PROJECTS IN THE SOCIAL INSECTS LAB AVAILABLE FOR 2019

Who are we? Ben Oldroyd, Madeleine Beekman, Ros Gloag, Nadine Chapman, Emily Remnant, Boris Yagound. For more details on us, the lab and what we do, go to:

http://sydney.edu.au/science/biology/socialinsects/index.shtml

What do we do? Behavioural ecology, behavioural genetics, genomics and molecular genetics of social insects, their pathogens and parasites, and slime moulds. We study honey bees (particularly Asian and African ones) and Australian native stingless bees, and perhaps weird for a lab that has social insects in its name, a slime mould. We are particularly interested in cheating behaviour: when workers start laying eggs or changing caste. In that context, we are increasingly fascinated by epigenetic inheritance: how do fathers manipulate mothers and daughters to enhance the father's reproductive success? We study population genetics of invasive bees, particularly the Asian honey bee in Queensland. We use RNA viruses of honeybees to understand the factors that allow some viruses to become more virulent. We use the slime mould to address general evolutionary questions about, for example, the inheritance of mitochondria and how mitochondria survive without sex. We also use the slime mould for more esoteric questions such as 'what is consciousness?', or 'can you be intelligent without a brain?'. We offer projects ranging from field biology to molecular genetics, phylogenetics and mathematical modeling.

What is our approach to Honours supervision? You will be treated as a colleague not a student. We promote a highly supportive and friendly environment. You will get heaps of help at every stage. We encourage Honours students to publish their work and we pay for their attendance at conferences. Most of our Honours students publish senior-authored papers. For example, 2016 Honours student Mathew Byatt received an award from the International Union for the Study of Social Insects for his paper published in their journal *Insectes Sociaux.*

A refereed publication is very helpful for acquiring an postgraduate scholarship.

What are our facilities? You will learn a lot in our lab. We have excellent molecular equipment including an ABI 3130 DNA analyzer and a real time PCR machine for quantifying gene expression. We have a fully equipped apiary, an observation hive room, nice field work facilities. We have two molecular research assistants and a field assistant. Our staff are there to help you get the best possible training and a productive year. The group has the critical mass to provide a stimulating intellectual environment. We have the international networks to help students establish a career in biological science.

Who are our collaborators?

Chulalongkorn University Bangkok, Bee Biology group, University of Stellenbosch, South Africa; Chinese Academy of Sciences, Kunming, China; York University Canada, Wageningen University, the Netherlands. We collaborate with Australian researchers at CSIRO, NSW DPI and QLD Biosecurity. Students are encouraged to be involved in these collaborations.

Papers arising from Honours projects in Social Insects Lab during the last 5 years (student name in bold)

Chapman NC, **Byatt MA**, dos Santos Concenza R, Nguyen LM, Heard TA, et al. 2018. Anthropogenic hive movements are changing the genetic structure of a stingless bee (*Tetragonula carbonaria*) population along the east coast of Australia. *Conservation Genetics* 19:619-627

Stephens, R., Beekman, M., Gloag, R. (2017) The upside of recognition error? The Australian stingles1s bee *Tetragonula carbonaria* tolerates high worker drift in artificial aggregations. *Biological Journal of the Linnean Society* 121: 258-266.

Byatt MA, Chapman NC, Latty T, Oldroyd BP (2016) The genetic consequences of the anthropogenic movement of social bees. Insectes Sociaux 63:15-24

Smith JP, Heard TA, Beekman M, Gloag R (2016) Flight range of the stingless bee *Tetragonula carbonaria*. *Austral Entomology* 56: 50-53.

Beekman, M., **Preece, K**, Schaerf, T.M. (2016). Dancing for their supper: Do honeybees adjust their recruitment dance in response to the protein content of pollen? *Insectes Sociaux* **63**(1): 117-126.

Beekman M, Makinson JC, Couvillon MJ**, Preece K** & Schaerf TM 2015 Honeybee linguistics – A comparative analysis of the waggle dance among species of *Apis*. *Frontiers in Ecology and Evolution* 3 (11): 10.3389/fevo.2015.00011.

Preece, K., Beekman, M., 2014. Honeybee waggle dance error: adaptation of constraint? Unravelling the complex dance language of honeybees. *Animal Behaviour* **94**, 19-26.

Roth K, Beekman M, Allsopp MH, Goudie F, Wossler TC & Oldroyd BP 2014. Cheating workers with large activated ovaries avoid risky foraging. *Behavioral Ecology* 25: 668-674.

Oldroyd BP, Allsopp MH, **Roth K.M**, et al. (2014) A parent-of-origin-effect on honeybee worker ovary size. *Proceedings of the Royal Society of London B* **281**, 20132388.

Lee G.M., Brown M.J.F., Oldroyd B.P. 2013 Inbred and outbred honey bees (*Apis mellifera*) have similar innate immune responses. *Insectes Sociaux* **60**, 97-102.

Lee G.M., McGee P.A., Oldroyd B.P. 2013 Variable virulence among strains of *Ascosphaera apis*: testing the parasite-pathogen hypothesis for the evolution of polyandry in social insects. *Naturwissenschaften* **100**, 229-234.

