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Industrial Case

BBSRC Studentship Proposals 2008

PROPOSAL

Document Status: With Owner

BBSRC Reference:
Your Reference Number: CSL/Sheff CASE

Contact

Name:

Research Organisation:

Department:

Project Details

Project Title (mandatory):

IPR and Ethical Information

The provisions of the Animals (Scientific Procedures) Act 1986 must be observed. Institutions and award holders are responsible for ensuring that all appropriate personal and project licences required under the Act have been granted by the Home Office. All BBSRC awards are made on the absolute condition that no work that is controlled by the Act will begin until the necessary licences have been obtained.

Would the project involve the use of vertebrate animals or other organisms covered by the Animals (Scientific Procedures) Act?: Yes No

- If yes, please specify which species of animal:
- Fish
 - Amphibian
 - Reptile
 - Bird
 - Rat
 - Mouse
 - Other Rodent
 - Guinea Pig
 - Rabbit
 - Cow
 - Sheep
 - Pig
 - Poultry
 - Equidae
 - Cat
 - Dog
 - New World Primate
 - Old World Primate
 - Other Animal

What would be the severity of the procedure ? : Mild Moderat Substantia

Please provide details of any areas of substantial or moderate severity:

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Please comment on any ethical or societal issues raised by the proposed work:

| |
|------|
| None |
|------|

Staff Numbers

| | |
|------------|------|
| Management | 70 |
| Production | 2500 |
| Research | 24 |

Supervisors

Details of supervisors connected with the application:

| Research Organisation | Supervisor | Main Supervisor? |
|-------------------------|--------------------------------|------------------|
| University of Sheffield | Professor Roger Kenneth Butlin | Yes |

Research experience:

More than twenty years research experience in evolutionary genetics, especially the genetic basis of reproductive isolation in insects. Principal model systems have been grasshopper hybrid zones, planthoppers, *Littorina* and *Drosophila*. Methods include quantitative and molecular genetics, behavioural studies, acoustic and chemical signal analysis and ecological analysis. Also worked with sexual and asexual reproduction using ostracods as a model system and collaborated in projects on evolution at range margins (using genetic approaches in *Arabidopsis lyrata* and also simulations), biology of insect vectors of disease and behavioural ecology and conservation of bats. Currently Co-investigator for an NERC-funded project on virulence of the *Varroa*-transmitted DWV virus in honey-bees.

Existing students and projects:

Principal supervisor:

One NERC-funded student, year 2, working on the genetic basis of sterility in a grasshopper hybrid zone.

One CSL- funded student, year 3 working on markers for the study of sex-specific dispersal in Daubenton's bats

One EU-funded student, year 3, working on phylogeny and phylogeography of a complex of sexual and asexual ostracods.

One Dorothy Hodgkin international student, year 4, writing up a thesis on gustatory receptor gene evolution in *Drosophila*.

Co-supervisor of three additional students.

Submission rates:

Supervised more than 20 PhD students to completion, all within 4 years.

Please provide details of the supervisor's most important publications:

Recent important papers:

Kawakami, T., Butlin, R. K., Adams, M., Saint, K. M., Paull, D. J., and Cooper, S. J.B. Genetic analysis of a chromosomal hybrid zone in the Australian morabine grasshoppers (*Vandiemenella viatica* species group). *Evolution*. In press.

Butlin RK, Galindo J and Grahame JW. 2008. Sympatric, parapatric or allopatric: The most important way to classify speciation? *Philosophical Transactions of the Royal Society, B* 363: 2997-3007.

Pedro PM, Sallum MA and Butlin RK. 2008. Forest-obligate mosquitoes suggest palaeoecological perturbations. *Heredity* 101: 186-195.

Wood, HM, Grahame, JW, Humphray, S, Rogers, J and Butlin, RK. 2008. Sequence differentiation in regions identified by a genome scan for local adaptation. *Molecular Ecology* 17: 3123-3135.

Gardiner A, Barker D, Butlin RK, Jordan WC, Ritchie MG. 2008. *Drosophila* chemoreceptor gene

evolution: selection, specialization and genome size. *Molecular Ecology* 17: 1648-57.

Kawakami, T., Butlin, R. K., Adams, M., Saint, K. M., Paull, D. J., and Cooper, S. J.B. 2007. Differential gene flow of mitochondrial and nuclear DNA markers among chromosomal races of Australian morabine grasshoppers (*Vandiemenella*, *viatica* species group). *Molecular Ecology* 16: 5044-5056

Drosophila 12 Genomes Consortium. 2007. Evolution of genes and genomes on the *Drosophila* phylogeny. *Nature* 450: 203-218.

Pope LC, Butlin RK, Wilson GJ, Woodroffe R, Erven K, Conyers CM, Franklin T, Delahay RJ, Cheeseman CL, Burke TA. Genetic evidence that culling increases badger movement: implications for the spread of bovine TB. *Molecular Ecology* 16:4919-4929.

Walton C, Somboon P, Harbach RE, Zhang S, Weerasinghe I, O'Loughlin SM, Phompida S, Sochantana T, Tun-Lin W, Chen B and Butlin RK. 2007. Molecular identification of mosquito species in the *Anopheles annularis* group in southern Asia. *Infection, genetics and evolution* 7: 93-102.

Mirol PM, Schäfer MA, Orsini L, Routtu J, Schlötterer C, Hoikkala A and Butlin RK. 2007. Phylogeographic patterns in *Drosophila montana*. *Molecular Ecology* 16: 1085-1097.

