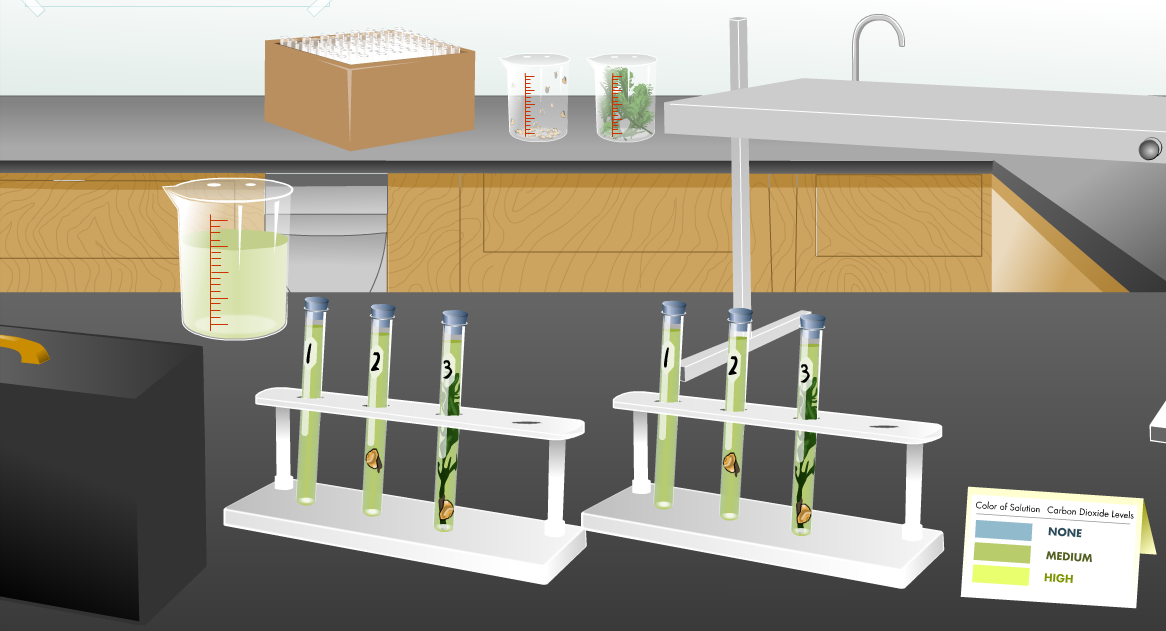
**Respiration indications**



Two groups of test tubes have been set up. Each group contains three test tubes:

* Test tube 1: Indicator solution
* Test tube 2: Indicator solution + a living snail
* Test tube 3: Indicator solution + a living snail + living pondweed

The indicator solution changes colour according to how much carbon dioxide is present:

|  |  |  |
| --- | --- | --- |
| **No carbon dioxide** | **Medium carbon dioxide** | **High carbon dioxide** |

One group of test tubes will be left in the dark for 24 hours.

The other group of test tubes will be left in bright light for 24 hours.

**Predict**

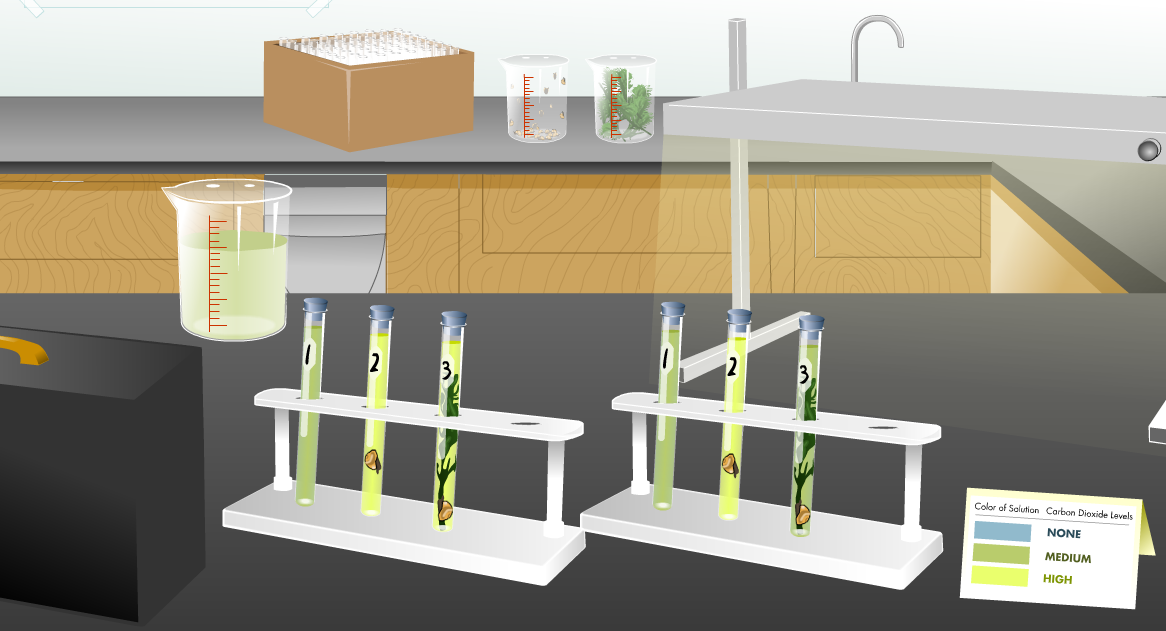
What will colour will the indicator be in each test tube after 24 hours?

