The Kapheim Lab: Behavioral and Evolutionary Genetics of Sociality in Bees

UtahStateUniversity
DEPARTMENT OF BIOLOGY

Research Overview

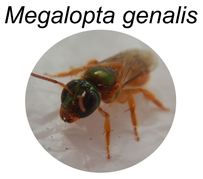
In **eusocial** species, some individuals (workers) forego reproduction of their own to cooperatively care for eggs laid by the queen. Bees are a great system for studying social behavior because there are both solitary and eusocial species, with a lot of variation in between. **We investigate the evolutionary drivers and physiological mechanisms of social behavior in bees.** This research involves comparative genomics, transcriptomics, neural imaging, and physiological and behavioral experiments with bees in the field and lab.

Megachile rotundata

Ancestrally Solitary

- No cooperative care
- No brood care
- No overlapping generations

Megalopta genalis



Facultative Simple Eusocial

- Small or no colonies
- Reproductive queen or foundress
- Daughters forego reproduction for cooperative care

Bombus griseocollis

Obligate Simple Eusocial

- Produces colonies
- Reproductive division of labor
- Independent nest founding

Apis mellifera

Complex Eusocial

- Reproductive division of labor
- Division of labor in worker caste
- Cooperative brood care
- Overlapping Generations

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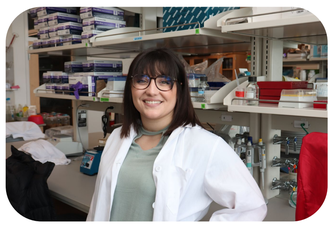

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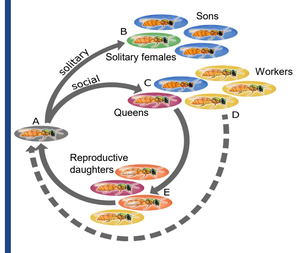
Genomic Origins of Phenotypic Plasticity

Phenotypic plasticity and social evolution

Phenotypic plasticity is one of the hallmarks of eusociality, because workers and queens have very different behavior, physiology, and anatomy, despite being highly related. We are investigating how plasticity is acquired and assimilated in the genome during social evolution, and how developmental plasticity shapes social behavior.

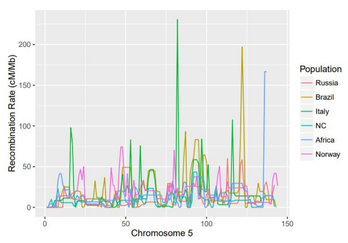


The social biology of Megalopta genalis *is ideal for studying the role of phenotypic plasticity in evolution, because both solitary and social types coexist in the same population.*

Social evolution and the recombination landscape

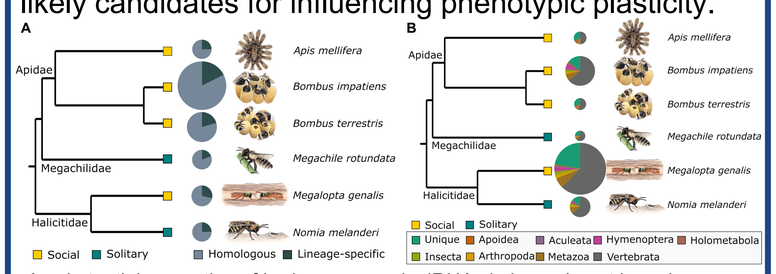
Frequency of meiotic recombination is correlated with the sociality in insects, and is variable within and across species. We study how recombination landscapes have shaped social evolution through the creation of novel traits.

Recombination rate is variable across Chromosome 5 in six populations of honey bees (Apis mellifera).



MicroRNAs and social evolution

MicroRNAs are small, non-coding molecules that target mRNA transcripts to affect downstream transcription and translation. This regulatory function makes them likely candidates for influencing phenotypic plasticity.

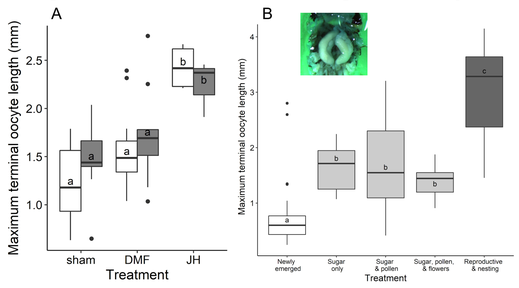


A substantial proportion of brain-expressed miRNAs in bees do not have known homologs in any other species (A). These disproportionately target lineage-specific mRNAs in each species (B), have similar or fewer predicted targets than older miRNAs, and target genes related to social behavior.

