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Ideas and inspiration supporting science and technology for all Local Authorities

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Professional Development @ SSERC

For a number of years SSERC has been receiving funding from the Scottish Government to support professional development activities for teachers, student teachers and technicians.

In previous issues of the SSERC Bulletin (see for example [1, 2]) we have highlighted aspects of our provision. More recently our collaboration with the National Science Learning Centre at York has allowed access to ENTHUSE and RCUK funding thereby increasing the range and scope of our support for science and technology practitioners. We like to think that we are pretty good at what we do and this has been borne out by a recent external evaluation of our CPD provision by the Scottish Council for Research in Education at the University of Glasgow [3].

So, what of the future? The most recent tranche of funding from the Scottish Government came to an end in March 2012 and we are delighted to be able to report that their support for the SSERC programme of professional development is to continue. As part of its response to the recent publication of a report [4] from the Science and Engineering Education Advisory Group, the Scottish Government has earmarked funds which will allow SSERC to continue its national programme of professional development. To support our work with the secondary sector a major investment of £1.8 M over a 3-year period, starting April 2012, has been announced. Our work with the primary sector is set to grow and we are in discussion with the Government about an investment of some £300 k for each of the next 3 years.

With this welcome news we are busy planning our programmes of activities for the new academic session. Fliers for a range of our courses have recently been sent to schools and colleges and bookings are already buoyant! So if you don't want to miss out contact us to see what we might have on offer to support you at this time of curriculum change!

References

[1] CPD - Leading for Excellence in Science (2010), *SSERC Bulletin*, **232**, 8-9.
[2] A Summer of CPD (2009), *SSERC Bulletin*, **229**, 12.
[3] Lowden, K., Hall, S., Lally, V. and Mancy, R. (2011) SSERC's Support for Science Education in Scotland through CPD: External Evaluation Final Report-February 2011. ISBN 978-0-9531776-5-3, SSERC, Dunfermline. Available for download at http://www.science3-18.org/images/Publications/SSERC%20SCRE_final.pdf (accessed May 16th 2012).
[4] Supporting Scotland's STEM Education and Culture (2012) Science and Engineering Education Advisory Group (SEEAG), Second Report. Available at http://www.scotland.gov.uk/Resource/0038/00388616.pdf (accessed May 16th 2012).

Photosynthesis and Respiration

The Biology Team in SSERC has previously published, in this Bulletin and elsewhere, details of methods involving the aquatic plant *Cabomba* [1, 2] and how these can be used to show the processes of both photosynthesis and respiration.

The construction of so-called *Cabomba* towers [1, 2] can be tricky and may require some practice before reliable results are obtained. We wish to report here a simplified version which overcomes some of the technical obstacles associated with *Cabomba* towers.

Materials and Methods

The following items are required:

- 50 cm^3 of hydrogencarbonate indicator (pH approximately 7.8) (see [1] for details of preparation)
- 5 cm^3 of a concentrated suspension of the alga *Scenedesmus quadrica*.
- 50 cm length of glass tubing (internal diameter *ca.* 1.0 cm) with 2 rubber bungs.
- Black card.
- Access to a light source (preferably a fluorescent tube).
- Retort stands and clamps.

The method for producing your 'algal tube' is as follows:

1) Cut a piece of black card to a length of approximately half of the length of the glass tube and make a cylinder which will fit around the tube. This should not be too tight because later on you will need to remove the cylinder without disturbing the contents of the tube.
2) Firmly stopper one end of the glass tube.
3) Pour the algal suspension into a beaker and add sufficient hydrogencarbonate indicator solution to give a final volume of about 50 cm^3.
4) Stir the mixture and add to the glass tube as quickly as possible (try not to let the algae settle). Top up the tube with indicator leaving about 1.0 cm. Add the second stopper.
5) Place the cylinders at one end of the tube.
6) Give the tube a thorough mix to ensure the algal suspension is uniformly distributed.
7) Place the tube under the light bank. We find it convenient to use retort stands as shown in Figure 1.

It is important not to disturb the tubes while they are being illuminated. There is no reason why tubes should not be placed in sunlight rather than under a light bank although control of the light intensity is more reproducible using the light bank! We have found that resting the tubes horizontally using stands and clamps is a convenient way of ensuring uniform illumination with minimal effects of diffusion being apparent.
As the tubes are illuminated the algae exposed to the beam will photosynthesise and the indicator will turn from its original orange colour to a deep purple as carbon dioxide is removed from solution (in our set-up after about 3 hours of illumination) whereas the algae covered by the black cylinder will undergo respiration and the indicator will turn to yellow as carbon dioxide is released into solution.
Before removing the black cylinder it is worth asking students what

Figure 1 *- Delegates at a recent Biology SSERC CPD event carrying out steps 6 and 7!*

Figure 2 *- Suspension of Scenedesmus quadricauda in hydrogencarbonate indicator.*

they might observe. Provided that the cylinder is removed carefully and mixing is kept at a minimum then the tube will look similar to the one shown in Figure 2. The algae were originally placed in indicator at pH 7.6 prior to illumination. The left-hand portion of the tube was exposed to the full beam while the right-hand portion was covered with black paper during illumination. Similar effects can be observed with immobilised algae which can be prepared using standard methods [3, 4] and this is shown in Figure 3. In this case approximately 150 immobilised beads, suspended in hydrogencarbonate indicator (pH 7.6), were distributed along the length of the tube and illuminated for some 3 hours under a light bank.

