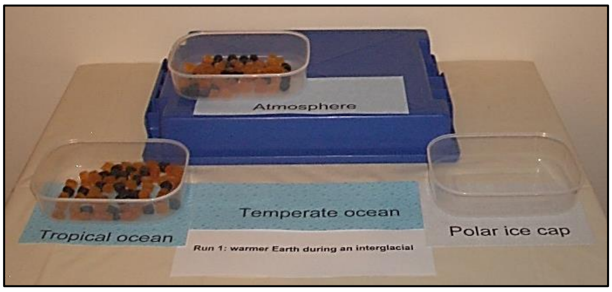
The oxygen isotope sweet simulation
Demonstrating how the oxygen isotope proxy records past Earth temperatures

Oxygen has two common isotopes; ^{16}O has an atomic mass of 16 and is the common oxygen atom whilst ^{18}O is heavy oxygen (which makes up about 1/500th of normal oxygen concentration). The proportion of heavy oxygen found in ice cores and in the shells of marine microscopic animals and deep-sea cores, can show how warm the Earth was at that time – it is a so-called climate 'proxy' that, when interpreted carefully, can be used to indicate past Earth temperatures.

Demonstrate how the proportions of the oxygen isotopes can change in different regions. Buy several packets of coloured sweets (such as Midget Gems™) and divide up the colours. Mix one set of sweets of a darker colour with a set of paler coloured sweets in one plastic container to represent the tropical ocean:

- darker-coloured sweets represent water with heavy oxygen – ^{18}O;
- paler-coloured sweets represent water with normal oxygen – ^{16}O.

Put another empty plastic container on top of the left-hand-side of an inverted tray (or similar), to represent the atmosphere, as in the photo. Put a third empty plastic container at the right-hand end of the tray to represent the polar ice cap; label each of these as shown. Then run the simulation twice, as below, in order of the numbers shown in the boxes, 1-2-3.



The set up. (Chris King.)

Note that, to highlight the effects, the proportion of dark to pale-coloured sweets in the simulation is around half and half, whereas the real proportion of ^{16}O to ^{18}O is 500:1.

Run 1: warmer Earth during an interglacial		
	Atmosphere	
	2. Slide the 'atmosphere' container along the top of the tray to represent an air mass moving from the tropics towards the pole. As you move it along, it rains and so some of the sweets are dropped from the 'atmosphere' container into the 'ocean' container sliding along below. Slightly more of the dark-coloured sweets rain down than the pale-coloured sweets because they condense more easily, being denser.	
Tropical ocean	**Temperate ocean**	**Polar ice cap**
1. Move about half the pale-coloured sweets from the 'ocean' container to the atmosphere container; then add just under half the darker-coloured sweets to the 'atmosphere' too. These are water molecules containing oxygen, evaporating from the tropical ocean to the atmosphere; water with heavy oxygen (^{18}O) evaporates more slowly (because it is denser) which is why there are fewer dark-coloured sweets.		3. The right-hand end of the tray is the polar region. Here the remaining water molecules 'rain' down into the polar ice cap container, as either rain or snow. Move all the sweets left in the 'atmosphere' container into the 'polar ice cap' container.
The ocean result		**The polar ice cap result**
Some of both coloured sweets have been added to the ocean, so there is still about a half-and-half mix		The ice of the polar ice cap contains mostly pale-coloured sweets but quite a lot of dark-coloured sweets as well – the proportion of dark to pale-coloured sweets is quite high.

<table>
<tr><th colspan="6">Run 2: colder Earth during a glacial period</th></tr>
<tr><td rowspan="2"></td><th colspan="3">Atmosphere</th><td rowspan="2" colspan="2"></td></tr>
<tr><td colspan="3">2. Slide the ‘atmosphere’ container along the top of the tray to represent an air mass moving from the tropics towards the pole. Now the Earth is much colder so, as you move it along, it rains much more into the ‘ocean’ container. Most of the dark-coloured sweets rain down, together with many of the pale-coloured sweets.</td></tr>
<tr><th colspan="2">Tropical ocean</th><th colspan="2">Temperate ocean</th><th colspan="2">Polar ice cap</th></tr>
<tr><td colspan="2">1. Return all the sweets to the ‘ocean’ container’ and repeat the first part of ‘Run 1’ since the tropical ocean is still tropical, with similar evaporation rates.</td><td colspan="2"></td><td colspan="2">3. The remaining water molecules ‘rain’ from the ‘atmosphere’ container down into the polar ice cap container – move all the remaining sweets into the ‘polar ice cap’ container</td></tr>
<tr><th colspan="4">The ocean result</th><th colspan="2">The polar ice cap result</th></tr>
<tr><td colspan="4">More of the dark-coloured sweets have been added to the ‘ocean’ than in Run 1, so the ocean is richer in heavy oxygen (^{18}O).</td><td colspan="2">The ice of the polar ice cap contains almost entirely pale-coloured sweets, with only a very few dark-coloured sweets – the proportion of dark to pale-coloured sweets is lower than in Run 1. So, the ice cap is poorer in heavy oxygen (^{18}O).</td></tr>
</table>

These two runs show how:

- during cold glacial periods, the ice caps build up lower proportions of heavy oxygen (^{18}O). So if cores drilled into the ice have layers with **low** ^{18}O proportions, the Earth must have been cold – a glacial period;
- but, at the same time, the oceans had high ^{18}O proportions which were built into the shells of animals that fell to the sea floor when they died, so deep ocean cores with **high** proportions of ^{18}O also show that the Earth was cold or glacial at that time.

