TEACHING AND LEARNING NOTES

KEY STAGE 3 RESOURCES [TIME REQUIRED = ONE HOUR+]
Starter activity: Case study and questions
Foundation activity: Testing plants for vitamin C
Higher activity: Calculating vitamin C concentrations
Extension activity: Plants as chemical factories
Plenary activity: The skills used by a researcher

For general information about Health and Safety and Risk Assessment please refer to our SAPS Health and Safety web page (**http://www.saps.org.uk/health-and-safety**)

AIMS

Careers education

Pupils should have opportunities to appreciate that science has a vital role in career opportunities and recognise the importance of understanding the applications of scientific knowledge, understanding and skills outside the classroom.

How science works

Pupils should be taught to:

- collect data from primary and secondary sources, including using ICT sources and tools
- work accurately and safely, individually and with others, when collecting first-hand data
- evaluate methods of collection of data and consider their validity and reliability as evidence

Living organisms and life processes

Pupils will:

- understand that cells become specialised to carry out different functions
- find out that variation can be measured in living organisms

KEY VOCABULARY

Vitamin C • oxidation • antioxidant • DCPIP • research

STARTER ACTIVITY: CAREER CASE STUDY AND QUESTIONS

Ask pupils to read through the career case study. They may then discuss the questions in small groups, noting their answers for a brief class discussion. Use this to establish what Jess and the team that she works with do and how this relates to the vitamin C activity. Aim to draw out reasons why Jess Chu finds a career in plant research is attractive and important, how antioxidants protect cells from harm and how the quantity of DCPIP decolourised by an extract indicates the amount of vitamin C present. This technique is similar to the DPPH assay used by Jess in antioxidant testing, which uses spectrophotometry to determine the extent to which 2,2-diphenyl-1-picryl hydrazyl is reduced to a compound with peak absorbance at 517 nm.

Answers

a) the stem: to support and transport water and food in veins; the leaf: large surface area to absorb light energy for photosynthesis; the flower: to reproduce

b) green plants use energy from the sun in photosynthesis in order to be able to synthesise organic molecules

c) plants will need vitamin C as an antioxidant to remove free radicals, but also as a vitamin to aid various processes such as cell division.

Science & Plants for Schools

FOUNDATION ACTIVITY: TESTING PLANTS FOR VITAMIN C

Pupils follow the procedure to compare parts of plants for their vitamin C content. A clear solution is not needed for testing – filtering with muslin removes debris only. Warn pupils not to pound the pestle and mortar, but to use a circular grinding motion. Depending on the practical skills of the pupils, you may wish to demonstrate the procedure before they start. The questions may be used to guide students to chart and interpret their results. Each group should attempt to compare the different regions of one plant, but may investigate other plants species if time permits. More time may be spent on the practical if follow up work is done for homework and/or in other lessons.

HIGHER ACTIVITY: CALCULATING VITAMIN C CONCENTRATIONS

Pupils who complete the practical in good time can be given the higher activity. It provides a method for calculating the vitamin C contents of the tissues tested. They might also be given a standard solution of vitamin C (to determine the amount of vitamin C required to decolourise each drop of DCPIP) and see if this confirms their calculated values.

EXTENSION ACTIVITY: PLANTS AS CHEMICAL FACTORIES

The foundation activity may be followed up with an investigation of plants as chemical factories, using the practical sheet with its associated questions. The questions may be used as a homework activity. This activity has been developed from http://www.saps.org.uk/secondary/teaching-resources/718-plants-as-chemical-factories. Information on artimesinin may be found at http://www.york.ac.uk/org/cnap/artemisiaproject/index.htm.

PLENARY ACTIVITY: THE SKILLS USED BY A RESEARCHER

Use the worksheet to consider how the skills pupils are acquiring and demonstrating in their science lessons relate to those needed by research scientists. Pupils may work in small groups and report back to suggest and explain one skill until ideas run out. (See the KS3 Science Programme of study for Experimental and investigative science.) An extended case study for Jess Chu may be found at http://www.saps.org.uk/students/careers/683 and information on The University of Nottingham's Centre for Biomolecular Sciences at http://www.nottingham.ac.uk/cbs/index.aspx (accessed 18 April 2012).

