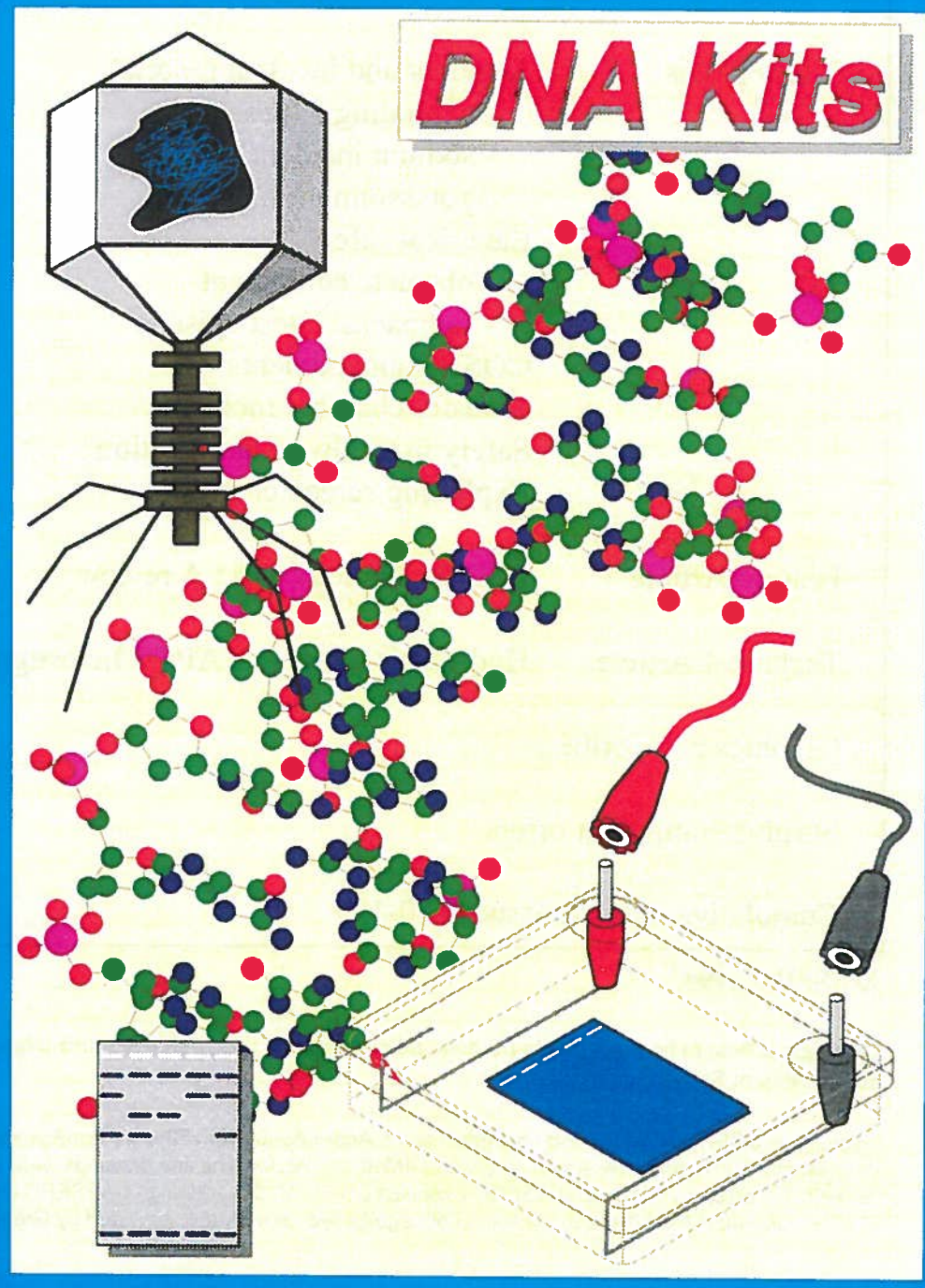
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE

Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences



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Foreword

Sponsorship reversal

Unfortunately for us, the putative commercial sponsor for this issue had to withdraw their support at short notice. The trading figures for the company, which for obvious reasons will remain nameless, had turned out somewhat gloomier than expected (we know all too well just how that feels!). Their and our misfortune have at least worked to someone else's advantage. That well known - and as yet the only - Scottish interactive science and technology centre, *SATROSPHERE* in Aberdeen is also not exactly basking on the sunlit financial uplands at present.

Dr Lesley Glasser, tireless Director of the Northern SATRO, recently sent us news of the *Satrosphere's* problems and details of the new "Friends of Satrosphere" scheme. We decided that our loss should be their gain. Hence the publicity on the outer rear cover of this Bulletin and the editorial material which appears below. We feel that the Satrosphere is far too important to lose. Indeed we think it a great shame that it remains the only such centre in Scotland. It would be a sad reflection on the scientific, technological and political state of the nation if Satrosphere were to have to shut its doors for the lack of such a relatively small amount of money.

SATROSPHERE - Dream and Reality

Satrosphere in Aberdeen is at present Scotland's only "hands-on" science centre open to the public. Founded in 1988 by a consortium of enthusiasts from education, business and public life, it is a limited company with charitable status. It aims to demystify science and technology, and to encourage everyone - especially young people - to take an interest in them.

Generous help from the Gatsby Foundation and other trusts, from industry, and from the local authorities, got Satrosphere off to a good start. It opened in February 1990 with about 60 exhibits and now has over 140, with some 90 on the floor at any one time.

These surplus exhibits enable Satrosphere to renew and refresh the exhibition and to run a programme of themes, such as *Energy*, *Materials* (the current theme) and *Our Senses* (coming up in the summer term). This constant change is necessary. At present about half the visitors have been before, some as many as fifteen times!

Satrosphere provides booklets to accompany the themes and other materials (including kits of parts) to help teachers use it effectively. Twilight INSET for primary teachers is a regular feature, much appreciated by those struggling to introduce the 5-14 syllabus.

Live shows such as *Sounds Fun* and *Light Fantastic* take a light-hearted look at the science behind some of the exhibits. There are workshops for children in the holidays, and our *Bubble Bonanza* is in demand all summer long at fêtes and charity events.

So, what's the problem? Money is (as usual). The recession hasn't helped - numbers have levelled off at about 50,000 per annum, a creditable total, but our business plan called for more than that. At the same time, money from sponsorship and trusts is increasingly hard to come by. About 10,000 of our visitors are school parties and schools find the transport increasingly difficult to afford. Everyone is in the same (impoverished) boat!

This impasse inspired us to launch a "Friends" campaign to celebrate our fourth birthday-and to ensure that we are still around to celebrate our fifth. We seek 1000 Friends willing to pay £10 or more, and in return receive concessions, newsletters and other benefits. If you would like to ensure that Scotland doesn't lose its last remaining "hands-on" centre send us your name and address and a suitable donation. You will find our address both in the Address List for this Bulletin and on the outside rear cover.

We'd be delighted to enrol you as a Friend of Satrosphere.

Dr. Lesley Glasser
Director, SATRO,
North Scotland

Opinion

Right reason - wrong response

As these fingers (all two of them) fly to (but not around) this keyboard the accusations of arrogance are inevitable. But, the chance to hit such a number of sitting ducks with the one blast is not one to pass up.

We have been fascinated of late how uncharacteristically often the great and the good seem to have got hold of the right stick. Unhappily they have yet to learn consistency in grasping it by the correct end and then hitting the right folk with it. This results in them doing the wrong thing to the wrong people but for the right reasons. You want specifics? Try these for size.

Curriculum innovation and workload

Environmental studies

Take, for example, the science and technology bits at 5-14. It is recognised that many teachers are by now totally fazed by the official documentation. It is widely agreed that they will have to be given time and help to work their way through the document and to digest its not insignificant content. What kind of help is then proposed? Easy answer : These teachers obviously need yet another weighty set of documents which they can work their way through in order that they will then fully grasp the implications of the first set of documentation and possibly of their own EA's guidance both of which they didn't originally have enough time to read anyway.

Sorry - wrong answer! You might as well market a combined shampoo and conditioner for unwanted body hair. Even we non-primary specialists understand those bits of the document we have read. It is after all printed. Joined up writing now, that we might have found a lot trickier.

Some have suggested that other kinds of help might now be more appropriate. Instead of yet more planning aids, checklists and definitely definitive guides on how to read all those other guides to The Guide, how about if we now begin identifying useful practical resources, equipment and training? In several quarters such suggestions have been howled down. How dare we suggest lists even of generally useful items when "all the learning outcomes haven't yet been identified and fully defined"? Here we go again - yet more jargon to restrict and obsfucate rather than simple, practical help to enable and liberate. It's a dandruff treatment for the totally bald.

Paperwork we have in abundance. Much of it, for example the PSDP stuff and several existing commercial courses, is of a more pragmatic nature and is actually quite useful. Perhaps we should be telling teachers more loudly about that instead of felling forests in the name of Environmental Studies (and in any event, what an irony).

Secondary science and technology

Similar phenomena have been observed too at the secondary level. For the sake of "workload" there appears to be little place for such projects as the Schools Chip. Again right reason - wrong response. By all means push back the pendula which have swung too far on issues like the overtight prescription of syllabuses and learning outcomes or the excessive bureaucracy which has snuck up on some of us in the name of assessment of practical work and investigations.

Certainly, let us find ways to cut back on unnecessary documentation for departmental policy planning or, whisper it, the management of health and safety. But, to deny professionals access to exciting, new and practical ways of teaching science and technology because they are already overloaded with excessive paperwork seems a classic case of grasping the wrong end of a wrong stick.

Health and Safety education

There is both a mood and a move throughout the EC to strengthen health and safety aspects of school curricula. This is perfectly proper since both those who may find work, as well as those who won't, need to know about these things. One approach however has been to develop special, stand alone courses on health and safety issues.Yet again right mood, right motive - wrong move. A technical article in the next issue will provide an example of how such topics may be more naturally and properly integrated into day to day science and technology teaching. Trustfully it will grasp the correct ends of several appropriate sticks.

Oscillatory optimism

Several of us at SSERC have already celebrated our silver weddings with the educational system (if indeed "celebrate" be appropriate). Throughout that time we have been hypnotised by its oscillations. One much-loved metaphor (i.e. cliché) has been that of the progress of the inebriated along the supposedly straight, white line.

At the moment though, I see little reason for too much pessimism. There are signs of a sobering up which, of course, can get a bit messy. Beyond that there is hope - at least for a while. After all, if the system has started asking even a few of the proper questions - who knows - perhaps it may eventually come up with at least some of the right answers?

Introduction

We apologise for the late appearance of this issue which has been due partly to excessive workloads and partly because of staff shortages through illness.