Walton C, Somboon P, Harbach RE, Zhang S, Weerasinghe I, O'Loughlin SM, Phompida S, Sochantha T, Tun-Lin W, Chen B, Butlin RK. 2007. Molecular identification of mosquito species in the *Anopheles annularis* group in southern Asia. *Medical and Veterinary Entomology* 21: 30-35

Routtu J, Mazzi M, van der Linde K, Mirol P, Butlin RK and Hoikkala A. 2007. The extent of variation in male song, wing and genital characters among allopatric *Drosophila montana* populations. *Journal of Evolutionary Biology* 20: 1591-1601.

Vanwambeke SO, Lambin EF, Eichhorn M, Flasse S, Harbach RE, Oskam L, Somboon P, van Beers S, van Benthem BHB, Walton C and Butlin RK. 2007. Impact of land-use change on dengue and malaria in northern Thailand. *EcoHealth* 4: 37-51.

Klappert K, Butlin RK and Reinhold K. 2007. The attractiveness fragment-AFLP analysis of local adaptation and sexual selection in a caeliferan grasshopper, *Chorthippus biguttulus*. *Naturwissenschaften* 94: 667-674.

Vanwambeke, SO, Somboon P, Harbach RE, Isenstadt M, Lambin EF, Walton C and Butlin RK. 2007. Landscape and land-cover factors influence the presence of *Aedes* and *Anopheles* larvae. *Journal of Medical Entomology* 44: 133-144.

| Research Organisation | Supervisor | Main Supervisor? |
|-------------------------|------------------------|------------------|
| University of Sheffield | Dr Stephen John Martin | No |

Research experience:

19 years of research experience, 5 years on hornet ecology, 7 years on honeybee diseases and 7 years on the chemical ecology of social insects.
 Excellent scientific track record with almost 150 publications (c.80% first author)
 Awarded DSc in 2006 for contribution to his fields of research.

Existing students and projects:

Ricky Kather (MSc/4th y) student, testing the blank slate hypothesis in honeybees by conducting a series of bioassays to elucidate the function of alkanes and alkenes in the honeybee recognition system.
 Rachael Hodgson a part time MSc student. This is a joint submission with the Maths and Statistics department. Rachael is using large cuticular hydrocarbon chemical datasets to look for patterns within the data that may or may not correspond with known honeybee behaviours.

Submission rates:

As main supervisor N/A
 As co-supervisor 100%

Please provide details of the supervisor's most important publications:

Martin, S.J., Beekman, M., Wossler T.C. & Ratnieks, F.L.W. (2002) Parasitic Cape honeybee workers, *Apis mellifera capensis*, evade policing. *Nature*, 415: 163-165.

Martin, S.J., Vitikainen, E, Helanterä, H., Drijfhout, F.P. (2008) Chemical basis of nestmate recognition in the ant *Formica exsecta*. *Proc.R. Soc. B.* 275, 1271-1278.

Martin, S.J., Helanterä, H., Drijfhout, F. P (2008) Colony-specific hydrocarbons identify nest mates in two species of *Formica* ant. *J. Chem Ecol.* Doi 10.1007/s10886-008-9482-7.

Martin, S.J., Takahashi, J., Ono, M., Drijfhout, F. P. (2008) Is the social parasite *Vespa dybowskii* using chemical transparency to get her eggs accepted? *J. Ins. Phys.* 54, 700-707.

Martin, S.J., Jenner, E. A. Drijfhout, F. P. (2007) Chemical deterrent enables a socially parasitic ant to invade multiple hosts. *Proc. R. Soc. B.* 274, 2717-2721.

Martin, S.J., Chaline, N., Jones, G., Ratnieks F., (2004) Role of hydrocarbons in egg recognition in the honeybee. *Physiol. Entomol.*, 29:395-399.

Martin, S.J., Jones, G., (2004) Conservation of bio-synthetic pheromone pathways in honeybees *Apis*. *Naturwissenschaften.* 91: 232-237.

Martin, S.J. Medina, L. M. (2004) Africanized honeybees possess unique tolerance to *Varroa* mites. *Trends in Parasitology*, 20: 112-114.

Sumpter, D. & Martin, S.J. (2004) The dynamics of virus epidemics in *Varroa*-infested honeybee colonies. *J. Animal Ecol.*, 73: 51-63.

Martin, S.J. (2001) The role of *Varroa* and viral pathogens in the collapse of honey bee colonies: a modelling approach. *Journal of Applied Ecology*, 38: 1082-1093.

Martin, S.J. (2001) Biology & Life History of *Varroa* mites. in *Mites of the HoneyBee*, eds. T. C. Webster & K. S. Delaplane, Dadant publication pp. 131-148.

