

RESEARCH INTERESTS, ACTIVITIES AND SERVICE: JENNIFER FEWELL

Research activities

My research focuses on the evolution and organization of social behavior, particularly division of labor. I bridge theoretical and empirical approaches to test whether fundamental principles of social organization hold across diverse groups, from insects to humans. Products of my research include 47 reviewed papers and book chapters, and 14 short papers or abstracts. My publications are almost exclusively in major journals of the field of Animal Behavior, or in higher impact journals of broad scope. In addition, I am co-editing, with Juergen Gadau, a book on social insect biology, which includes contributions from most of the top researchers in our field. Below I present an overview of work in my major research areas. Each project has had NSF or NIH funding. I am the lead investigator in each case, but they represent collaborations with colleagues across disciplines, from biologists to mathematicians and social scientists.

The emergence and early social evolution of division of labor:

My lab's research program is at the forefront of a paradigm shift in social biology, from a linear view of the group as an aggregate to viewing groups as interactive and self-organizing networks. Division of labor provides a unique context in which to explore self-organization. It is a property of the colony as a whole, which can be quantified across behavioral contexts and stages of group living. It also appears pervasively across social taxa, from algae to insects and humans, and can be analyzed within comparative and evolutionary contexts. Its impact as an emergent property resonates across levels of complexity and social structure.

My work provides some of the first empirical tests of the hypothesis that division of labor emerges from interactions where performance of a task by some group members reduces the probability that others will perform it. This hypothesis derives from the response threshold model, which assumes that individuals have intrinsic thresholds for performing a given task, and that they perform it when external stimulus levels meet that threshold. Although the response threshold and emergence hypotheses have been proposed in several theoretical models, they have rarely been tested. To translate from theory to practice, my lab has: developed a quantitative measure for division of labor, examined how gene expression (dominance versus additive effects) and genotypic diversity contribute to division of labor, and explored how division of labor changes with group size, network structure and availability of tasks. This work moves across scales from the level of genetic mechanisms for individual decisions to global models of how division of labor functions at the group level.

A fundamental question in my research is how do selection and self-organization interact to shape division of labor during social evolution? My lab has provided the first experimental studies testing how division of labor and social dynamics can emerge during the early evolution of social groups. We have shown that division of labor consistently appears even in artificial associations of normally solitary individuals, suggesting that it emerges spontaneously at the origins of sociality. Mechanisms underlying this emergence include task separation via differences in task sensitivity (response thresholds), and spatial separation caused by aggression.

We also show that, counter-intuitively, division of labor is generally higher in associations of normally solitary individuals than in evolved communal associations, leading to the hypothesis that division of labor in some contexts is a barrier rather than a benefit to the evolution of social groups. These data illustrate how social dynamics within a group can shape individual phenotype and fitness. Within our communal associations, the specific task role an individual takes on, and her consequent fitness, is highly dependent on the group in which she finds herself. An ant foundress may survive and inherit the colony or die, depending on whether she lands in a group

where she becomes the excavator or brood care specialist. This finding is counter to current game theoretical models of social evolution, in which individuals bring fixed phenotypes with set fitness payoffs into the group.

Genetic task specialization and genotypic diversity:

In eusocial colonies, division of labor clearly benefits colony efficiency and function. However, increased colony size can generate a problem of information overload for individual workers in choosing and performing tasks. One mechanism for coping with this problem is genetically based individual task specialization. However, if individuals are genetically predisposed to specialize on one task the colony needs some mechanism for making sure all tasks are performed adequately as colony needs change. My lab has tested whether genetic diversity contributes to division of labor in highly eusocial colonies. Our studies on leafcutter ants and honey bees show that subfamily groups within a colony do indeed vary in task performance, and that genotypic diversity contributes to colony function as the environment changes. As an example, in honey bee colonies, a narrow subset of subfamilies collects pollen under low stimulus levels. As pollen need or availability increases, a wider array of genetic subgroups are recruited, allowing the colony to respond resiliently to changing needs for this foraging task.

Variation in metabolism and foraging in African and European honey bees:

My lab has taken the link between genotype and task performance in honey bees a step further to explore intrinsic differences in individual behavior between African and European honey bees. In a study of task performance by cross-fostered workers, we found that African and European bees differed in only a few tasks, particularly those related to pollen foraging. Concurrently, higher pollen foraging rates are associated with higher flight metabolic rates in Africanized foragers. In a collaborative project Jon Harrison and Greg Hunt, and I are testing whether higher flight metabolic rates enable higher foraging effort. We are also performing QTL analyses of the genetic bases to variation in metabolic rates, foraging effort and response thresholds for foraging.

Genetic caste determination in harvester ants:

During explorations of genetic variation and task performance, my lab discovered an unusual system of genetic caste determination (GCD), in two species of harvester ant, *Pogonomyrmex rugosus* and *P. barbatus*, in which queens are homozygous for multiple loci, and their worker siblings are heterozygous. This seeming anomaly in reproductive caste determination has become a significant test of sociobiological theory for the evolution of eusociality, because it is counter to the general expectation that worker sterility should not have a genetic basis. In the most comprehensive study to date on the extent and mechanisms of GCD my lab, in collaboration with Juergen Gadau, showed that each of the two species contains at least two genetically inter-dependent lineages. Queens must mate with males of both lineages to produce both workers and new queens. We also found that workers can recognize and cull brood of specific genotypes to reduce the production of new queens before colonies need them; the ability to recognize genotypes was previously assumed to be generally absent in social insects. The GCD system does not fit within classical models of Darwinian selection for social evolution. It highlights, instead, that both micro- and macro-evolutionary evolutionary processes, such as hybridization and lateral gene transfer, shape the complex social behavior we explore. It importantly reinforces the need to move outside of the box of considering only individual fitness or single population dynamics in developing models of social evolution.

