Regulation of body temperature in humans

Introduction

In endothermic animals such as mammals and birds, normal metabolism requires that the body remain at a relatively constant temperature. In order to do this, the body must achieve a balance between heat loss and heat production by the body. If the body becomes too cold it will attempt to minimise heat loss at the same time as it increases heat production. If the body becomes too hot it will attempt to minimise heat production and maximise heat loss.

Aim

To decsribe how humans respond to changes in temperature and relate these responses to heat production and heat loss.

Data

Table 1: Human responses to environmental temperature

Environ. temp (°C)	Body temp (°C)	Observed responses	Observed behaviour
0	21	fingernails, toenails, lips and nose appear blue, sleepiness and disorientation, coma and death	
10	35	skin feels cold to the touch, fingers, toes, nose and ears cold, lips appear blue, violent shivering	curled in a ball
20	37	skin feels cool to the touch, muscle tension, slight to moderate shivering	arms crossed, hunched shoulders, rubbing skin, swinging arms, moving around
30	37	slight perspiration	appears comfortable and relaxed, moving freely
40	37	perspiration, redness in the face and skin	sitting still, arms and legs apart, fanning
50	38	increased perspiration, redness spreading to body	sitting still, arms and legs spread out
60	40	profuse perspiration, redness over whole body, dizziness	lying down, arms and legs spread out
70	48	sweating diminishes, coma and death	collapse

Table 2: The influence of head temperature on heat production and heat loss in humans

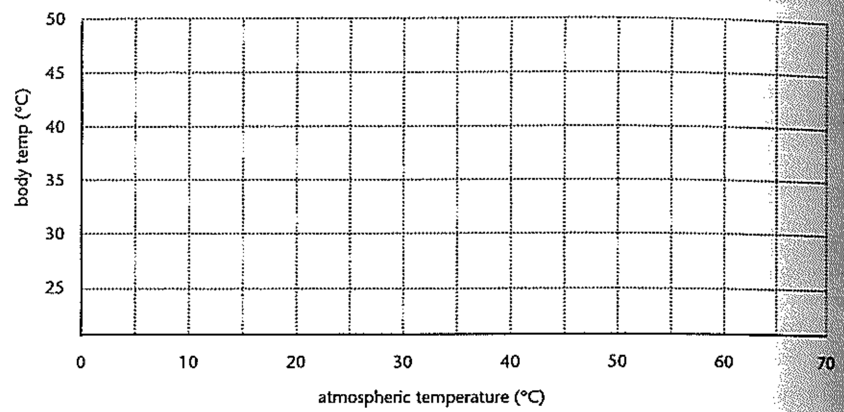
Head temperature (°C)	36.4	36.5	36.6	36.7	36.8	36.9	37.0	37.1	37.2	37.3	37.4	37.5	37.6
Heat production (joules/second)	336	320	294	275	252	205	147	86	86	86	86	86	86
Evaporative heat loss (joules/second)	8	8	8	8	8	8	8	95	190	245	300	345	390

Reference
Guyton, A. C. *Textbook of medical physiology*, W. B. Saunders Company, Philadelphia, 1976.

