SAPS
SCIENCE & PLANTS FOR SCHOOLS

# OSMOSIS

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# Life study: Biology A level in the 21st century . . . and a response from SAPS and FSC

A team from the University of Warwick was commissioned by the Wellcome Trust to carry out a piece of education research focusing on A level Biology. In March 2004 the findings of the team were published and the full report can be accessed at www.wellcome.ac.uk/education/lifestudy.

This short article summarises the responses of SAPS and FSC (Field Studies Council) in relation to a number of the statements and recommendations contained in the Wellcome report. In particular, we try to identify the threats to the study of ecology and plant science and possible actions for the future.

Teachers at a SAPS workshop
© SAPS

The stated aims of the research were to investigate:

- *the response of students and teachers to current biology A level courses*
- *factors that make biology a popular option at AS and A level*
- *the effectiveness of current biology A level courses in preparing students for progression in the biosciences*
- *the extent to which biology A level courses reflect changing research priorities in biosciences*

In order to gauge student and teacher interest, the researchers gathered data on the level of interest in the various topic areas covered in A level specifications. For the purposes of the survey, the following topic areas were identified.

| | | |
|---|---|---|
| *Animal biology* | *Ecology* | *Human biology* |
| *Biochemistry* | *Environmental biology* | *Living organisms* |
| *Biotechnology* | *Food production* | *Medical biology* |
| *Brain and behaviour* | *Genetics* | *Microbiology* |
| *Cell biology* | *Growth and reproduction* | *Plant biology* |

## Important? . . . but boring

The report contained both good and bad news for our two organisations. A level students and their teachers rated living organisms, food production and plant biology - topics that are at the core of our activities - as being important and supported their inclusion in the curriculum. But it was disappointing to find that ecology was rated as the least important topic. Even more worrying is the fact that all of these topics were considered to be the least interesting in biology by the students. Another disappointing aspect of the survey is the observation that teachers' perception of importance of a given topic is almost exactly mirrored by their interest in that topic. Without wishing to sound patronising, we could perhaps anticipate that students might generate such a response but the fact that their teachers also arrive at those conclusions is disturbing.

Fieldwork with FSC © FSC

The Wellcome report points out that recent advances in the biosciences has meant that there is increasing pressure to change the content of post-16 biology programmes with, for example, an underlying shift from whole organism to molecular or cellular biology. As new topics are incorporated into the curriculum there is consequent pressure to reduce content in other areas. Inevitably, those aspects that are reduced are likely to be those with fewer advocates. This could exacerbate existing trends, which are already worrying. For example, there is considerable evidence that fieldwork opportunities have diminished amongst secondary biologists (e.g. see the Wellcome Trust report and Barker et al. 2001, FSC Occasional Publication **72**), and there may also have been a decline in classification and taxonomic skills. More recently,

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(new address as from 1.4.06)

Anne Bebbington (Journal of Biological Education (2005) **39**(2): 62-67), has shown that nearly half (41%) of A level biology students (in a sample size of 816 students) could, at best, name only one wild flower from a selection of 10 such flowers. Trainee teachers fared little better (36%). Of course, one might argue that such taxonomic skills are not required as the 21st century unfolds but if there are corresponding decreases in awareness and understanding of environmental issues, and of applied ecological skills - environmental literacy in its broadest sense - surely this must further threaten areas of biology such as living organisms, food production and plant biology.

## Stimulating interest

So where do we go from here? Clearly we will need to do more if we are to reverse the trends described in the Wellcome report. We don't admit to having a crystal ball and even if we did our competence in their use might be open to question! The government's decision not to fully implement the Tomlinson Report (in 2002) is likely to mean that A level provision will remain intact for the foreseeable future. If developments in biosciences continue apace, perhaps we will see the emergence of a 'double A level' in Biology in order to ensure students are able to access the full suite of existing and emerging HE programmes that call for a background in biology. Our great fear is that a constant squeeze on content will lead to a decline in both requirement and opportunities for students to engage in fieldwork and plant biology studies.