Figure 3 *- Immobilised Scenedesmus quadricauda in hydrogencarbonate indicator.*

The immobilised algae were originally placed in indicator at pH 7.6 prior to illumination. The left-hand portion of the tube was exposed to the full beam while the right-hand portion was covered with black paper during illumination.

An interesting experiment is to take the tubes in Figures 2 and 3 and illuminate them but in this case cover the purple region with the black paper during the illumination. In both cases a reversal of the colour changes is observed i.e. purple → yellow/orange and yellow/orange → purple.

We believe this to be a simple, effective and above all 'nice' system for demonstrating photosynthesis and respiration in aquatic plants.

References

[1] *Cabomba* Tricolour (2011), *SSERC Bulletin*, **235**, 2-4.

[2] Adams, A., Moore, G., Rutherford, A., Stewart, F., Crawford K. and Beaumont, P.C. (2012), Cabomba - an exocharmic plant! *School Science Review*, 93, 9-12.

[3] Eldridge, D. (2004) A novel approach to photosynthesis practicals, *School Science Review*, **85**, 37-45.

[4] SAPS Photosynthesis Kit: the use of algal balls to investigate photosynthesis (2006), *SSERC Bulletin*, **219**, 2-5.

Nature's Neons

Figure 1 *- Female glow-worm (Lampyris noctiluca). Image courtesy of David Savory/UK Glow-Worm Survey [9].*

Background

Now that the Arrangements Documents for the Revised and *CfE* Highers in Biology [1, 2] and Human Biology [3, 4] have been published the Biology Team within SSERC is preparing to publish a series of protocols to support practical work contained therein. Many of these protocols will appear on the SSERC website [5] or in this Bulletin (see for example [6]). The Arrangements Documents [1-4] all include a suggestion that students might explore *'Experiments on ATP dependent reactions, e.g. luciferase, luminescent reactions'*.

The luciferin/luciferase reaction is probably one of the most alluring in nature and is characteristic of bioluminescent organisms; bioluminescence may be conveniently defined [7] as *'the production and emission of light by a living organism'*. Bioluminescence is not an evolutionarily conserved function; in the different groups of organisms capable of undergoing the process the genes, proteins and substrates involved are mostly unrelated and probably originated and evolved independently [8]. It is worth pointing out that although the substrates and enzymes involved from one species to another are often unrelated the terms luciferin and luciferase are still used to describe key reactants in the process. So, firefly luciferin is chemically different from luciferin found in bacteria; possibilities for confusion abound!

An amazing diversity of organisms is capable of emitting light and

these include bacteria, fungi, crustaceans, molluscs, fishes and insects. The specific biochemistries of bioluminescence vary from one species to another but all involve an enzyme-mediated reaction between molecular oxygen and an organic substrate leading to the production of light; no external light source is required.

Functions of Bioluminescence

Bioluminescence is a good example of a function that is not metabolically essential but one which confers an advantage on the individual.

Many organisms utilise their ability to bioluminesce in order to attract a partner. So, for example, a female glow worm of the species *Lampyris noctiluca* (Figure 1) glows in an attempt to attract a sexual partner - males of this particular species do not bioluminesce. Thus, in this case the functional importance of bioluminescence is based largely on the need to be detected by another organism.

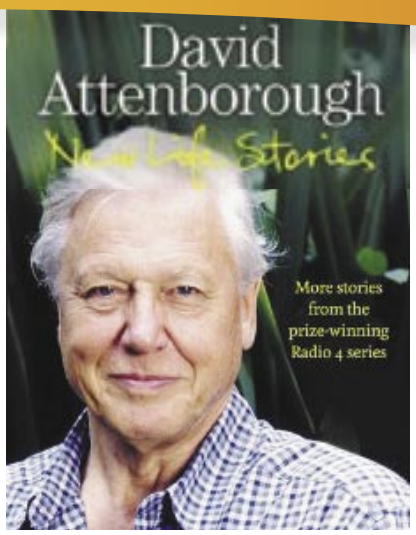


Figure 3 *- A recent anthology by David Attenborough.*

Important defensive strategies include the ability to frighten, serve as a decoy, to provide camouflage and to aid in vision.

Figure 2 *- Photinus pyralis (taken from [10]).*

Firefly Bioluminescence

Probably the best know example of an organism which can bioluminesce is the firefly (Figure 2). The variety of fireflies with their different habitats and behaviours is impressive. The major function of light emission in fireflies is for communication during courtship, in which one sex emits a flash as a signal to which the other responds usually in a species-specific pattern. Typically one sex (often the female) is stationary and emits light or a flashing signal and the other sex is attracted to it. The time delay between signals is an important characteristic of a species. For example, at 24° C the female of the eastern US firefly species, *Photinus ignitus*, waits for 3 s before answering the male signal; the time delay increases to about 9 s at 13° C. Timing is crucial - a firefly with a poor sense of timing will be doomed to a life of celibacy!