Environmental Studies

This issue sees the launch of a 5-14 supplement in the shape of a four page insert. We have no funding (euphemism for siller, cash, money, molula what you will) for the distribution of this mini-bulletin directly to each Scottish primary school. For the moment we have yet again to rely on what a teacher once famously christened our "carrier snail" system of communication. We would be most grateful therefore if the secondary teachers reading this could ensure that at least some of these inserts are passed on to colleagues in the primary sector.

Many Scottish EAs have already set up neighbourhood or cluster groups of secondary and primary schools. Such arrangements usually also include the nomination of a 5 - 14 primary/secondary liaison person. This may be one way to assist the dissemination of our humble broadsheet. By far the best insurance however will be for us to make the supplement of high quality and practically useful. It may then become essential reading so that both primary and S1-S2 teachers actively seek it out.

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More on SSERC Courses

As indicated in the last issue of the Bulletin, the Centre will again be offering a wide range of courses in the coming session (1994-95). These will aim to meet some of the diverse needs of teachers, technicians and management teams in secondary, primary and FE sectors.

Formerly we have tended mainly to provide advisers and development officers with details of our course provision who have then included SSERC entries in their own EA's directory of courses. Structural changes in the educational development services of a number of authorities mean that we can no longer solely rely on such mechanisms. We have therefore decided to publish our own Staff Development Directory and to make it directly available to subject co-ordinators in individual schools and to neighbourhood group INSET co-ordinators.

Practical, hands-on courses

The emphasis will remain on such courses. We will continue to adopt a flexible approach toward both the overall programme and the specifics of any particular course. In general we are able to offer training in nearly every aspect of practical work or technical support in science education. We can offer similar coverage for several important aspects of technology curricula and training is offered in the educational aspects of technologies such as electronics, pneumatics and mechanics, as well as in applications of information technologies for data-gathering, control and graphic communication.

Health and Safety

Existing health and safety training programmes cover a range of topics from COSHH through Electricity at Work to the safe educational use of ionising and non-ionising radiations. Courses just trialled or under development include work on the new Management Regulations as well as other relevant parts of the so-called six-pack of regulations made in response to European Community Directives. Practical training on health and safety can also be provided for the primary sector but we prefer wherever possible to integrate such training with more general courses which also cover several other aspects of practical, project and investigative work.

Negotiation

We are prepared to tailor any of our courses in order to meet the specific needs of groups of teachers, technicians or school managers. Pick and mix selections from the SSERC Directory are possible. Any reasonable subject matter will be considered just so long as it relates to our particular expertise. Training can be given in the Centre when that proves convenient or provided on an out-reach basis.

Evaluation and quality

The Centre has long been in the business of quality assurance and not just for its training courses. A considerable body of evaluation evidence as to the success of SSERC courses has been accumulated. Relevant sections of this are open to inspection by potential clients.

Course fees

These are comparable to those charged by other public sector providers in Scotland. We usually charge on a per-head, per-day basis rather than a fixed daily fee regardless of numbers. This is subject to a minimum overall fee and travel or other out-of-pocket expenses are charged at cost.

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Hands-on courses are usually subject to maximum numbers in order that participants can derive full benefit from the practical, active aspects of such training.

The Directory

To obtain a copy of the SSERC Training Directory your department, your school staff development co-ordinator or other designated person should write to the Executive Director of SSERC at the address given on the inside rear cover of this Bulletin.

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Competition results

We received a number of entries for the competition in the last issue. Readers may recall that this was in three sections : Firstly a prize was offered for the best suggestion as to the identity of the person represented by the skeletal animatronic figure in the illustration for the front cover of Bulletin 179 (see Fig.1). An identical prize was offered for the best caption to put alongside the figure.

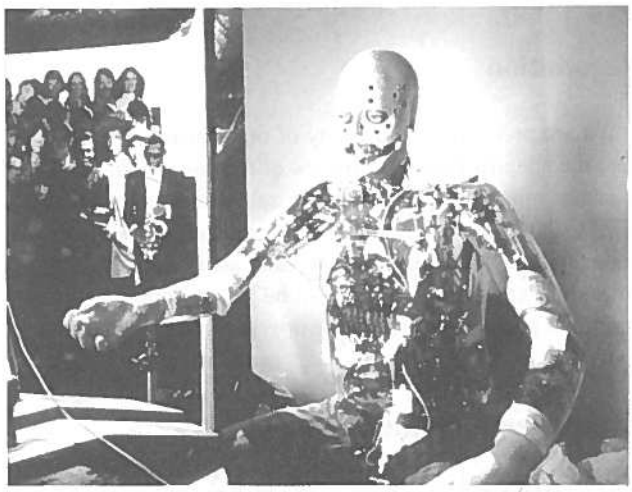

Fig. 1 Reduced monochrome version of illustration from cover of Bulletin 179.

We eventually decided that the caption did not necessarily have to be linked to the identification, but that the degree of such aptness would earn bonus points. Finally we offered a special prize for any innovative pneumatic circuitry which could be incorporated into a robotic design.

Teachers being wordly souls and feeling the way some of them do right now, it should come as no suprise that some of the suggestions for each competition section were unprintable. This is especially so since we know that Techy teachers will be watching eagerly for these results. We also know of their especially delicate sensibilities.

And now . . . . . da!da!

The Winners!

In our view the two best entries combined identity and apposite caption. No-one provided a sufficiently novel circuit design. The spare prize therefore goes to a third combined identity and caption entry.

First prize is awarded to Alan Frame of Wick High School for the identity/caption combination :

'John Major' - "Back to basics"

Runner up was Bill Maxwell of the Gordon Schools again with a combined entry :

"Michael Jackson fails in bid to prevent publication of intimate photograph . . . . . allegedly!"

The third prize goes to someone who, perhaps not suprisingly, did not name their school but wrote from their home address. For their own protection we have decided to call them "Mr or Ms X (name and address supplied)". In their view the figure was :

"A Quality Assurance Insurance Inspector made up from TVEI Electronics Modules wired up with 5 - 14 Strands."

We also got a stonking entry from a Scottish Civil Service reader but for their sakes and ours we don't dare publish it. Suffice to say that it draws a parallel between Lord Charles (if you're old enough you will recall that he was one half of a ventriloquism act) and a certain other ennobled dummy.

Many thanks to everyone else who took the trouble to enter. When we are knocking our pans out writing the Bulletin it's nice to know that somebody takes the time to read this stuff!

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Safety Notes

Accident reports

Two accidents have recently been reported to us. Fortunately in neither was anyone hurt. We very much appreciate schools sending us such information on either accidents or near-misses. These may act just as reminders of certain hazards and risks or act as a warning to us all. The first involved an explosion in a Kipps apparatus and the second an accident which occurred when a piece of sodium was added to water.

Exploding Kipps

A Kipps generator had been used for generating and dispensing test-tube quantities of hydrogen. At the end of the lesson, as the technician lifted it to carry it away, it exploded. A hole was blown through the plastic basin in which the generator had been placed to provide containment against possible spillage.

The explosion was not thought to have been that of the hydrogen with oxygen of the air. Rather it was due to a build-up of pressure a possible cause of which could have been a blockage at either the delivery end of the reservoir or in the layer of granulated zinc. Otherwise any excess pressure would have been gradually relieved by the acid being driven back up into the reservoir.

We would recommend that for the simple examination of the properties of hydrogen that the gas is prepared on a small scale by :

- either test-tube preparation by pupils themselves with collection by downward displacement of air from one tube held inverted over the reaction tube or

- using a smaller scale hydrogen generator enclosed in a box with only a rubber thistle funnel and a plastic delivery tube protruding from it.[1]

If a Kipps generator is to be used, and Kipps apparatus does have its good points, then :

- a small scale version be selected rather than the giant types which in former days were used to generate and dispense hydrogen sulphide;

- a safety screen is to be used, possibly with a small hole for the tap and gas outlet poking through and

- the free movement of the liquid reagent (acid in this case) be checked by seeing if the liquid level falls rapidly when the gas delivery tap is opened.

[1] See Bulletin 146 [1]. Bulletin 127 [2] provides another alternative which is the electrolytic hydrogen generator.

Sodium incident

The sodium that jumped over the safety screen?

No, that's not the start of a nursery rhyme variant. It is very seldom that you can do this nice wee demo of the reaction of sodium with water without a small piece of sodium leaping out. But this jump has to be a new world record. Please do not try to emulate or beat it!

In this particular demonstration the teacher had taken all bar one of the recognised precautions :

(i) a large volume of fresh water was used;

(ii) a safety screen was placed between the trough of water and the pupils;

(iii) only a small piece of sodium was taken and

(iv) everyone was wearing eye protection.

The sodium cleared the screen and hit a pupil on the way down, fortunately without causing any injury.

A major difference from the established procedure was that a clean, freshly cut piece of sodium had not been taken. It was the end of the bottle and it was a case of using up some old scrappy pieces; these would have been coated in a mixture of liquid paraffin and some unknown oxidation products.

One possible explanation for this prodigious leap depends on the existence of this protective layer or skin which will be intact over all or most of the surface of the lump. When a small amount of water breaches the skin at one point, the rapid expansion caused by the hydrogen generated in a confined space will propel the lump. The restriction and enclosing of the sodium by the coating would also have reduced the dissipation of heat into the body of the water. That in turn would have further accelerated the rate of reaction, probably igniting the sodium.

Incidents of exploding pieces of lithium were attributed to the same phenomenon, where a crust of hydroxide rapidly formed on the surface; being so enclosed the piece explodes violently on heating. The rate of formation of this skin is dependent on the humidity and offers an explanation of the haphazard occurrence of such explosions.

cont./p.6

Bretherick reports that small pieces of sodium do not ignite the evolved hydrogen provided the temperature of the water is kept below 40 degees Celsius and the sodium is not constrained. (Unauthorised experiments in the past have seen students deliberately do this by wrapping sodium in filter paper and then squirting water on it.)

Recommendations

1. Use only a *freshly cut* piece of sodium. Pick a lump out of the jar with tongs, mop off the liquid paraffin or other immersion fluid and cut off for use a small piece not more than about the size of half a pea. Return the lump to the jar, replacing the lid and setting the jar away from the scene of the action.

2. Carefully drop the sodium into the centre of a large trough of cold water placed behind a safety screen. Position the screen hard against the trough so that any trajectory paths at an angle will be intercepted by the screen. Any piece being flung up vertically should fall again vertically. There is almost a case for having a partial roof on the safety screen.

3. Use two safety screens one between the teacher and the apparatus in addition to the one between the apparatus and the pupils.

4. Because of this incident the school concerned were considering carrying out any future demonstrations in a mobile fume cupboard. This will give very good all round protection, but the insides of the glazing and the roof (if ducted) or the pre-filter (if a recirculatory cupboard) would have to be checked afterwards for any stray bits of sodium.

5. If the demonstration is to be repeated several times and the trough is small, the sodium hydroxide solution formed in the reaction should be replaced with fresh water.