*Out in the field with FSC* *©FSC*

## The SAPS-FSC commitment

Both FSC and SAPS will continue to provide new curriculum resources which are well-respected by the educational community [see, for example, Reiss, M.J. (2005). SNAB: a new advanced level biology course, J. Biol. Ed., **39**(2), 56 – 57]. Both SAPS and FSC will offer high-quality CPD programmes for teachers and trainee teachers. We will also continue to lobby in parliament and with decision-makers (see www.field-studies-council.org/campaigns)

One thing is certain - our respective organisations will work together in order to provide rich curriculum opportunities for students, trainee teachers and teachers. These are critical elements in ensuring recruitment to biology, as highlighted in the Biosciences Federation education report (Enthusing the next generation, 2005) available at www.bsf.ac.uk/responses/enthusing.pdf. We have recently produced new materials for KS1 (see Plants for Primary Pupils at www-saps.plantsci.cam.ac.uk/worksheets/activ/pp4p.htm) and we are delighted to report that Anne Bebbington has been working with both SAPS and FSC since April 2005 on a series of joint initiatives which we fully anticipate will further strengthen our offerings.

We would welcome your comments.
**Dr Paul Beaumont (Director of SAPS)** can be contacted at 01223 507168 or by email at pb288@cam.ac.uk.
**Dr Steve Tilling (Director Communications for FSC)** can be contacted at 01743 852100 or by email at steve.tilling@field-studies-council.org.

## Medical science of the future?? . . . launch of a writing competition

Cancer Research UK is launching a writing competition on 10 March to coincide with the start of National Science Week. The competition is called the **Science of Tomorrow**. Young people aged 11-18 are asked to describe the medical science of the future. What types of medical research will scientists be working on in fifty years time? Imagine it is 2056, what developments will scientists have made and what new problems will they be tackling? And what will a lab of the future be like?

From 10 March 2006 there will be more information on the web at **www.scienceoftomorrow.org.uk/**
The website will also include examples of medical milestones from the past 50 years and quotes from some Cancer Research UK scientists, who make their own predictions.

The judges will be looking for some good ideas and clear written style.
The word limit is 700 words and the closing date is **Friday 7 April 2006**.
There will be regional winners in the 11-14 and 15-18 year old categories and one overall winner for each age category. Entries can be submitted online or by post.

# Making the invisible visible
# . . . or bringing carbon dioxide to life

Many schools and colleges have an oxygen sensor linked to a meter, and this can be used to monitor the percentage of oxygen in air or water. These sensors are often very fickle to get working and the margin of error of the readings can be too large for reliable results. Yet the most important metabolic processes that involve gaseous oxygen (photosynthesis and respiration) also involve carbon dioxide.

Measurement of gaseous carbon dioxide is now something that can be achieved, at a realistic cost, in the school classroom. A gaseous carbon dioxide sensor has been developed by the USA based company Vernier and is distributed in the UK by Instruments Direct Services Ltd. If a room is available with a data-projector or interactive whiteboard, you can then monitor carbon dioxide with a sensor and watch the results with a dataprojector as they happen. A dramatic lesson is possible!

*A carbon dioxide gas sensor - useful in the laboratory and in the field - for taking direct measurements of carbon dioxide concentration*

The sensor can be used with primary pupils and beyond post-16. With primary pupils you can demonstrate photosynthesis (but no need for any calculations) but with post-16 students there is lots of potential for more sophisticated data analysis.

## A fantasy lesson . . . on the carbon cycle and the importance of plants

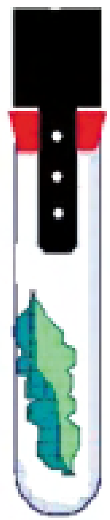
Imagine a lesson that begins with a class entering a laboratory. It is a warm day and the pupils notice the windows are closed. Any plants that are present have been covered with black plastic bin liners. A data projector throws a display on to a screen. It shows a scrolling graph of the carbon dioxide level in the room, measured in parts per million. The door is closed and the class settles down. The pupils soon notice the rising level of carbon dioxide on the display.

The carbon dioxide expelled in the breath of the teacher and pupils causes the graph to rise. The gradient of the graph gives the rate in parts per million (ppm) per second. This rather strange figure can be converted by a simple calculation to equivalent units of glucose or energy (see Box 1). For even more drama, light the Bunsen burners in the laboratory. The pupils will soon notice an increase in the gradient of the graph. This offers a nice parallel with fossil fuel combustion and the amount of carbon dioxide in the global atmosphere.

