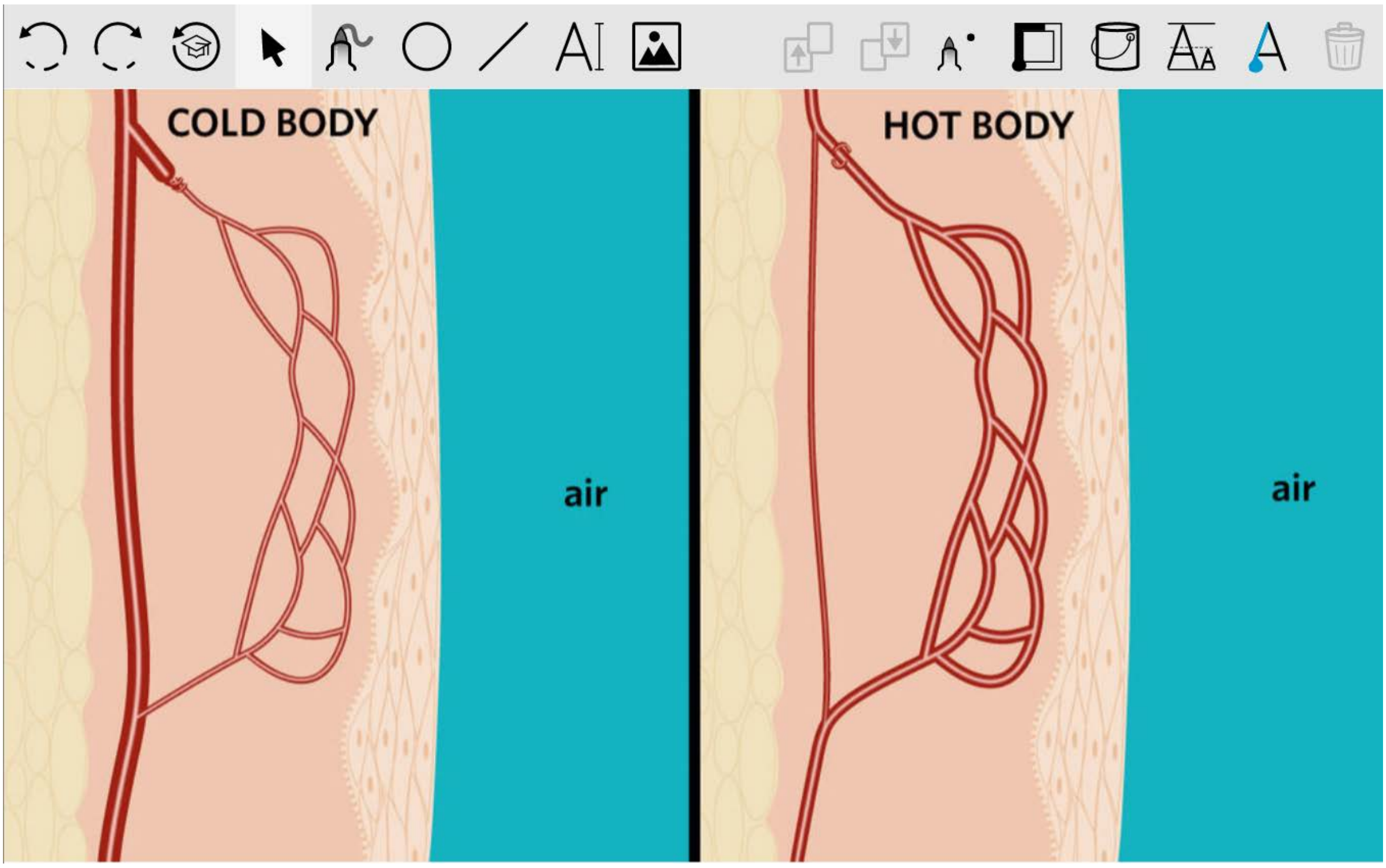
Question 2

Label: A colleague studying the human body has discovered intricate networks of blood vessels just under the skin. What's more, she's noticed that **more blood** flows through the branches **near to the skin's surface** when the body is **hot**. She has illustrated this for you in the diagrams in the sketchpad below. She has shown how much blood flows through the vessels by their thickness.

