The Signal

Monthly newsletter of the W. M. Keck Center for Behavioral Biology
at North Carolina State University
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Exploring Science and Society

From left to right: Paul Lombardo, George Church, Sara Richardson, and Amy Harmon

The W. M. Keck Center for Behavioral Biology together with the Genetics and Society Program, the North Carolina State University Genetics Program, and the NC State Libraries hosted a professional development workshop and symposium on the theme of "Genetics and Society". The workshop, largely organized by Fred Gould, brought together a group of prominent thought leaders on ethical and cultural issues that arise with the development of new scientific capabilities with the power to change the genetic composition of organisms, including people. The panel included Paul Lombardo from Georgia State University, who is the Bobby Lee Cook Professor of Law and serves as a Senior Advisor to the Presidential Commission for the Study of Bioethical Issues, George Church, renowned genomics pioneer from Harvard University, Sara Richardson, John L. Loeb Associate Professor of the Social Sciences and philosopher and science historian, and Amy Harmon, Pulitzer Prize winning journalist of the New York Times.

The workshop and symposium provided a unique forum for interdisciplinary discussions between scientists and representatives from the arts, history and social science arenas. The event was extremely well attended with active participation of students, postdocs and faculty. The event provided a glimpse of the ongoing trend at NC State towards greater cross-collegiate and interdisciplinary integration of programs with overarching themes. A detailed description of the workshop and symposium is provided by Kate Coyle and Melissa Lamm on page 4 of this issue.

The Executive Committee of the W. M. Keck Center for Behavioral Biology would like to thank all our affiliated faculty students and postdoctoral fellows for their positive participation in the Center's recent external review. We received valuable and positive feedback from the review team. Their recommendations and implementations will be discussed with the university administration. Thanks to all of you for your involvement and support.

The W. M. Keck Center for Behavioral Biology greatly acknowledges its corporate sponsors.

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Viruses as Mutualists:
Life History Evolution, Genome Architecture, and Function

by Angela Bucci, Angela Sierras and Hongmei Li-Byarlay

On September 15, 2014 the W. M. Keck Center for Behavioral Biology hosted Dr. Michael Strand, Regents Professor at the University of Georgia. Strand's primary research focuses on parasitic wasps and understanding how the host's immune system protects the insect from invasion by the parasitoid and, conversely, how the parasitoid can overcome the host's immune response.

Strand's seminar focused on the common misconception that all viruses have negative effects on their host. He discussed how certain specific bracoviruses replicate within the ovaries of parasitoid wasps and are then transferred to the host caterpillar during oviposition. The virus then makes changes in the host, which offers the developing parasitoid larvae protection from the host immune system and a rich food source. Without this virus infecting the host, the larval parasitoids would not be able to survive. Strand has assessed the genetics of these peculiar bracoviruses and found that their genome becomes dispersed within the genome of the host, unlike many other viruses whose genomes remain as a cassette within the host. The bracovirus' interactions with specific parasitoid hosts have driven their genetic diversity. No longer do they have the capacity to replicate on their own, but rather need their specific wasp hosts in order to propagate. Propagation of the virus depends on the survival of the wasp larvae, and the survival of the wasp larvae depends on the virus. Thus, these bracoviruses have a mutually beneficial relationship with the wasps.

Strand's primary interest is in the study of animal-microbial interactions, mainly focusing on insect-microbe relationships in general, but he became particularly interested in the mechanism of how this special group of virus turns from a pathogen-like ancestor to mutualism using functional genomic tools. Strand's talk gave a broad view on the life history of polydnaviruses (PDV) which evolved around 100 million years ago from a pathogenic nudivirus. The genus of bracovirus provided a unique system to study this relationship in parasitoid wasps (*Microplitis demolitor*) (MdBV). *M. demolitor* reproduce by laying eggs into other insect hosts (such as caterpillars) that provide food consumption for their offspring. MdBV exists in *M. demolit*or's ovary, and replicates in parasitoid ovaries, and this step is required for wasp offspring to survive naturally. This feature of bracoviruses as an obligate virus mutualist differentiates them from nudivirus ancestors. Strand's team used Illumina Hiseq techno-logy to sequence the genome of the parasitoid wasp ovary during virus replication in order to characterize the proviral genome of MdBV.