| Research Organisation | Supervisor | Main Supervisor? |
|--|----------------|------------------|
| | Dr Giles Budge | No |
| <u>Research experience:</u> | | |
| Dr. Giles Budge has worked in applied research for 11 years. He specialises in using molecular diagnostics to answer epidemiological questions about the pathogens under study. Giles started working for the National Bee Unit (CSL) as the research co-ordinator in November 2007. Prior to this, he was responsible for the development of real-time PCR-based diagnostics for bee pests and diseases and has experience characterising fungal pathogens. | | |
| <u>Existing students and projects:</u> | | |
| PhD Student - Molecular taxonomy of honey bee viruses with Professor Mike Carter at the University of Surrey (Defra funded) | | |
| PhD Student - Investigation of mechanisms of insect-virus interactions with Professor Mike Boots at the University of Sheffield (NERC funded) | | |
| PhD Student - Investigating exotic threats from <i>Tropilaelaps</i> mites with Dr. Panuwan Chantawannakul at Chang Mai University, Thailand (Royal Jubilee Fellowship) | | |
| <u>Submission rates:</u> | | |
| I have previously supervised one student (Carlos Garrido) in 2005-7 who submitted successfully. | | |
| <u>Please provide details of the supervisor's most important publications:</u> | | |
| V Tomkies, V, Flint J, Johnson G, Marris, Budge G and Brown M. (2008) Development and validation of novel field test kits for European foulbrood. <i>Apidologie</i> (submitted) | | |
| Budge, G.E., Ratti, C., Rubies-Autonell, C., Lockley, D., Bonnefoy, M., Vallega, V. et al. (2008) Response of UK winter wheat cultivars to Soil-borne cereal mosaic and Wheat spindle streak mosaic viruses across Europe. <i>European Journal of Plant Pathology</i> 120: 259-272. | | |
| Garrido, C., Carbu, M., Fernandez-Acero, F.J., Budge, G., Vallejo, I., Colyer, A., and Cantoral, J.M. (2008) Isolation and pathogenicity of <i>Colletotrichum</i> spp. causing anthracnose of strawberry in south west Spain. <i>European Journal of Plant Pathology</i> 120: 409-415. | | |
| Ward, L., Koenig, R., Budge, G., Garrido, C., McGrath, C., Stubbley, H., and Boonham, N. (2007) Occurrence of two different types of RNA-5-containing beet necrotic yellow vein virus in the UK. <i>Archives of Virology</i> 152: 59-73. | | |

| | | |
|---|--------------------|------------------|
| Research Organisation | Supervisor | Main Supervisor? |
| | Mr David Bancalari | No |
| <u>Research experience:</u> | | |
| <p>David Bancalari is a bee farmer with over 50 honey bee colonies. Prior to moving to apiculture, he was the European Director of IT for an American insurance company specialising in researching and implementing network security. During his time in IT he supervised many undergraduate projects for IT students. He is a member of the West Norfolk and Kings Lynn Beekeepers' Association (WNKLBA) who are affiliated to the BBKA. He is also the Editor of the Bee Farmers Bulletin.</p> | | |
| <u>Existing students and projects:</u> | | |
| None | | |
| <u>Submission rates:</u> | | |
| N/a | | |
| <u>Please provide details of the supervisor's most important publications:</u> | | |
| None | | |

Research Organisation

Organisation: University of Sheffield
Department: Animal and Plant Sciences

Collaborating Organisations

Organisation: Central Science Laboratory
Department: Plant Health Group

| Unit of Assessment | Rating |
|--------------------|--------|
|--------------------|--------|

Organisation: British Beekeepers Association
Department: West Norfolk and King's Lynn Branch

| Unit of Assessment | Rating |
|--------------------|--------|
|--------------------|--------|

Project Summary

AIMS
The principle aim of this studentship is to investigate the effect of viral diseases on honeybee recognition systems and how these are exploited by the ecto-parasitic Varroa mite. Specifically the studentship aims to (1) understand how Varroa mites are able avoid detection by their honeybee hosts; (2) to investigate the interactions between, viral diseases, honeybee recognition cues and mite feeding behaviour.

BACKGROUND
Honeybees (*Apis mellifera*) are essential pollinators that contribute over £200 million p.a. to UK agriculture. The ectoparasitic mite *Varroa destructor* continues to represent the most significant risk to sustainable UK honeybee populations. In addition to the stress caused by Varroa feeding on honeybee haemolymph, the mites are known to transmit several honeybee viruses including Deformed wing virus (DWV) and Slow paralysis virus (SPV). Varroa operate within honeybee colonies, which are chemically complex environments. Despite strong colony recognition cues in honeybees, Varroa mites appear to be able to evade detection by mimicking the chemical recognition signals of the hosts they are feeding on although how this is achieved is not understood. Such chemical mimicry has to be very flexible as mites may often move between colonies, each with its own con-specific odour. The critical question as to whether the mites simply acquire the hydrocarbons from their hosts or synthesize them has never been resolved. This will be studied by comparing internal and external CHC profiles as well as the speed of change when challenged with different hosts e.g. bumblebees that have very different chemical profiles.

The other key aspect of the Varroa story is that parasitised honeybees are known to exhibit an altered CHC profile compared to healthy bees, demonstrating the possibility that altered external chemistry is a response to stress, parasitism, or viral infection. This chemical information may be used by both the mites and honeybees to alter their respective behaviour. For example, parasitized bumblebees behave differently to healthy individuals, whereas aphids seek out virus infected plant material. We have a unprecedented opportunity to study this aspect in great detail since for the first time we have the knowledge and detection methods at Sheffield to link the chemical profiles of healthy bees and those infected with viral diseases which can both quantified and qualified at CSL. The ability of Varroa to transmit or activate honeybee viruses is the first step that ultimately leads to the death of the colony. It is possible that the strong correlation between Varroa and some viruses, like DWV, is enhanced by preferential feeding on virus-infected bees. Likewise, it is known that sap from diseased plants can be more nutrient rich than healthy plants and favoured by some parasites. Such a discovery of the chemical signals between honeybees and their pathogens would be key to understanding the current and future evolution and interactions of virus, host and ecto-parasites. In addition, identification of the key chemical signals involved in such a relationship could lead to novel, non-lethal methods for disease detection in honeybee colonies, which would be of great benefit to the beekeepers that are the key stakeholders.