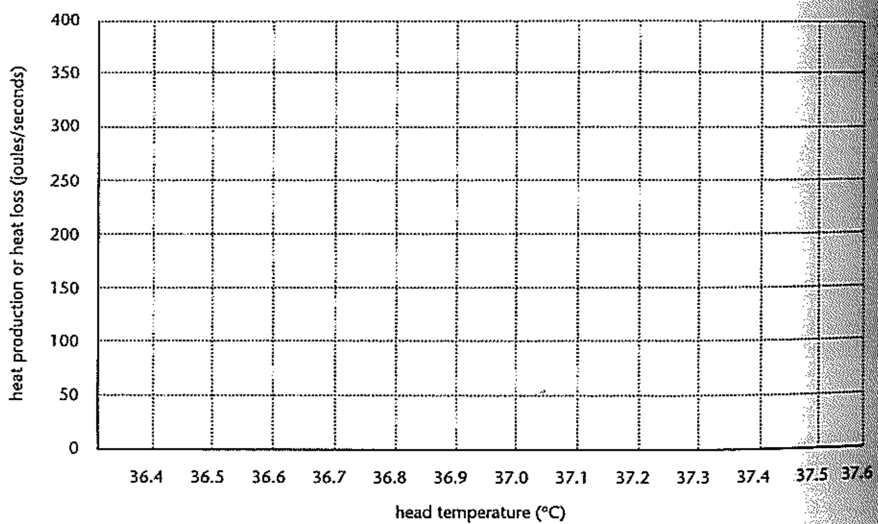
Graphing the data

1 Graph the data in Tables 1 and 2 on the axes below

Body temperature at different atmospheric temperatures



Heat production and heat loss against head temperature



Describing the data

1 Between what atmospheric temperatures is the body able to maintain a relatively stable body temperature?

2 What are the two main body responses to environmental temperatures over 30°C?

3 What are the three main body responses to prolonged exposure to temperatures below 20°C?

4 Between what head temperatures does the body switch from heat production to heat loss?

Interpreting the data

5 Link each of the body responses and behaviours below to a physiological explanation. One has been done for you. *Please note:* in some cases, more than one body response or behaviour can have the same physiological explanation.

Body response or behaviour	Physiological explanation
Sleepiness and disorientation	
Curled in a ball, arms crossed	These behaviours reduce the surface area of the body exposed to cold and so reduce the rate of heat loss.
Lips and nose appear blue	These behaviours increase the surface area of the body and so increase the rate of heat loss.
Swinging arms, moving around	Person has hypothermia and their low body temperature is now disrupting the biochemistry of the brain.
Skin feels cold	Perspiration evaporates from the skin causing evaporative cooling. Heat moves from the blood into the cool skin.
Shivering	Peripheral blood vessels (those in the skin) are constricted (closed up) reducing the blood supply to the skin. This cools the skin and reduces the rate of heat loss.
Perspiration	Peripheral blood vessels are dilated (opened up) increasing the blood supply to the skin, increasing heat loss.
Arms and legs spread out	Due to prolonged exposure to heat, the body has become dehydrated and, as a result, is no longer able to perspire at the same rate.
Redness in the face and skin	Body movement increases heat production by the body.
Sweating diminishes	

6 Explain how behaviour, perspiration and the dilation of peripheral blood vessels work together to maintain a constant body temperature at high environmental temperatures.

7 Explain how behaviour, increased metabolic rate and constriction of peripheral blood vessels work together to maintain a constant body temperature at low environmental temperatures.

8 Describe the evidence in the data that supports the hypothesis that the control of body temperature is located in the brain.

Temperature control and water loss in humans

Introduction

Humans, like birds and other mammals, are endothermic. The human body is maintained at a relatively constant temperature by a number of mechanisms:

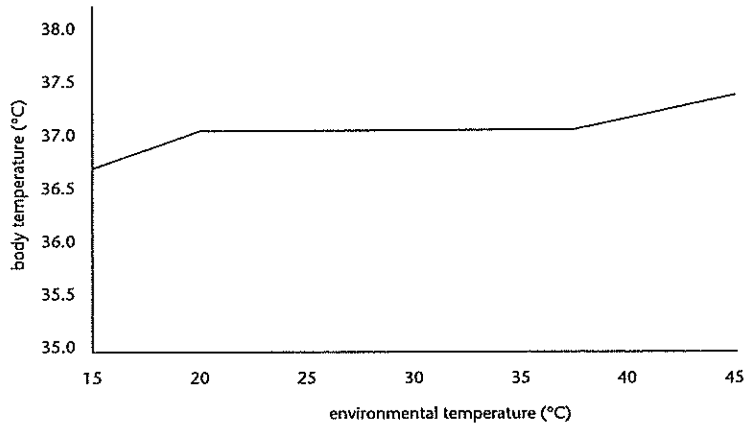
- If the core temperature drops, the body can limit heat loss by constricting (narrowing) the peripheral blood vessels (in the skin), raising body hair and generating extra heat by shivering.
- If the core temperature rises, the body can lose heat by sweating. As the sweat evaporates, it cools the skin and the blood flowing through the skin. This process is made more efficient by dilating (widening) the peripheral blood vessels so that more blood comes in contact with the cooled skin layer.