Dr. Michael Strand

A fascinating finding was that the MdBV proviral genome is widely dispersed in multiple locations of the *M. demolitor* genome. Several scaffolds of wasp genome have nudivirus-like genes from a wide range of sizes, and even more interestingly, they are isolated by large stretches of wasp genes. This was a piece of important evidence to show that the rearrangements in genome architecture have been a key factor in bracovirus evolution. MdBVs do not encode their own DNA polymerase, which means the virus cannot replicate itself. Indeed, the wasp's DNA polymerase drives viral replication. Because MdBV has a close relationship with nudiviruses and baculoviruses, Stand's team did comparative analyses of MdBV nudivirus-like genes and identified a nudivirus/baculovirus-like helicase, but not any nudivirus/baculovirus-like DNA polymerases. Finally, Strand focused on the functional analyses of important viral replication genes after knocking down their expression via RNA interference. This revealed the functions of two genes (*lef-4*, *lef-9*) during transcription, which are RNA polymerase subunits, two genes (*vp39*, *vlf-1*) which are likely to encode components for viral capsid assembly, as well as genes associated with envelope formation (*p74*, *pif-1*) during baculovirus replication.

At the end of his seminar Strand described the "zombie caterpillar". In order to secure the survival and development of the wasp cocoon post-infection of the parasitoid wasp, the host caterpillar acted as a "zombie", thrashed around, and pushed the predator away from its body. It will be quite interesting to find out how parasitoids manipulate neuronal activity of the host system. In a nutshell, Strand delivered a very compelling, engaging and intriguing talk.

Solving the Fly Brain: Understanding Brain Functions in Insects

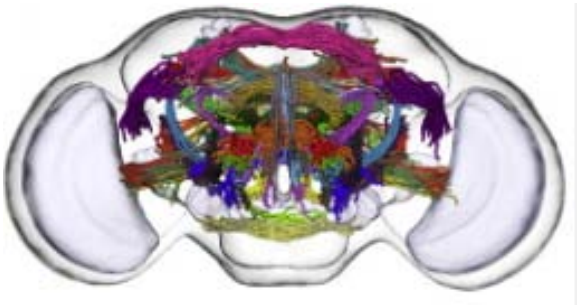
by Alexis M. Barbarin

Have you ever found yourself wondering, "How does the brain work?" This month's W.M. Keck Center for Behavioral Biology seminar co-sponsored by Allen Distinguished Microscopy aimed to answer this question. Dr. Ann-Shyn Chiang presented research from his lab in a seminar titled "*Solving the Fly Brain*." Chiang currently serves as a Professor of Life Science and Director of the Brain Research Center at the National Tsing Hua University in Taiwan. He concurrently serves as an international faculty member at the Kavli Institute for the Brain and Mind at the University of California at San Diego. After receiving his Ph.D. in Entomology from Rutgers State University in New Jersey under Dr. Coby Schal, Chiang spent an additional two years in Schal's laboratory as a postdoctoral fellow studying cockroach neuro-endocrinology, and subsequently returned to his native Taiwan. Since that time, Chiang's research has focused on outlining the memory circuits of the Drosophila brain in an effort to understand how the relationship between genes and neural circuits mediates complex behaviors in flies.