The opposite is also true:

- high ^{18}O proportions in ice core layers indicate an interglacial period;
- low ^{18}O proportions in deep-sea core layers also indicate an interglacial period.

The back up

Title: The oxygen isotope sweet simulation.

Subtitle: Demonstrating how the oxygen isotope proxy records past Earth temperatures.

Topic: Two runs of an activity to simulate, using coloured sweets, how the relative proportions of ^{16}O and ^{18}O can indicate past Earth temperatures.

Age range of pupils: 16 years and above

Time needed to complete activity: 15 minutes

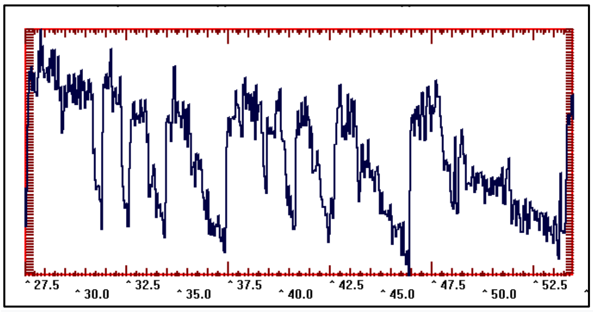
Pupil learning outcomes: Pupils can:

- explain why the density of a water molecule (whether it contains ^{16}O or ^{18}O) affects its rates of evaporation and condensation;
- explain how, in air masses moving from the tropics to the poles, the ^{16}O:^{18}O proportion changes;
- explain how the amount of change depends upon the amount of rainfall which depends, in turn, on the temperature of the Earth at the time.
- explain how high ^{18}O proportions in ice core layers indicate an interglacial period (and *vice versa*), whilst low ^{18}O proportions in deep-sea core layers also indicate an interglacial period (and *vice versa*).
- use a simulation to support these explanations.

Context:
The explanations of the proportions of ^{18}O relative to ^{16}O in the oceans, atmosphere, polar ice cap and deep ocean sediments can be difficult to understand. Meanwhile, there is a potential misconception in realising that **high** ^{18}O in sediment cores indicates a glacial period, when a glacial period is also indicated by **low** ^{18}O ratios in ice cores. The two runs of this demonstration help to clarify this issue.

This understanding can be used to interpret temperatures from the oxygen isotope graph produced by an ice core.

An ice core.



Part of the NGRIP ice core oxygen isotope curve. Colder is up, warmer is down. Figures are thousands of years ago.

Following up the activity:
Try the follow up '*The oxygen isotope sweet simulation of cores*' Earthlearningidea.

Underlying principles:
- ^{18}O has a higher vapour density than ^{16}O and therefore evaporates less easily and condenses more easily than ^{16}O.
- Water molecules containing heavy oxygen (^{18}O) are less easily evaporated and condense more easily than 'normal' ^{16}O oxygen, because of the vapour density difference.
- The more rain produced by an air mass, the more ^{18}O it loses, in proportion to ^{16}O.
- Air masses that are carried from the tropics to the poles during glacial times, lose more rain and so more ^{18}O than similar air masses during interglacial times.
- Snow layers that accumulate on polar ice caps contain less ^{18}O during glacial times than in interglacials.
- The rain from air masses carried poleward falls into the ocean, enriching it in ^{18}O.
- Oceans, the shelly animals in them, and the deep sea cores they produce, contain more ^{18}O during glacial periods than in interglacials.
- The ^{18}O:^{16}O ratio can be used as a proxy for climate change, indicating when the Earth was subjected to glacial and interglacial periods in the past.

Thinking skill development:
The simulation allows a pattern to be developed through construction; cognitive conflict is caused because high ^{18}O content in an ice core has a different temperature meaning from that in a sediment core. The link between the simulation and reality involves bridging skills.

Resource list:
- several bags of sweets that can be divided into different colours (e.g. Midget Gems™)
- three plastic containers, like those in the photo
- a tray or something similar to raise the 'atmosphere' container' above the table top
- the labels attached to this Earthlearningidea

Useful links:
- *Global warming – the complete briefing*, by Sir John Houghton Cambridge University Press.
- ESTA's '*Science of the Earth'* '*Changes to the atmosphere'* at:http://www.esta-uk.net/pubarchive/index_htm_files/SoE1_Changes_to_the_Atmosphere.pdf

Source: Devised by Duncan Hawley.

Atmosphere

Temperate ocean

Run 1: warmer Earth during an interglacial

Run 2: colder Earth during a glacial period

Tropical ocean

Polar ice cap