Aim

To investigate the mechanisms for temperature control in humans and the loss of water through sweating.

Data

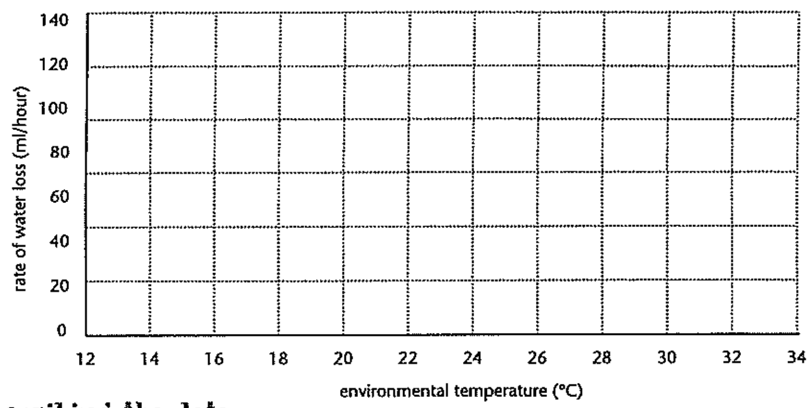
Effect of increasing environmental temperature on body temperature in humans



Rate of water loss in humans during increasing environmental temperature

Environmental temperature (°C)	Rate of water loss (ml/hour)	Observations
12	20	constant shivering
14	22	extremities cold
16	24	shivering
18	26	skin cold to touch
20	28	goose bumps appear on the skin.
22	30	
24	32	
26	34	
28	36	sweating
30	40	thirsty
32	68	skin colour becomes redder
34	118	lower volume of darker coloured urine.

Graph the environmental temperature and the rate of water loss below



Describing the data

1. Describe the relationship between body temperature and environmental temperature.
2. Describe the relationship between water loss and environmental temperature.
3. At what temperature does water loss due to sweating begin?
4. What other effects does increasing environmental temperature have on the body?

Making links

The observations in the table above show how the body responds to water loss by sweating

5. Draw lines to link the body's response with the organs involved and the explanation. Two are done for you.

Body responses to change in environmental temperature

Body's response	Organs involved	Explanation
shivering	kidneys	reduced blood volume and increased blood concentration→ hormone signal→kidneys reabsorb more water→less water in urine→urine more concentrated→less water lost
skin cold to touch	brain and peripheral blood vessels	decrease in body temperature→brain signals an increase in muscle tension→increasing muscle tension results in shivering→heat production increased by up to 500%
feeling thirsty	brain	increase in body temperature→brain signals to blood vessels →blood vessels in skin dilate (widen)→more blood flows to skin→blood cooled →body temperature returns to normal
redder skin colour	brain and peripheral blood vessels	blood more concentrated→thirst centre in brain activated →person feels thirsty and drinks→blood returns to normal concentration
lower volume of darker urine	brain and body muscles	decrease in body temperature→brain signals to blood vessels →blood vessels in skin constrict (become narrower)→less blood flows to skin→heat loss reduced

Write a brief summary of:

- the effect of the peripheral blood vessels on temperature control.
- the effects of sweating on temperature control and water loss.