To date, Chiang and his colleagues have mapped roughly 20,000 of the 100,000 single neurons (20%) in the Drosophila brain. Though the process of mapping the brain is no easy feat, Chiang explained the methodology in a way that even a neurobiology novice could understand. The brain is composed of six hubs, 41 local processing units, and 58 tracts that link those 41 local processing units to other sectors of the brain. One may ask, "How is it possible to visualize these neural connections in the brain?" Chiang has created a super-cool technique for making the fly brain transparent. A gene for a green fluorescent protein is inserted into the fly genome, which can be expressed in each neuron independently, allowing the complex structure of each individual neuron to be seen. Because the sizes of male and female brains vary between genders and individuals, an algorithm was developed to create a 3D image of each neuron that falls in line with standardized dimensions of the brain, allowing researchers to take images of the previously mapped 20,000 neurons in each fly and compare them to the neurons of other flies. Then, information is gathered about what areas of the brain the neuron connects to, and what behaviors those neurons control.

While Chiang has made great strides in the area of animal neurobiology, there is still much work to be done. At the current speed of mapping, roughly 5,000 neurons annually, it will take 20 more years to complete the fly wiring diagram. However, Chiang is confident that advances in technology, particularly multicolor Brainbow labeling of single neurons and automated three-dimensional imaging and processing, will expedite the process. The completion of the neural map of the fly brain is a critical step to understanding how the brain operates. More importantly, advances in understanding how the fly brain works can be used to develop a greater understanding for how the human brain works. A greater understanding of the underlying wiring patterns that determine how messages are transmitted between neurons and how complex behavioral action patterns are generated could lead to further advances in medicine and improved treatments for neurological and behavioral disorders.

Dr. Ann-Shyn Chiang



Color-coded tracts in the Drosophila brain

Intersections of Genetics and Society

by Kate Coyle and Melissa Lamm

On September 19th, the Keck Center, the Genetic Engineering and Society Center, the Genetics Program, and the Science, Technology and Society Program co-sponsored a graduate professional development workshop entitled "Intersections of Genetics and Society." The workshop featured a panel of four speakers: Dr. George Church and Dr. Sarah Richardson of Harvard University, Dr. Paul Lombardo, JD, of Georgia State University, and Amy Harmon of *The New York Times*. This diverse group first participated in a morning panel discussion, followed by a series of talks after lunch.

The first panel session focused on "Pathways to Leadership, Interdisciplinarity, and Innovation." Moderator Dr. Jason Delborne first asked the four panelists to introduce themselves and describe their personal paths to their interdisciplinary professions. Lombardo stressed the importance of remaining grounded in a particular field, while allowing yourself to follow your curiosity. Richardson noted the need to translate across disciplines while maintaining the sophisticated language of a particular field. Church pointed out that collaboration has been a significant impetus to many a major scientific breakthrough. Harmon described her personal struggles to convince editors to allow her to write about science and society, illustrating the need to push beyond the dividing lines between disciplines.

The panelists had additional wisdom to offer when asked about how leadership had worked in interdisciplinary projects in which they had participated. Richardson shared a story about a review paper written in collaboration, and stressed the need for someone to take the lead in order to keep the project on track and organized, though taking everyone's opinions into account can be very challenging. Harmon noted that being a leader can also mean knowing when to get out of the way and let the experts work. Lombardo agreed, emphasizing the need to allow people with the tools you lack to help steer the project, and also suggested that leadership in collaborations is less about setting directions and more about acting as a mediator.

In the second panel session, which focused on "Navigating Controversies in Genetics and Society," the speakers were asked to share their thoughts on the controversies surrounding the prospects of genetically engineering humans. Harmon pointed out that this is already done to some extent today, by selecting embryos for particular traits after they are generated by *in vitro* fertilization; the fact that we already *can* select for traits in such a way grants some urgency to the question of whether we *should*. Church suggested that ultimately, the controversy could be resolved if the treatments in question could be made reversible. Richardson asserted that much controversy surrounding genetics and genomics in general was due to forward-looking, ambitious rhetoric aimed at generating hype and controversy in order to garner press and funding, and that the inability to deliver on such overzealous claims ultimately hurt the reputation of the field. Lombardo agreed that hype can be a significant problem, but that the line between marketing the work properly and over-hyping it can be blurry, especially because hype is part of the incentive structure in the field. Furthermore, Lombardo stressed that exuberance for the work being done is great, but needs to be translated properly in order to avoid sounding overly promising.