6. Old fragments of sodium should be disposed of by dissolving them in propan-2-ol and then greatly diluting the alkaline propoxide solution before running to waste. If the quantities were other than small, it might be advisable to roughly neutralise the residue before disposal. You do want to protect your drains!

Potassium problems

Finally a word of warning about potassium. Do not start cutting it if it has formed a yellow coating. Put aside any old yellow, encrusted pieces of potassium for disposal by a specialist contractor. Potassium forms a crust of superoxide on the outside of the first formed oxide layer. This oxide middle of the sandwich insulates the powerfully reducing potassium from the powerful oxidiser.

When a blade is driven through the three layers the two powerful reactants will be mixed and this has sometimes resulted in violent explosions with severe consequences.

On account of this readiness to form superoxides potassium has a short safe shelf life and should be purchased in the smallest quantities available and not be kept much longer than a year.

We have recently heard reports of some educational firms supplying potassium which is aready showing obvious signs of yellowing. Clearly you should not accept delivery of any such samples of potassium. You should complain - loudly - and insist that the supplier takes them back.

* * *

Electrical safety

Obsolete equipment

Readers may recall earlier accounts of trials and tribulations with old models of mains powered electrical laboratory apparatus such as power supplies. An accident with a faulty Radford Labpack reported in the Safety Notes section of Bulletin 176 [3] and other problems since have been increasingly causing us concern. Some of these difficulties have arisen because of the complexities attendant on the renovation of old equipment.

With the advent of the Management of Health and Safety at Work Regulations and the Provision and Use of Work Equipment Regulations (both 1992) there is now a statutory requirement for a far more systematic approach to the control exercised over such procedures. As a result we have concluded that some general guidance on the treatment of aged electrical apparatus might prove useful to teachers and technicians as well as to school or college managers.

Management requirements

Regulation 4 of the Management Regulations deals with "Health and Safety Arrangements" and lays down general requirements for planning, organisation, control, monitoring and review.

More specific requirements are made in HSE guidance on the Work Equipment Regulations 1992. Therein the HSE recommend that employers should plan for regular preventive maintenance of equipment to stop it from failing in any dangerous way. Part of that overall system or scheme however is planning for periodic replacement of equipment before it finally reaches the end of its safe and useful working life.

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Criteria for replacement planning

In any replacement section of a preventive maintenance scheme for electrical equipment the criteria listed below may be used to aid decisions.

1. *Effective age* - score according not only as to the chronological age of the equipment but weight this according to the nature and frequency of use. In this scheme, items heavily used by pupils may need replacement long before little used items or those used largely for teacher demonstrations.

2. *Diversity of models* - where there are many versions or models of what is still basically the same device, there is opportunity for confusion and error on the part of those arranging or carrying out the repairs. The advantages of replacement over renovation will appear sooner than would be the case with devices where the range of types is restricted. This is related to the costs of instruction, supervision and control which are likely to increase multiplicitively with the diversity of types.

3. *Number of potential or actual defects* - the greater the number the greater the potential for error in the repair or renovation process (related to 2 above) the stronger the argument for replacement. It should be noted also that many electrical accidents can be traced to the simultaneous occurrence of several defects each of which by itself would not have caused harm.

4. *Competence required* - weight replacement more heavily when maintenance or renovation require a higher degree of competence if items are to be upgraded to reasonably safe standards (related to items 2 and 3).

5. *Assistance* :

(a) external

- bring replacement times forward if the original manufacturer or supplier goes out of business and this affects the availability of technical assistance and information.

(b) internal

- lengthen replacement cycles where high grade in house technical expertise with a suitable background in education is available (Regulation 6 of Management Regulations - competent assistance means experience in a relevant context - not just in the technicalities of electrical safety).

The factors identified should not be considered in isolation but weighed together. Some may sway the balance one way whilst others lend weight to the opposite view. They do at least provide the beginnings of a systematic and objective framework for making such decisions between renovation and replacement.

When the additional costs of managing refurbishment, together with the costs of labour, components and specialised technical assistance, begin to approach or even outweigh the price of new equipment, it clearly becomes a nonsense to embark on further renovation programmes. It is our opinion that if such criteria were more widely and consistently applied the evidence would overwhelmingly favour replacing a number of types of educational laboratory electrical equipment.

Items so identified would extend far beyond old Radford Labpacks. A likely list would take in many more types of power supply, several models of oscilloscope, microscope lamps and centrifuges to name but a few. When many such items are twenty to thirty years old there are powerful economic arguments, as well as those on safety grounds, to halt the drain on revenue expenditure and go instead for capital investment.

Funding

The counter argument will of course be made that there is no money available for such purposes. That's only ever partly true else the whole service would have been at a standstill twenty or more years ago rather than as now just staggering onward. As always, it is a question of priorities (something else that the Management Regulations require be taken into account).

The evidence is there to show that there now may well have to be a period wherein some investment is switched away from some of the more glamorous and hi-tech areas and toward more basic bread and butter items of kit. The economic arguments are in themselves sufficient but add in the safety aspects and they provide powerful management incentives.

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Labpacks - the latest episode

The most recent development in the Radford Labpack saga serves well to illustrate the principles set out above. For one thing this is an area where the problems are compounded by the diversity of models and where each model may exhibit several varieties.

Because Radford no longer trade and because we do not have a complete record of all of the design variations, we are unable to provide definitive directions for any modifications necessary on safety grounds. We can only draw up generalised directions, and trust that repairers are sufficiently competent to be able to carry these through to a reasonably safe standard.

On some models of Radford Labpack, there may be up to eight or more defects to be sorted out. Some of these are awkward to remedy. There is therefore scope for error in the repair process. In putting right one defect a repairer may cause others or more simply just miss some faults equally important in maintaining safety and preventing shock or fire.

No cut-outs

The most recent of these problems came to our attention when we had cause to look closely again at a Labpack fitted with two L.T. outlets neither of which is protected by a cut-out or fusing. One of these is intended for powering rayboxes (12V, 8A) and the other is a 6V, 3A outlet intended to power a heater.

This is not necessarily, in itself, a serious problem but the details of the wiring layout of the Labpack make it so. Pupils are sometimes given to short-circuiting LT outlets - either accidentally or deliberately. This is why most modern designs incorporate cut-outs. In the absence of such a device the insulation on the LT wiring may melt exposing bare wires or strands.

In the sample we looked at, the insulation on the LT supply wiring to the 12 V sockets had so melted. This again would be little cause for concern if this conductor didn't run past, almost brushing, the HT terminals (240 V etc.) on the transformer.

When this latest design fault is added to the existing list of potential Labpack defects, we begin to seriously question the point of continuing with any attempts to sort out many of the older models. This is but one example where the advantages of replacement now far outweigh any apparent cost savings from renovations.

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COSHH flow

The COSHH Regulations do keep changing in little bits and pieces, these changes being published in official amendments.

Benzene ban

Many of these minor changes to COSHH are of little relevance to schools. Because of a suspected link with leukaemia, nearly all Education Authorities banned the use of benzene years ago; a few did permit its use in a fume cupoard on a small scale to demonstrate the properties of benzene (as recommended in ASE's Topics in Safety). Benzene is now however legally banned for use in educational establishments. So it will be necessary to arrange for its disposal.

For the purposes of demonstrating aromatic substitution there is no problem as many alternatives are available, eg methyl benzene or esters of benzoic acid. There may be difficulties, however, if for a CSYS project a particular compound has to be synthesised. This will add another challenge to the ingenuity of the preparative organic chemists.

One unavoidable and ironic afterthought is the contrast between this ban on the educational use of benzene and the fact that you are still allowed to stand beside your car at the filling station forecourt with benzene fumes streaming out of the filler pipe on a largish scale.

Other changes

These will be apparent once the new 1994 COSHH Regulations become available this Spring. Several of the new amendments were made necessary when the CHIP Regulations [4] replaced the CPL Regulations. This is because COSHH had relied on the latter for definitions of 'hazardous substances', 'carcinogens', etc and now these have to redefined. Provisions on the control of biological agents are also to be included.

One area of particular and growing concern is that of sensitisers, but these will be covered by separate guidance, instead of being incorporated in the COSHH Approved Code of Practice alongside other hazardous substances. Unfortunately many more people are becoming sensitised to a wide range of chemicals from a variety of sources and not necessarily from exposure in laboratories. This sometimes leads to severe consequences and is a matter of concern to everyone.

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Shattering experience

We have had a report of an incident with a Harris Transfer Chamber (Cat.No. Y84406/9) in which the sloping glass window to the front of the chamber shattered. The technician who reported this incident to us had been using the chamber for about five minutes or so and then turned away to get some other items. When she was about two feet or so from the chamber the glass suddenly shattered with some falling into the interior of the chamber and other pieces falling onto the floor.

On further investigation it was discovered that although the glass and the metal sides of the chamber were warm the chimney or flue was quite cold. The most likely cause of the breakage was thus a failure in use to accurately position the micro-burner fitted to the chamber under the flue.

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Safety in fieldwork

When they first appeared in 1980 we thought that the Institute of Biology's guidance notes for codes of practice on safety in biological fieldwork would be difficult to better. They were a model of clarity in several respects not least in their careful definitions, and consistent use, of words such as "must", "shall", "should" and "may".

The guidance notes were however improved upon, with a second edition coming out in 1983. Now a third revised and extended edition (1990) has just been brought to our attention.

This goes beyond the immediate needs of most schools but is nonetheless a very useful source of advice and ideas. Certainly any secondary school or college which arranges expeditions or field trips to mountainous areas, isolated coasts or any other potentially hazardous sites would do well to consult these guidance notes.

In addition to a wide coverage of types of habitat, the notes now provide wider treatment of field techniques and special procedures such as the safe use of ladders, tree climbing, boat handling etc.

Copies of these notes, the full title of which is :

Safety in biological fieldwork - Guidance notes for codes of practice"

are available from the Institute of Biology at the address given in the list on the inside rear cover of this bulletin issue. The price is £6 per copy to members and £8-60 to non members.

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Exploding screen cleaner

We have received a "Safety Bulletin" for Trading Standards Officers via Lothian's Central Purchasing Unit. This concerned a less than user-friendly anti-static foam screen cleaner for computer monitors.

This is manufactured by Helix Ltd and sold through a distributor network under the trade name "Sapona" with the Product Code number SP6300 or SP6302. Apparently about one can in two hundred of those supplied in the last six months or so has either leaked, or in extreme cases, exploded.

Great care must be taken in handling any such cans which appear to be leaking, however slightly. Wear gloves and eye protection whilst removing the can to a safe place to await disposal.

References

1. *The burning of hydrogen*, SSERC, Chemistry Notes, Bulletin 146, June 1985.

2. *Hydrogen generator (Electrolytic preparation of hydrogen)*, SSERC, Chemistry Notes, Bulletin 127, April 1981.

3. *Electrical safety problems : Radford Labpack accident report*, SSERC, Safety Notes, Bulletin 176, March 1993.