In a recent publication (Figure 3 and [11]) David Attenborough describes one of the most fascinating displays of cooperation amongst fireflies. In the mangrove swamps of southeast Asia [12] just after dusk male fireflies sitting on the leaves of so-called display trees will start to flash in an attempt to attract a female for sex. After several minutes the males coordinate their activities in such a way that they all flash at the same moment in time followed by a pause before the process is repeated. The overall effect is of a tree which 'lights up' at regular intervals. Because of the large numbers of fireflies present at any one time the flashes of light become so strong that the trees are used by local inhabitants as navigational aids. Written observations of the firefly tree phenomenon are not new - indeed in 1949 Somerset Maugham wrote [13] *'The fireflies give the shrubs the look of a Christmas tree all lit up with tiny candles. They sparkle softly; the radiance of a soul at peace.'*

Figure 4A *- mating fireflies (Photuris hebes) hang in the shelter of a leaf.*
Figure 4B *- a female (Photuris versicolor) dismembering an alien male firefly. Images taken from [16].*

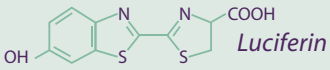
Video clips of the phenomenon are available (see for example [14]) but few are as impressive as that first shown in the Wildlife on One TV programme entitled *'Nature's Neons'* [15]. Sadly copies of the programme are difficult to locate.

The images in Figure 4 demonstrate potential outcomes arising from the light displays [16]. In the first case (Figure 4A), male and female fireflies from the species *Photuris hebes* have exchanged signals and are mating. Figure 4B shows the results when food rather than sex is the goal. A female firefly *(Photuris versicolor)* has cracked the code of a male firefly from an alien species and captured him. Despite his imminent demise, the male firefly in Figure 4B is still signaling in the hope that he might mate with the female.

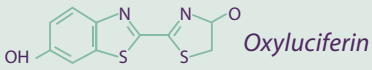
Biochemistry

The firefly system was the first to be well-characterised. The series of reactions (catalysed by the enzyme luciferase) can be summarised in the reaction sequence shown.

$$Luciferin + ATP + O_2 \longrightarrow Oxyluciferin + AMP + PP_1 + CO_2 + Light$$



Luciferin



Oxyluciferin

The mechanism is not yet fully understood but it appears that luciferase amino acid residues promote the addition of molecular oxygen to luciferin, which is then transformed to an electronic excited state oxyluciferin molecule and carbon dioxide. Visible light emission results from the rapid loss of energy of the excited state oxyluciferin molecule via a fluorescence pathway. The very high quantum yield for this process (in alkaline solution, nearly each reacted luciferin molecule emits a photon) reflects not only efficient catalytic machinery, but also a highly favorable environment for the radiative decay of an electronic excited state.

It should be noted that ATP is not a reactant in the light-generating reactions in all organisms (see for example [17-19]).

School Practical Work

As noted previously the Arrangements Documents [1-4] for the revised and *CfE* Highers in Biology and Human Biology suggest that students might explore luminescent reactions. In our experience the costs associated with such experiments will be prohibitive for most school budgets. We have recently used the Firefly Bioluminescence BioKit (see Figure 5) from Carolina Biological Supply www.carolina.com) and sold in the UK by Blades Biological

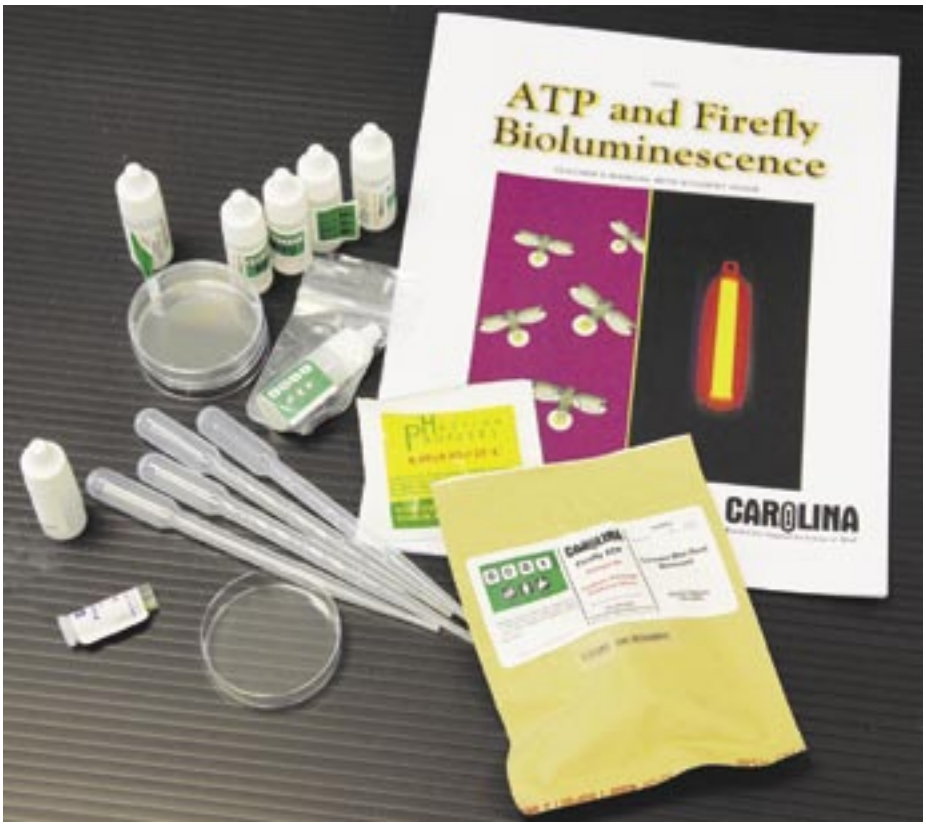


Figure 5 *- Contents of the Firefly Bioluminescence BioKit from Carolina Biological Supply.*