Following the panel discussions and lunch with the speakers, the Intersections of Genetics and Society Symposium moved to the Hunt Library on Centennial Campus. Paul Lombardo commenced the symposium with a fluent and poignant history of cases from the American eugenics movement in his talk "Eugenics: Past and Future." Eugenics is the belief and practice of improving the genetic quality of the human population through prevention of reproduction of individuals deemed "defective" or "socially inadequate." Lombardo described eugenics as a marriage of the rules of heredity with biostatics. In the 19th century, Gregor Mendel provided the world with general rules of heredity, while Sir Francis Galton, who first coined the term "eugenics," provided statistical methods to study differences among human populations. The American eugenics movement began with the intent to eradicate diseases, but was quickly overtaken by unethical practices that violated human rights in favor of "societal good."

Lombardo highlighted the 1927 Supreme Court case of Buck *versus* Bell, which is also the focus of his book *Three Generations, No Imbeciles: Eugenics, the Supreme Court and Buck v. Bell*. The Bucks included three generations of women who were from the lower class and deemed "feebleminded." Carrie Buck of the middle generation, after birthing a "defective" daughter out of wedlock, was ordered to undergo forced sterilization to prevent her from passing her "feeblemindedness" and "promiscuity" afflictions to future children. Lombardo later interviewed an elderly Carrie Buck, who revealed that she was not promiscuous, but in fact had been raped. Furthermore,

Carrie's daughter turned out perfectly normal, but sadly died young from an intestinal disease.

Eventually, 60,000-65,000 people deemed socially inadequate, feebleminded, defective, incompetent, and/or promiscuous would be sterilized as part of the eugenics movement. When asked of his concerns about a potential modern-day eugenics movement given technological advances in genetic engineering, Lombardo answered that he is more troubled by outdated ideas and attempts to blame certain social groups than by technology.

The second speaker of the afternoon was Dr. George Church. In his talk "The Future of Human Genomics and Synthetic Biology," Church discussed the exponentially fast pace of emerging genetic technologies (due in part to his own inventions and advancements in the fields of genetics and synthetic biology) and the application of these technologies to present and future work. Synthetic biology, which includes altering gene sequences and expression of genes in living organisms, relies on existing and emerging technologies to manipulate and reconstruct genes and genomes.

Church noted that we have been genetically engineering humans for decades. The first recombinant DNA (DNA joined from different sources) was achieved in the 1970s and paved the way for advances such as gene knock-in and knock-out applications, which are widely used today in biotechnology, medicine, and research. Advances in genome sequencing have also led to targeted gene therapy techniques, including regulation of gene expression using technologies such as RNA interference, which can selectively degrade the messenger RNA of a specific gene or prevent translation of a gene's mRNA into protein. Church's own technology, the use of the CRISPR/CRISPR associated protein 9 (Cas9) system to edit specific gene sequences, is a new contender for targeted gene therapy and potential alteration of genomes of entire populations, such as disease transmitting *Aedes aegypti* mosquitoes.

Many technologies in synthetic biology exist and continue to develop. The difficulty largely lies in deciding which technological implementations to allow. Church noted future applications such as releasing more genetically modified organisms (GMOs)into the wild, altering ageing genes to extend human life, and manipulating genes to help humans adapt to life in space

Dr. Sarah Richardson followed Church with her talk "How Culture Impacts Choices by Genetic Researchers." Richardson focused exclusively on how cultural assumptions about gender influence scientific knowledge at all levels of the scientific process, from generating questions and hypotheses to experimental design to conclusions and assumptions drawn from data.