Proposed Project Details

Please provide a brief summary of the relevance of the proposed project to the subject domain of the RC. Please refer to Help for further details. (mandatory, maximum 4000 characters)

The studentship consists of two distinct parts with a rough 30:70 split in time. The first section in addition to testing a specific hypothesis will also provide valuable information for the second part of the studentship.
1) How Varroa mites avoid detection: the working hypothesis is that mites are using chemical mimicry by tracking

chemical changes in the host

Varroa mites are highly specialised parasites that are able to survive in a very hostile environment of a honeybee colony containing ten's of thousands of adult bees. Despite their large size they appear to be able to avoid detection by chemical mimicry. Recent advances at Sheffield and other institutions in understanding the chemical recognition mechanisms in social insects e.g. honeybees and ants, allow us to investigate how the Varroa mites avoid detection. The student will investigate a range of cuticular hydrocarbon and fatty acids compounds found on the surface of both the mite and host during a one week period starting just prior to bee emergence. Work at Sheffield has just established (current MSc project) that during this period the bees hydrocarbon profile undergoes rapid change, and may explain why Varroa mites move rapidly off newly emerged bees. The student will also transfer mites onto Bumblebees that have a completely different chemical profile. Mites can survive on Bumblebees for several weeks and during this period the student will investigate using non-destructive chemical sampling i.e. SPME-fibres, how the mites profile adapted to this new host.

(2) Investigate interactions between, viral diseases, honeybee recognition cues and mite feeding behaviour: the working hypothesis is that pathogen replication changes the chemical profile of the host and this changes the behaviour of mites. This section will make up about two-thirds of the studentship and break new ground on several fronts. The first step will be to locate viral free honeybee colonies. Monitoring by CSL will be of great assistance in this as honey bee samples from the Isle of Man, a area free of Varroa, are currently been collected. The colony fatty acid and cuticular hydrocarbon profile will then be established. Then viral carrying mites will be introduced into developing honeybee cells and the emerging bee marked and later sampled at various time points so the effect of the pathogen on its individual and later colony profile can be determined. The timing of sampling points will be determined by the first part of the studentship. It is known that hydrocarbons are synthesised by the fat bodies in insects and this is tissue also invaded by viral pathogens so changes in the bee's profiles are expected.

To test with these predicted changes impact on behaviour interactions between the hosts, and host-mite. Classical two-way choice tests will be performed where a discriminator mite or bee will be given a choice of a healthy or infected honeybee and see which one is chosen averaged out over a large number of trials.

Although the bulk of the work i.e. chemical work, data analysis, bioassays ect will be carried out at Sheffield, all viral preparation, analysis and beekeeping training will be carried out at CSL with assistance from the BBKA.

What are the perceived benefits of this collaboration for both the academic and non-academic partners ? (mandatory, maximum 4000 characters)

The benefits for the academic partner is the studentship will provide a bridge between two closely related fields of research currently been carried out in the environment centre at Sheffield University. These are the maintenance of recognition cues in ants and the evolution of virulence using the honeybee-mite-pathogen system. Although the studentship will remain distinctive they will be part of a small but highly integrated team since similar technical problems are faced by each project and the various solutions can be shared between all team members. Findings generated by the studentship may well impact on the other fields of studies and will be a great benefit to all the studies and lead us to a more complete understanding to the systems we are studying, i.e. chemical communication. The academic partner would also benefit from a close association with the end users of any recommendations for disease management. Also, the scietific expertise of Sheffield staff is complemented by the world-leading diagnostic facility at CSL.

Although fronted by the West Norfolk and and Kings Lynn Beekeepers Association (WNKLBA), the project has financial backing from six other bee keeping associations (Bedfordshire, Cambridgeshire, Peterborough, Huntington, Essex and Suffolk). This studentship is the first to channel money from the beekeeping industry into a BBSRC grant. The effective management of Varroa and viruses is the biggest challenge to apiculture in this country for 100 years. Management strategies need to be supported by sound fundamental science. A better understanding of the communication pathways and chemical recognition systems between honey bees, Varroa and viruses would directly contribute to the beekeeper's ability to mange these problems.

The National Bee Unit at CSL manages the honey bee health programme in England and Wales using a network of apiary inspectors. The inspection programme is underpinned by sound applied science. So the NBU at CSL will benefit by interacting with world-leading researchers and channelling the knowledge gained through to the honey bee inspection programme. The student will gain access to CSL diagnostic facilities and samples field samples from bee insepctors. The addition of CSL as a third party offers increased value to this studentship.

The department at Sheffield is a natural choice for such a collaboration due to the record of achievement of Dr. Stephen Martin in the field of Varroa-virus interactions (35 publications in the area) and also due to the availability of state-of-the-art facilities. This proposed studentship brings together committed end users in the industry with leading government and academic scientists.

Knowledge Transfer

The truly inter-disciplinary nature of this studentship i.e. academic (Sheffield University), government (National Bee Unit at CSL), and beekeepers (WNKLBA) will allow the knowledge gained from this proposed studentship to be widely disseminated. This will include talks in the department as these are part of student training at Sheffield University, talks at CSL to scientists and policy makers, in addition to talk's at key beekeeping conferences. Furthermore, Dr. S. Martin is a Science Ambassador and very active participant in National Science Week talking to c.500-1000 school children each year about scientific research in addition to talks to the general public and local interest groups. Dr. Giles Budge regularly speaks at local, national and international beekeeper meetings.