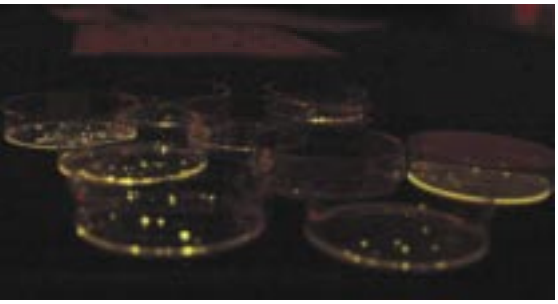


Figure 6 *- Firefly tails glowing in Petri dishes after addition of ATP and buffer. (Image supplied by Ian Birrell).*

www.blades-bio.co.uk, telephone 01342 850242) although the kit is not listed on the latter's website. The current cost via Blades is about £130 including VAT and carriage.

In our opinion some aspects of the kit worked really well. The manufacturers claim that the kit contains sufficient materials for 30 students. Detailed and easy-to-follow instructions are included with the kit and we have adapted those to produce 3 protocols which will shortly be available on the SSERC website [5]. In terms of laboratory facilities we would emphasise 2 things:

- to make observations effectively requires a room which can be efficiently blacked out
- ensure that students' eyes are well-adapted to dark conditions at the start of any given experiment since changes in light intensity can be subtle.

We trialled the protocols at a recent Summer School for Biology teachers (Figure 6) and overwhelmingly the participants thought the experiments were 'very useful' although the cost of kits is an issue for most schools. In due course we will place additional support materials on the SSERC website although we recognise that video materials are a poor substitute for the 'wow' factor which students will experience when dried firefly tails light up after addition of ATP.

References

[1] SQA (2010) Biology (revised) Higher - the Arrangements Document can be downloaded at http://www.sqa.org.uk/sqa/files_ccc/HigherBiologyCourseSpec.pdf (accessed 25th April 2012).

[2] SQA (2012) Higher Biology Course Support Notes - can be downloaded at http://www.sqa.org.uk/files_ccc/CfE_CourseUnitSupportNotes_Higher_Sciences_Biology.pdf (accessed May 12th 2012).

[3] SQA (2010) Human Biology (revised) Higher - the Arrangements Document can be downloaded at http://www.sqa.org.uk/sqa/files_ccc/HigherHumanBiology CourseSpec.pdf (accessed 25th April 2012).

[4] SQA (2012) Higher Human Biology Course Support Notes - can be downloaded at http://www.sqa.org.uk/files_ccc/CfE_CourseUnitSupportNotes_Higher_Sciences_HumanBiology.pdf (accessed May 12th 2012).

[5] The SSERC website is available at www.sserc.org.uk. Please note that to access all resources on the website you will need to register and be provided with a log-on ID and password.

[6] Polymerase Chain Reaction - don't assume what it says in the text books - prove it! *SSERC Bulletin* (2010), **233**, 4-5.

[7] Bioluminescence - available at http://en.wikipedia.org/wiki/Bioluminescence (accessed 25th April 2012).

[8] Hastings, J.W. (1995), Bioluminescence. In Cell Physiology (N. Sperelakis e.d.), Academic Press, 665-681.

[9] Image reproduced with permission from http://www.glowworms.org.uk/gallery/GW-10730.htm (accessed 25th April 2012). Credit David Savory/*UK Glow Worm Survey.*

[10] *Photinus pyralis* - image available at http://en.wikipedia.org/wiki/File:Photinus_pyralis_Firefly_2.jpg. © Art Farmer.

[11] Attenborough, D. (2011), New Life Stories, Collins; also available as an audiobook published (August 2011) by BBC Audiobooks Ltd.

[12] Chey, V.K. (2004), Fireflies of Sungai Klias and their display trees, *Sepilok Bulletin*, 67-69 (available at http://www.forest.sabah.gov.my/frc/English/pdf/ 8%20Fireflies%20of%20Sungai%20Klias%20and%20their%20display%20trees.pdf (accessed 25th April 2012).

[13] Maugham, W.S. (1949), A Writer's Notebook. Heinemann, London.

[14] *Fireflies sync* (2007) available at http://www.youtube.com/watch?v=sROKYelaWbo (accessed 25th April 2012).

[15] Wildlife on One (1994) Nature's Neons, Season 21 Episode 4.

[16] Lloyd, J.E. (1981) Mimicry in the sexual signals of fireflies, Scientific American, **245**, 111-117.

[17] Lin, L.Y-G. and Meighen, E.A., Bacterial bioluminescence: biochemistry and molecular biology - available at http://www.photobiology.info/Lin.html (accessed 25th April 2012).

[18] Branchini, B.R., Firefly bioluminescence - available at http://www.photobiology.info/Branchini.htm (accessed 25th April 2012).

[19] Viviani, V., Terrestrial bioluminescence: biological and biochemical diversity - available at http://www.photobiology.info/Viviani.html (accessed 25th April 2012).

Additional Resources

[1] A series of videos from the BBC Blue Planet series is available at www.bbc.co.uk/nature/adaptations/Bioluminescence#p006v478 (accessed 25th April 2012).