|  |  |  |  |
| --- | --- | --- | --- |
| **Tube** | **Contents** | **Left for 24 h in…** | **Predicted colour after 24 h** |
| 1 | Indicator solution | Dark |  |
| 2 | Indicator solution + snail | Dark |  |
| 3 | Indicator solution + snail + pondweed | Dark |  |
| 1 | Indicator solution | Bright light |  |
| 2 | Indicator solution + snail | Bright light |  |
| 3 | Indicator solution + snail + pondweed | Bright light |  |

**Explain**

Explain why you think the indicator in each tube will be that colour.

|  |
| --- |
| **The test tubes have now been left for 24 hours.** |



**Observe**

What colour is the indicator in each test tube after 24 hours?

|  |  |  |  |
| --- | --- | --- | --- |
| **Tube** | **Contents** | **Left for 24 h in…** | **Actual colour after 24 h** |
| 1 | Indicator solution | Dark |  |
| 2 | Indicator solution + snail | Dark |  |
| 3 | Indicator solution + snail + pondweed | Dark |  |
| 1 | Indicator solution | Bright light |  |
| 2 | Indicator solution + snail | Bright light |  |
| 3 | Indicator solution + snail + pondweed | Bright light |  |

**Explain**

Were your predictions correct?

If not, how would you explain what you have observed?

*Biology > Big idea BCL: The cellular basis of life > Topic BCL3: Biochemistry > Key concept BCL3.2: Cellular respiration*

|  |
| --- |
| **Response activity** |
| **Respiration indications** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Energy for life processes is provided by a chemical process called cellular respiration inside all living cells, which uses glucose (from food) as fuel. |
| Observable learning outcome: | Describe aerobic cellular respiration using a simple model of the process, including what it uses as fuel (glucose plus oxygen) and what it makes as waste products (carbon dioxide and water).  Apply understanding of photosynthesis and cellular respiration to explain when and why they take place in plants. |
| Activity type: | Practical PEOE (predict-explain-observe-explain) |
| Key words: | cellular respiration, photosynthesis |

This activity challenges students to apply their understanding of a simple model of cellular respiration by applying it to predict how cellular respiration in animals and plants changes the colour of an indicator solution that is sensitive to carbon dioxide levels. It helps develop students’ understanding through prediction, explanation, observation and group discussion, and can be used in response to the following diagnostic questions:

* Diagnostic question: A simple model of aerobic cellular respiration
* Diagnostic question: Making gas (Part 1)

**What does the research say?**

The EEF *Improving Secondary Science* guidance report advocates explicitly teaching pupils about models to help them develop a deeper understanding of scientific concepts (Holman and Yeomans, 2018).

Students should be able to apply their understanding of simple models of aerobic cellular respiration and photosynthesis to explain changes in carbon dioxide levels (e.g. as shown by the colour of an indicator solution). At ages 11-14, simple models of the inputs and outputs of the two processes may be good enough to enable students to do this. (Note, however, that the use of word or symbol equations has been avoided in the BEST 11-14 resources, as they may reinforce the misunderstanding that each process is a single reaction.)

|  |  |
| --- | --- |
| Aerobic  cellular  respiration  energy  water  glucose from carbohydrate food  oxygen  carbon dioxide | light  water  oxygen  carbohydrate food  Photosynthesis  carbon dioxide |

However, In a review of numerous research studies published over 20 years, Cañal noted the “frequency and extraordinary persistence” of the misunderstanding that photosynthesis is simply ‘inverse respiration’ in students of all ages from primary school to university level, in countries such as Australia, France, Israel, New Zealand, Spain, the UK and the USA (Cañal, 1999). This misunderstanding can lead to incorrect beliefs such as that cellular respiration does not take place at all in plants because they photosynthesise instead (“plants do photosynthesis, animals do respiration”), or that cellular respiration only happens in plants when there is no light for photosynthesis (e.g. during the night) (Haslam and Treagust, 1987; Maeng and Gonczi, 2019).

In a study with 13-year-old students by Marmaroti and Galanopoulou (2006), 20% of the students thought cellular respiration only occurs in plants when photosynthesis is not taking place. Only 33.9% of the students could correctly identify carbon dioxide as a requirement of photosynthesis; a further 30.1% chose oxygen instead of carbon dioxide.

**Ways to use this activity**

This activity takes the form of a predict-explain-observe-explain (PEOE) activity, which allows students to apply what they know to make predictions, and to build explanations for what they have predicted and what they observe.

