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Keeping things steady

Go for a walk on a crisp winter's morning and the chances are that the only animals you'll see will be mammals or birds — certainly no lizards or frogs. How is it that birds and mammals are up and about, whatever the weather? This article looks at why homeostasis matters.

GCSE key words
Homeostasis
Internal environment
Enzymes

Mammals and birds are able to be active on cold days because they have the capacity to maintain a more or less steady body temperature. Why is this an advantage? For the most part, the rates of chemical reactions increase with increasing temperature — and this is true of chemical reactions within organisms as well as in test tubes.

Chemical reactions in organisms almost always involve enzymes. Enzymes **catalyse** — speed up — reactions which otherwise would be very very slow. But enzymes are proteins and above a certain temperature their molecular shape starts to change. Once this happens they lose their ability to catalyse the reaction, which slows and stops. The enzyme may be irreparably damaged, in which case it is said to be **denatured**.

So, as Figure 1 shows, there is a huge benefit in maintaining a body temperature that allows reactions to proceed quickly but without running the risk of damaging enzymes. It is not just the temperature of cells that is kept pretty steady, other variables in the environment of the cell are important too (Box 1).

KEEPING ENZYMES IN SHAPE

As well as temperature, pH has a direct effect on the shape of a protein. If an enzyme is at the wrong pH its shape changes and it won't work. Our bodies work to maintain the optimum pH for our enzymes in the surroundings of our cells. This *internal* environment of our bodies — the tissue fluid that bathes our cells — is derived from our blood. Constant monitoring and regulation of the composition of our blood, its temperature and its pH is therefore the order of the day. In fact, the blood pH is affected greatly by how much carbon dioxide is dissolved in it as carbonic acid:

water + carbon dioxide ⟶ carbonic acid

Blood pH changes when we exert ourselves because our muscle cells are producing more carbon dioxide. Breathing harder and deeper, together with an increase in heart rate, gets rid of carbon dioxide, raises pH and helps keep enzymes in shape (and of course brings in more oxygen which is being used up more quickly). Neat.

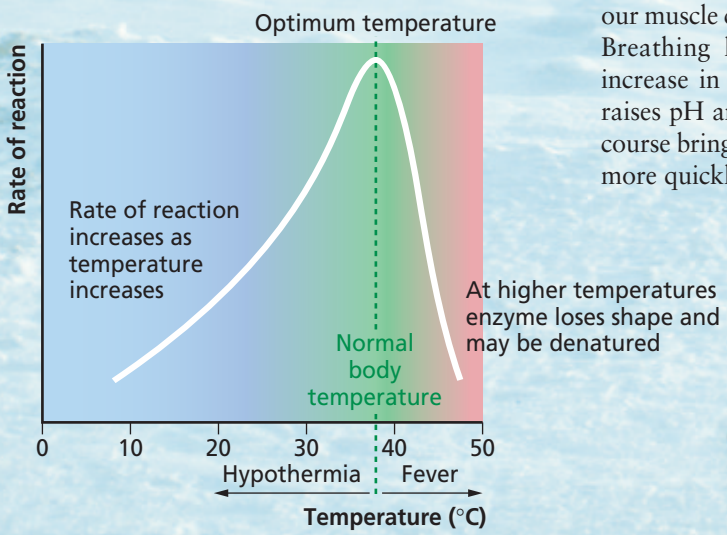


Figure 1 *Why a more or less steady temperature matters. What happens to the rate of reaction if you experience the range of temperatures described in Box 2?*

● **Why do you feel the need to urinate on a cold day? A clue or two: to reduce heat loss less blood circulates near the surface of the body. This blood is redistributed to deeper blood vessels but there is a limit to the volume that can be fitted in and blood pressure will be rising. The solution is to reduce blood volume.**

A polar bear in the snow. How does it maintain its body temperature?

Ingram

In *Life at the Extremes: the Science of Survival*, Frances Ashcroft tells fascinating stories about the effect on people of extreme conditions: cold, hot, low pressure, high pressure, intense exertion.

***Right:** Andre Agassi working up a sweat at Wimbledon*

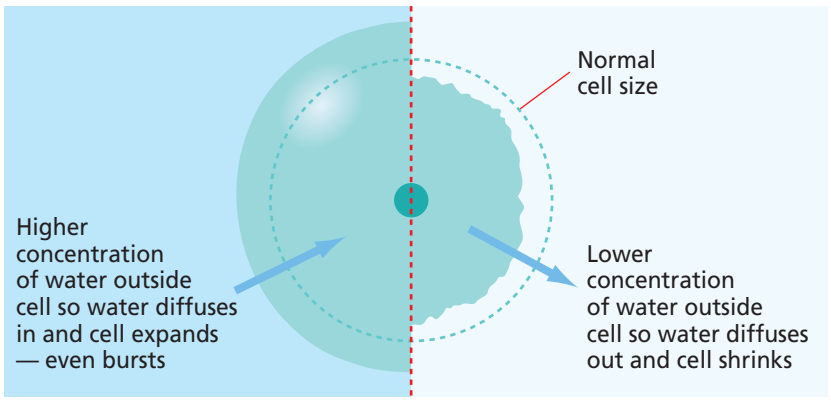
CELLS DON'T SWELL

Diffusion is the tendency for particles (atoms and molecules) of liquids, gases or solutes to disperse randomly. It results in net movement from areas of high concentration of the particles to areas of low concentration.