Richardson drew from her book "*Sex Itself: The Search for Male and Female in the Human Genome"*, highlighting the example of researchers of one study who claimed that in humans, the genome of males and females differs by 1.5-2% (while male-male and female-female differences are agreed to be 99.9%). The scientists reached these conclusions largely by comparing X and Y chromosomal differences, arguing that 200-300 genes on the X chromosome (1-2% of the coding genome) are expressed at higher doses in females because females have two X copies. However, Richardson explored their data and drew a different conclusion: males and females were genetically less different than claimed. Richardson argued that a number of genes on the Y chromosome are present on the X chromosome, and only a few genes on the Y chromosome are unique to males. Furthermore, Richardson noted that many of the genes on the Y chromosomes are pseudogenes, duplicates, or only expressed in the testes and therefore contribute less to whole-body differences. Richardson claims that the researchers' assumptions about gender skewed their interpretation of the results to find sex differences.

From Richardson's talk, one could not help but think of cases in which researchers expect to find sex differences and are disappointed when they instead find negative results. Rather than considering these results uninteresting, researchers should view them as important and publishable since they may still advance our understanding of biology.

The final speaker of the symposium was Amy Harmon, winner of the Pulitzer Prize for "*The DNA Age,"* a series of articles in *The New York Times* exploring the impact of genetic technology on everyday American life. Comparing herself to Alice who followed the White Rabbit down the hole to Wonderland, Harmon talked about her "interesting" year investigating and reporting on GMOs. Many rumors about GMOs existed at the time and still persist, including hazardous effects on health. Harmon sought to investigate the facts and report on the impact of GMOs on people's lives.

Harmon focused on her time reporting on GMOs in Florida and Hawaii. In the Florida story "*A Race to Save the Orange by Altering Its DNA*," Harmon reported on the citrus greening disease that devastated over half the orange crop in Florida and the very difficult decision by one farmer to turn to genetic engineering to control the bacterial disease in his oranges. The option to trial a GM orange that expressed a spinach protein, which conferred resistance to citrus greening disease, ultimately won over other options, including continuing to lose oranges, laying

off workers, and watching the price of orange juice rise. Animal testing supported the safety of the spinach protein in the GM oranges, though this GM orange has not yet been put to use commercially.

Harmon then spoke about a 2013 anti-GMO bill in Hawaii that she reported on in her article *"A Lonely Quest for Facts on Genetically Modified Crops."* Harmon followed Councilman Greggor Ilagan's struggle between public opinion and GMO facts prior to voting on a bill to ban GM crops in Hawaii (not including GM papaya and corn, which were already established). Ilagan originally thought a GMO ban was a good idea. But after speaking with GM papaya farmers and scientists and researching the benefits and risks of GMOs, Ilagan voted against the anti-GMO bill. The bill passed 6-3, banning the use of new GMOs in Hawaii.

The speakers of the Intersections of Genetics and Society symposium brought their own perspectives on genetics in the modern age. Society always has important decisions to make regarding the use of new technologies intended to produce favorable outcomes. Communication among scientists, bioethicists, the general public, and law makers needs to be transparent and frequent in order for people to make informed, ethical decisions that affect health, society, and nature for present and future humans.

Grants

Heather Patisaul received a one-year $300,000 grant from the National Institute of Environmental Health Sciences to study toxicokinetics and metabolic disrupting actions of the flame retardant mixture FM 550.

David Tarpy received a two-year $44,000 grant from the United States Department of Agriculture, APHIS, to study management practices that affect virus intensity and genetic diversity with respect to varroa prevalence.

David Tarpy received a one-year $15,000 grant from the North Carolina Department of Agriculture and Consumer Services, Plant Industry Division for studies on utilizing the NC State Queen & Disease Clinic: Testing factors of queen reproductive quality.

David Tarpy received a one-year $33,025 grant from the California State Beekeepers Association for studies aimed at quantifying sperm viability in honey bee queens and addressing factors of diminished drone and queen reproductive quality.