Begin by showing the class the test tubes containing indicator, snails and pondweed **before** they have been left for 24 hours (or show the first stages of the simulation – see below). Use of a visualiser may be helpful, so that all of the class can watch together.

Students should then be allowed time to work in pairs or small groups to discuss *what* they think will happen (prediction), and then to explain *why* they think it will happen (explanation). It is through the discussions that students can check and develop their understanding. If students in any group cannot agree, you may be able to direct them with some careful questioning.

You should now show the class the test tubes **after** they have been left for 24 hours (or show the end of the simulation).

After the practical each group should be given the opportunity to change, or improve their explanation in light of their observations. A good way to review your students’ thinking might be through a structured class discussion. You could ask several groups for their explanations and put these on the whiteboard. Then ask other groups to suggest which explanation is the best and why, the through careful questioning work up a clear ‘class explanation’.

A useful follow up is for individual students to then write down explanations in their own words – without reference to the class explanation on the board (i.e. cover it up).

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in each group. For example, you may choose to select a student with strong prior knowledge as a scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

*Practical demonstration or simulation?*

You may wish to run a practical demonstration of this activity. Note that the tubes must be left for 24 hours, so you may want to have both ‘before’ and ‘after’ sets of tubes set up in advance for the lesson.

This version of the classic snails and pondweed activity is based upon an intervention described by Maeng and Gonczi (2019), which used the “Carbon Transfer Through Snails and Elodea” virtual labs simulation at <https://www.classzone.com/books/hs/ca/sc/bio_07/virtual_labs/virtualLabs.html>

Maeng and Gonczi (2019) found that the simulation helped students to develop their understanding that plants perform both cellular respiration and photosynthesis.

The simulation could be operated by the teacher and projected for the whole class to watch. Some of the early steps in the simulation require the user to ‘explore’ various bits of apparatus in the virtual laboratory and type something (even just a single letter) into various fields in a ‘lab notebook’ before they can advance to the next step; to avoid boring students with this, these steps could be completed in advance and the simulation shown to students from step 3 onwards.

The simulation runs in Flash Player, so may not work in all web browsers. An alternative is to simply use the screenshots of the simulation provided in the PowerPoint presentation for this activity, and talk students through it.

**Equipment**

For each student/pair/group:

* pencil and paper to record predictions and observations

For a practical demonstration of this activity (optional):

* 6 test tubes
* 6 stoppers or bungs for the test tubes
* test tube rack(s)
* bromothymol blue (BTB) indicator solution
* living snails
* living pondweed
* cover or dark room (to exclude light from one set of test tubes for 24 h)
* lamp (to ensure one set of test tubes receives bright light for 24 h)

**Technician notes**

CLEAPSS guidance sheet “L197 - Giant African Land Snails” offers advice on keeping, handling and using snails that is applicable to most species, including native British species, with the exception that most species do not need the vivarium in which they are kept to be heated.

In the UK there are restrictions on which species of pondweed can be imported and how they should be disposed of, as *Elodea* and some species of *Cabomba* are classed as invasive. See CLEAPSS guidance sheet “GL322 – Pondweed” for further information.

**Health and safety**

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answers**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tube** | **Contents** | **Left for 24 h in…** | **Result** | **Explanation** |
| 1 | Indicator solution | Dark | green (no change) | Control tube – nothing in there to cause any change in the indicator |
| 2 | Indicator solution + snail | Dark | bright green/yellow (high CO2) | Respiration in snail has produced CO2 |
| 3 | Indicator solution + snail + pondweed | Dark | bright green/yellow (high CO2) | Respiration in snail and pondweed has produced CO2 |
| 1 | Indicator solution | Bright light | green (no change) | Control tube – nothing in there to cause any change in the indicator |
| 2 | Indicator solution + snail | Bright light | bright green/yellow (high CO2) | Respiration in snail has produced CO2 |
| 3 | Indicator solution + snail + pondweed | Bright light | green (medium CO2) | Respiration in snail and pondweed has produced CO2, but photosynthesis in pondweed has used CO2 |

**Acknowledgments**

Developed by Alistair Moore (UYSEG), Maeng and Gonczi (2019).

Images: simulation screenshots from the WOW Biolab Virtual Biology Labs “Carbon Transfer Through Snails and Elodea” at www.classzone.com © Houghton Mifflin Harcourt Publishing Company

**References**

Cañal, P. (1999). Photosynthesis and 'inverse respiration' in plants: an inevitable misconception? *International Journal of Science Education,* 21(4)**,** 363-372.

Haslam, F. and Treagust, D. F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education,* 21(3)**,** 203-211.

Holman, J. and Yeomans, E. (2018). Improving Secondary Science. London: Education Endowment Foundation.

Maeng, J. and Gonczi, A. (2019). Do plants breathe? *Science Teacher,* 86(7)**,** 28-34.

Marmaroti, P. and Galanopoulou, D. (2006). Pupils' understanding of photosynthesis: a questionnaire for the simultaneous assessment of all aspects. *International Journal of Science Education,* 28(4)**,** 383-403.