Beyond the series of high quality scientific publications expected to arise from this studentship, the collaboration with CSL and WNKLBA will ensure that the knowledge gained during the studentship will be transferred directly to both the policy makers (National Bee Unit/CSL) and the stakeholders (WNKLBA). This studentship will have a high profile within the industry as it sets a precedence for direct sponsoring of research by beekeepers. David Bancalari is the editor for Bee Farmers Bulletin, ensuring coverage of the positive outcomes of the studentship to key industry players. Dr. Giles Budge and David Bancalari regularly write for trade publications such as Beecraft and BBKA news, which reach an audience of over 11,000 beekeepers.

Such an inter-disciplinary approach will maximise the benefit of this studentship the UK economy by improving bee-health and maintaining pollinator populations. This year the bee farmers were unable to fulfil pollination contracts due to the low number of surviving bee colonies. NBU research suggests Varroa and viruses have made a major contribution to colony mortalities in recent years. Despite a recent resurgence in interest for beekeeping, a third of new beekeepers give up very quickly due to the difficulties encountered, many of which are linked to the effects of Varroa. Insights provided by this research will go a long way to steady the craft of beekeeping and to ensure healthy pollinator populations that offer a huge contribution to the UK economy.

Research Strategy

Describe the research strategy. Please refer to Help for scheme specific guidance.

Understanding the chemical communication systems in invertebrates of vital importance, since it underlies the greater part of insect behaviour. Investigating the role of viral pathogens on this system will be breaking new and exciting ground by providing detailed fundamental empirical data on a very well studied host-parasite-pathogen system. This is only possible by the integrative biology approach that is combining chemistry, virology and biology. Currently the honeybee-Varroa mite-pathogens system is been developed, with funding from NERC into a model system which can be used in predictive biology. Already predictive modelling of this system help explained the reasons why millions of honeybee colonies died. With the recent completion of the honeybee genome this allows the honeybee to become one of the new key model systems to be developed. Due to the importance of honeybees to the economy developing the honeybee as a model organism will help beekeepers and bee researchers understand better how to manage the various honeybee diseases and in turn this knowledge will improve the quality of life in the UK and all other parts of the world where honeybees are maintained. In addition, the compounds the studentship will study, hydrocarbons, are very stable and as such have the potential to be used as species-specific signal disrupters in pest control. Therefore, the studentship wider aims and approach are in total agreement with the BBSRC's current 10 Year Vision and current BBSRC Strategic Plan. That is taking an integrative biology approach to help in the development a new and exciting model system than can be used in a predictive way to improve the quality of life in the UK.

Supervisor Training and Selection

Describe the selection process for the project and supervisor.

The successful management of Varroa is key to apiculture in the UK. Poorly managed Varroa often leads to colony losses. Rather than Varroa acting alone, there is evidence that Varroa acting in concert with viruses causes the serious damage. Therefore the industrial partner was keen to front money to investigate Varroa interaction with viruses. The ability of Varroa to chemically interact with honey bees in a complex environment is a much understudied area. Approaching the University of Sheffield was the obvious choice due to the residence of Dr Stephen Martin, who is world renowned for his work on Varroa virus interactions.

The industrial supervisor was chosen to have complementary skills to those of the academic supervisors whilst retaining a close link with industry. David Bancalari is an active member of the WNKLBA and is also a bee farmer with years of beekeeping knowledge to contribute to the studentship. David holds several formal beekeeping qualifications and is working towards the advanced bee husbandry qualifications. Before participating in beekeeping he was the European Director of IT for an American insurance company specialising in researching and implementing network security. David will bring a unique industry perspective to the studentship, something that is key for the eventual success of the work. David will have regular communications with other members of the contributing beekeeping associations where the project progress and supervision will be monitored.

Whist under third party supervision, at CSL, the student will have access to a Student coordinator who will formally monitor the standard of supervision received by both all supervisors at 6 monthly intervals. The student co-ordinator is also on hand to assist supervisors with any questions arising from student supervision. Finally the Student coordinator will conduct exit interviews with the student as a final monitoring exercise.

Describe the supervisor training provided.

All supervisors in the department must comply with the University of Sheffield's Code of Practice for Postgraduate Research Degrees which complies fully with QAA requirements. The code of practice dovetails with additional recommendations and requirements arising from the department's own postgraduate monitoring procedures managed by the Graduate Committee. The code of practice is revised and circulated annually to all staff and students together with the department's Graduate Handbook. New requirements are brought to the attention of staff via newsletters and at staff meetings. Supervisory teams are composed of the supervisor(s) - around 70% of students have at least two supervisors - and a Project Supporter, a member of staff with relevant research interests, who plays a full role in the department's student monitoring procedures and who also acts as a supporter for the supervisor(s). New members of staff usually have supervisory experience when they join the department, but any first-time supervisors are expected to supervise students jointly with an experienced colleague. In addition, new staff members are assigned a senior member of staff as a mentor from whom advice on any matter, including postgraduate supervision, can be sought. In addition to departmental procedures for guidance and training, the university's induction programme for new academic staff includes training in postgraduate supervision, and the Staff Development Unit runs regular courses to directly support supervisors including on 'Leading and Managing Teams' and 'Supervisory Skills'.