Answers

Among the specific skills mentioned in the KS3 Science Programme of study are:

- develop their experimental and investigative skills and their understanding of science
- adopt safe practices when undertaking scientific experiments
- make predictions where appropriate to do so
- consider the factors, qualitative and/or quantitative, which need to be taken into account in investigations
- use apparatus and materials in a safe and competent manner
- understand the need, where appropriate, to repeat observations or measurements
- record observations or measurements systematically using methods appropriate to the information collected and to the purpose of the investigation
- present results in ways appropriate to the data collected and the purpose of the investigation, including, where appropriate, the use of graphs
- interpret and evaluate results using, where appropriate, simple calculations
- identify any trends, patterns and conclusions emerging from consideration of the results
- draw valid conclusions and decide whether these conclusions agree with the original idea
- explain the conclusions in the light of their scientific knowledge and understanding
- consider their observations and measurements, including anomalies, and suggest, where appropriate, improvements that could be made if they were to repeat the investigation

Pupils may have other suggestions which can also be discussed, such as enjoying their work, thinking their work is important, working to meet deadlines, being a good team member. Jess says that a PhD is more about problem solving, finding and optimising techniques/assays that fulfil the objectives set by the 'boss'. Employers can see that you are capable of learning new skills and can problem solve.

TECHNICIAN NOTES

FOUNDATION ACTIVITY: TESTING PLANTS FOR VITAMIN C

Equipment and materials

For class:

- Plants – entire if possible with flowers and/ or fruit, for example herbs such as thyme, parsley, chives, coriander, sage, mustard, cress or radish
- Balances (to 0.1 g)
- 0.1% DCPIP [LOW HAZARD]

For each group:

- Scissors
- Weighing boats
- Pestle and mortar
- Clean fine sand (optional)
- 10 cm^3 graduated syringe or measuring cylinder
- Filter funnel
- Muslin to fit filter funnel
- 2 or 5 cm^3 graduated syringe
- Test tube
- Test tube rack
- Teat pipette 0.1%

For modified method for coloured extracts:

- white spotting tile

Summary of method

Pupils cut plants into separate parts (roots, stems, leaves, flowers, fruits), weigh out 2 g samples (or as near as possible) and macerate in 10 cm^3 of distilled water using a pestle and mortar and fine sand if available. The extract is filtered through muslin and 2 cm^3 is added to a test tube. DCPIP is added dropwise until the colour is retained (it may become pink if the extract is acid). The number of drops used is recorded and a second sample is tested to check for consistency. Coloured extracts (for example extracts may be green due to the presence of chlorophyll) can still be investigated using the modified method using a spotting tile. Comparison with a reference sample makes it possible to detect when the colour of the DCPIP is being retained, provided the sample is not too dark. Extracts may be diluted x5 if >25 drops of DCPIP are required.

Note: DCPIP is LOW HAZARD.

EXTENSION ACTIVITY: PLANTS AS CHEMICAL FACTORIES

Equipment and materials

For each student:

- Leaves or plants, for example tomato, potato and herbs such as basil, mint, sage, thyme
- Basic microscopes without sub-stage lighting (or used without switching on)
- Microscope slides
- Optional: Microscope lamp (to illuminate from side)

Summary of method

Pupils place leaf samples on slides and view at different powers to look for hairs and trichomes.

Safety: Avoid using microscopes in direct sunlight. Demonstrate safe and effective use of the microscope, to prevent students ramming the slide with the higher power objectives, releasing splinters of glass.

Jess Chu

Plant Science Researcher

Starter activity: Career case study and questions | PAGE 1 OF 2

CAREER CASE STUDY

WHAT DOES JESS DO?

Jess was studying for a three-year Doctor of Philosophy degree (PhD) at Nottingham University – a research-based degree, carrying out experiments and investigations with plants. She spends most of the day in the lab.

Jess was based at the University of Nottingham, part of a team which includes scientists working in Malaysia investigating Malaysian rainforest plants to see if they have any antioxidant, anticancer or antibacterial properties.