[2] Widder, E. (2010) Glowing life in an underwater world is available at http://www.ted.com/talks/edith_widder_glowing_life_in_an_underwater_world.html (accessed 25th April 2012).

[3] Science Friday (2010) Bioluminescence. Available at http://www.sciencefriday.com/program/archives/201005074 (accessed 25th April 2012).

[4] The film Apollo 13 contains an interview with Flight Commander Jim Lovell (played by Tom Hanks) in which he describes how a bioluminescent trail helped him locate his aircraft carrier off the Sea of Japan when all his instruments and radar failed.

(Son of) Flash Chromatography

Almost all science teachers are familiar with chromatography in one form or another. Though they differ in many respects, all forms of chromatography work by exploiting different interactions between the dyes and the two components of the chromatography setup.

The stationary phase - this is a solid. As the name implies it does not move and the fluids pass through it. (In ordinary paper chromatography, the paper is the stationary phase.)

The mobile phase - this is the fluid that moves through the stationary phase (like the water through filter paper).

Paper chromatography is a familiar technique in schools. A mixture of dyes (often an ink) is placed on some filter paper and a solvent is allowed to run up or along the paper carrying the different dyes different distances. Column chromatography works on the same principle. The dye mixture is washed down a column filled with a permeable solid. The different dyes move through the column at different speeds, depending on their size and interactions with the stationary phase, and so come out of the bottom at different times. The advantage of this is that you can get samples of your separated dyes to do further work on.

The problem, particularly in schools, is that column chromatography is slow - taking several hours. It can be speeded up by applying pressure to force the liquid through - a technique called *Flash Chromatography* [1]. Previous versions of this use a glass tube filled with a starch slurry. This is then linked by rubber tubing to a syringe to apply the pressure.

Unfortunately, this method is rather fiddly, as the stirring of the slurry is critical and the tube tends to pop off when pressure is applied.

In this new method, the syringe itself is used as the column and the stationary phase is packed dry, making the whole process much simpler.

The Method

Preparing the column

a) Insert a loose plug of mineral wool into the syringe (Figure 1) and tamp down with a stirring rod.
b) Use a spatula to put your medium into the barrel of the syringe, compressing with the plunger and adding more if need be.

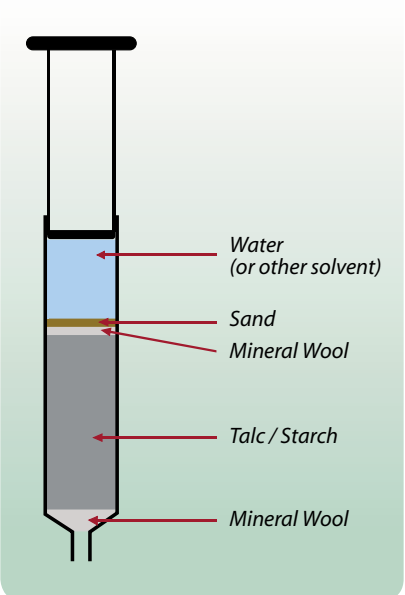


Figure 1 *- Setup of syringe.*

c) Insert another plug of mineral wool and tamp it down - quite firmly.

Running the Column

a) Take a 1 cm^3 Pasteur pipette and use it to pick up about 0.5 cm^3 of the dye mixture. Carefully dot this over the mineral wool in the barrel of the syringe (try not to get any on the sides).
b) Put a layer of silver sand on the top, a few mm thick, then carefully add solvent, trying not to disturb the sand too much so you keep the solvent clean.
c) Insert the plunger and apply pressure.
d) When you see the first hint of colour, move the syringe so it is over the first test tube and keep pressing. (Be careful, in some dye mixtures the first colour is literally one or two drops.
e) As you see the colour changing, move to the next tube and keep the pressure on.
f) If your syringe runs dry, pull out the plunger, use a glass rod to push back the plug that will probably have been pulled up by the suction, put more solvent in, replace the plunger and carry on.

Hints and Tips

Syringe size - The best separation seems to come using a narrow bore such as a 1 cm^3 syringe but they are very fiddly to pack. Generally, 5 cm^3 or 10 cm^3 syringes are the best. (It is a good use for old syringes with the markings worn off).

Packing - It is quite possible to run the column dry - i.e. without running solvent through first. Running some solvent through first does help with the packing but it is by no means essential.

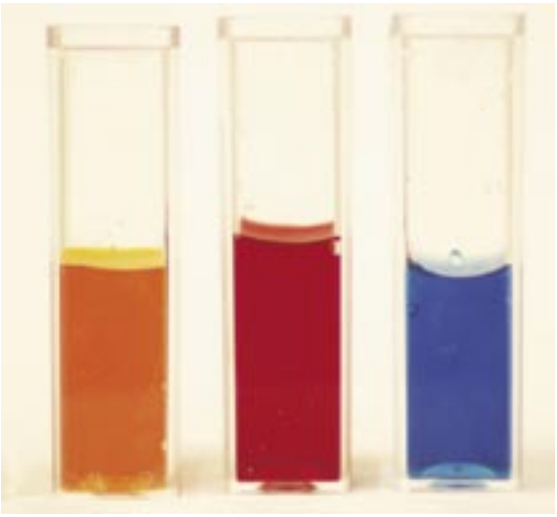


Figure 2 *- Dyes in black food colouring.*

Figure 3 *- Dyes in a purple Skittle®.*

Pressure - Maintaining the pressure can be a bit tiring but it seems not to cause problems if you release the pressure for a bit, to rest or change hands. Alternatively, if you use a 5 cm^3 syringe, you can place it in the jaws of a clamp and use that to apply the pressure.