Reproductive Physiology

Reproductive maturation

In social insect colonies, queens lay eggs, but workers are sterile. Understanding the factors that influence variation in reproductive development in bees offers insights into understanding sociality.

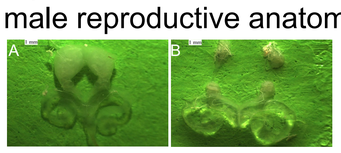


Lab experiments with the solitary alkali bee (Nomia melanderi) *show juvenile hormone (JH) (A), but not protein from pollen (B), is necessary for complete oocyte maturation (inset).*

Diapause is an adaptation for insects to delay reproduction during suboptimal conditions. We study how temperature regime during diapause influences bumble bee queen survival and colony production.

Bombus impatiens *queens overwintering in artificial hibernacula under different temperature regimes.*

Almost nothing is known about patterns of male reproductive maturation in bees. We investigate how male reproductive anatomy changes with age.

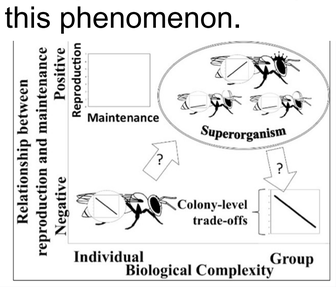


Reproductive apparatus of male Bombus vosnesenskii *in a new adult (A) and at 14 days old (B).*

Life history trade offs

In most organisms, survival and reproduction are negatively correlated, because each is metabolically expensive. In social insect colonies, queens are both long-lived and highly fertile, suggesting these life history traits have been decoupled. We study the evolutionary and molecular mechanisms for this phenomenon.

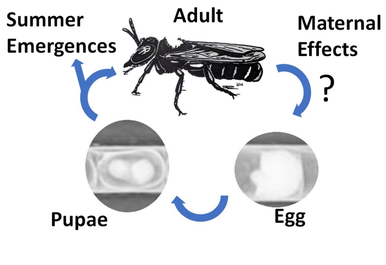
Decoupling of life history trade-offs at the individual level in solitary and colony-living bees followed by recoupling at colony level.



Maternal Effects and Social Behavior

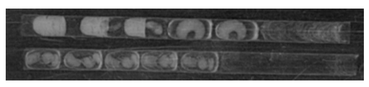
Maternal effects and offspring diapause

Female bees have the potential to influence the phenotype of their offspring in several ways. Most bees exhibit maternal care by feeding and protecting their offspring during development, and many interact with their offspring as adults. We are investigating the role of maternal condition in shaping offspring traits.



We use field and lab experiments to investigate how alfalfa leaf cutter bees (Megachile rotundata) adjust reproductive strategy based on variation in their fat stores, including how they provision their larvae, sex ratio, and the RNA transcripts they deposit in their eggs. All of these may influence whether offspring enter diapause or emerge later in the summer.

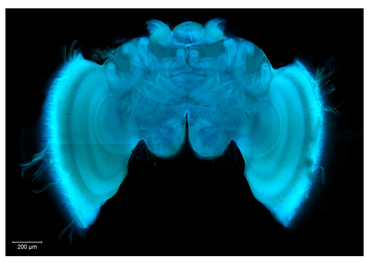
Field cages for tracking M. rotundata *reproductive strategy*



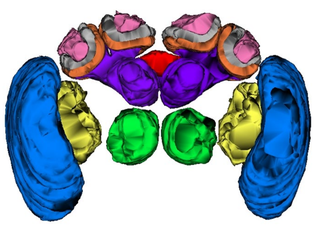
X-rays of M. rotundata *nests. Developing larva and overwintering prepupa (top); Offspring that will emerge in the summer (bottom)*

Maternal care and neuroplasticity

In eusocial colonies, workers cooperate to rear their mothers eggs without having laid any of their own. We are investigating the neural basis of this pre-reproductive expression of maternal care in bumble bees (*Bombus impatiens*).



Optical slice from a whole brain image stack used to measure neuroplasticity.



3D brain rendering generated for volumetric analyses from optical slices.

Support

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