Proposed Training & Support

Describe the postgraduate management research training policy (mandatory, maximum 4000 characters)

Academic partner

Within the department, postgraduate training is managed by the departmental Graduate Committee (GC) comprising ten members (six academic staff, the graduate secretary and three elected student representatives; including at least one overseas student). The Chair of the GC reports to the departmental Policy Committee and to the Head of Department. The GC holds a minimum of six meetings each year, and the Chair of the GC also attends Faculty of Pure Science Graduate Committee meetings. The GC has responsibility for all aspects of postgraduate study including recruitment, induction, training and monitoring of progress and ensures that research training conforms to the University's Code of Practice for Research Degree Programmes. Postgraduate research within the University is managed by the Graduate Research Office and delivered via the University of Sheffield's Research Training Programme (RTP) which is compulsory for all students (further details on the scope of the RTP are provided in the following section). The RTP has been developed by the University in accordance with the QAA Code of Practice for postgraduate research programmes. The RTP is administered centrally in the University and encompasses a wide range of training modules, but most students in the Department of Animal & Plant Sciences choose to take modules provided by the Department and administered therein. These modules are planned by the department's Graduate Committee (GC) and coordinated and delivered by departmental academic staff. Their content is reviewed annually in GC meetings. As a consequence, the form and content of the RTP continually evolves to match the requirements of students, and new modules are developed to recognise additional training requirements.

All modules are assessed through evaluation forms specific to each course that provide students with the opportunity to give anonymous feedback and suggest modifications to the department's RTP provision. Teaching staff receive details of this feedback and, where necessary, implement changes to the training to improve provision further. A summary of evaluations from each module (including details of any resulting changes) is submitted to the University annually. Feedback on RTP provision is also solicited directly by postgraduate representatives on the GC for discussion at GC meetings. In addition, the University conducts an online Student Evaluation of Research Degrees, administered by the Graduate Research Office and conducted by the external Oxford Research Agency with datasets compared within faculties. This survey solicits the views of students on the wider graduate experience: induction, supervision, RTP, academic progress and research support (including research facilities). In addition, an Independent Review of Research Support and Supervision is conducted at the University at faculty level as part of a rolling programme. The department is required to propose and document recommendations and revisions of training modules in response to any perceived shortcomings of RTP provision identified in these evaluations.

Industrial partner

As a member of the British Beekeepers' association (BBKA) the industrial collaborator adheres to the BBKA constitution to promote the craft of beekeeping. The industrial partner is committed to improving husbandry and training all beekeepers to national standards. The student will be trained to a certified standard in apiary management and disease diagnoses using the BBKA Examination and Assessment Programme.

Describe the generic and employability skills development training (mandatory, maximum 4000 characters)

The department complies with the University's policy that the Research Training Programme (RTP) meets three objectives:

1. The development of generic skills that contribute to the understanding of research methods, techniques and the context in which research takes place
2. The development of generic skills that contribute to the personal and professional development of a research student
3. The broadening and deepening of subject knowledge

Students must undertake and pass the RTP (45 credits, across the PhD). The RTP provides students with: a broad understanding of the context in which research is undertaken; transferable skills of value for future careers; analytical and research skills of long-term value; and an appropriate and detailed subject-based training. Students identify their training needs (see following section) selecting modules from those provided by departments in the School of Biological Sciences and across the University. Specific areas covered by the RTP are: (A) Research skills/techniques: Training is provided within the supervisor's lab, by collaborative partners (CASE students) and by RTP workshops on advanced methodologies. Example units include: Techniques for the Analysis of Genes; Biological Electron Microscopy; Image Acquisition, Processing and Analysis. Students also attend the departmental seminar series (20 each year), exposing them to a diverse range of methodologies both within and outside their areas of expertise. (B) Research environment: Attendance at a health and safety course, covering good laboratory practice, electrical safety/fire hazards, COSSH regulations and risk assessment, is compulsory. Specialised courses (compulsory for users) are also provided, eg. on genetic manipulation, biohazards and isotopes. (C) Research management/IT: As part of a compulsory unit at the start of their PhD, students receive training in library skills, literature searches, information management, project design and budgeting. They must produce a literature review that establishes and justifies a framework for their PhD programme and a budget for management of research funds in their research training and support grant. Students also attend a course on statistical analysis (compulsory and developed with Roberts funding) and receive training in data handling and presentation, experimental design and scientific writing from their supervisory team. (D) Personal effectiveness: Students pursue their research in a supportive and interactive environment that encourages collaborative work. Students join one of five research groups, which provide a high quality research environment as well as a social base. Students have the opportunity to assist in undergraduate practical classes, allowing development of personal skills. (E) Communication: A compulsory RTP module run by an external consultancy and funded from Roberts funding trains students to communicate their science with specialist and non-specialist audiences as well as encouraging skills for acquiring, processing and presenting written and oral information. Students give an oral presentation in each year of their PhD, and a poster presentation in their final year. (F) Networking/teamworking: Research group seminars and discussion groups facilitate the exchange of ideas and good practice. Students participate in national and international meetings during their PhD, providing an opportunity to establish networks of contacts and to investigate career opportunities. (G) Career Management: Students are introduced to the University Careers Service during their induction, and are expected to keep and develop a Personal Development Plan (PDP). Students are also encouraged to apply to the University's Excellence Exchange scheme (providing funds for research training placements in external international institutions) and to attend national or regional courses and workshops run by the UK GRAD programme and/or by VITAE.

Please detail how the student's training needs will be identified, met & monitored throughout the period of his/her award (mandatory, maximum 4000 characters)

Academic partner

Selection of Research Training Programme (RTP) courses by students at the start of their PhD is preceded by two information sessions during induction week, one focused on departmental training provision, and one on University-level training provision; students also consult with their supervisors with whom they undertake a training needs analysis. If necessary, students will also consult with module coordinators before final module selection. Final approval for RTP modules is given by the Chair of the department's Graduate Committee. Through this process a comprehensive assessment of student training needs is made; with further opportunities for assessment of training needs are provided through the formal departmental monitoring procedures that continue through year 1. To ensure students' training needs are met and monitored, over the course of their entire degree, all students must obtain a minimum of 5 credits in each area covered by the RTP (see preceding section), and hence making the development of generic and employability skills a compulsory component of training provision.

