‘Tag’ a carbon atom – and explore the carbon cycle
A thought experiment to investigate carbon cycle processes

We can ‘mark’ genes with glowing colours to discover how they work – and so can produce mice that glow bright green. We can also tag organisms, from butterflies to whales, to find out about their lives and movement.

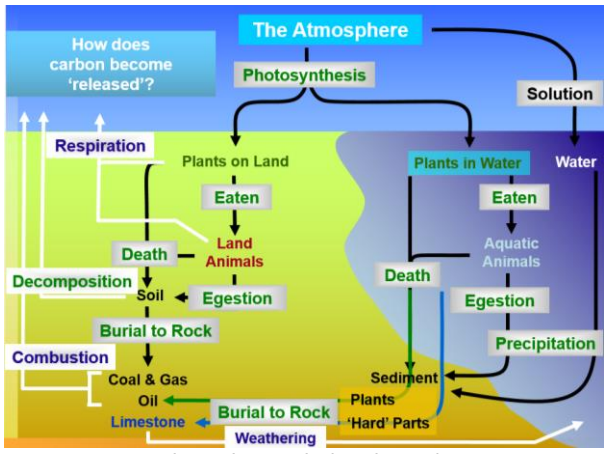
Help your pupils to understand the carbon cycle by pretending to ‘tag’ a carbon atom so that they can ‘see’ it as it is carried around different parts of the carbon cycle.

Begin by showing that your breath contains a gas that makes water become acid (as described in the ‘Context’ section below)

Explain that the gas is carbon dioxide and that each molecule contains one carbon atom and two oxygen atoms (CO_2).

Take a green pen and, as you breathe out, prod your breath with your pen – pretending you have ‘tagged’ a carbon atom in a carbon dioxide molecule – and turned it bright green.

Now you have ‘tagged’ a carbon atom – you can follow its progress through different parts of the carbon cycle.



The carbon cycle (*Paul Grant*)

Open a window, and pretend to watch the ‘tagged’ carbon atom as it is carried out of the window. Ask where it might go next - there are many possibilities that include these.

- It stays as part of the CO_2 in the atmosphere as a green spot in the sky – absorbing some of the Earth’s heat radiated from the Earth’s surface, and so ‘trapping’ the heat as a greenhouse gas.
- It is absorbed by a leaf on one of the trees through the window and, through photosynthesis, becomes changed to starch as part of a growing leaf – where it can be seen as a bright green spot. When the leaf falls off and decomposes, the green carbon is released as carbon dioxide back into the atmosphere – and so is recycled.
- The same leaf could be buried, with lots of other organic material and eventually become part of a coal seam. As the coal forms, the carbon atom is released as part of a methane molecule (CH_4) that becomes trapped in a gas trap in the rocks. When a borehole drilled down into the trap releases the methane, it is piped to a gas cooker in the school kitchen where it is burnt, becoming part of a carbon dioxide molecule.

  $$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

  This carbon dioxide molecule will add extra CO_2 to the atmosphere, where it will absorb extra heat from the Earth’s surface – contributing to global warming.
- It becomes dissolved in a falling raindrop making the water slightly acid (carbonic acid).

  $$CO_2 + H_2O \dashrightarrow H_2CO_3$$

  When it falls onto any limestone (e.g. the limestone chippings through the window), the acid dissolves the limestone (calcium carbonate) and carries it away in solution (as soluble calcium hydrogen carbonate).

  $$H_2CO_3 + CaCO_3 \rightarrow Ca(HCO_3)_2$$

  If the calcium hydrogen carbonate is carried into a river and eventually into the sea, it might be absorbed by a growing sea shell, becoming calcium carbonate again – seen as a bright green spot in the shell.

  $$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2CO_3$$

  If the shell became fossilised in limestone and the limestone was uplifted and weathered again – the carbon atom would be recycled over millions of years.

After these ‘starter’ ideas, the pupils could ‘watch’ the carbon atom being taken on many more thought experiment ‘adventures’.


A leaf on a tree – with a ‘green tagged carbon atom’.

The back up

Title: 'Tag' a carbon atom – and explore the carbon cycle.

Subtitle: A thought experiment to investigate carbon processes.

Topic: An activity asking pupils to 'visualise' stages of the carbon cycle by 'following' a 'tagged' carbon atom.

Age range of pupils: 11-16 years

Time needed to complete activity: a few minutes or longer, depending on how many different carbon cycle ideas are developed and discussed.

Pupil learning outcomes: Pupils can:
- describe the movement of carbon through various parts of the carbon cycle;
- link the different elements of the carbon cycle together.

Context:
Pupils visualise the movement of a 'tagged' bright green carbon atom through the carbon cycle. We can actually tag molecules with radioactivity, so the idea is plausible, even in if the bright green colour isn't.

To show that breath contains a gas that turns water acid, put a little tap water into a small beaker and add some Universal indicator, which will usually go green, showing the pH of the water is neutral (if not, try using deionised water instead), then ask a pupil to use a drinking straw to blow into the water. After a few seconds, the water will turn orange and maybe even pink, as the carbon dioxide from their breath dissolves in the water, making it more acid. Explain that this shows how their breath contains carbon dioxide (which dissolves in water forming carbonic acid).

(*Earth Science Education Unit*)

If your pupils want to know how long recycling carbon actually takes – then these figures will give them an idea.

Element of carbon cycle	Estimated average residence time
land plants	5 years
atmosphere	3 years
soils	25 years
oceans	350 years
fossil fuels (coal, crude oil, natural gas)	150 million years
carbonate and other rocks	150 million years
Estimates from: www.colorado.edu/geolsci/courses/GEOL3520/Carbon_cycle.pdf	

Because of the publicity, some people think that the atmosphere is largely made of carbon dioxide when, in fact, it contains only 0.04% (4 molecules in 10,000 molecules of air). Nevertheless, this is enough to give the warming for the Earth to be maintained at current temperatures – whilst an increase in this is likely to lead to enhanced global warming and problematic increases in global temperatures.

Following up the activity:
Ask pupils to 'visualise' what would happen if other atoms or molecules could be 'tagged' in bright colours and observed as they cycled around systems.

Underlying principles:
- Carbon atoms 'flow' around the carbon cycle as a part of a series of different molecules through a wide range of processes.

Thinking skill development:
Visualising the movement of a carbon atom through various elements of the carbon cycle involves creativity and imagination as well as the use of bridging skills to apply the carbon cycle diagram to reality.

Resource list:
- unlimited imagination

Useful links:
See the other Earthlearningidea carbon cycle-based activities at:
http//:www.earthlearningidea.com

Source: Devised by Chris King of the Earthlearningidea Team.