Stationary Phase - We have had success with starch and, especially, talc (using simple cornflour and talcum powder). Work is still ongoing to investigate other materials. Different materials will interact with dyes in different ways so colours will sometimes come out in a different order.

Eluent volume - when all the solvent has gone into the column you can add more solvent by simply pulling out the plunger (carefully), re filling the barrel of the syringe and carrying on. If the plug of talc/ starch gets pulled up the tube, or it breaks and part of it does, pushing back down and carrying on seems to cause few problems.

Mobile Phase - Most dye mixtures can be separated using water or propanone but other solvents may work just as effectively. If you find a colour remains stuck in the column, if you change the solvent you will probably be able to elute it.

Technique - there is usually overlap between the dyes so you will need to watch carefully to make sure you are getting pure samples of the individual dyes. A good way is to have an array of tubes and allow the same volume to fall into each one (5 or 10 drops, say) before moving on.

Experiments (sources of dyes, colourings and pigments)

1) Food colouring - You will need to select your food colouring carefully. Green and black food colours seem to be the only ones containing more than one dye (and not all of those) so check first.

Figure 2 shows the dyes in Dr Oetker black food colouring* separated by this method using talc as the stationary phase in a 1 cm^3 syringe and water as the solvent.

The yellow dye is only one or two drops so care is needed when the colour first comes through.

2) Sweets - the colours can be extracted by putting two in a test tube with just enough water to cover them, though better results are obtained by using more sweets and evaporating some of the water to concentrate the colours. Many sweets don't have different colouring dyes, so try the brighter ones like Skittles® and M&Ms®. Figure 3 shows a purple Skittle ® using talc and water - you can see the red and yellow have come out well. In addition, a blue dye remained in the column.

3) Plant Extracts

It is possible, with care to separate out at least some of the different leaf pigments. Grass is a good source of chlorophylls and is certainly the most readily available. Grind up a few grams of chopped grass with some silver sand and extract with the minimum quantity of propanone. Load it onto the 'column' and elute using propanone (or another solvent).

Figure 4 shows sample results, using propanone. As it is a polar solvent, the constituents come out in order of polarity. The yellow tube on the left contains chlorophyll b, then comes the green chlorophyll a and then the yellow on the right is a mixture of xanthophylls and β-carotene.

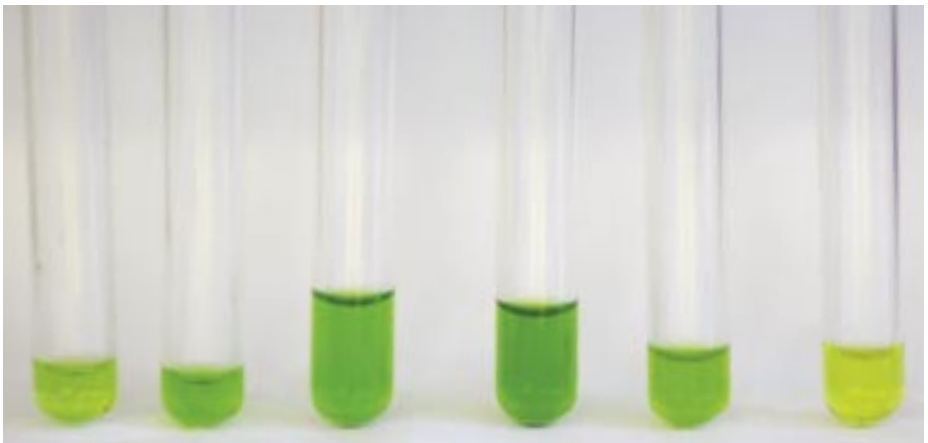


Figure 4 *- Photosynthetic pigments from grass.*

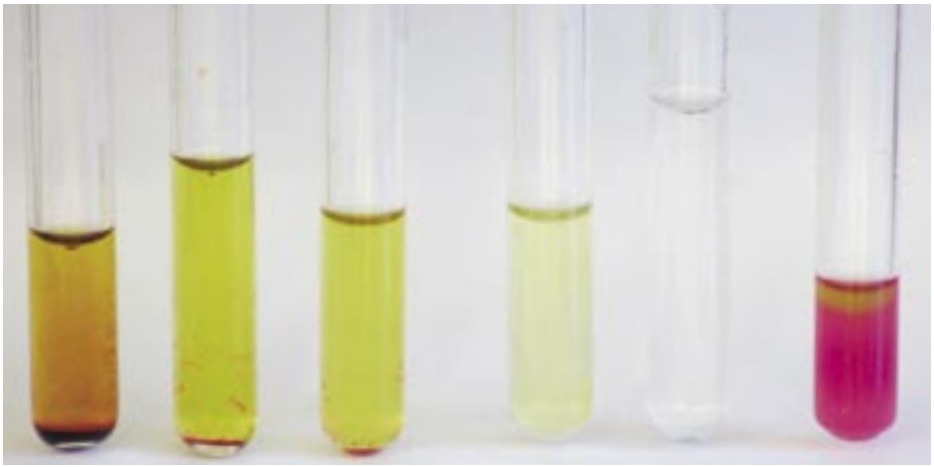


Figure 5 *- Anthocyanins from dried cotinus leaves.*

If you choose a red-leafed plant, it is possible to separate out the pigments that give it the red colour as well. These need extracting in acidified methanol or ethanol (1 cm^3 $HCl_{(c)}$ in 100 cm^3 alcohol).