WHY IS THIS RESEARCH IMPORTANT?

Jess is looking into the anticancer properties of the rainforest plants. Cancer causes millions of deaths worldwide every year: "More than 60% of all anticancer treatments come from, or are based on, natural products, including some from plants. About 85-90% of the estimated 320 000 plant species haven't been looked at! So the potential to find other good treatments is huge."

Many parts of the rainforest are being destroyed for timber, paper and other uses. This threatens many tropical plants with extinction, due to the loss of their natural habitat. If useful plants can be found the government might stop the rainforest from being totally wiped out.

HOW DID JESS GET TO BE A RESEARCHER?

She says: "During my undergraduate degree, we had several lectures on cancer cell biology and I found all of it fascinating, such as how they [cells] develop, grow and gain mutations in order to avoid being killed. So I went on to do a Master's degree in Oncology – the study of cancer. In the second term I had the opportunity to spend five months in the lab I am now working in. I really enjoyed being in charge of my own work, hence I thought of doing more of it."

WHAT ADVICE DOES JESS GIVE TO YOUNG PEOPLE WHO WANT TO BE SCIENTISTS?

"Go for it. Don't worry if you change your mind on whether it's biology, chemistry or physics that you like more, because being a scientist is to have lots of different ideas and incorporate them together to solve problems. Some projects involve areas of all three sciences. After learning about different topics in an undergraduate degree, you might want to apply for a PhD and do research in a topic that really fascinates you.

"Now, as a PhD student, I am in the lab almost every day to work on new experiments or repeating old ones to confirm my findings. No day is the same, so once we have finished with one set of experiments and analysed the results that will direct us on to what to do next. There are also opportunities to do field research so you are not stuck in the lab, but it depends on the project.

"If finding answers/discoveries that no one in the world has found before (being a little expert in the area) is something you will find interesting, then doing research might be for you. For me the potential to find a new anticancer treatment from plants to help millions of patients, whether it is by relieving pain or finding a cure, keeps me motivated – and if it's successful, it's very rewarding.

"There are many opportunities to visit other labs – and there might be chances to go the rainforest or ocean to look at the materials you are working with in natural research. My project so far allows me to do experiments in different departments such as chemistry and biology – so I meet and talk to different people. This means I get to learn to use different types of machines, and that keeps my job interesting. It is so important to enjoy the work, and then it won't really feel like working. Also you can attend international conferences to present your work, which could be anywhere (sunny) e.g. Hawaii, Singapore, Florida etc."

WHAT PLANT SCIENCE RESEARCH CAN YOU DO?

Jess works in a team looking for anticancer chemicals and antioxidants in plants. Vitamin C is essential in your diet to maintain your health by preventing scurvy – a disease which causes the gums to bleed. It also acts as an antioxidant. You can carry out your own investigation of the presence of vitamin C in the different parts of different plants.

WHY DO PLANTS AND ANIMALS NEED ANTIOXIDANTS?

Chemical reactions in the body can produce highly reactive substances called free radicals. These can cause oxidation reactions which may damage proteins and DNA (the molecule that codes for genes). Oxidation involves the transfer of electrons or hydrogen.

Damage to DNA can cause cancer, when cells divide out of control and spread to form tumours (swellings) that destroy tissues/organs. Tumours can occur in both plants and animals.

Antioxidants can neutralize free radicals before they cause any damage.

TESTING FOR VITAMIN C

Vitamin C is a reducing agent which reacts with the blue dye DCPIP (short for dichlorophenolindophenol), turning it colourless. This can be used as a test for vitamin C.

Vitamin C will dissolve in water. So pieces of plants can be ground up with water to make vitamin C extracts. Jess also starts by grinding up parts of plants. The quantity of DCPIP that loses its colour when mixed with a plant extract indicates how much vitamin C is present. Jess uses machines like spectrophotometers, which measure the amount of light of a certain wavelength that passes through a sample. They accurately measure any colour change.

You will use DCPIP to carry out some research of your own by using ***Testing plants for vitamin C***.