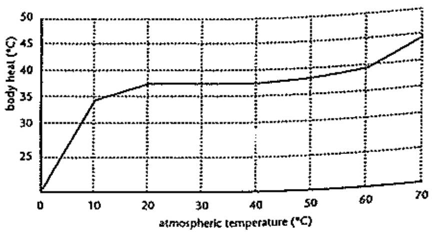
Making links

Adaptation	Reason or advantage
Large thin ears	Radiate heat into surrounding air
Lizard lying in the ground in the early morning	Avoid extremes in temperatures
Roll into a furry ball	To warm the body
Thick fur	To insulate, keeping heat inside body
Lizard burrowing	To prevent heat loss by reducing the SA/Vol

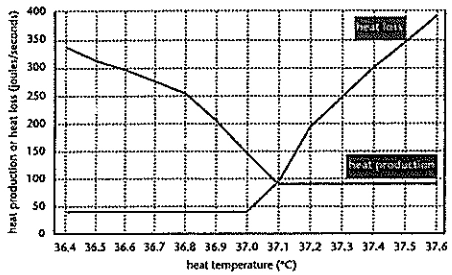
Activity 5: Regulation of body temperature in humans

Graphing the data

Body temperature at different atmospheric temperatures



Heat production and heat loss against head temperature



Describing the data

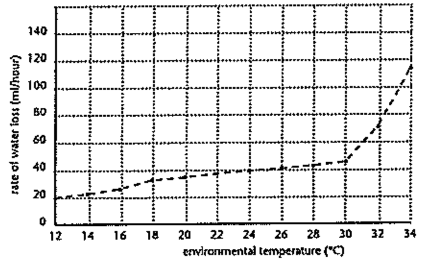
1 Between 20°C and 50°C
2 Perspiration and redness
3 Cold skin, shivering, extremities and lips appear blue.
4 Between 37°C and 37.1°C

5 **Interpreting the data**

Body response or behaviour	Physiological explanation
Sleepiness and disorientation	These behaviours reduce the surface area of the body exposed to cold and so reduce the rate of heat loss.
Curled in a ball, arms crossed	These behaviours increase the surface area of the body and so increase the rate of heat loss.
Lips and nose appear blue	Person has hypothermia and their low body temperature is now disrupting the biochemistry of the brain.
Swinging arms, moving around	Perspiration evaporates from the skin causing evaporative cooling. Heat moves from the blood into the cool skin.
Skin feels cold	Peripheral blood vessels (those in the skin) are constricted (closed up) reducing the blood supply to the skin. This cools the skin and reduces the rate of heat loss.
Shivering	Peripheral blood vessels are dilated (opened up) increasing the blood supply to the skin, increasing heat loss.
Perspiration	Due to prolonged exposure to heat, the body has become dehydrated and, as a result, is no longer able to perspire at the same rate.
Arms and legs spread out	Body movement increases heat production by the body.
Redness in the face and skin	
Sweating diminishes	

6 Dilation of peripheral blood vessels sends more blood to the skin to be cooled by perspiration. Spreading the arms and legs exposes the skin surface to the air for evaporative cooling. These adaptations all increase heat loss.
7 Movement, shivering and increased metabolic rate increase heat production. Constriction of peripheral blood vessels reduces the volume of blood that flows through the cool skin and reduces heat loss.
8 A very small change in head temperature stimulates metabolic changes. Other parts can fluctuate more in temperature.

Activity 6: Temperature control and water loss in humans



Describing the data

1 Body temperature remains constant despite changes in environmental temperature.
2 Water loss increases as environmental temperature rises.
3 At about 28°C.
4 The body starts to sweat and the skin colour becomes redder.