Then place the carbon dioxide sensor in a boiling tube, together with a small, freshly detached leaf from a plant - arranged neatly inside (not folded onto itself). Cover the tube with a lightproof sleeve (e. g. encased in aluminium foil). You will have to make a new adaptor rubber bung in order to get the sensor to fit the boiling tube (the one supplied with the sensor is too large). You can do this by using a cork borer to fit the boiling tube.

The pupils see that the carbon dioxide levels are still rising – this allows a discussion about the fact that plants have to respire as well as animals. Finally, remove the sleeve and shine a bright light on the tube . . . within a couple of minutes, the carbon dioxide levels begin to fall (thunderous applause from the class?!).

Finish the lesson with an attempt to estimate the number of such leaves that would be needed to stabilise the carbon dioxide levels in the lab – by balancing the carbon dioxide output of the class with photosynthetic uptake of carbon dioxide by illuminated plant leaves. Guidance on this calculation is given in box 2.



*The carbon dioxide sensor placed in a boiling tube with a green leaf. The changes in carbon dioxide concentration are recorded as they occur and can be read off from a computer screen*

## *Box 1: Calculations based on rates of change in carbon dioxide concentration*

If the rate of carbon dioxide uptake or production is known, this can provide a means for calculating the equivalent number of glucose molecules that this amount of carbon dioxide represents, either being synthesised into carbohydrate during photosynthesis, or broken down during respiration. If this assumption is made, then it is possible to estimate the amounts of energy being used in photosynthesis or released in respiration.

Select an area of the graph, and select the rate button to get the rate of carbon dioxide change figure for this region. The software provides units for the rate of carbon dioxide change in ppm per second.

This rate of change in carbon dioxide is different for different sized containers, so the next step is to take account of the volume of gas in the container being used, in units of $cm^3$.

**If we assume that six carbon dioxide molecules are either used in photosynthesis to form a glucose molecule or are released by the respiration of a glucose molecule**
then the number of **moles glucose being formed per second**

**= (rate of change (ppm) x volume of container in $cm^3$ / 144) x $10^{-9}$**

The complete aerobic respiration of glucose is worth 2840 kJ $mol^{-1}$.

So the rate of **release of energy (or uptake of energy in photosynthesis) by the organism in kJ per second**

**= (moles glucose per second) x 2840 kJ**

For many purposes, it would be a good idea to have an Excel worksheet set up so that simply entering the volume of the container and the ppm per second figure, leads to the automatic calculation of glucose and energy equivalents. This can be displayed to the class so that ppm figures can be entered and instant glucose equivalents presented.

Naturally this figure can be adjusted to provide a rate in kJ per minute, per hour, or per day! To allow fair comparisons between different samples, the figure should also be related to the mass of biological material involved, to provide a rate as units of energy per unit mass per unit time.

## *Box 2: Calculating the need for plant leaves to reprocess an individual's carbon dioxide and to replenish the oxygen consumed in respiration*

Find the volume of the laboratory by multiplying its length, breadth and height in meters, then multiply the answer by $10^6$ to give its volume in $cm^3$.

Assume that in the laboratory, with the doors and windows closed (and plants covered), the gradient of the carbon dioxide is largely due to the respiration of the people in the room. Then you can use the formula below to calculate the number of **moles glucose being respired per second** by the people present:

**(Rate of change (ppm per second) x volume of container ($cm^3$) / 144) x $10^{-9}$**

Divide this figure by the number of people in the room to find out the number of **moles of glucose per second being respired by each person**.