PROJECTS OFFERED IN 2019-2020

1. Epigenetic inheritance in honey bees

An unexpected finding of the honey bee genome project was that the honey bee has a fully-functional DNA methylation system which is absent from *Drosophila*. It was quickly shown that this system is used to cause differential expression of genes in queens and workers.

Honey bees are haplodiploid, and this means that males have grandsons, but no sons. So if males could manipulate their daughter workers to raising females preferentially to males they should. Thus 'patrigenes' inherited from males have different interests from 'matrigenes' inherited from queens.

We have a range of projects for Honours students in this area including:

- Determining the cytoplasmic factors that determine sex in unfertilized honey bee eggs
- Looking for signs of epigenetic modifications in bees with active and no-active ovaries
- Investigating differences in sperm DNA methylation

Drewell R.A., Lo N., Oxley P.R. and Oldroyd B.P. 2012. Kin conflict in insect societies: a new epigenetic perspective. *Trends Ecol. Evol.* **27**:367-373

Start: any time

2. Biology of Australian stingless bees

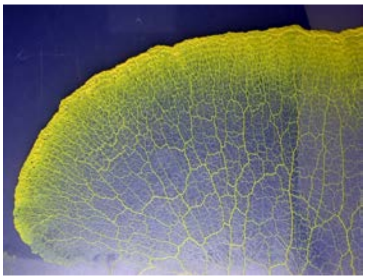
Australia has 12 species of native eusocial bees known as stingless bees. Like honey bees, these bees live in colonies with a single queen and thousands of workers. Stingless bees play an important ecosystem role, have commercial potential as pollinators of crops and are valuable models for evolutionary biology, yet they remain extremely understudied! Projects could involve both fieldwork (either in Sydney, Brisbane or Cairns) and molecular labwork. They could focus on a range of aspects of stingless bee ecology and behaviour, including:

- Foraging ecology e.g. how do stingless bees ensure efficient foraging, and are they threatened by competition with introduced bees (like honey bees)? Do they benefit from “eavesdropping” on the food-marking signals of other social bees?
- Fatal fighting e.g. stingless bees have no sting but workers still sacrifice themselves for the colony by engaging in ‘death-locks’ with other bees. How and why has fatal fighting evolved and how can it be managed by bee-keepers stocking colonies for crop pollination?
- Queen production e.g. How do stingless bees chose a new queen and why do they produce so many ‘spare’ queens?

We definitely want to have stingless bee researchers in our lab! So if interested, let’s talk.

Start: Second semester 2019.

3. Genetic bottlenecks, rates of evolution and aging



We often think of genetic bottlenecks as the cause of declines in genetic variation in populations. And such declines are mostly deleterious. But bottlenecks also provide the opportunity for selection to purge deleterious mutations.

Every cell in your body contains a large number of mitochondria. And each mitochondrion contains multiple copies of mtDNA. Because mitochondria divide independent of the cell cycle, their numbers keep increasing in the cell. High copy rate results in high mutation rates within mtDNA. In fact, damage to mtDNA is one of the causes of aging. It is therefore important that the cell has mechanisms that allow the purging of bad mitochondria during cell division.

In this project we investigate the role purging plays in selecting against bad mtDNA and the effect of aging. Again we will use the slime mold as our model system. When left undisturbed but well-fed, the slime mold will continue to grow. Because there is no cell division, mitochondria will accumulate even faster in slime molds than in multicellular organisms. Moreover, a slime mold plasmodium has no means to select against bad mtDNA.

We will compare slime mold plasmodia that have been left untouched (and therefore continue to grow) with those that we regularly force to go through a bottleneck by breaking off small bits of the plasmodium. We will use rate of growth as our measure of health. At the end of the experiment we will compare the mtDNA sequences of the slime molds that did not experience bottlenecks with those that did. We can then directly link the behaviour of the slime mold with the mitochondria that it carries.

Start: any time.

4. Pollinator conservation: The impact of the invasive honey bee, *Apis cerana*, in Australia's tropics

In 2007 the honey bee *Apis cerana* was accidently introduced to Northern Queensland from its native Asia and has since become invasive. The risks posed by this intruder to our tropical ecoystems, and to our commercial *A. mellifera* populations (which are used as crop pollinators) are not known. Projects to investigate the current state of the invasive population and their interactions with resident bees would require fieldwork in the beautiful Cairns region, Far North Queensland. This would suit an intrepid fieldworker type looking for a field-based project! There is also scope to combine a field component (collecting samples) with a molecular lab component (analyzing samples) to investigate the population biology of invasive species.

Possible project questions include:

- Is the tropically-adapted *A. cerana* outcompeting the temperately-adapted *A. mellifera* in Far North Queensland? Is *A. cerana* competing with native pollinators?
- Are feral *A. cerana* pollinating tropical fruit crops in Far North Queensland? i.e. Is this invasive pest providing an economic benefit?
- This population recently experienced a severe genetic bottleneck. Does the genetic substructure of the expanding population help to maintain genetic diversity following such a bottleneck?

