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Making research fly in schools: *Drosophila* as a powerful modern tool for teaching biology

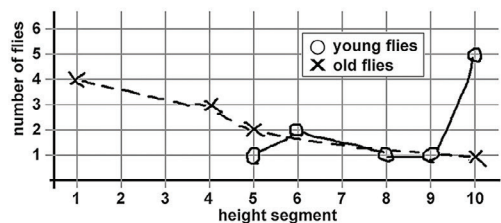
Jennifer Harbottle, Patrick Strangward, Catherine Alnuamaani, Surita Lawes,
Sanjai Patel and Andreas Prokop

ABSTRACT The *droso4schools* project aims to introduce the fruit fly *Drosophila* as a powerful modern teaching tool to convey curriculum-relevant specifications in biology lessons. Flies are easy and cheap to breed and have been at the forefront of biology research for a century, providing unique conceptual understanding of biology and exciting, memorable experiments that reflect relevant contemporary research. To provide adequate resources, PhD students worked as teaching assistants in partner schools to develop and test free-to-download sample lessons with support materials, two educational *YouTube* videos and a dedicated *droso4schools* website providing resources for lesson preparation, homework tasks and revision.

The fruit fly *Drosophila* offers unique opportunities to teach biology in inspiring and memorable ways, involving experiments with living organisms that often reflect modern research. Through the *droso4schools* project, it is easy to implement this at your own school and teach a broad range of topics from the school curriculum. For example, you can teach a lesson on data analysis in which students measure the motor performance of old and young flies using a simple and cost-effective 'climbing test' that reflects contemporary research on ageing and neurodegeneration (Figure 1; for key stage 3/4, ages 13–14). In a synoptic lesson on the socially relevant topic of alcohol, students dissect and stain maggots while learning about fermentation, the genetic and enzymatic basis of alcohol metabolism, mechanisms of genetic variance, and even principles of evolution (Figure 2; for key stage 5, ages 16–18). Another lesson explains how nerve cells, action potentials and synapses constitute nervous system function, illustrated by shaking epileptic flies into seizure



Figure 1 The 'climbing test'. Top: young (left) and old (right) flies in two parallel tubes are tapped down and then given 15 seconds to climb up again, at which point a photo is taken. Climbing data from each student group are plotted (bottom) and collected from across the class for statistical analysis (not shown).



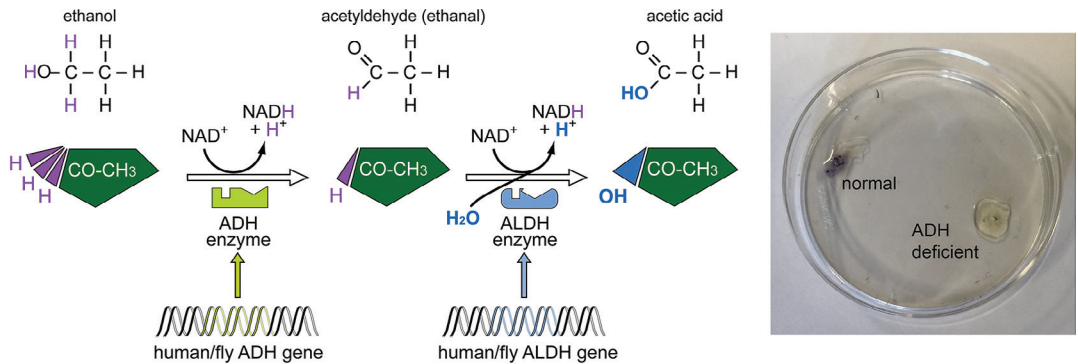


Figure 2 The biology of alcohol metabolism. Left: genes encode enzymes that break down alcohol. Right: Flies lacking these enzymes fail to break down alcohol; students test this using 5 minute colour reactions on normal and alcohol dehydrogenase (ADH)-deficient maggots dissected by themselves.

or paralysing flies by warming them to body temperature (key stages 4 and 5, ages 14–18).

These exciting and didactically valuable lessons are possible using *Drosophila* as a teaching tool as it is one of a few established laboratory organisms that is easy to breed and use in schools, cheap and ethically unproblematic. A century-long history of intense *Drosophila* research at the forefront of biology means that there is a thorough understanding of its fundamental biology, as explained on our website and in our two educational films (Box 1, C). More importantly, the comprehensive knowledge and breadth of experimental approaches developed for the fly model, and the multitude of readily available mutant stocks, provide excellent teaching opportunities for schools. Translating these into curriculum-relevant biology lessons creates an opportunity for researchers and school teachers to collaborate. Guided by teachers, scientists can use their profound conceptual understanding of a science topic to provide ideas and resources that will enhance the regular teaching agenda.