Could this be an example of thermoregulation?

Explain your answer in the question below the sketchpad. In the sketchpad label the diagrams to illustrate your explanation, e.g. with arrows to represent heat transfer.

Hint: Elephant ears.



Question 3

Explain: Explain how the structures and changes in blood flow that your colleague drew for you in the sketchpad could be a method of thermoregulation.

Question 4

Interpret: Another colleague has captured some great footage of someone sweating (right).

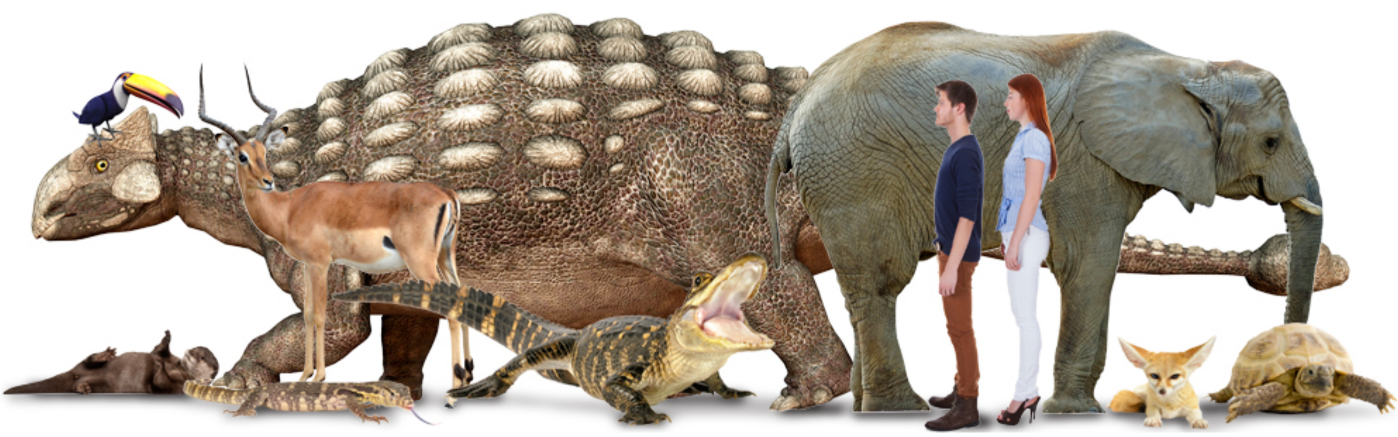
1. How might this be a means of thermoregulation?
2. Elephants don't sweat, but this could be similar to something you have observed for them.
   What method of elephant thermoregulation is sweating most similar to, and how is it different?

Question 5

Connect: A third colleague studies koalas and has noticed that on hot days they spend a lot of time wrapped around tree branches, as you can see in the photo above. He has also supplied an infrared image, showing the temperatures of the koala and its surrounds.

The scientist also tells you that koalas have thinner fur on their bellies than on their backs and limbs.

Do you think this is an example of thermoregulation? What would you say to your colleague to explain?



Question 6

Design-a-critter

Create: Using all that you have learnt about thermoregulation, design an animal that is well-suited to staying at the right temperature in its environment. It can be a bird, mammal, reptile or something else that you make up, but you need to decide if it is an ectotherm or an endotherm.

1. First, say what environment your animal lives in – in water or on land, hot or cold, or hot *and* cold. What about wind, sun, shade, rain and snow?
2. Draw your animal in its environment and label the drawing to point out the thermoregulating features. Draw diagrams of any small or internal features used for thermoregulation.
3. Describe any thermoregulating behaviours your animal has.

Make use of any of the tools below and let your imagination go!