In years 2, 3 (and 4), students will regularly review their training needs both with their supervisory team, and additionally at their formal review meetings with a member of the GC. Consequently, students will identify and undertake additional training activities as part of optional modules. Whilst there is the minimum requirement to obtain 45 credits on the RTP, many students benefit from attending additional University of Sheffield training courses including those on 'Career Management Skills for Graduate students' (run by the University of Sheffield Careers Service), 'Project Management and Commercial Awareness' and 'Entrepreneurship and Business Planning'.

Industrial partner

The student will spend time with experienced apiarists learning many aspects of beekeeping including the standard methods for Varroa control. In addition, the student will accompany inspectors from the National Bee Unit (CSL) on apiary visits to gain experience of monitoring honey bee pests and diseases.

The industrial partner will provide training for the student to complete the BBKA Basic Beekeeping course which covers beekeeping equipment, colony management, apiary arrangements, swarm control, honey production, labelling & disease control. The course combines oral and practical assessments and certified examiners assess competence. The industrial partner has one of the highest pass rates nationwide for this exam. In addition, the industrial partner will ensure competence in disease and pollen recognition by supporting the student to attain a microscopy certificate. Certified Master Apiarists, who are members of the collaborating beekeeping associations, will monitor the progress of the student.

Detail the student selection, recruitment and induction procedures (mandatory, maximum 4000 characters)

The department has a student selection procedure that seeks to identify high quality, motivated candidates who are well-matched to their research project. Studentships available in the department are advertised on recruitment sites on the web (FindAPhD.com and naturejobs.com), on departmental web pages and details of individual projects are sent to colleagues at other institutions. Meetings with undergraduates and MBiolSci students at Sheffield are also held to provide information on opportunities for postgraduate research in Sheffield (and training and guidance on the wider postgraduate application process). The University also holds an annual Graduate Recruitment Fair when staff are available to meet potential students and provide tours of the department. Applications are administered centrally within the Department by two graduate secretaries, following submission of applications (and CVs) to the University admissions section (either online or by post). Full applications are circulated to named (or appropriate) members of staff. Two references are sought for all promising candidates and a short-list of candidates is drawn up for interview. Prospective interviewees are sent documentation about the University, the department and its research activities and also information on specific projects within their field of interest, in advance of their interview. Interviewees have extensive discussion with the prospective supervisor(s) and they also have a second interview with an independent member of staff. Students are given a tour of the department and any other university facilities they wish to see by a current postgraduate student from within the research group to which they are applying. Interviewers submit independent reports on interviewed candidates to the graduate secretary. Having interviewed all likely candidates, prospective supervisors submit details (CV, references, covering letter and interview reports) of their preferred candidates to the Head of Department and GC director. Offers of studentships are then made according to the student's potential for research, their perceived motivation and their suitability for the project for which they have been nominated.

Prior to starting their PhD, students receive information packs from the department and the University and at the start of their studies they attend a postgraduate student induction week. During this time, in addition to university registration, students attend introductory sessions on the PhD process, an overview of the University Research Training Programme (RTP) and information on specific RTP modules. They have initial and follow-up meetings with their supervisors which includes a training-needs analysis, and attend seminars on health and safety, finance, library and computing facilities, career and personal development planning, scientific writing and environmental sustainability. They are also given a tour of departmental facilities by a member of their new research group, and the induction week concludes with a departmental postgraduate reception attended by staff and students

Research Environment

Describe the research environment in which the student(s) will work and the student(s) training programme (mandatory)

The Department of Animal & Plant Sciences is a 5* department with substantial research funding and very extensive national and international collaborative links. Postgraduate students pursue their research in a supportive, interactive and intellectually stimulating environment that provides ample opportunity for collaborative projects. Research interests in the department cover key areas of development in whole organism biology, many of which lie at the interface between traditional biological disciplines. Research within the department is organised within five non-exclusive research groups, each providing a high quality, well-equipped and well-funded research environment, as well as a social base. These groups are:

1. Evolutionary Biology and Behavioural Ecology. Research seeks to integrate mechanistic and functional approaches to the study of evolution and behaviour, working at the interfaces between selection on genes/individuals and population biology. The NERC-funded Sheffield Molecular Genetics Facility is located within the group.
2. Global Change Biology. Research focuses on the effects of climate and atmospheric change on plants, plant environmental and biotic interactions, and molecular plant physiology. The group includes the NERC Centre of Excellence in Terrestrial Carbon Dynamics.
3. Ecosystem Ecology. Research in this group focuses on the interactions between organisms and their environment, at a range of spatial and temporal scales. Key research areas include spatial processes, ecosystem functioning and environmental impact and biogeochemical processes.
4. Population and Community Ecology. Research addresses pure and applied issues including: host-parasite relationships; the importance of species diversity and interactions in the structuring of communities and the provision of ecosystem services; and the impact of pollutants on communities.
5. Plant Science. Research in plant biology covers a broad spectrum of topics, from whole plant interactions with the abiotic and biotic environment (microbial and fungal) to precise analysis of metabolic pathways.