QUESTIONS

a) Why does Jess enjoy being a plant scientist? Give three reasons.

b) Why does your body need antioxidants?

c) How can you find out if part of a plant contains more vitamin C than another part?

TESTING PLANTS FOR VITAMIN C

Jess told us that her team investigate plants for antioxidants and anticancer chemicals.

As well as being a vitamin essential in small quantities in your diet, vitamin C is an antioxidant, helping to protect cell proteins and DNA from damage by harmful substances called free radicals produced in cell reactions. You can use your practical skills to use a DCPIP solution to compare the vitamin C contents of parts of plants. Try to identify the best sources of vitamin C.

EQUIPMENT

Plants • Scissors • Balance (to 0.1 g) • Weighing boats • Pestle • Mortar • Fine sand (optional) • 10 cm^3 graduated syringe or measuring cylinder • Distilled water • Filter funnel • Muslin • 2 or 5 cm^3 graduated syringe • Test tube • Test tube rack • Teat pipette • 0.1% DCPIP

PROCEDURE

01) Choose a plant and use scissors to cut it into separate parts, for example roots, stems, leaves, flowers, fruits.

02) Cut a sample of one type of plant material into small pieces and weigh out 2 g. Record the type and part of the plant you are using. (If you have less than 2 g, record the weight.)

03) Grind up the plant tissue in a pestle and mortar. If available, add a small pinch of fine sand to help break it up.

04) Use a graduated syringe or measuring cylinder to add 10 cm^3 of distilled water to the sample and grind it gently to mix it well. (For less than 2 g of plant tissue, multiply its weight by 5 to get the volume of water in cm^3 that you need.)

05) Filter the extract into a small beaker, through a piece of muslin in a filter funnel. If the plant extract is very cloudy, allow it to settle for a few minutes.

06) Use a graduated syringe to transfer 2 cm^3 of filtered extract to a test tube. Take it from the clearer top of the solution if it is cloudy.

07) Use a teat pipette to add one drop of blue 0.1% DCPIP solution to the extract in the test tube. If the plant extract is acid, the blue colour will become pink. If vitamin C is present, the colour should disappear. If the colour does not disappear, make 0.01% DCPIP by adding 1 cm^3 of the 0.1% solution to 9 cm^3 of distilled water. Use this to test for low concentrations of vitamin C.

08) Continue to add DCPIP one drop at a time, shaking the tube very gently to mix, until the colour does not disappear. Count and record how many drops of DCPIP have been added. If your plant extract is to dark or too coloured to be able to see a clear colour change, ask your teacher if you should use a modified method.
Note: Stop if you get to 25 drops. Dilute the plant extract by 5x by adding 1 cm^3 of extract to 4 cm^3 of distilled water. Repeat the test for the diluted solution, but record the number of drops used x 5.

09) Test a second sample of extract and record the average number of drops of DCPIP used. If your results are not consistent, test a third sample. Record the average number of drops for the two closest results. (For comparison with 0.1% DCPIP, remember to divide by 10 if you used 0.01% DCPIP.)

10) Rinse your apparatus clean and repeat steps 2-9 for different parts of the plant. If you have time, obtain results for different plants. Record your results in a table.

11) Wash your hands – some plants may contain toxins or allergens.

INTERPRETING YOUR RESULTS

a) Use your results table to construct a bar chart to compare parts of plants and/or different plants.
b) In your results, which part of which plant was the best source of vitamin C?
c) If you can see any, describe any patterns in the results.

CLASS RESULTS

Compare your results with the rest of your class and make notes on the following:
a) In the class results, which part of which plant was the best source of vitamin C?
b) Describe any patterns you can see in the results.
c) Suggest possible explanations for any patterns in the results.
d) What are the possible sources of error in the investigation?
e) Suggest how the investigation might be improved.

MORE ABOUT PLANTS

a) What are the functions (jobs) of the different parts of plants: roots, stems, leaves, flowers, fruits?
b) Where does the energy that plants use to make vitamin C come from?
c) Why might a plant need vitamin C?

FURTHER INVESTIGATIONS

Suggest what other investigations might be carried out using DCPIP to test for vitamin C in plants.