Koetz A (2013) Ecology, behaviour and control of *Apis cerana* with a focus on relevance to the Australian incursion. *Insects* **4**, 558-592.

Gloag, R., Ding, G., Christie, J., Buchmann, G., Beekman, M., Oldroyd, B. (2016). An invasive social insect overcomes genetic load at the sex locus. *Nature Ecology and Evolution* 1:0011.

Start: Second semester 2019

5. Why are all the bees dying?

You may have heard that all the bees are dying due to colony collapse. Don't believe the media hype, but nonetheless the hive losses in the United States and Europe are alarming. In this project we will investigate the effects of brood rearing temperature on longevity and cognitive ability of honey bees, and establish whether it is population decline, caused by any phenomenon (pesticides, mites, viruses) that causes colonies to be unable to thermoregulate properly, thereby producing stupid, short-lived bees.

Jones JC, Helliwell P, Beekman M, Maleszka RJ, Oldroyd BP (2005) The effects of rearing temperature on developmental stability and learning and memory in the honey bee, *Apis mellifera*. J Comp Physiol A 191:1121-1129

Start. Semester 2, 2019.

6. Evolution of virulence of RNA viruses of honeybees

In countries other than Australia, honeybee colonies are suffering from the ectoparasitic mite *Varroa destructor*. Interestingly, it has been suggested that it is not the mite *per se* that causes damage to the bees, but the RNA viruses it vectors. Female mites reproduce in brood cells, sucking haemolymph from the developing pupa. When the bee emerges, the mite and her daughters emerge too and immediately find a new developing bee. By biting many bees *Varroa* females can potentially spread the RNA viruses contained in the bees' haemolymph. Evolutionary theory predicts that vector-transmitted viruses are more virulent than viruses that do not depend on a mobile vector. So, it seems that *Varroa* does to the viruses what theory predicts! However, the link between virulence and *Varroa* is correlational only and really should be tested experimentally. Such experiments can only be done in Australia because our bees do not have *Varroa*. In this project you would investigate how mode of transmission and competition amongst viruses affect virulence.

Start: any time.

7. Does Australia's honeybee industry have enough sex locus diversity?

In honeybees sex is determined by zygosity at the *complementary sex determination* locus. Individuals that are haploid are males, those that are diploid and carry two variants of the locus are females, while diploid individuals that carry two copies of the same variant are inviable males. When queens mate with a male carrying the same *csd* variant as themselves this places a cost on the colony, as half of their brood will be inviable. Polyandry (queens mate with more than one male) makes it unlikely that the proportion of inviable offspring will be anything like 50% in practice. However this depends on the number of *csd* locus variations in the population. This project will quantify the number of *csd* variants, particularly within the stock of Australian queen bee breeders, and develop an inexpensive test for use in breeding programs.

11. How do honeybees organise their pollen foraging?

We know a lot about the ways a honeybee colony organises its nectar foraging. Using the famous waggle dance, foragers adjust the details of the dance to encode information regarding the quality of the nectar source. A previous Honours student, Kait Preece, showed that the bees are unable to tell if the pollen they are foraging for contains high or low amounts of protein. Yet, protein is essential for the developing brood. So how do the bees decide what pollens to collect? This project aims at answering this question.

Beekman, M., Preece, K, Schaerf, T.M. (2016). Dancing for their supper: Do honeybees adjust their recruitment dance in response to the protein content of pollen? *Insectes Sociaux* **63**(1): 117-126.

Start: Second semester.

12. Rapid evolution following genetic bottlenecks and the genetic paradox of invasive species

Often populations of invasive species are founded by very few individuals (i.e. pass through a severe genetic bottleneck) but nevertheless thrive and succeed in their new environment. This is often referred to as the genetic paradox of invasive species, because theory predicts that the loss of genetic diversity associated with bottlenecks should increase the deleterious effects of inbreeding and reduce their ability to adapt. One possible solution to the paradox is that while overall genomic diversity is low after a bottleneck, key fitness-relevant genes are able to restore diversity more quickly than typically assumed. The biogeography of Asian honey bees, such as the giant honey bee *Apis dorsata* and the cavity-nester *Apis cerana*, provide an opportunity to explore this question: these bees are native to Asia but at some point in the past they colonized several islands of Indonesia east of the Wallace Line. Furthermore, a key fitness-critical gene is known for honey bees: the complementary sex determiner (*csd*) requires diversity within the population to produce the female sex. This project will make use of Asian honey bee samples previously collected from various locations in Asia and Indonesia to characterize the allelic diversity of *csd* in each population and map this to the species' biogeography. Is there evidence that *csd* has evolved more rapidly in island populations that experienced bottlenecks than in mainland Asia populations?

Gloag, R., Ding, G., Christie, J., Buchmann, G., Beekman, M., Oldroyd, B. (2016). An invasive social insect overcomes genetic load at the sex locus. *Nature Ecology and Evolution*. **1**:0011.

Allendorf FW, Lundquist LL. 2003 Population Biology, Evolution, and Control of Invasive Species. *Conservation Biology* **17**, 24-30.

Start: any time 2019