Making links

Body's response	Organs involved	Explanation
shivering	kidneys	reduced blood volume and increased blood concentration→hormone signal→kidneys reabsorb more water→less water in urine→urine more concentrated→less water lost
skin cold to touch	brain and peripheral blood vessels	decrease in body temperature→brain signals an increase in muscle tension→increasing muscle tension results in shivering→heat production increased by up to 500%
feeling thirsty	brain	increase in body temperature→brain signals to blood vessels→blood vessels in skin dilate (widen)→more blood flows to skin→blood cooled→body temperature returns to normal
redder skin colour	brain and peripheral blood vessels	blood more concentrated→thirst centre in brain activated→person feels thirsty and drinks→blood returns to normal concentration
lower volume of darker urine	brain and body muscles	decrease in body temperature→brain signals to blood vessels→blood vessels in skin constrict (become narrower)→less blood flows to skin→heat loss reduced

- *The peripheral blood vessels help control temperature by regulating the volume of blood passing through the skin: reducing the volume when it is cold to reduce heat loss and increasing the volume when it is hot to increase heat loss.*
- *Sweating causes evaporative cooling to increase heat loss. This also results in water loss.*

Activity 7: The adaptations of mangroves

Interpreting the data

1 Plants need oxygen to respire.
2 They get oxygen from air spaces between soil particles.
3 They have above ground roots (pneumatophores) with lenticels which allow oxygen absorption from the air.
4 The seed needs to become buried in moist soil containing air spaces. This usually occurs on the ground surrounding the tree.
5 Grey Mangrove seeds are more likely to fall into the water or onto waterlogged soil than seeds from terrestrial plants.
6 The seeds germinate while they are still in the fruit on the plant and then float on the water until they make contact with land.
7 Soil water in terrestrial habitats is relatively low in salt. Water moves into the roots by osmosis because the salt concentration inside the roots is greater than in the water. The same thing happens in mangroves except the salt content in both the water and roots is greater than in terrestrial habitats.
8 Water would move out of the roots and into the soil, causing the plant to dehydrate.

Activity 4: Water Balance

Background Information:

Two hormones, aldosterone and antidiuretic hormone (ADH) influence the volume and concentration of urine produced by the kidney.
Aldosterone acts on the distal convoluted tubule to actively reabsorb salts from the filtrate.
ADH acts on the permeability of the collecting ducts to reabsorb water.

Purposes:

- to observe the affect of different fluid intake on urine production
- to explain the roles of ADH and aldosterone on urine volumes and concentration
- to appreciate the importance of hydration on body functioning.

1. Complete the following table:

Sources of water for the body	Ways in which water is lost from the body

Procedure:

The volume of urine produced by Student A was measured every half hour for several hours. Student A drank a litre of tap water 1 hour after the measurements started and then stayed quiet watching movies during the time the data was collected.
The results are shown in the table below.

Time (hours)	Volume of urine collected (mL)
0	45
0.5	40
1 (water drunk at this time)	50
1.5	280
2	450
2.5	250
3	120
3.5	80
4	45
4.5	50

a. Graph the data on the grid provided below.

2. Why were urine volumes collected before the person drank the water?

3. How long did it take for the water to affect urine volumes? Explain why.

4. **Draw lines on the graph to indicate the expected levels of ADH and aldosterone during the time of the investigation.**

Student B also collected data on urine volumes, but he drank a litre of hypertonic saline - water that has a higher concentration of salt than that found in normal body fluids. He drank the saline water at time 1 hour. Student B also had access to facilities to measure the concentration of urine produced. He made a quick sketch of his results which is shown below.