4. *Labelling regulations*, SSERC, Safety Notes, Bulletin 179, December 1993.

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Feature Article

DNA technology kits - a review

This article describes the general approaches to practical work on aspects of DNA technology adopted by two educational kits. The contents of the kits are described and some evaluation of their use in practice given.

Introduction

The two kits under review here are the National Centre for Biotechnology Education (NCBE) DNA Gel Electrophoresis Kit and the Science and Plants for Schools (SAPS) DNA Kit. Both kits adopt broadly similar approaches to the introduction of practical work on DNA into schools and colleges. Whilst a comparative review is feasible across a number of features of both kits there are a number of significant differences between them. It would not be fair to present all our findings as though there were a direct comparison of like with like. Distinctions will thus be drawn whenever necessary in the course of this account.

General approaches

Both kits have similar educational aims and both use some simple practical protocols which are in turn based on long established genetic engineering procedures used in research or commercial processes.

There are some parallels with the Schools Chip project. Both genetic engineering and large scale integration of electronic circuits are largely technology driven. The basic science behind both is by now mostly well-kent stuff. Nonetheless in both instances the gap between practice in schools and the world outside continues to widen.

Supply

There are also differences between the two DNA projects and their respective materials. One such major difference currently lies in the pattern of supply of kits from the two organisations. Neither NCBE nor the SAPS Project are commercial educational supply houses. In both cases the primary role is educational development work. They seem to have reached different conclusions, at least in the short term, as to the way forward in encouraging school practical work on DNA technologies.

Kit supply - NCBE

The staffs of both institutions have been running in-service courses on DNA gel electrophoresis for some time now. NCBE, with its early work on simple protocols for the extraction of DNA from plant material, can properly claim also to have been long active in that field.

One minor motivation behind their DNA kit was a desire to take some of the pressure off NCBE staff because of a heavy demand from teachers for practical workshops on DNA gel electrophoresis. NCBE intended from the outset that their kit would be made commercially and directly available without any need to first attend a training course. The prototype of this commercial kit is at the time of writing undergoing field tests in about 80 schools. Thereafter it will be on direct sale at about £95 (plus VAT) per kit. Members of their Biotechnology Club will qualify for a 10% discount.

Replacement agarose, enzymes, pipette tips, and DNA will all be available from NCBE at reasonable prices. The bulk supply costs of enzymes and DNA are still under negotiation with NCBE's own suppliers but they assure us that they will strive to obtain the best possible terms so that replacement materials will be affordable for schools.

SAPS kit

The trustees of the SAPS project seem to have taken an almost opposite view. For now, whilst supply of the SAPS kit is free it is also dependent on first having attended a SAPS run training session. Taking such a free kit away after training is, obviously, optional. At each course a minority of teachers may decide that, having used the kit, it's not for them or their pupils. Many though take away a kit (which are in any case limited to one per school).

At the turn of the year some 160 kits had already been given out throughout the UK and SAPS intend that by June 500 free kits will have been so distributed. In Scotland, some 200 teachers should have been on a course by the summer of this year. As at the end of January, 110 Scottish teachers had been trained.

It is at the end of this training and initial dissemination exercise that the free supply of kits will cease. Thereafter Philip Harris will market the SAPS kit commercially but at a price yet to be decided. It is also currently intended that, possibly by adding materials and expanding the documentation, Philip Harris may extend the range of practical work possible with the kit. Replacement enzymes, DNA and other materials will also be available from Harris.

Activity	NCBE kit	SAPS kit	Notes and comments
Extraction and restriction analysis of plant DNA (calf thymus and Lambda phage DNA run for comparison and marker respectively).	No	Yes	White Mustard (*Sinapis alba*) or salad cress (*Brassica napus* or *Lepidium sativa*) as recommended sources. Uses the powerful detergent SDS to disrupt cell membranes liberating the nucleic acids.
Restriction analysis of Lambda DNA.	Yes	Yes	NCBE Lambda protocol utilises three restriction enzymes (*EcoRI, HindIII and BamHI*). SAPS kit uses *EcoRI and HindIII* only but both separately and together in a double digest.

Table 1 - Scope of kits

Scope of kits

The two kits differ slightly in the practical work and educational objectives which they support (Table 1 and Table 2 [overleaf]) and that, not suprisingingly, is reflected in their respective contents (Table 3). Each also requires the use of a number of additional items of biological laboratory equipment (Table 4) most of which should already be held in schools.

Background theory

This is well covered in the NCBE students' instruction booklet. A set of background notes is planned for the commercial version of the SAPS kit. Whilst it would be tedious to repeat in detail such material here, readers (especially non biologists) may find it difficult to understand the review in the complete absence of any basic interpretation of the DNA technologist's jargon. A general glossary of relevant terms is thus given below. Further explanation may also be provided where necessary when the practical procedures are described and evaluated.

The DNA

DNA stands for deoxyribonucleic acid. This is the material which, by means of a restricted pattern of nucleic base pairings, encodes the information necessary for the cell to make specific structural and functional proteins (such as enzymes). Though not much in demand for school use, pure samples of various forms of DNA have been available from specialist biochemical suppliers for many years now.

The NCBE kit contains DNA from the Lambda (λ) phage virus. *Phage* is short for bacteriophage, meaning a virus which invades a bacterium, in this case *Escherichia coli*, taking over its genetic mechanisms. This results in the bacterium making copies of the virus rather than encoding its own bacterial structural or functional proteins.

The entire genetic makeup (genome) of λ phage has been known for some years. It is contained in a piece of DNA just over 48.5 thousand base pairs long (or 48.5 kb).

A significant length (20 kb) of that encoding is non-essential in the sense that it is not required in the business of packaging phage DNA, carrying it into bacterial host cells or achieving duplication of that viral DNA once delivered. It is into this section of λ DNA that the genetic engineer splices new genes which are to be ferried into bacteria.

The SAPS kit also contains λ DNA, but provides another form as well as the means to obtain a third. The additional type in the SAPS kit is DNA from the calf thymus gland. Reagents and a procedure are provided for the extraction of both nuclear DNA and the much shorter chains of chloroplast DNA from plant material.

The enzymes

Enzymes which cut up DNA into fragments are called *restriction enzymes* or - more properly - restriction endonucleases. Made by bacteria in response to invasion by viruses they restrict the proliferation of the viral DNA. These enzymes have come to be named after the bacteria which produce them. They are sequentially numbered according to when they were first discovered in any particular bacterial strain.

For example : the EcoRI used in both kits comes from *Escherichia coli*, strain **RY**13 and was the first (hence Roman numeral one - **I**) such enzyme to be isolated from that strain. Similarly HindIII comes from **H***aemophilus* **in***fluenzae* R_d and is the third such enzyme to have been discovered. It should be a small suprise by now to learn that the BamHI used in the NCBE kit was the first to come from **B***acillus* **am***yloliquifaciens* strain **H**.

cont./p. 15

Activity	NCBE kit	SAPS kit
Precise dispensing of µlitre volumes of reagents (manipulative skills).	Uses microsyringes with 2 µl and 10 µl pipette tips supplied.	Micropipettor tips have to be calibrated against a marked master tip (ready calibrated tips to be provided in eventual commercial kit).
Basic biological lab. skills - extraction, centrifuging, resuspending pellet etc.. to extract and separate the plant DNA.	Not applicable	Provides practice in a variety of basic skills with procedures which are in themselves each fairly simple but which taken together make up a complex sequence which first time through needs a degree of organisation and cool head.
Resuscitating the DNA. Reinforces the micro-scale of these procedures with µg quantities providing more than enough DNA.	Dried DNA is supplied in poly-propylene tubes. Ready to use 15 min after adding 100 µl deionised or distilled water.	With early versions of the kit the calf thymus and λ DNAs had to be stored at - 20°C. DNA now supplied is dried (lypholised) and needs soaking for 24 hours before use. SAPS plan to replace this with a dried DNA which will dissolve very quickly.
Cutting the DNA into fragments at specific sites. Reinforces understanding of DNA code sequences and of specificity of enzymes. Develops organisational and manipulative skills (to avoid cross contamination of samples etc.).	Three single digests suggested, using each of EcoRI, HindIII and BamHI on λ phage DNA. Uncut λ DNA as a control and marker. Cutting complete in 30 - 45 minutes at 37°C.	Single digest of plant DNA with HindIII and single digests of calf thymus DNA and λ phage DNA. Undigested plant and calf thymus DNAs as controls and digested λ DNA as marker. Material also provided for single and double digests of λ phage DNA by EcoRI and HindIII. Cutting may take up to 60 min at 37°C but can be stopped, possibly incomplete, after 30 min.
Preparing agarose gel, pouring gel plates, forming and loading the wells. Provides excellent practice of all the manipulative skills learned earlier - handling µl quantities and new pipette tips to avoid contamination etc.	Gel plate poured and wells formed in-situ in purpose made, moulded mini gel tank. Wells then loaded using a microsyringe and a fresh 2 µl tip for each well.	Gel plate with wells prepared separately using a jig made up from microscope slides. Gel plate then transferred to tank when set. Alternatively the gel may be loaded *dry* and then transferred to the tank but this requires very great care if spillage from the wells is to be avoided.
Running the gel. Provides first hand experience of an application of gel electrophoresis. Theory is related to fragment sizes. Parallels to be drawn with more familiar paper or thin layer chromatography.	Uses one 9 V dry cell or two in series to give 18 V. At 9 V the run time is about 12 hours and at 18 V, 5 to 6 hours. *(Both kits provide opportunities to discuss electrical safety in a biological laboratory context).*	Uses a mains to low voltage (12 V) transformer and the gel is run overnight.
Staining, examining, analysing the separated fragments. Reinforces previous theory in other steps and provides an opportunity to discuss genetic fingerprinting and engineering, gene transfer, chromosome mapping, bacterial resistance to viral infection etc.	DNA stain not precisely identified but timing more exact than for SAPS kit and 70% ethanol needed for de-staining step. *(Natural contexts are provided by both kits for the discussion of a number of safety points including the need for care in handling stains and other biologically active compounds etc. There may also be opportunities for more informed discussion of any ethical issues raised by students).*	DNA stain is 0.1M methylene blue in sodium ethanoate and only warm water is needed for de-staining.