To implement this strategy, the Manchester Fly Facility initiated the *drososchools* project, in collaboration with two teaching institutions, an inner city secondary school and a sixth form college, and created two internships supported by PhD studentships from the Biotechnology and Biological Sciences Research Council (BBSRC). The interns worked for one month as teaching assistants in the partner institutions to gain valuable teaching experience, and discussed strategies, requirements and suitable biology topics with teachers. Capitalising on these experiences

and existing knowledge and resources available at the Manchester Fly Facility (Box 1, E), sample lessons for key stages 3–5 (ages 11–18) were developed and subsequently tested in class. A number of these sample lessons and supporting materials can be downloaded free of charge, and are further supported by additional online materials on other websites (details in Box 1).

The first lesson, successfully tested on 60 year 9 pupils (ages 12–13), asks students to perform a low-cost and easy to set up experiment known as the ‘climbing test’ (Figure 1). This experiment compares the motor performance of 1- and 5-week-old flies, equivalent to comparing human teenagers and seniors. In this test, flies in two parallel vials are tapped down and then given 15 seconds to climb back up, at which point a photo is taken. Students then determine how far the ten individual flies in each vial have climbed, on a scale of 0–10. They usually find that the young flies show much better motor performance compared with their older counterparts. Students are subsequently asked to draw graphs from their own results, and class data are collected and collated into a spreadsheet to perform standard statistical tests on this larger data set.

This lesson addresses important GCSE and A-level aims, such as learning to organise data into tables and graphs, interpreting and describing trends in data, understanding sample size, calculating means and best estimates, identifying outliers, and understanding experimental design and how methodology affects repeatability, reproducibility and precision. Further background information is provided to enhance the learning

Box 1 Useful resources

- A The *droso4schools* website (droso4schools.wordpress.com) provides relevant information.
- 1 An overview of the project and available sample lessons is provided, accompanied by a *YouTube* video with comments by *droso4schools* project members and students.
 - 2 The 'Why fly?' page explains the advantages of *Drosophila* in research.
 - 3 The 'L1-Climbing Assay' tab provides 6 pages of information supporting the motor skills experiment: an overview, a description of the experiment, background information on neurodegenerative diseases and ageing, information of how flies are used to study these conditions, a glossary of relevant terms, and explanations of relevant statistics.
 - 4 The 'L2-Alcohol' tab provides background information on alcohol, covering fermentation, principles of enzymes, drug treatment of alcohol addiction, natural variation in alcohol tolerance and the genetic basis, the geographical distribution of variations and their evolutionary basis.
 - 5 The 'L3-Neurons' tab provides background information on the principles of neuronal function and networks to accompany an additional lesson on the nervous system (soon to be uploaded).
 - 6 The 'Organs' page compares tissues and organs of flies and humans and provides helpful overview images.
- B Our sample lessons can be downloaded from figshare.com/articles/Biology_lessons_for_schools_using_the_fruit_fly_Drosophila/1352064. Lessons are provided as zip files that contain:
- 1 *PowerPoint* files for the sample lesson;
 - 2 teacher notes;
 - 3 risk assessments;
 - 4 experimental explanations;
 - 5 activity and homework sheets.
- C Two educational *YouTube* videos can be obtained from www.youtube.com/watch?v=qDbJnFLI3kU. Part 1 'Why the Fly' describes the origins and importance of fly research; Part 2 'Making research fly' describes how research in flies can help to understand disease and find potential treatments.
- D The *Gedankenexperimente* blog (poppi62.wordpress.com/2015/08/28/school-flies) provides a constantly updated overview of all school resources from the Manchester Fly Facility.
- E The Manchester Fly Facility (www.flyfacility.lis.manchester.ac.uk/forthepublic) has also put together additional information for the public that is useful for teachers.
- 1 The 'Why the fly?' page complements the information on *droso4schools*, listing simple facts and more than 80 lay articles about fly research.
 - 2 The 'Teachers and schools' tab explains the rationale for our school work and lists the services we provide for schools, as well as our past/future school events.
 - 3 The 'Outreach Resources' page lists about 100 links to information and resources that can be useful for outreach work and teaching at school and university levels.

outcomes. For example, from testing this lesson in class, it was found that students benefit from first being introduced to the concept of using fruit flies as a model organism, which was achieved using the 5 minute *YouTube* video 'Small fly, big impact: why the fly?' (see Box 1, C). Students were also given information and activity sheets on ageing, the nervous system and neurodegeneration. Finally, examples were provided to illustrate how the climbing assay is used in current research into ageing and neurodegeneration, thus conveying

relevance of the classroom activity. Teachers are provided with a *PowerPoint* presentation, teacher notes, a risk assessment, experimental instructions and a homework sheet (Box 1, B). Furthermore, the *droso4schools* website offers extensive information on all the above topics, including a dedicated and well-illustrated page on statistics (Box 1, A3). These supporting resources are ideal for lesson preparation, revision and homework tasks.