Apply: Thermoregulation

COSMOS LESSONS

Experiment: Fat, feathers or fur – modelling insulation

Animals use a range of insulating materials: walruses use blubber, Victoria crowned pigeons use feathers (although their crowns presumably don't help thermoregulation), and yaks use fur. The almost hairless sphynx cat runs a hotter body temperature than other cats, at 39° C, perhaps to help compensate for the lack of insulation.

Background

Many animals use insulation to keep heat in their bodies. The main insulating materials in nature are fat (e.g. seals), feathers (e.g. penguins), fur (e.g. otters) and wool (e.g. sheep). How effective are these materials as insulators?

Aim

To model body insulating materials found in nature and measure their effectiveness.

Safety

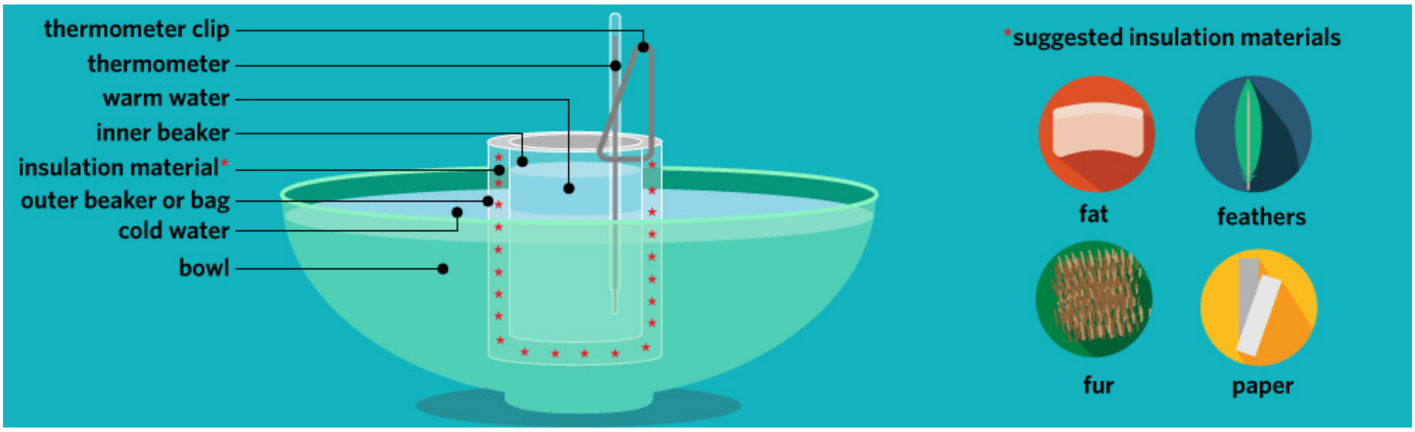
If using glass beakers take care not to overfill the insulating material so that you have to force the small beaker into the larger one. That could break one or both of them. Take care with the thermometer which is fragile and contains poisonous mercury.

Materials

The materials below are to test one material.

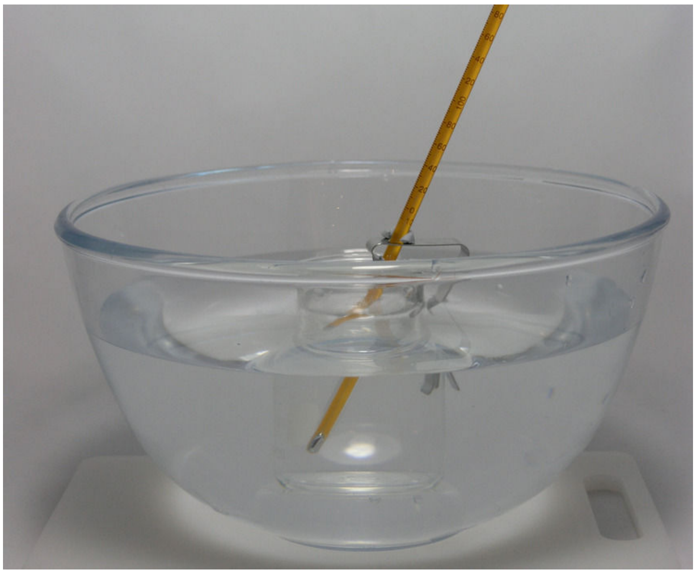
- 2 beakers of different sizes, so that one fits inside the other. There needs to be enough space between the beakers to pack the insulating material all around and underneath – say about 1 cm. Standard 100 mL and 250 mL beakers are about right. You can use old food tins too – just make sure there are no sharp edges.
  Another alternative is to replace the large beaker with a plastic bag. The bag needs to be the right size so it fits snugly around the inner beaker and insulating material.
- 1 bowl large enough for the beakers to sit in with a reasonable amount of water around them.
- tape to hold beakers down if they float.
- 1 thermometer and, if you have it, something to hold it in the small beaker. Otherwise you will have to hold the thermometer by hand.