Table 2 - Summary of sub-procedures and their educational significance or applications

Kit component	Quantities and comments	
	NCBE kit	**SAPS kit**
Apparatus :		
Gel tank	5 per kit, purpose made moulding	1 per kit, adapted square Petri dish
Staining tank	Use gel tank with electrodes removed	1 per kit, made as above
Electrodes	Disposable, cut from carbon fibre issue	1 pr (stainless steel) integral with gel tank
Gel comb	5 per kit	1 per kit
Microscope slides (76 x 26 mm)	Not applicable	8 per kit (for packing up when pouring gel plate on 76 x 38 mm slide (next item)
As above 76 x 38 mm	Not applicable	6 slides per kit - form gel plate support
Bulldog clips	Not applicable	Also part of d-i-y plate pouring jig
Power source	1 or 2, 9 V dry cells **not included**	a.c./d.c. mains adaptor : 1 per kit
Microsyringes	5 per kit	Not applicable, uses disposable syringes in 1 ml and 2 ml sizes
Pipette tips (2 µl or 10 µl)	15 + (& spares for practice) per student making ca. 300 in total per kit	1 pre-marked master plus 200 unmarked tips to be calibrated against the master
Syringes	Not applicable	1 x 10 ml per kit for dispensing
leads	5 pairs (i.e. 5 red, 5 black)	Integral with output leads on a.c./d.c. 12 V transformer (female 4 mm sockets fit male terminations on gel tank
Materials :		
DNA :		
plant DNA	Not applicable	Materials provided for extraction
λ phage DNA	Sufficient for 15 uses by students, supplied in white microtubes plus 1 set for teacher	12 tubes per kit for 50 lanes @ 0.5 µg/lane (15 µl) totalling 25 µg per kit
calf thymus DNA	Not applicable	5 tubes per kit for 20 lanes @ 2.5 µg/lane (15 µl) totalling 50 µg per kit
Restriction enzymes	Scale of provision as for λ phage DNA	
EcoRI	In red coloured coded microtubes	20 microtubes per kit
HindIII	Green microtubes	50 tubes per kit (20 for λ DNA and 30 for plant DNA experiment)
BamHI	Blue microtubes	Not applicable
Agarose powder	1 bottle per kit	20 x 0.1 g aliquots makes 200 ml per kit at 1% or about 20 gels
Loading dye	5 tubes	1.5 ml per kit (bromophenol blue)
DNA stain	1 bottle (to be diluted 1 : 1 v:v with deionised water (actual dyestuff not identified but is a derivative of methylene blue)	20 ml of concentrate to be diluted with 180 ml deionised water to make 200 ml (dyestuff is methylene blue)
Gel buffer	1 bottle of gel buffer to be diluted 1 : 9 v:v	20 ml of TBE buffer (makes up to 400 ml)
Extraction buffers	Not applicable	SDS extraction buffer 2 x 26 ml and 2 ml 10% SDS to make 200 ml DNA extract sol'n and 25 ml TE to re-dissolve the DNA
Instructions :	1 teacher/technician and 5 students' guides	1 set of instructions per kit

Table 3 - Summary of kit contents

Additional item or material	NCBE kit	SAPS kit
Apparatus :		
bench centrifuge	not required	1 per student pair
centrifuge tubes	not required	2 per student
leads with crocodile clips or battery clips	extra required if more than one cell or battery used	
mortars and pestles	not required	1 per pair for plant DNA extraction
scissors	up to 5 pairs	1 pair between 2 students
-20°C frost free freezer	not required	1 where old kit with frozen DNA not required for newer kits and dried DNA
thermometers (electronic or liquid filled)	not strictly necessary but 1 or 2 would be useful	1 or 2 per kit
Materials, consumables :		
batteries (dry cells)	sufficient to provide 9 or 18 V to each of 5 tanks	not required
washed, sterile sand	not required	few grams per student

Required in more or less equal amounts for either kit :

Apparatus :	balance, preferably electronic, access to 1 or 2 per kit (weighing to 0.1 g) standard laboratory ware - selection of beakers, conical flasks and measuring cylinders water bath (1 or 2 per kit). In both cases the use of 2 waterbaths would be more convenient. One can be held at 37°C for the DNA cutting exercise and the other at 60 to 65°C for either extracting plant DNA with SDS and, or, for holding agarose in the sol state. NCBE advise that an incubator set at 37°C is an alternative to a water bath for cutting the DNA.
Materials :	deionised or distilled water; ethanol (IMS will do), black card or paper to provide contrast when loading the wells; coloured marker pens and small rectangle of foam or polystyrene with holes of suitable diameter to hold microtubes and so float them in the water bath.
Safety items : ***(PPE)***	personal protective equipment - eye protectors and gloves (latter preferably lightweight nitrile for resistance to penetration of stain in alcoholic solution with reasonable sensitivity).

Table 4 - Items required but not included in the kits

Cont. from p.11

Like most enzymes, these restriction endonucleases are highly specific. They cut DNA strands only at certain sites where particular base sequences occur. This results in a characteristic pattern of fragments of varying size. DNA fragments are measured in numbers of base pairs (bp - see note on "The DNA" above). A typical pattern of fragments is provided by the six, ranging in length from 3,530bp (or ca. 3.5 kb) to 21,226 bp (21.23 kb) and which result from the action of EcoRI on viral (Lambda [λ] phage) DNA. This pattern is also known as a *restriction map*.

EcoRI cuts λ and other DNAs only between guanine (G) and adenosine (A) where they occur as part of the sequence GAATTC (and obviously in the mirrored sequence CTTAAG see figure 1). Parallel attack of the bacterial DNA is prevented by protective methyl groups on the equivalent bases at the restriction sites[1].

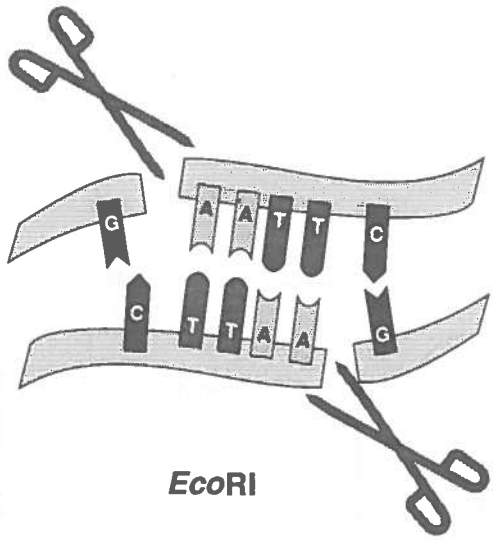

Fig. 1 Action of the restriction enzyme EcoRI

Gel electrophoresis

This separation technique has parallels with several aspects of chromatography in its various forms and that may provide a good starting point for introducing it to students.

It is obviously a little more sophisticated than paper and thin-layer chromatographic techniques, but there are several similarities in the factors which determine how fast and how far elements to be separated will travel. The major additional factor here of course is the application of a voltage across the supporting and separation media. This influences the velocity of charged particles in the mixture which is to be separated.

[1] This is a somewhat simplified account. Sometimes two enzymes may be involved.

DNA Electrophoresis

Agarose gel is the supporting medium used by both kits. Researchers and other professional workers may use other media such as polyacrylamide gels but these are largely inappropriate for educational use. Agarose is prepared from marine algae and is a very pure form of agar. Its gel structure provides a tortuous path through which any DNA fragments have to move in migrating from one electrophoresis electrode to another.

A buffer covers and permeates the gel and provides both a conducting medium for electricity and a partitioning effect beween gel and solution. The final elements in the process are the applied voltage, the charges carried on DNA fragments and their physical size.

The phosphate groups on the bases in the DNA fragments bestow upon them a negative charge. The fragments thus tend to move toward the positive electrode at a speed dependent largely upon their length. Small fragments travel more quickly and thus farther in a given time than do the larger fragments. However, in the absence of an applied voltage their migration ceases and thus the parallel with chromatography breaks down.

This results in a distribution of the various fragments along a line between the electrodes. This pattern can be revealed by treating the gel with certain stains which are taken up differentially by the charged DNA fragments. Washing away surplus stain then leaves residually stained collections of fragments, which can be seen as bands and streaks.

You may recall that different endonuclease enzymes each have their own restriction maps. Specific patterns will thus emerge on the stained electrophoresis gels depending on which enzyme - or combination of enzymes - has been used to cut the DNA.

Practical activities

The various activities supported by the two kits will first be described or summarised graphically in various figures. This account will give additional detail not provided by Tables 1 and 2. The ease of carrying out each practical may be commented upon at this stage. An overall evaluation is then presented which is based on our own practical experience of carrying out those same activities.

Practising techniques

The use of syringes and calibrated micropipette tips in handling μl quantities requires some practice. Both SAPS and NCBE suggest some preliminary activities which provide such opportunity for practice.

In the current versions of the SAPS kit, the preparation of calibrated tips from a supplied master is in any case a necessary preliminary. Opportunities are provided in the SAPS training courses to prepare calibrated tips and to practise using them to dispense the tiny volumes needed. One SAPS suggestion is to use pipettes to dispense progressively smaller volumes of methylene blue as drops ranged along a microscope slide with variants based also on gathering droplets back together again.

The NCBE kit uses inexpensive microsyringes which can be fitted with ready calibrated (2 or 5µl) tips.

cont./right col.

The NCBE suggestion is that "Lesson 1" provides an introduction to the topic, immediately followed by practising loading wells with loading dye.

It is recommended that practice gel plates are prepared using ordinary agar rather than the more expensive agarose.

Extraction and analysis of plant DNA

Only the SAPS kit offers this activity. NCBE had earlier published a relatively simple protocol for such an extraction but have not included it as part of their DNA kit (see Tables 1 and 2).