The collaborations on this project also highlight the value of integrating student training with research. NSF funding from international programs for this project allowed me to take four students (one graduate and three undergraduate) in a research exchange to the University of Wuerzburg, with Juergen Gadau and Bert Holldobler (both now at ASU). All of the undergraduates went on to post-graduate training.

Foraging ecology and food choice

Beginning with my dissertation research, I have had an ongoing interest in how individual social insect foragers make foraging decisions, and particularly in the interactions between individual and group-level decisions. My work in this area has included measuring energy costs and gains of food choice by honey bees, and seed harvesting and nectivorous ants, and explorations of the connection between individual foraging decisions and individual versus colony experience. In recent work, we have shown that seed harvesting and leafcutting ants use food stores (seeds or fungus) as information centers, and that individual foraging decisions are based on colony-level experience. We have also developed network models of information flow within ant and honey bee colonies in relation to the regulation of foraging behavior, an approach we call “ergonomic networks”. We are also applying stoichiometric principles to exploring the flow of nutrients, particularly phosphorus and nitrogen, through social insect colonies.

Modeling Social Dynamics in Children’s Play Groups

In addition to my work on social insects, I am interested in pursuing application of algorithms developed for social insect groups to social dynamics in humans. In human social dynamics the complexity of each individual is often considered paramount, but both insects and humans share group level attributes, including division of labor, that suggest their social dynamics follow similar self-organizing rules. I am co-PI, with Bill Griffin, a social scientist and Paul Torrens a geographer, on a recently NSF-funded project that uses agent-based and spatial modeling to examine how children form social bonds and differentiate into play groups. My question in the project is whether their social dynamics map onto the rule sets we use to describe division of labor in social insects.

Integrating research and service

Throughout my career, I have been interested in developing collaborative enterprises that move the field of social behavior forward. These include efforts to integrate across the diverse fields that investigate behavior, from human to biological perspectives, and also to integrate between theoretical and empirical approaches. Below, I outline my service activities professionally and at ASU directed to these goals.

Development of the Center for Social Dynamics and Complexity

Over the past two years, I have been involved in the creation and leadership of the new Center for Social Dynamics and Complexity at ASU. The mission of the center is to leverage the new field of complex systems to foster interdisciplinary research on fundamental questions of social life. The Center includes over 40 faculty associates from such diverse fields as anthropology, biology, mathematics, philosophy, physics, psychology, and sociology. The center is particularly focused on combining theoretical and empirical approaches to address the question of how social groups are organized, from insects to humans.

I led the organizational team that created the center, and I am currently co-director with Bill Griffin from the School of Social and Family Dynamics. In the first year of the center’s

operation, we have already held six workshops on topics ranging from social insects as models for evo-devo, to how to build and maintain repositories for agent-based models. We hold weekly seminars in complexity theory, and host guest speakers from diverse fields addressing this topic. Student training is an important part of the center's mission; we provide possibly unique opportunities for students to collaborate across disciplines. As an example, Shana Schmidt, a graduate student in the School of Social and Family Dynamics, whose specialty is agent-based modeling of human social dynamics, will join my lab as a postdoctoral fellow in the spring.

Professional Service:

In addition to my work with the Center, I have also been actively involved in volunteering for professional research organizations. I was elected as president of the North American Section of the IUSSI in 1999, and co-hosted the 2004 IUSSI-NAS meeting with Bob Johnson. I have also been active in the Entomological Society, serving as a student competition judge and organizing two symposia.

I most recently served extensively in the Animal Behavior Society (ABS) as the Senior Program Officer (an elected position) and member of the ABS Executive Committee; I have previously been Chair of the Membership Committee, a member of the Liason Committee with the International Ecological Congress, and a judge for student competitions. As SPO, I was responsible for the organization of the annual meeting programs for 2006 and 2007, including evaluating and editing presentations, arranging the meeting program, inviting plenaries and producing the program and abstract book. I read, edited and judged over 500 abstracts for each meeting, I organized the program schedule, including all presentations, and I reviewed and funded the program symposia. Finally, I drafted and was editor for the program and abstract book, an approximately 200 page document. Prior to serving as PO, I served for two years as Junior Program Officer, where I assisted the previous PO in these duties. Although a tremendous amount of work, this job has been extremely rewarding. It has exposed me to the breadth of research being done in animal behavior, especially in the wide community of researchers working on vertebrate models. It has also conversely provided an opportunity to highlight to ABS the range of research using social insects as model systems.

Service at Arizona State University

As a faculty member in SoLS, I have participated in a number of service activities, including organizing departmental seminar series (two years), serving on the graduate programs committee (five years), and on five search committees. In activities promoting research synergies, I have helped organize the Center for Insect Science Hexapodia (joint seminars between University of Arizona and Arizona State University, held three times per year) for the past seven years, and I led the Social Insect Reading Group (a seminar for students and faculty) from 1994 through 2005. My outreach activities to the general community include lectures at the Arizona Science Center, to the Science and Religion Lecture Series of the American Association for the Advancement of Science (Washington, DC), and to local citizen groups. I have also provided information for local press and NPR on Africanized honey bees. One of my favorite activities has been visits to local elementary schools to present science activities, especially on bugs.

However, my primary service activities at ASU have involved undergraduate teaching and mentoring, including five years on the Undergraduate Programs Committee, Directorship of the Minority Access to Research Careers program, and other activities directed at improvement of undergraduate education and research at ASU. These are discussed further in my Teaching and Mentoring Statement.