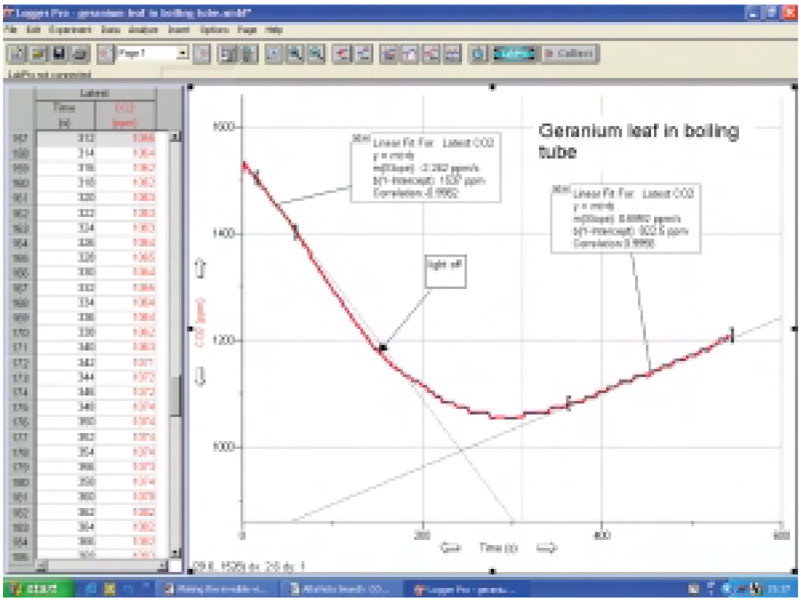
Assume that the leaf in the boiling tube is in a volume of 50 $cm^3$ of air. Then use the formula above to calculate the **number of moles of glucose per second being made in the tube when the leaf is photosynthesising in the light**. This represents the net productivity of the leaf. Note that the leaf has to make the glucose to pay off its respiratory needs, before it actually makes a 'net profit' of extra glucose for use in growth etc. This net productivity is what is needed to reprocess the carbon dioxide released on an individual's breath, back to oxygen.

Divide the figure for the carbon dioxide output of an individual, by the figure for the carbon dioxide uptake by an illuminated plant leaf. The answer gives **the number of illuminated leaves that would be essential to reprocess the exhaled oxygen of an individual student**.

A sobering thought for students is that plant leaves are only naturally illuminated for half of the 24 hour day/night cycle, and that climatic conditions, seasons, disease and many other factors will further reduce the capacity of a leaf to help us breathe in this way! In addition, the draughtiness of the room will mean that the values for class respiration will be significantly less than the textbook values.

To find the gross productivity of the leaf, employ the formula above to calculate the number of **moles of glucose per second being respired by the plant leaf in darkness** (because this is still happening when the leaf is in the light). The gross productivity of the leaf is the sum of this figure plus the net productivity figure.

## Using the carbon dioxide sensor in studies of photosynthesis




*Watching changes of carbon dioxide concentration on the computer screen, as they happen*

### *Box 3: Suggested investigations using the carbon dioxide sensor*

Effects of the following on leaf photosynthesis

- carbon dioxide concentration
- temperature
- stomatal density
- herbivory

Effects of the following on gaseous carbon dioxide concentrations in the teaching room

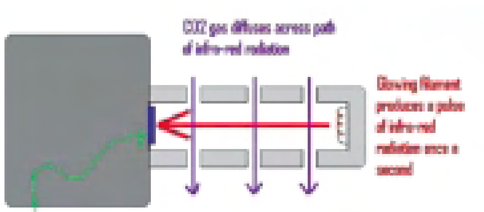
- number of people in the room
- biomass of people in the room
- physical activity in the room (compare a day when everyone is doing written test, with another day)

The true value of the system for measuring carbon dioxide lies in the rapid, robust and simple manner in which data can be collected. When studying photosynthesis, even the youngest pupils will readily grasp the fact that when the graph goes down, the carbon dioxide must be going somewhere in the plant leaves (to form sugar).

The sensitivity of the sensor means that the metabolic rates, even of single insects or other invertebrates, can be measured accurately. You can place animals and plants together until you achieve a balance between input and output of carbon dioxide. This has obvious parallels with the problems of achieving carbon dioxide stability in the atmosphere of the world today. Important ecological messages should be loud and clear after such classroom activities.