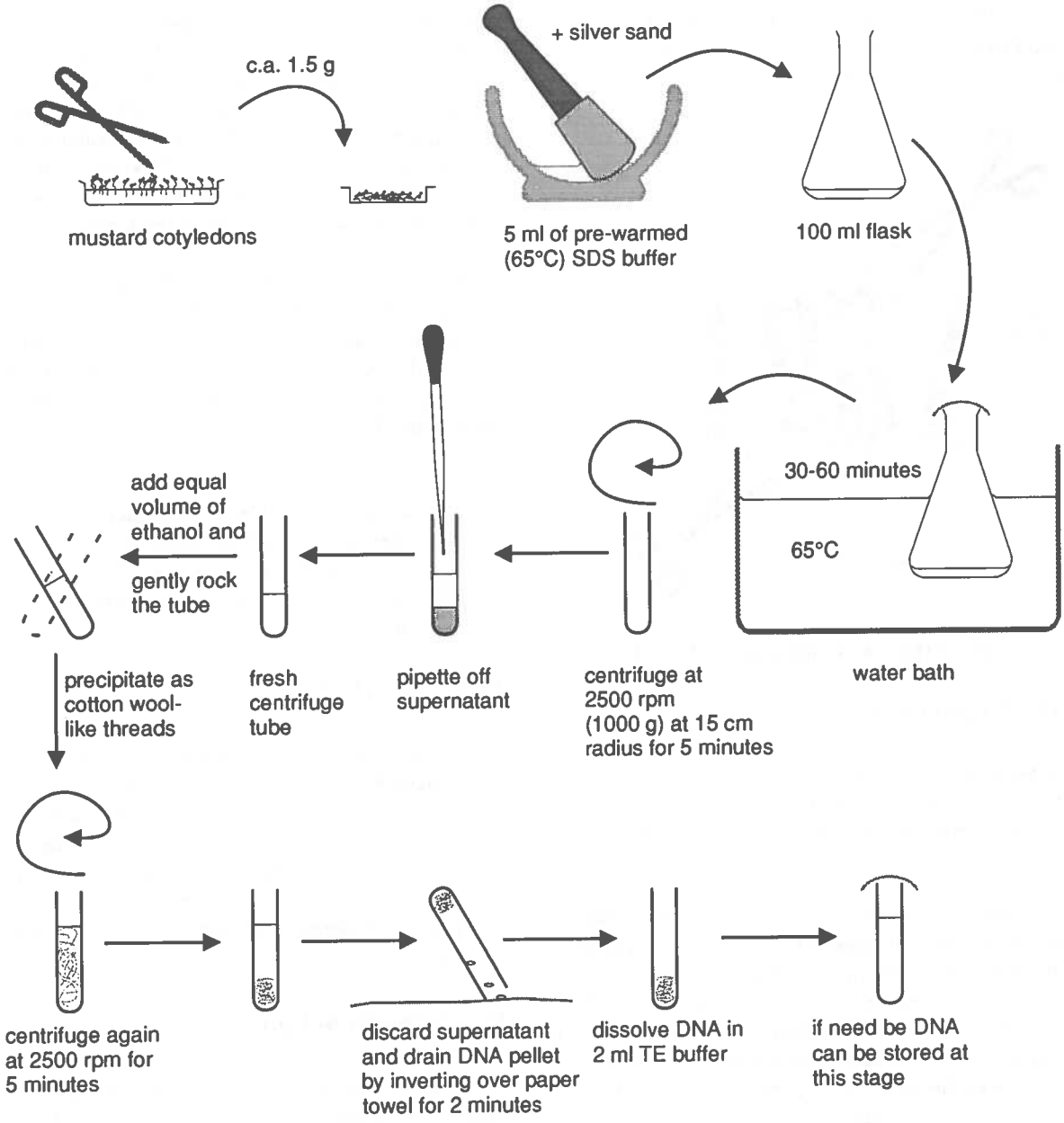

Fig. 2 Extraction of plant DNA : SAPS kit

The SAPS procedures are comprehensively described in the paperwork with the kit. For the sake of brevity therefore they are summarised here in Figure 2 at foot of page 16 showing extraction and in Figure 3 below which illustrates the protocol for restriction analysis. The 12 V supply for the gel tank shown in Figure 3 is the mains to low voltage adaptor supplied with the SAPS kit.

Restriction analysis of λ DNA

Both kits provide for this. The NCBE and SAPS protocols are summarised here in figures 4 and 5 respectively.