- warm water and cold water
- 1 timing device
- different materials to use as insulation. Discuss with your teacher what materials to use.



Procedure

1. Place the small beaker inside the large one with insulating material carefully packed between them.
2. Place the beakers in the bowl with warm water in the small beaker and cold water in the bowl.
    a. Plan this step ahead so you can do it quickly and without spillage.
    b. In your plan, remember that you will have to repeat this step for other insulators and/or a control, where you will use no insulating material. Plan to ensure that the temperatures of the warm water and cold water are the same for each trial.
    c. Where you are using a light material to insulate, e.g. fur or feathers, be prepared for the large beaker to float. Tape across to to the bowl on either side to hold it firm.
3. Record the temperature of the water in the small beaker immediately you have completed the previous step, and then repeat every 2 minutes for 20 minutes.
4. Repeat this procedure for as many insulating materials as you are testing.
5. IMPORTANT: Repeat the procedure a final time with the small beaker placed directly in the cold water. This is your control experiment.



Control experiment, with no insulation.

Results

Question 1

Record: Record your measurements in the table below (there is room for 5 insulating materials). Make sure you add which insulation was used at the top of each column.

	Control: no insulation					
Time (minutes)	Temperature (°C)	Temperature (°C)	Temperature (°C)	Temperature (°C)	Temperature (°C)	Temperature (°C)
0						
2						
4						
6						
8						
10						
12						
14						
16						
18						
20						

Question 2

Identify: What are the independent and dependent variables in this experiment?

Hint: The independent variable is something that changes with each measurement and that you control, or you know beforehand what it will be. The dependent variable is what you are measuring.

Question 3

Graph: Graph your results. Decide what values to put on each axis and label the axes and name the graph. Don't forget to include the units.

Note: The Graph tool in the project space below has a maximum of three plots, so you can use it if you test two insulating materials plus the control. If you need more plots either draw your graph on paper then photograph and upload, or draw it in the sketchpad.

Discussion

Question 4

Compare: Compare the results you got for the different insulating materials and contrast all of them with the control. Note any results that surprised you or that stand out as interesting.

Question 5

Review: Review your experimental procedure. Did it go well? If not, why not? What changes would you make if you did the experiment again?

Conclusion

Question 6

Conclude: Write a short paragraph to summarize the results of the experiment. This should directly address the experiment's aim.

Career: Thermoregulation

Brought to you by Edith Cowan University

Question 1

Ponder: Do you think you would like to be a paleontologist? Why or why not? Which parts of the job would you like best, and least?

Cosmos Lessons team

Lesson author: Deb Taylor
Profile author: Bill Condie
Editors: Jim Rountree and Campbell Edgar
Art director: Wendy Johns
Education director: Daniel Pikler

Image credits: iStock, Shutterstock, "BFAL SOTE shade" by Duncan Wright, BBC Nature, USFWS; Witmer Lab, Leonello Calvetti, Duncan Wright USFWS, Steve Griffiths, Matt Rece, Université de Strasbourg/Centre National de la Recherche Scientifique (CNRS)

Video credits: Nisar Ahmad Shah, Brevard Zoo, Mash Medics, Untamed Science, YouTube