## What are the advantages of using a gaseous carbon dioxide sensor, as opposed to a gaseous or aqueous oxygen sensor?

Gaseous diffusion is thousands of times faster than diffusion in water, allowing results in minutes rather than hours (and so this allows time for replications and modifications). As a fraction of the atmosphere, there is much less carbon dioxide so changes are more obvious, allowing results to be obtained in minutes rather than hours (and by using small container volumes, only small amounts of biological materials are needed). No difficult experimental concepts are required to understand the fate of the carbon dioxide in photosynthesis – what you see is what you get. The analogy between the principle on which the sensor works and global warming, can be explored. Vernier software allows dramatic real-time plotting and annotation of data whilst it is being collected, as well as sophisticated analysis tools.



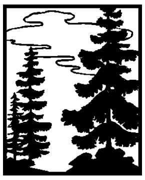

*How the sensor works - the sensor measures the reduction in the amount of radiation reaching it and computes the concentration of carbon dioxide gas in ppm (parts per million). This information is then passed to the datalogger at a rate of 1 reading per second.*

Since this carbon dioxide sensor was purchased by the author, several other manufacturers in the UK and the USA have produced carbon dioxide sensors of various designs and sensitivities. This article is based solely on the use of the Vernier system. Agents for Vernier International are: Instruments Direct (Services) Ltd, Unit 10, The Courtyard, Stenson Road, Coalville, Leics LE67 4JP Tel: 01530 832500.

A longer version of this article, which includes a wide range of suggested further applications for the carbon dioxide sensor, will be published in the March 2006 edition of the *School Science Review*.


***Roger Delpech, Haberdasher's Askes' School for Boys***

# Conifers, MRSA and inhibition of plant growth . . . how to turn a project starter into an investigation



**"What can I do for my investigation?" . . . a familiar cry from a 6th year student!**

This article gives some examples of how an idea could be developed into an investigation. From this a 'project starter' is then produced and, in time, can be used to help other students with their investigations in the future. On the SAPS website you can find examples of ideas in the Project Starters section.

The examination boards and teachers want to encourage genuine pupil interest to lead to the formulation of a hypothesis and the aim for a project. But in reality, this is a tough task for teachers and students for a whole variety of reasons - time and technical.

This article describes a sequence of events that can be used as a case study - how the ideas started amongst a group of students, the practical work they did, how they moved forward and what happened.

**The beginning**

- Sixteen sixth form students (in Scotland) are ready to begin their Biology Advanced Higher investigations
- Teacher tries to encourage individual interests and yet set realistic goals
- An experiment had previously been done in class that showed the inhibitory effect on plant growth of extracts from conifer needles
- One student reads an article about inhibitory effects of conifer extracts on MRSA
- An aim and hypotheses is formulated by the student, who then plans to investigate this inhibitory effect on the growth of microbes

**The practical work**

- The student produces bacterial and fungal lawn plates of agar
- Extracts from conifer needles are placed into wells in the plates
- Evidence of inhibition is **not** found on any plates
- Different bacterial species, fungal species and conifer species were tried and still produce no microbial inhibition

**Trying a new way forward**

- Further discussion with teacher and student . . . "What do we already know about conifer inhibition?" . . . "What exactly is the claim relating to inhibition of MRSA?"
- So for the next thoughts . . . Why not start with an experiment to show any inhibition of growth of seedlings, using different extracts of conifers? Try needles and cones
- Depending on these results go on next to look at inhibition of microbes

**What happened next**

- Different conifer species showed very different and measurable inhibitory effects on germination and on growth of cress seedlings
- Extracts from cones, particularly cypress cones, had marked inhibitory effect on plant growth
- Cypress cone extracts also had marked and measurable inhibitory effects on bacterial growth

This led to the production of a new 'project starter' and a full account of this project starter can be found on the SAPS website. The following description suggests ways that this idea (in the form of a 'project starter') can be taken forward and turned into an investigation.

*continued on page 7*

## Summer Schools for Science Teachers and Technicians

In order to allow teachers to keep pace with recent advances in biotechnology, the SAPS Biotechnology Scotland Project has, for a number of years, organised a residential Summer School at the University of Edinburgh. During the Summer School, participants are exposed to a rich diet of lectures, discussions, visits to industrial and/or research organisations, and practical activities. The provisional programme for the 2006 Summer School is available at www-saps.plantsci.cam.ac.uk/summer/2006/flyer2006.pdf together with a registration form which can be downloaded from www-saps.plantsci.cam.ac.uk/summer/2006/bookingform2006.pdf

Book early to avoid disappointment!