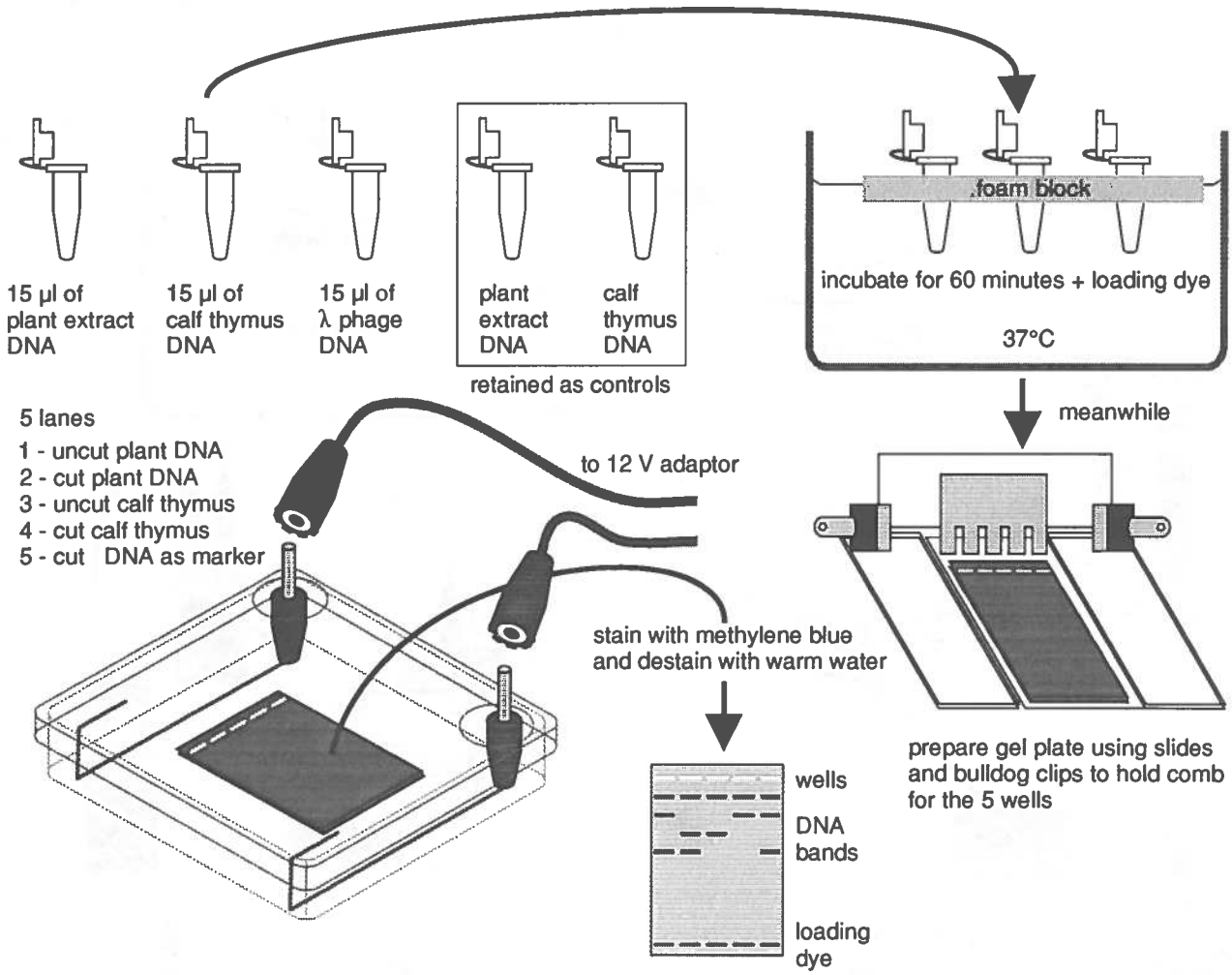

Fig. 3 Restriction analysis of plant DNA : SAPS kit

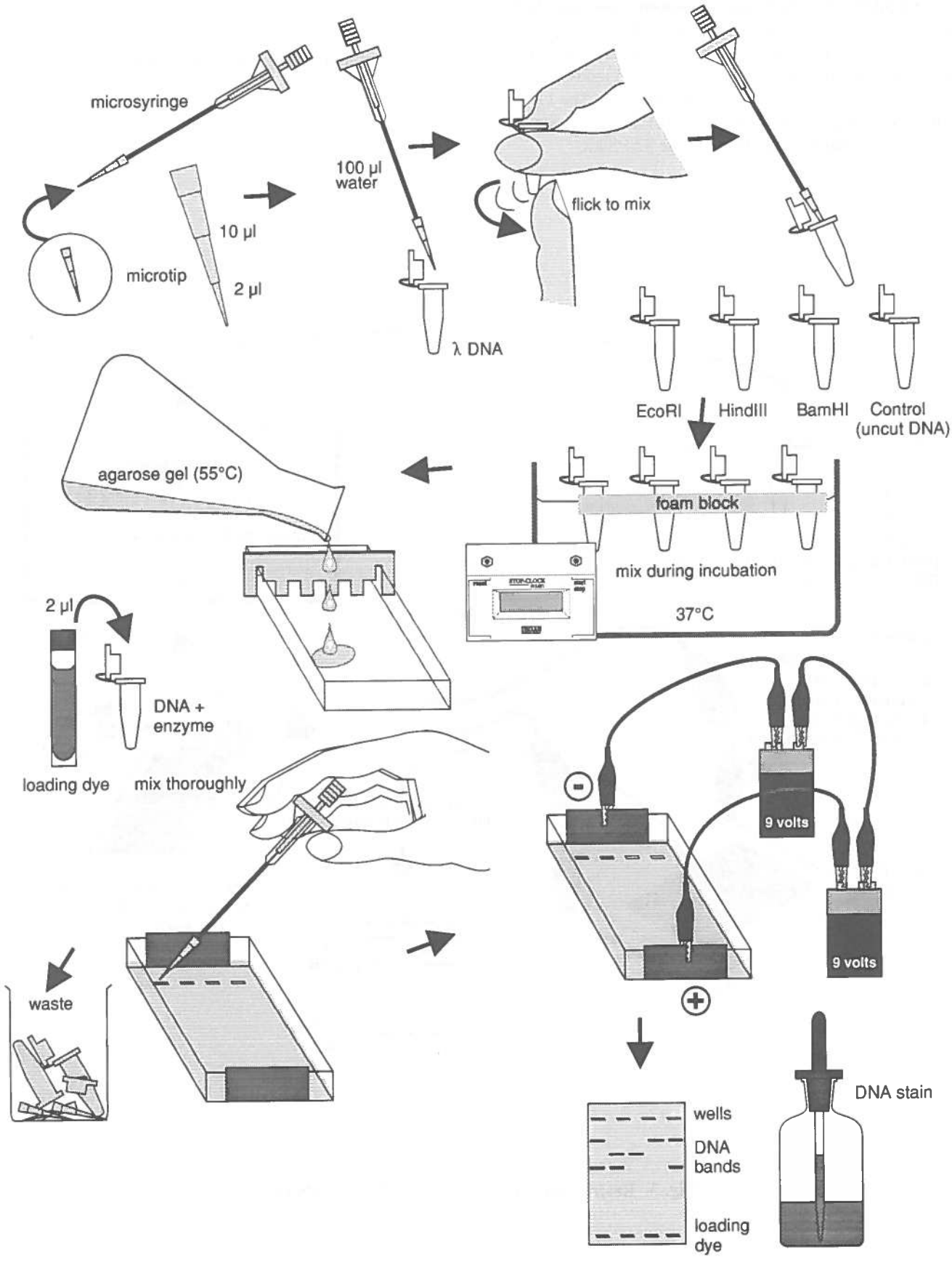

Fig. 4 Restriction analysis of phage DNA : NCBE kit

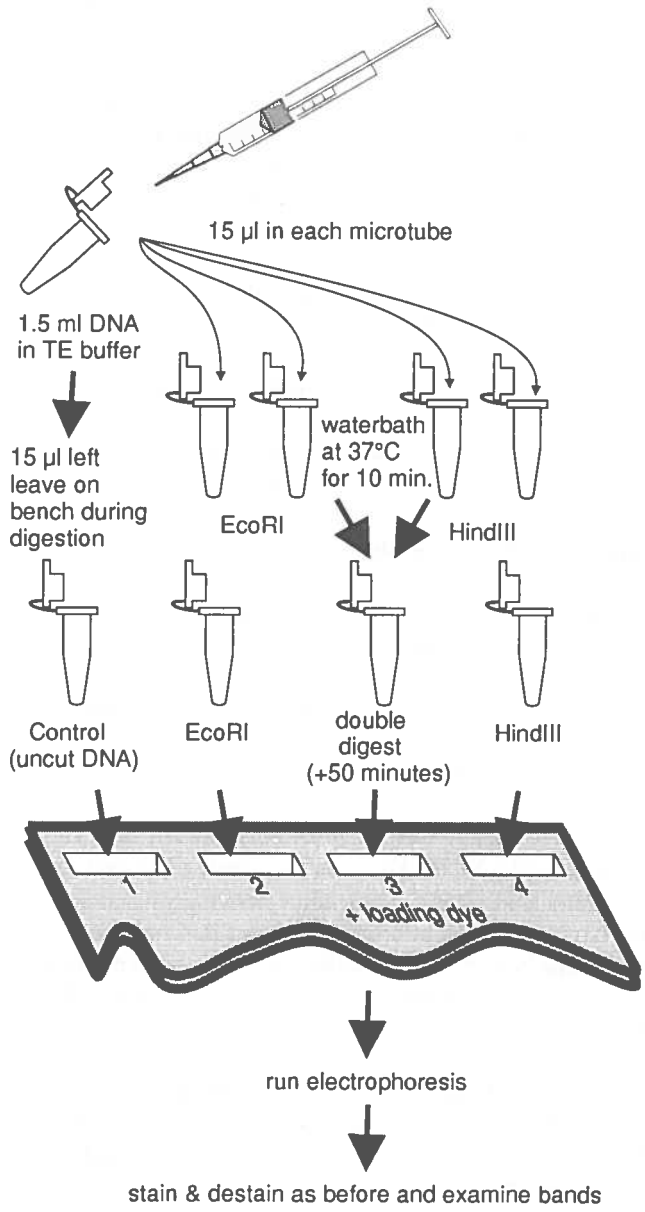

Fig. 5 Restriction analysis of phage DNA SAPS kit

Evaluation criteria

For each kit the described procedures were each carried out several times. The following broad criteria were used to structure the evaluation somewhat :

- comparative ease of use of various supplied items such as gel tanks and combs, and the micropipetting apparatus etc.;

- quality of documentation and clarity of instructions;

- quality of the end results (developed gels etc).

Evaluation results

Ease of use

The NCBE kit was in general easier to use than that from SAPS. This was because a number of items of apparatus supplied with the kit were better designed and, or, finished than were the SAPS items.

Micropipettes

Examples would include the microsyringe and ready calibrated pipette tips in the NCBE kit. We found that these were simply more reliable and required far less work on the part of the experimenter to become adept at their use. In contrast the tips for the SAPS kit have to be cut, d-i-y calibrated from a crude master and then used with an ordinary syringe. We found that some tips did not reliably fit the Luer fittings on the syringe. This sometimes resulted in leaks and wastage of materials.

Gel tanks and combs etc

Similarly the SAPS kit's arrangements for the preparation of gel plates means fiddling about with bulldog clips and using microscope slides as spacers. A five point comb is always used and if only four wells are needed one is simply left empty.

In contrast the gel for the NCBE kit is poured in situ and a positive location mechanism is provided for the comb in the tank itself. Four wells are formed and there is no choice of lane numbers. But that is because the NCBE kit only currently covers the one protocol.

DNA

The different forms of DNA supplied again make the NCBE kit easier to use. This is because the NCBE kit DNA is in a form which doesn't have to be stored frozen and very quickly dissolves. The DNA initially supplied by SAPS had to be kept in a freezer. Now they supply a form of dried DNA but that needs prolonged soaking before it fully dissolves. SAPS assure us however that at the time of our going to press they were going over to a dried DNA similar to that supplied by NCBE.

Power supplies

SAPS provide a mains to low voltage plug top transformer whilst NCBE have been even more cautious and have opted for the use of dry cells (skinflints that we are, we used re-chargeables in our trials). The use of 9 V batteries isn't a bad idea. Swapping between one or two to provide either 9 or 18 V the run shortens or extends thus coping with some of the vagaries of school timetables. It would have been better however to have used proper battery connectors rather than rely on crocodile clips.

Similarly the SAPS transformer is switchable between 3, 9 and 12 V again allowing some flexibility of timing.

The use of an unearthed (i.e. double insulated) mains to low voltage adaptor for electrophoresis in the SAPS kit has caused concern in some quarters. This is because of the presence in the gel tanks of a highly conducting buffer solution and the possibility of mains voltage being applied across the electrodes in the event of an insulation fault in the supply transformer.

In response to such concerns SAPS did change the type of supply they provide with the kits. We are not convinced that the risks are significant so long as the adaptor supplied with the kit is used and not one of inferior design or construction.

Clearly NCBE's use of dry cells is even more reassuring. Accordingly we looked at the obvious solution and attempted to run gels in the SAPS tanks applying 9 or 18 V from rechargeable batteries. Unfortunately, these attempts proved unsuccessful. Stainless steel wires (actually wire trace material used for sea fishing) form the electrodes in the SAPS gel tanks. It would seem that, as presently designed, these draw too much current and the use of batteries just isn't feasible.

Centrifuges

This comment applies only to the SAPS plant DNA extraction protocol. The centrifuge used for first spinning down the gross plant debris and then the precipitated DNA has to be provided by the user. Too little guidance is given on the choice of a suitable centrifuge. We found however that the speeds and 'g' forces specified were possibly too narrow.

First trials with a relatively sophisticated angled head model (Janetzki T51) gave times in agreement with those quoted by SAPS. We found however that the protocols still worked satisfactorily with slower models provided the times were suitably extended. In some cases that meant doubling or even trebling the centrifuging time. Examples included use of a Damon IEC *Spinette* and an ancient Philip Harris model with a swing-out rotor. With this last type of centrifuge, spin-down times had to be extended several-fold.

Instructions

The documentation for the NCBE kit was of noticeably higher quality than that supplied by SAPS. It may well be that this merely reflected the different stages of development of the kits, the one from NCBE being a final prototype and thus much nearer the marketing stage.

There are a few minor errors in both sets of instructions but it seems that both suppliers are aware of these and are taking steps to correct them.

Few are material to the use of the kits but a lack of clarity in the SAPS kit instructions for the preparation of the SDS buffer used in the extraction of plant DNA was however irritating.

Similarly some confusing information on the use of the SAPS kit's power supply setting to determine polarity was also both annoying and wasteful. Despite our checking with a multimeter, we still managed to run one gel the wrong way round.

NCBE supply student booklets with both background theory and clear graphically represented instructions. There are five copies per kit. A single copy of a useful teacher's and technician's guide is also included.

We understand that new editions of the documentation are under preparation for each kit type.

Quality of the end results

This is starting to get a bit boring but yes - you guessed it - the NCBE kit again came out ahead. Whether this was due to the use of a different locating stain or some other factor we cannot tell, but nonetheless the DNA bands usually showed up sharper and clearer in the gels run and developed with this kit.

The locating dye was about the only vaguely worrying thing about the NCBE kit. It isn't precisely identified and we would have liked to know more about any hazards. We have since been informed that it is a derivative of methylene blue. NCBE state that its use presents no more risk than handling a blue food colouring of the type sold for domestic use.

The locating dye for the SAPS kit is methylene blue itself. Whilst not exactly harmless this dye is acceptable for use at this level and normal good laboratory practice should provide adequate control.

Please note however that we have had some anecdotal reports of more hazardous stains being included with other kits imported from the USA.

Stop points

We have demonstrated both kits to teachers and one common concern was fitting the practical activities into tight timetables. As already indicated some limited flexibility is provided by adjusting the electrophoresis voltage (see "*Power Supplies*"). It is important to realise though that both kits also offer some *stop points*.

The SAPS plant DNA extraction procedure, for example, may be interrupted both at the alcoholic precipitation stage and at the point where the DNA is redissolved in TE buffer (see Fig.2).

In both kits the restriction enzyme stages do not have to stop at the end of the prescribed incubation times. These times may be significantly extended beyond completion of the cutting of the DNA and no harm will be done.

Finally, the electrophoresis runs may be stopped at any time. With the SAPS kit unplug the supply and for the NCBE kit simply disconnect the batteries. In the absence of an applied voltage the fragments will not move significantly. That this is so is borne out by the fact that completed gels show no significant changes on restaining even though they may have been stored for several weeks or months.

Overall conclusion

Other factors being equal we would rate the NCBE kit the better product. The factors are not however equal, since the two kits are not at the same stage of their development, do not cover the same activities and one of them has yet to be properly priced.

Whilst the SAPS kit is at the moment supplied free it can only be obtained after training. Because of financial support from a variety of sources no tuition fees are charged for these courses.

But, as every EA or independent school manager can tell you there is no such thing as "free" training. The costs of travel and cover have to be met. The tuition fees for a course can be the least significant part of the expenditure. So, whatever else the SAPS kit may offer it does not really come for free.

The NCBE kit in contrast already has a rough price attached to it - it will be about £95. You won't have to attend a training course to get your hands on one. It is simpler than the SAPS kit and so well documented that such formal training, although still useful, is certainly not a pre-requisite.

Verdict

For the moment this has to be not proven. A direct comparison and a recommendation as to a best buy will have to await the marketing of a fully commercial version of the SAPS kit. Even then we will not be strictly comparing like with like.

Putting to one side the matter of costs, our preference would be SAPS for DNA extraction but the NCBE kit for its simple restriction enzymes protocol. That is notwithstanding the fact that in the absence of a double digest the NCBE protocol cannot currently provide a true restriction map but only demonstrates fragment patterns. We do not see that as a serious disadvantage at this stage of developments on DNA technology in biology curricula.

So, it's a matter of "yer pays yer money (or not as the case may be) and yer takes yer choice".

If you have the cash, are desperate to get your hands on fairly straightforward materials allowing practical activities on DNA technology and want to be up and running for next term or session then the NCBE kit may well be the one for you.

Should you wish to cover more activities, have no previous knowledge or experience whatsoever in this field, would first like some hands-on training and are in no particular hurry, then the SAPS route is probably the one to take. That pre-supposes that SAPS will be offering training in your locale, that you can get a place on a course and claim your free kit. Otherwise you shall have to await the commercial version from Philip Harris and pay whatever price they put on it.

Endpiece on training

At the moment an added bonus of attending a SAPS training course, but only if you're an Apple computer user, is access to software with DNA sequences and related routines. It has to be said however that similar software and database material is already available and much is in the public domain - if you know where to look.

SAPS project staff assure us that their subsidised training courses will not cease once the commercial version of the kit is available. In keeping with their original philosophy, they see such formal training exercises as a way of enthusing teachers and of getting across a fair amount of the background theory. With that we have to concur.