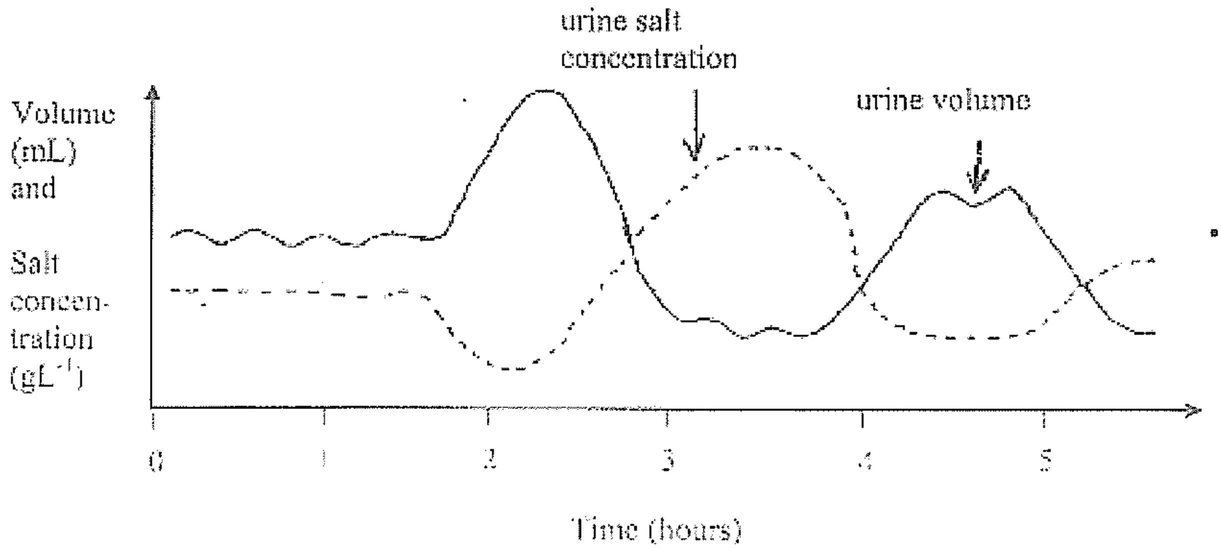


Figure 1: Changes in urine volume and concentration after drinking 1 L of hypertonic saline.

5. Why were urine volumes collected prior to drinking the water?

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6. Explain the relationship between urine volumes and concentration during this investigation.

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7. What two factors are being changed in the internal environment by drinking a litre of saline water?

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8. What does the body excrete first - excess water or excess salt? What evidence is there to support your answer?

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9. Indicate on the graph, the times when ADH and aldosterone levels would have been high. Use a different colour for each hormone.

10. How would blood pressure change during this investigation?

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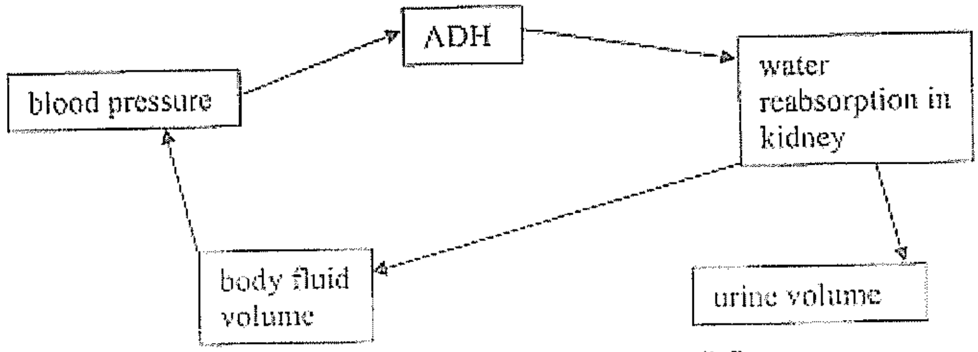
11. In cold weather blood vessels in the skin constrict causing blood into the body core circulation. This increases blood pressure. Indicate with up or down arrows what would happen in the following feedback loop.



12. How would this change if the person was sweating heavily?

People suffering from heat exhaustion or a hangover share a symptom: a headache. Alcohol inhibits the production of ADH. Heat exhaustion is caused when the body loses fluids due to heat. The headache is caused by the effect of very concentrated blood on the brain cells.

13. Explain how low ADH can cause dehydration.

14. How would the change in blood osmotic pressure affect the movement of materials into / out of the brain cells?

15. How could you avoid a hangover after drinking alcohol?

16. In industries located in hot, dry climates eg. Pilbara area, there is usually a urine colour chart on the back of the door of the toilet. Why is it important to know if you are dehydrated?

Am I hydrated? Urine colour chart http://www.striders.net/programs/coach/handouts/hydration.pdf