## Here is how one student developed these ideas for her project

*These extracts are reproduced (with permission) from the project submitted by Robyn Daniel at Dollar Academy, Scotland as part of her Advanced Higher Biology investigation for the Scottish Qualifications Authority (SQA) examination in 2005.*

### Title of Robyn's AH Biology investigation

*To investigate the Inhibitory Effects of Natural Plant Extracts on Bacterial, Fungal and Plant Growth*

### Robyn's summary

*"The aim of this investigation was to determine the inhibitory effects of natural plant extracts (from needles and cones where possible) of* Pinus sylvestris, Taxus baccata *and* Chamecyparis lawsoniana *on the growth of the bacteria,* Micrococcus luteus*, the fungus* Saccharomyces cerevisiae *and cress seedlings.*

*The hypothesis being tested was that all of the extracts would have an inhibitory effect on the growth of the bacteria, fungi and plants. It was predicted that the extracts would have the greatest inhibitory effect on plant growth.*

*The experimental results showed that pine had a greater inhibitory effect on cress seedlings, than on the bacteria and fungi, where it appeared to have no significant effect. Yew was seen to have an inhibitory effect on cress seedlings producing seedlings with stubby roots and many root hairs. Yew had minimal effect on inhibiting the growth of bacteria and fungi. Cypress needle extract appeared to have the most inhibiting effect on fungi with minimal effect on bacteria. However, interestingly, the extract from immature cypress cones had a significant inhibitory effect on the growth of the bacteria. Cypress also inhibited the growth of cress seedlings significantly."*

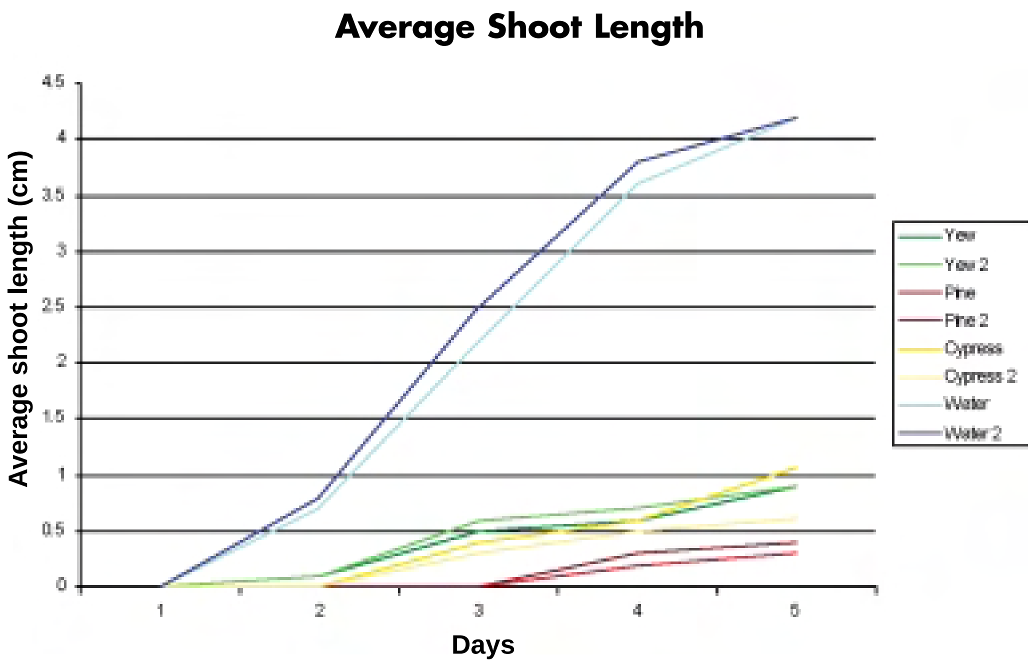
### A snapshot of Robyn's results

As part of her investigation, Robyn tested the effect of extracts on the germination of cress seeds and growth of the seedlings. She soaked filter papers with the different extracts and placed them in Petri dishes with a number of cress seeds. The dishes were then placed under a light bank. The table below is taken from a larger results table, which summarises (over a period of 5 days) the results obtained for percentage germination, average shoot length in mm and average root length in mm.