MODIFIED METHOD FOR VITAMIN C IN COLOURED EXTRACTS

ADDITIONAL EQUIPMENT

- White spotting tile with wells

PROCEDURE

01) If you cannot see when the DCPIP is just retaining its colour, add 0.5 cm^3 or 10 drops of extract to each of five wells in a spotting tile.

02) Keep one well free of added DCPIP as a reference to show what the colour should look like when the DCPIP is completely decolourised.

03) Use a teat pipette to add one drop of blue 0.1% DCPIP solution to the extract in one well. Gently rotate the tile to mix.

04) If there is a clear colour change, make 0.01% DCPIP by adding 1 cm^3 of the 0.1% solution to 9 cm^3 of distilled water. Use this to test for low concentrations of vitamin C.

05) Continue to add DCPIP one drop at a time until a clear colour change has taken place compared to the reference well.

06) Add one less drop of DCPIP to another well of extract and two fewer drops to another well. Decide which well just gives a colour change compared to the reference well and record the number of drops of DCPIP used.

07) Repeat using another well of extract to test another sample of extract and record the average number of drops of DCPIP used. If your results are not consistent, test a third sample. Record the average number of drops for the two closest results. As you have used only 0.5 cm^3 of extract you will need to multiply by four to compare with 2 cm^3 of extract used in the test tube method.

CALCULATING VITAMIN C CONCENTRATIONS

Each 1 cm^3 of 0.1% DCPIP (molecular weight 290) solution is decolourised by 0.000607 g (6.07×10^{-4} g) of vitamin C (molecular weight 176).

a) Assuming that the volume of one drop of DCPIP solution is 0.05 cm^3, calculate how much vitamin C is present in each gram of plant material tested by you.

b) How much of your best source of vitamin C would you have to eat to get your entire recommended daily amount of 40 mg?

PLANTS AS CHEMICAL FACTORIES

Plants are chemical factories, able to make a huge variety of chemical substances.

Many plants have cells called trichomes on their surfaces, including hairs and glandular hairs. Glandular hairs can make highly concentrated compounds which are often useful for defence against, for example, insects.

You can look at the surfaces of plants with a microscope to see if trichomes are present, or rub the surface to see if smelly compounds are released.

EQUIPMENT

Variety of plants · Basic microscope, no sub-stage lighting · Microscope slides · *Optional*: lamp

PROCEDURE

01) Place a piece of leaf on a slide under a microscope. If the area is not well lit, use a lamp to illuminate the leaf sample from the side. Safety: Do not work in direct sunlight.

02) Work thorough the powers of the microscope. Can you see any structures on the leaf surface? They may be hair-like or appear as glistening globules. Draw or describe what you can see.

03) Remove the leaf and rub the surface gently. Can you smell anything? Make a note of what you can smell. Safety: Do not do this if there is a risk that you are allergic to plant material.

CONCLUSIONS

Is there a pattern? Is there any association between what you can see on the surface of the leaf and what you can smell?

Write a sentence or short paragraph to summarise your observations.

FINDING OUT

Many compounds found in trichomes are used by industry. For example, peppermint trichomes secrete menthone.

01) Use suitable sources to find some uses of peppermint. Make a list.

The Centre for Novel Agricultural Products at the University of York (CNAP) has worked for many years developing new varieties of ‘Sweet Annie’ (*Artemisia annua*). This plant has glandular trichomes which produce several compounds, including one called artemisinin.

02) Why is artemisinin important?

Jess Chu is investigating plants from the tropical rainforest in Malaysia.

03) Explain why conservation of rainforest plants is important.

THE SKILLS USED BY A RESEARCHER

You have found out about the work done by Jess Chu and carried out your own piece of research.

What do you think makes a good research scientist?

What skills did you use in your investigation that are similar to those used by Jess?

a) Write three or four sentences to describe the qualities or skills that you think a good researcher needs. Consider how? what? what kind? when? where? and think about:

- knowledge
- safety
- predictions
- using apparatus
- collecting data (getting 'results')
- using data
- 'fair tests'
- conclusions
- timing
- motivation

b) Which of these qualities or skills did you use in your investigation?