Figure 5 shows *Cotinus* (a common ornamental shrub) leaves extracted in propanone and then eluted with cyclohexane (any other non-polar solvent should work). The results below were from some dried leaves so the chlorophylls are much less evident than is the case with fresh leaves. One of the red colours (an anthocyanin) comes through first with the chlorophylls next. The bright pink colour (another anthocyanin) remains resolutely in the talc medium until you add a more polar solvent, in this case ethanol, to extract it.

Conclusion

While this technique does not give as good separation as a proper column, the availability of the materials, the simplicity of the preparations and the speed of the procedure make it an excellent introduction to the more complex and time-consuming methods that are in widespread use. In particular, it is a valuable method of introducing chromatography as a purification technique, rather than a simple, though valuable, analytical tool.

* We have recently learned that the Dr Oetker range has been changed and the black colour no longer contains this mixture of dyes. At the time of going to press, we are still exploring suitable alternatives.

Reference

[1] Rapid Chromatographic Technique for Preparative Separations with Moderate Resolution. Still, W. C.; Kahn, M.; Mitra, A. J. Org. Chem. 1978, **43**, 2923-2925.

Health & Safety

Advanced Higher Students and SSERC

We encourage students to work with SSERC on AH investigations. We lend equipment, invite them to our premises and answer queries concerning their practical work. This last area does raise one or two issues concerning safety and child protection. To address these, we ask that the following protocols are observed:

- If using e-mail, initial contact should be established by a teacher or technician. Alternatively, the student may e-mail SSERC directly, provided that a member of staff is cc'd into the initial communication. The teacher or technician will thereafter be cc'd or, if preferred, bcc'd into all correspondence, or can act as an intermediary between SSERC and the student.
- If using the telephone, again initial contact should be made by a teacher or technician. Students should not contact SSERC using their personal mobile phones. Should they do so, SSERC staff will ask to speak to a teacher or technician. A member of school staff should be present during subsequent phone calls.
- Students should never contact SSERC about chemical disposal, spillage or immediate remedial measures. This should always be done through a member of staff.

We trust that the reasons for these measures are obvious and that having to comply with the protocols will not dissuade anyone from seeking help.

Inductors - the shocking truth

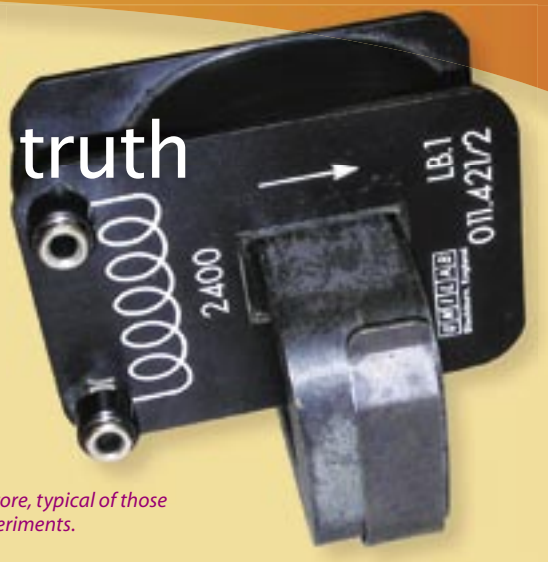


Figure 1 *- Coil with core, typical of those used in inductor experiments.*

Most teachers are familiar with SSERC's guidance on Van de Graaff generators, most recently updated in Bulletin 223. Recently, we have had a couple of enquiries on shocking pupils with inductor coils, along the lines of, "I've been doing this for years, but is it allowed?" The obvious answer is, "If you don't know, don't do it until you find out." Having said that, there seems to be no readily-accessible information available to teachers on whether or not this is a safe thing to do. What is more, pupils may accidentally shock themselves when working with inductors.

When an inductor is connected to a smooth dc source, a back emf is established that opposes the current. This diminishes with time, with the current eventually reaching a steady state value equal to V/R where V is the supply voltage and R is the resistance of the circuit. This will largely be due to the resistance of the inductor's windings. The time to reach the steady state depends on the circuit resistance and the coil's inductance L. Roughly speaking, it will be around $5L/R$.

When the inductor circuit is broken, a back emf attempts to maintain the current. The circuit resistance is now much larger. If a switch is used to make the break, the resistance will now be of the order of megohms. This has two consequences. Firstly, $5L/R$ is now very small. The current is going to fall to zero in a very short time. Secondly, the back emf will be large. The circuit resistance may have increased one hundred thousand fold. The emf required to sustain the current will increase proportionately, albeit for the aforementioned very short time. We are now in the realms of Van-de-Graaff-generator voltages.

When assessing risk associated with Van-de-Graaff shocks, we looked at the energy stored in the system and applied a safety limit of 500 mJ, knowing that, in practice, the actual spark energy is almost always rather lower. No special pleading should be made for inductors. The safety limit for the spark energy from an inductor should be 350 mJ, the level above which discharges are considered to be a direct hazard to health.