One has to set against such perceived advantages of formal training that presently courses may also be tending to compensate for some inadequacies in SAPS documentation. Hopefully they will be dealt with in any Philip Harris commercial version.

There is still the further problem of the level playing field. Previously we have expressed strong views in these pages on subsidised or grant-aided educational apparatus.

Eventually we shall be asked to choose between two apparently commercial products. Both will have been developed by non-profit making bodies supported by charitable and public funds. As this review should have demonstrated, a choice will be difficult enough on any objective criteria, price and educational grounds.

It is a point for debate whether one kit and not the other should be so underpinned by subsidised training and thus effectively advantaged in the market-place.

* * *

Technical Article

Hydrolysis of urea : TAPS 3 Chemistry Investigation C30

Modifications to the TAPS (Teacher Assessment of Practical Skills) method for this investigation are described and sample results provided.

Introduction

The basic action of urease is to break down urea into ammonia and carbon dioxide. It is thus possible to follow the rate of this hydrolysis by monitoring pH changes. This may be done with a pH electrode but should also be feasible using a suitable indicator. The TAPS publication [1] suggests the latter.

In Bulletin 179 [2] we reported that this investigation did not work as written, on account of the fact that soya flour is now heat-treated before being sold to the public. Such heat treatment destroys most, if not all, of the urease activity.

There is a second problem in the TAPS method as originally published, and this involves the choice of a suitable indicator. The work on that aspect wasn't quite concluded as Bulletin 179 was going to press. In this article we describe two ways of overcoming that problem.

The indicator problem

As published, the method is virtually impossible since the indicator suggested - bromothymol blue - changes colour in the pH range 6.0 to 7.6. We found the urea itself to be sufficiently alkaline to change the indicator to the blue colour. That is, before any urease was added!

We first modified the bromothymol blue method by using an initial pH adjustment or offset. Then Robin Murray of Queen Anne High School, Dunfermline, did a bit of lateral thinking and came up with a simpler method using phenolphthalein which has covers a higher and more suitable range of pH 8.3 to 10.0.

This is a nice topic for investigations, but only with luck will a Standard Grade pupil, or indeed a qualified chemist, designing experiments to investigate the effects of concentration of urea, amount of enzyme and the temperature hit on suitable combinations of concentrations, etc in the short space of time allowed. We think some hints as to suitable concentrations and amounts should be given if a time limitation is set.

There is nothing special about the amounts and concentrations given below, and there will always be variation in the rates of hydrolysis as the enzyme ages. So the motto must be to first have a few trials with your batch of enzyme.

Phenolphthalein as indicator

The range of this indicator is well above the pH of an aqueous solution of urea and it will therefore still be in its acidic colour in the initial, untreated solution.

Colour standards

Since the indicator changes from colourless gradually through pale to deeper shades of pink, some reference colour is needed. Robin Murray of Queen Anne High made his standard by adding dilute ammonia to water until the phenolphthalein acquired a distinct pinkish hue.

It is not possible to make up such references consistently, all with the same depth of colour. An alternative is to use a paint shade card as your colour standard. We found the colour block for the shade "Country Clover" in ICI's Dulux range to be quite suitable. This has the virtue of not fading quickly. The results shown in Table 1 below were obtained using it.

Method using phenolphthalein

Jack bean meal was used as the source of enzyme. The meal was 'diluted' by grinding it gently with icing sugar in the ratio of 1 part meal to 5 parts of icing sugar. This mixture was then used either in varying mass to study the effects of varying amounts of enzyme (Table 1) or in fixed amount whilst other variables, such as the amount of substrate were studied (Table 2).

temp	mass of urease mix	vol of 0.025% urea	vol water	times
37°C	0.1 g	5 cm^3	15 cm^3	41 s
	0.2 g	5 cm^3	15 cm^3	28 s
	0.3 g	5 cm^3	15 cm^3	21 s

Table 1 - Varying amount of enzyme
(Phenolphthalein as indicator - 6 drops added to each tube)

temp	mass of urease mix	vol of urea solution	vol water	times
37°C	0.1 g	5 cm^3 0.5%	15 cm^3	13 s
	0.1 g	5 cm^3 0.1%	15 cm^3	19 s
	0.1 g	5 cm^3 0.05%	15 cm^3	25 s
	0.1 g	5 cm^3 0.025%	15 cm^3	38 s
	0.1 g	5 cm^3 0.01%	15 cm^3	97 s

Table 2 - Varying concentration of urea
(Phenolphthalein as indicator 6 drops added to each tube)

Using bromothymol blue

It is possible to retain the use of bromothymol blue as indicator and earlier attempts to solve the problem took such an approach. Here it is necessary to add a small fixed quantity of acid to the urea before each run. This shifts the initial pH so that the indicator retains its colour until sufficient ammonia is produced to bring about a change. We are then measuring the time taken to produce the same amount of ammonia, ie that amount needed to neutralise the acid added. Although an extra step, this device gives some flexibility in that the time period can be adjusted to a reasonable length according to the amount of acid added.

As for the phenolphthalein method, the urease was 'diluted' by grinding it gently with icing sugar in a mix of 1 part urease to 5 parts icing sugar. Results are shown in Tables 3, 4 and 5. Note that stirring is necessary to obtain consistent results. Even so we found sizeable differences between sets of results obtained on different days, but on any one day results were consistent within any set of measurements.

temp	mass of urease mix	vol. 1% urea sol.	vol. HCl (0.025M)	vol. water	time
37°C	0.1 g	5 cm^3	0.1	15 cm^3	97 s
	0.2 g	5 cm^3	0.1	15 cm^3	49 s
	0.3 g	5 cm^3	0.1	15 cm^3	22 s

Table 3 - Varying amount of enzyme
(Bromothymol blue as indicator 6 drops added to each tube)

temp	mass of urease mix	vol. 1% urea sol.	vol. HCl (0.025M)	vol. water	time
37°C	0.1 g	20 cm^3	0.1	0 cm^3	38 s
	0.1 g	10 cm^3	0.1	10 cm^3	43 s
	0.1 g	5 cm^3	0.1	15 cm^3	68 s
	0.1 g	2.5 cm^3	0.1	17.5 cm^3	90 s
	0.1 g	0.5 cm^3	0.1	19.5 cm^3	180 s

Table 4 - Varying urea concentration
(Bromothymol blue as indicator 6 drops added to each tube)

temp	mass of urease mix	vol. 1% urea sol.	vol. HCl (0.025M)	vol. water	time
16°C	0.1 g	5 cm^3	0.1	15 cm^3	26 s
19°C	0.1 g	5 cm^3	0.1	15 cm^3	26 s
25°C	0.1 g	5 cm^3	0.1	15 cm^3	22 s
45°C	0.1 g	5 cm^3	0.1	15 cm^3	16 s

Table 5 - Varying temperature

(Bromothymol blue as indicator 6 drops added to each tube)

The change in rate over the range of temperatures in Table 5 is small; an additional measurement near ice temperatures is needed to show a strikingly clear effect.

Risk assessment

Bromothymol blue indicator - may irritate eyes. Solution is usually in propan-2-ol.

Urease - enzymes may cause sensitisation. Take care to avoid raising dust and do not handle directly - keep off the skin.

Acknowledgement

We are most grateful to Robin Murray, Principal Teacher of Chemistry, Queen Anne High School, Dunfermline for his assistance with and keen interest in the work described herein.

Addendum

Since our concluding the work and preparing this article, we have been given to understand that this particular investigation is in future to be omitted from the list of those suggested as assessable for Standard Grade.

That may seem a pity after much work by Robin Murray and ourselves but, we still think that this investigation is somewhat difficult as an assessment exercise at Standard Grade mainly because it is too complex to both design and carry out in such a limited time.

However, as described here these methods are now a basis for some interesting investigational work. They have the distinct advantage that they do not require any sophisticated or hi-tech equipment. But, do first trial the use of your own batch of enzyme source.

References

1. *TAPS 3 : How to Assess Open-ended Practical Investigations in Biology, Chemistry and Physics*, Bryce, T.G.K., et. al., Heinemann Educational, 1991, ISBN 0 435 57076 5.

2. *More on enzymes*, Technical Articles, SSERC, Bulletin 179, December, 1993.

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778 Stepper motor, Philips MB11, been stored in damp conditions but unused and retested. 4 phase, 12 V d.c., 100 mA per coil, 120 Ω coil per phase, step angle 7.5°, with 7 mm x 2 mm dia. output shaft. Dimensions 21 mm x 46 mm dia. on oval mounting plate with 2 fixing holes, diam. 3 mm, pitch 42 mm, at 56 mm centres. Circuit diagram supplied. £2.50

755 Pulley wheel kit comprising:
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The whole making up a kit devised for SSERC tacho-generators with 3 mm shafts. Specially supplied to SSERC by Unilab. £1.25

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614 Miniature motor, 3 V to 6 V d.c., no load current 220 mA at 9600 r.p.m. and 3 V, stall torque 110 mN m, dims. 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia. 45p

593 Miniature motor, 1.5 V to 3 V d.c., no load current 350 mA at 14800 r.p.m. and 3 V, stall torque 50 mN m, dims. 25 mm x 21 mm dia., shaft 8 mm x 2 mm dia. 30p

621 Miniature motor, 1.5 V to 3 V d.c., open construction, ideal for demonstration, dimensions 19 x 9 x 18 mm, double ended output shaft 5 mm x 1.5 mm dia. 20p

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772 Encoder disk, 4-bit Gray code, stainless steel, 81.28 mm dia., 3 mm fixing hole, slots sized to register with components mounted on 0.1" stripboard. Applications: shaft position sensing, wind direction indicator.
For related electronic circuitry see Bulletin 146 £3.00

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723 Microswitch, miniature, SPDT, lever operated. 40p

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738 Relay, 6 V coil, DPDT, contacts rated 3 A, 24 V d.c. or 110 V a.c. 75p

774 Solenoid, 12 V, stroke length 30 mm, spring not provided £2.25

742 Key switch, 8 pole changeover. 40p

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688 Croc clip, miniature, insulated, red. 5p
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712 Smoke pellets. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans, etc. 50p

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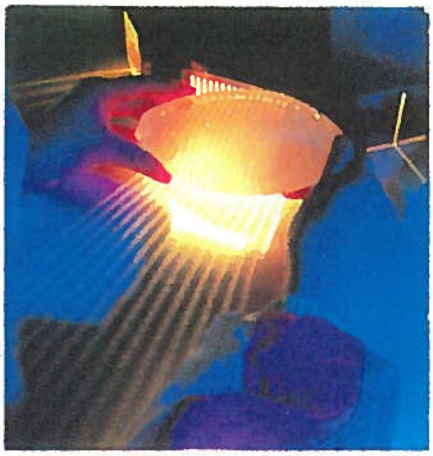

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