Taken together, the climbing test lesson covers aspects of the curriculum from key stage 3 to 5.

It offers an exciting option to meet the demand for investigation skills in the new UK National Curriculum which, in future, will be examined via paper-based questions. Introducing these skills at key stage 3 (ages 11–14) will engage pupils early on with ways of working that will remain important up to key stage 5 (ages 16–18). In addition, the lesson introduces students to concepts of the nervous system as a further important biology specification and provides opportunities to discuss ageing and neurodegenerative disease as socially relevant topics.

A second lesson was successfully tested in four sessions with 80 year 13 students (ages 17–18), which included one class of high achievers, two mixed-ability classes and one support class with weaker students. The lesson relates to the topic of alcohol and represents an excellent synoptic end-of-year revision lesson which establishes conceptual links across at least seven curriculum-relevant biology specifications. These include fermentation, the gene-to-protein concept, enzyme function, pharmacology and associative learning, genetic variation, and even principles of evolution through explaining the geographical distribution of alcohol tolerance levels in flies and in humans. During this lesson, students dissect normal and alcohol dehydrogenase (ADH)-deficient fly maggots and use a colour reaction to assess the maggots' ability to metabolise alcohol (Figure 2). In further activities, students observe the effect of alcohol consumption on normal and ADH-deficient flies, and compare different alleles

of the *Adh* gene by translating their DNA code into RNA and protein. Differentiation was achieved by including concepts of apoenzymes and holoenzymes when teaching to students aspiring to high A/A* grades, thus stretching their knowledge beyond the curriculum.

By using the core topic of alcohol to interlink and recapitulate a range of biology concepts, accompanied by exciting experiments and activities, this lesson offers an engaging way to deal with the element of linearity in the new curriculum. It also offers valuable opportunities to talk about the social relevance of alcohol and alcohol abuse (Figure 3). As with the previous resource, this lesson is also accompanied by teacher notes, activity sheets, health and safety information (risk assessment) and a homework sheet, as well as detailed online information on the *droso4schools* website (Box 1).

Many more topics and school materials are available (Box 1, D and E) and some of them are being prepared for download as sample lessons. One lesson currently being developed covers genetics and marker mutations in the fruit fly (Figure 4). During this lesson, students learn the practical uses of marker mutations (including Punnett squares), how it was discovered that genes lie on chromosomes and how this finding

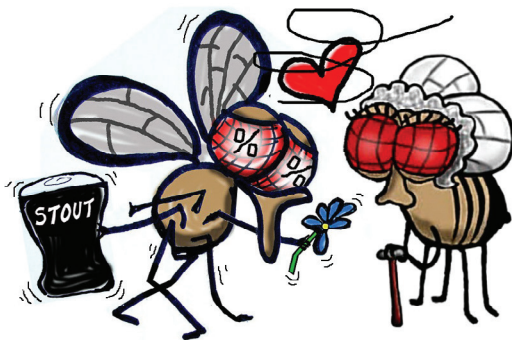


Figure 3 Flies show behaviours that we expect to be typical of humans: they get addicted, turn to alcohol when frustrated and show the 'beer goggles' effect (see details under the L2-alcohol tab on the *droso4schools* website; Box 1, A4)

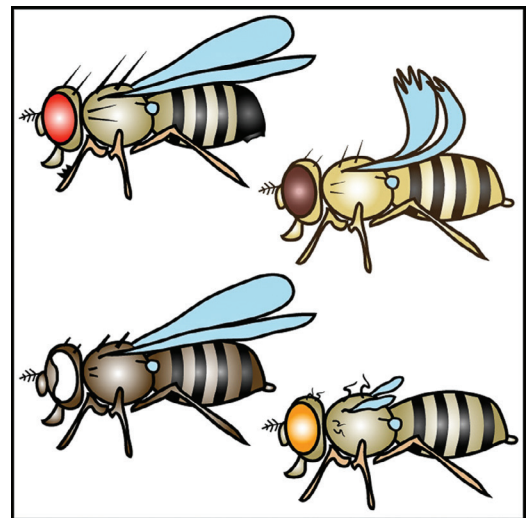


Figure 4 The Manchester Fly Facility provides further tools and resources (Box 1). For example, the Genotype builder is an easy tool that can be used to generate pictograms of mutant flies for classic genetics lessons.

helps understand biological phenomena in humans, such as male predisposition to colour blindness. Another lesson introduces students to the fundamental principles of nervous system function, including action potentials, synapses and neuronal networks, spiced up by simple yet memorable experiments (see first paragraph). Many more topics can be addressed and we are happy to collaborate with anyone who would like to develop curriculum-relevant lessons capitalising on *Drosophila*. Please contact the Manchester Fly Facility with any queries you might have or if you

would like us to present our strategies at teacher conferences or training courses, as we have done on a number of occasions already.

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