The energy stored in an inductor's magnetic field is given by $\frac{1}{2} L I^2$, where I is the steady-state current. Using manufacturer's data for the inductance, we calculated the energy for two sets of coils (Table 1).

A coil typical of those used in this investigation is shown in Figure 1. In conclusion, a shock from coils such as those above is unlikely to be harmful to a healthy pupil. If using coils other than these types, carry out an energy calculation for yourself, or consult SSERC. Adopt the following control measures:

- Do not shock or expose to the risk of shock a pupil who has a heart condition.

Our Van de Graaff guidance asserts that charging pupils should be limited to volunteers. If you are setting out to deliberately shock pupils, you must ask yourself whether this is an ethical thing to do. What is the educational point? If it is to show that there is a large back emf induced when an inductor circuit is broken, or that energy is stored in a magnetic field, you could do so by using the inductor to strike a neon bulb. It could be argued that the "shock" method is more memorable and therefore more effective. But don't use it as a covert form of corporal punishment.

Table 1 - Energy stored by inductors

Coil	Inductance (H)	Steady state current (A)	Energy (mJ)	Comments
Unilab 60 turn transformer coil with full core.	0.01	8	320	Current taken as maximum available from typical school PSU. This exceeds the rating of the windings by a factor of 4.
Unilab 2400 turn coil with full core.	5	0.2	200	Resistance of windings measured as 70 Ω. Current calculated for PSU set at 12 V.

The Signs are still a-changin'

Now the shiny new diamond-shaped labels are becoming commonplace in your laboratories, the time has come for an update on the process so far. There is still, you may be surprised to know, a long way to go. In December 2010, it became the law to label all 'substances' for sale in the EU according to the new CLP system. Old stock already labelled was allowed to be sold until June 2012.

The next stage is the labelling of 'mixtures'. This comes into force in June 2015 and existing stock can be sold until June 2017. Until then, the old CHIP labelling system can still be used (though it probably won't be). This could theoretically lead to the odd situation of the same supplier sending you in the same package copper sulphate labelled according to CLP and copper sulphate solution labelled according to CHIP - quite legally.

So where does all this leave teachers and technicians?

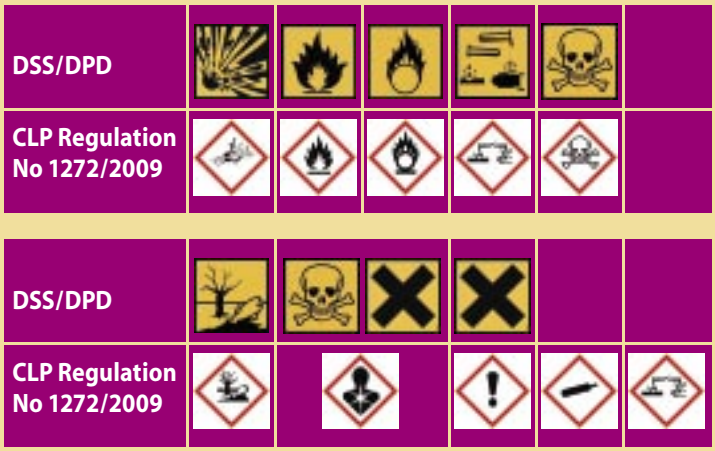
The answer to this is 'pretty much as you were'. The new labelling system is only mandatory for suppliers and manufacturers so, as end users, you need not, according to the law, take any notice of it. That, however, would not be good practice. The new symbols will soon start appearing in text books and exam papers as well as on bottles and jars, so your bottles and jars should really be labelled similarly. There is no need to panic, though. You don't have to have it all done by the end of the summer holidays.

If you do want to get things under way quickly then this chart shows a rough comparison between the two systems. You need to note that it is more complex than just swapping one set of symbols for similar ones but if you label according to the diagram in the interim, you won't be far wrong and can re-label as the up-to-date information appears on our website.

What effect will it have on what is taught and how it is taught?

Just because a sign has changed, that does not mean the hazard has changed. In most cases it is simply a case of lines being drawn in slightly different places, between the different degrees of flammability for example. So if the hazard has not changed, the risk has not changed and thus your risk assessment will still be valid.

It is important to mention here, however, that you cannot just blithely assume a risk assessment, once done, can be filed away and merely glanced at from time to time. As the science improves chemicals are reclassified as has always been the case. For instance, methanol is now classified more severely because research shows it is uniquely harmful to humans, more so than animal studies would suggest. So you should, as a matter of good practice, check with the SSERC website from time to time to make sure your risk assessments are up to date.



What are we doing at SSERC?

It is going to be quite a long process but over the next few months you will see the entries on the SSERC website gradually being updated. To keep you up to date, there will be regular progress reports on the chemistry home page of the site.

What can you do to help?

This whole process is a big upheaval, especially for the manufacturers, and there is plenty of room for mistakes to be made. So we would ask you to keep an eye on any new deliveries and if you see some labelling that seems not to make sense, get in touch with us at SSERC and we'll investigate. The same goes if you see something odd on our website. You might find it hard to believe but we are only human and things can occasionally slip under our guard too.

The most important thing to remember, though, is that the advice about handling, storage, safety etc. is still valid and you should still follow it, irrespective of whether the classification has been updated.

Links

1) If you want to try to look up a chemical in the ECHA database, it can be found here http://bit.ly/IG6C1f.

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