*Petri dish as used for growing cress seedlings*

| Extract | | Day 4 |
|---|---|---|
| | | % germination |
| Yew | 1 | 93 |
| | 2 | 93 |
| Pine | 1 | 12.5 |
| | 2 | 2 |
| Cypress | 1 | 73 |
| | 2 | 60 |
| Water | 1 | 100 |
| | 2 | 100 |

*Extract from Robyn's table*




*A graph from Robyn's investigation*

## . . . and the teacher's viewpoint

The reason behind this article in OSMOSIS is to illustrate how initial ideas can progress and develop into a worthwhile investigation for a student. Despite early rather negative responses and not much inhibition (cries of "oh! it isn't working!") the student persisted, took another approach and found clear examples of inhibition. So she moved on from her original plan and did develop an idea "that worked" and was able to generate useful data for subsequent analysis in a way that was appropriate for examination requirements at this level. It also illustrates the simplicity of the methods used (cress germination alone could have given plenty of results, without the more elaborate procedures necessary for growing bacteria and fungi). Perhaps the key is that it generated plenty of data and, by the end, took the student back to pondering the original discussion - something that is relevant in the real world in terms of finding a way of combating MRSA.

This simple experiment could be adapted and offer a means of exploring ecological relationships, say in terms of ground cover inhibition noted in conifer forests. This would provide a nice link between indoor laboratory investigations and outdoor field activities. A final benefit (to the teacher) is that the student's research led to refinement of the suggested method, now incorporated into the instructions in the project starter. This, with other 'project starters', is available on the SAPS website for a much wider audience and, hopefully, more inspiration for projects for students.

## The NEW project starter - Inhibitory growth effects of conifers

These ideas are presented as a project starter, given on the SAPS website (www.saps.org.uk). The details include background information and this draws together some of the ideas originally put forward by these students. This leads on to the idea of carrying out investigations into the inhibitory effects of conifer extracts on plant and microbial growth. The 'Starter Experiment' gives basic instruction for preparing the conifer extract and a method for growing seedlings and monitoring their growth. The project starter includes suggestions for possible investigations using these methods, for example, for plant growth inhibition, a comparison can be made of the inhibitory effects on plant growth of extracts from cones or needles or of extracts from old and immature cones. Methods that can be used for investigations on microbial growth can be found in the project starter 'Antimicrobial', also on the SAPS website.

***Marjorie Smith, Dollar Academy and SAPS Biotechnology Scotland***

# Plants for primary pupils

This series of publications supports work that must be undertaken with plants in the Primary Curriculum. These booklets are being developed by SAPS in collaboration with Field Studies Council (FSC).

### 1. Parts of a plant and their functions

If you are a primary teacher and on the SAPS mailing list for *OSMOSIS,* in February 2005 you should have received a copy of the first booklet in this series *(Parts of a plant and their functions)*. We hope you have found this useful in your teaching and that your pupils have enjoyed the different activities (and begun to learn something about plants!). This came to you instead of an issue of *PRIMARY OSMOSIS*. Feedback on the booklet would be most welcome! Why not email us (saps@homerton.cam.ac.uk) with your comments?

### 2. Reproduction and life cycles

*Part 1: Parts of a flower*

The second booklet in the series will soon be published. This is issued in two parts, each with a CD containing even more material (including templates for items needed for different activities in the booklet). Part 1 should be available from March 2006 and Part 2 soon after Easter 2006. This booklet builds on material in the first booklet, giving more independence to the pupils and packed with activities, games and role play that are fun and should help the pupils to understand the processes relating to reproduction in flowering plants. Again, we are pleased to offer a free copy of Part 1 *(Parts of a flower)* to all primary schools on the SAPS mailing list.

*Part 2: Pollination, fertilisation, fruits and seed dispersal*

Additional copies may be purchased from FSC Publications (£3) www.field-studies-council.org
All will be available on the SAPS website if you prefer to download your copy.