Box 1 lists the concentration of water in the tissue fluid (and blood) as something which is kept more or less steady in the body. Why? You need to recall that cell membranes have a special property — they are semi-permeable. Water can pass freely across the membrane, but larger molecules may not. If there is a greater concentration of water molecules in the tissue fluid (and blood) than in the cells it bathes (forget all other molecules, concentrate on water!), then more water molecules will diffuse into the cell than out and the cell will expand — and in theory explode. In fact this is what happens when blood cells fall into water.

The consequences for an animal cell are potentially dire (Figure 2). But this doesn't happen of course, because another homeostatic mechanism is operating all the time. You can look up how kidneys work to ensure that the water/salt balance in our blood — and the water concentration — is kept more or less steady by checking your textbook or logging on to the web addresses in Box 1. But the body's capacity to regulate its water/salt balance can be instantly recognised by the fact that if you drink a lot, you pee a lot and if your body is short of water, you develop a thirst.

***Figure 2** Why it is important to keep the concentration of the tissue fluid steady*



BOX 1 HOMEOSTASIS

All the cells in our bodies are surrounded by a liquid called **tissue fluid**, derived from blood. Our bodies use a number of mechanisms to maintain this fluid in a more or less steady state in terms of:

- carbon dioxide concentration (which also has a significant effect upon pH)
- oxygen concentration
- ion concentration
- sugar concentration
- water concentration, compared with dissolved substances
- temperature

This article is not about the mechanisms which control these factors but about why maintaining a near steady state matters. You can find information about the mechanisms of control in your *GCSE Science Exam Revision Notes* (received free with the November issue of CATALYST) or at the following websites:

http://www.bbc.co.uk/schools/gcsebitesize/biology/humans/homeostasisrev1.shtml
http://www.s-cool.co.uk/subject_index.asp?stage=G
http://www.biologyonline.org/4/1_physiological_homeostasis.htm

DISSOLVED SUBSTANCES

What about other molecules in the blood? Some are needed by cells. **Glucose**, the essential fuel for respiration in all living cells, all the time, in all living things, is regulated closely. Levels are controlled by various hormones produced by the body, including

BOX 2 WHY WALKING ON FROZEN PONDS IS A BAD IDEA

If you fall through ice into a pond you will seriously mess up enzyme-controlled reactions in your body! Your core temperature is normally between 36 and 38°C and **hypothermia** occurs when it drops below 35°C.

Even at this temperature you start to slip down the curve in Figure 1. You become clumsy and shiver, your reaction times slow without you realising it, your speech becomes slurred, you feel tired. Below 32°C you stop shivering because shivering has used up your energy reserves — muscles need glucose to contract. You are likely to become unconscious at around 30°C. Your heart slows right down, together with your breathing rate. Below 28°C the heart's rhythm is broken and heart muscle may twitch in an uncoordinated way. The heart usually stops when the body temperature reaches 20°C.

BOX 3 DRINKING WATER

Fifty years ago a Canadian study showed that we need about 2 litres of water per day. The study pointed out that we get most of this from our food. However, only the first part of the study's findings has entered the mythology of healthy diet, and it is much promoted today, particularly by producers of bottled water.

insulin and glucagon, so that cells receive a steady supply, whatever they are up to. What might a cell be doing that requires extra glucose? And where and how does the body store this sugar? (Find out more from your *GCSE Science Exam Revision Notes*.)

Oxygen is also needed all the time, in greater or lesser amounts, again depending on what the cells are doing. Active muscle cells need lots of both glucose and oxygen. **Amino acids**, for making proteins, and **lipids** are also needed but other molecules are not. These include **carbon dioxide** above a particular concentration and **urea**. Homeostatic mechanisms are involved in excreting them.

A BALANCED SYSTEM

It's a beautifully integrated system — pH is important for enzyme function and is determined by how much carbon dioxide is present, which in turn reflects the level of oxygen. These homeostatic mechanisms maintain optimum conditions for cell function. And if you are a mammal, you've evolved the extra homeostatic temperature control trick that allows you to appreciate the beauty of a snowy morning as birds visit a bird table when most other animals are merely ticking over.

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