The department runs a weekly seminar series with national and international speakers covering the whole range of departmental interests. In addition, there are three separate research seminar series providing specialised, yet informal forums for discussion. These research seminars include both internal and external speakers. All postgraduate students are required to present a seminar, open to all members of the department, in each year of their PhD. Seminars are attended by undergraduates, postgraduates, postdoctoral researchers and academic staff, and they provide an important platform for the exchange of ideas. Individual academic staff, or several staff with close interests also hold regular lab meetings at which postgraduate students are expected to make a full contribution to discussions. Students are actively encouraged to participate in national and international conferences and in recent years a number of our students have won prizes for their presentations at such meetings. The department has extensive links (including ~10 CASE partnerships) with external UK and international research organisations and institutes, industry, and other end-users

including government departments and environmental agencies.

Describe the current facilities available within the department

The Department of Animal & Plant Sciences has an extensive range of modern equipment and facilities with appropriate technical support. Since 2000, it has benefited from a £7M JIF award in plant sciences and a £3.4M Wellcome/SRIF award for animal biology. For plant sciences, these have provided state-of-the-art controlled environment facilities suitable for transgenic work, together with extensive laboratory refurbishment, including molecular, analytical and imaging laboratories. This award also provided new equipment, including spectrophotometers, GC-MS, LC-MS, photodiode array HPLC, RT-PCR, and bioimaging facilities for chlorophyll fluorescence, GFP and radioactive isotopes at whole plant and cellular resolution. For animal sciences, this funding supported new facilities for housing and culturing a wide range of organisms, including insectaries, aquaria, aviaries and a suite of other controlled environment rooms and also enabled the extension and refurbishment of laboratories for molecular ecology, molecular genetics, microscopy and immunology, including liquid handling robotics, high throughput PCR and capillary DNA sequencing and genotyping, and clean room facilities with associated equipment for transcriptomic analysis. The department has excellent light and fluorescent microscopy facilities and we have access to SEM and TEM in adjacent departments in the School of Biology. During 2008, the department will open a new £4.2 million state of the art Environment Centre which will house the laboratory for Apiculture and Social Insects which will provide key facilities for this proposed studentship; in addition to a suite of controlled greenhouses and cold-climate environment chambers. The department hosts a NERC Centre of Excellence in Terrestrial Carbon Dynamics (co-directed from the Department of Applied Mathematics) and also the NERC-funded Sheffield Molecular Genetics Facility, a national facility to provide equipment and expertise in molecular genetics. Postgraduate students have full access to facilities relevant to their area of research. They also benefit from sole or shared access to appropriate computing facilities within the department, for which there is excellent support from a dedicated technician. The Department's proximity to important natural and industrial sites of scientific interest facilitates extensive environmental and ecological research in the vicinity of Sheffield.

Monitoring Arrangements

Describe the student monitoring and assessment arrangements.

Within the university, student progress is monitored and assessed by a comprehensive and integrated approach at three interconnected levels namely, the student's supervisory team, the department's Graduate Committee (GC), and the University (Graduate Research Office; GRO). Monitoring and assessment take the following forms:

Supervisory team. This includes the University supervisor/s (and the CASE partner supervisor) and a project supporter; an experienced researcher with specialist knowledge relevant to the student's research who is available to offer additional advice and support. Supervision is conducted as according to the University Code of Practice for Research Degree Programmes detailing responsibilities of supervisors and students. This stipulates that supervisors must have (at least) monthly meetings with a student (although meetings are typically far more frequent with additional input via day-to-day contact and in research group meetings). Supervisory meetings focus on progress made on the research (assessed against previous objectives), agree objectives for the next research period, and discuss wider training needs. Records of meetings are prepared by the student, with comments from supervisors and an agreed version maintained by both parties. For CASE studentships, the student will have regular email and telephone contact with the CASE supervisor and where possible the CASE supervisor will attend supervisory meetings held either at the University or at the CASE partner organisation.

Departmental level. Student progress is formally assessed within the department at regular intervals throughout the PhD (administered and monitored by the GC). Formal review meetings involve the student, project supporter and a GC member and discuss research progress, future objectives and research- and generic-skills training. Supervisors also provide input into the review process. Meetings review progress based upon preparation of written reports and/or presentations and provides the basis for feedback and assessment. In year 1, students prepare a literature review and project proposal and then give an oral presentation at the annual Graduate Symposium. Students prepare a report in advance of an upgrade meeting (to upgrade from MPhil to PhD level) at the start of year 2. All students at Sheffield initially register for a MPhil degree and a recommendation for upgrading to a PhD degree is made only on the grounds of satisfactory progress during year 1. For students not upgraded at the first attempt, a second upgrade meeting is held later in year 2. In years 2 and 3, all students present seminars in a Graduate Seminar series (organised by the students) within the department and have a review meeting following these presentations. During year 3 students prepare a written thesis plan which is again used for a review meeting. Year 3 students also present a poster at the University of Sheffield Biologies Division Poster Day. Students entering their completion year (year 4) or who are on a four year programme will have formal progress review meetings with their supervisory team and/or a GC member at 3-monthly intervals during year 4 to discuss progress on thesis writing until submission

University level. Student progress is also monitored by the University of Sheffield's GRO following a formal report, submitted annually by the supervisor(s) and approved by the GC Director.

In addition to these procedures, students evaluate the quality of their supervision, research environment and progress

every three months in a questionnaire, submitted in confidence to the GC. Students may ask for matters to be raised at GC meetings and/or they may request a meeting with any member of the GC to discuss confidential issues. In addition to these formal structures and procedures for monitoring student progress, students may raise matters at any time with members of the GC