David Tarpy, **Steven Frank** and **Rob Dunn** received a two-year $139,500 NCSU-CALS Dean Enrichment Core Strategic Themes grant to study impacts of global climate change on bees, how urbanization and management practices affect honey bee immunology and disease ecology.

Seminars

On **October 2**, 3:30 pm, Dr. Douglas J. Emlen from the Division of Biological Sciences at the University of Montana (Missoula, MT) will present a seminar titled "Mechanism(s) of extreme growth."

The seminar will be in 101 David Clark Laboratories.

On **October 2**, 7:00 pm, Dr. Emlen will present a public lecture at the North Carolina Museum of Natural Sciences in the Daily Planet Theater, Nature Research Center, 121 West Jones Street, Raleigh, NC 27601, titled "Extravagant weapons: A natural history."

On **October 6**, 1:30 pm, Dr. Marcus W. Feldman from the Department of Biology at Stanford University (Stanford, CA) will present a seminar titled "Some dynamics of cultural evolution."

The seminar will be in 3503 Thomas Hall.

On **October 16**, 3:30 pm, Dr. Andrew Sih from the Department of Environmental Science and Policy at the University of California at Davis (Davis, CA) will present a seminar titled " Behavioral syndromes (aka animal personalities): Sex, invasions, and parasites,"

The seminar will be in 101 David Clark Laboratories.

On **October 30**, 3:30 pm, Dr. Bruce S. McEwen from the Rockefeller University (New York, NY) will present a seminar titled "Stress, sex and the brain: Hormone actions over the life course via novel mechanisms."

The seminar will be in 101 David Clark Laboratories.

On **November 3**, 1:30 pm, Dr. Michael B. Eisen from the Howard Hughes Medical Institute (HHMI) and the Department of Molecular and Cell Biology at the University of California at Berkeley and the Genomics Division of the Lawrence Berkeley National Laboratory (Berkeley, CA) will present a seminar titled "Activation of gene expression and the onset of gene regulation in early Drosophila development."

The seminar will be in 3503 Thomas Hall.

Publications

The following publications from the W. M. Keck Center for Behavioral Biology have appeared in print:

Shik, J. Z., Santos, J. C., Seal, J. N., Kay A., Mueller, U. G. and Kaspari, M. (2014) Metabolism and the rise

of fungus cultivation by ants. *American Naturalist* **184:** 364-373.

Simone-Finstrom, M., Foo, B., Tarpy, D. R. and Starks, P. T. (2014) Effects of food availability, pathogen exposure, and genetic diversity on thermoregulation in *Apis mellifera*. *J. Insect Behav.* **27:** 527-539.

Rogers, S., Tarpy, D. R. and Burrack, H. J. (2014) Bee diversity and pollinator dynamics affect agroecosystem services. *PLoS One* **9:** e97307.

Tarpy, D. R. and Schneider, S. S. (2014). Mechanisms of social evolution: linking adaptive function with proximate mechanisms. *Apidologie* **45:** 285-288.

Steinhauer, N., Rennich, K., Wilson, M. E., Caron, D. M., Lengerich, E. J., Pettis, J., Rose, R., Skinner, J. A., Tarpy, D. R., Wilkes, J. T. and vanEngelsdorp, D. (2014) A national survey of managed honey bee 2012-2013 annual colony losses in the USA: results from the Bee Informed Partnership. *J. Apicultural Res.* **53:** 1-18.

Rogers, S., Tarpy, D. R. and Burrack, H. J. (2013) Multiple criteria for comparing pollinator performance in highbush blueberry agroecosystems. *Environ. Entomol.* **42:** 1201-1209.

Li-Byarlay, H, Rittschof, C. C., Massey, J. H., Pittendrigh, B. R. and Robinson, G. E., 2014. Socially responsive effects of brain oxidative metabolism on aggression. *Proc. Natl. Acad. Sci. USA.* **111:** 12533-12537.

Hunter, C. M. and Singh, N. D.(2014) Do males matter? Testing the effects of male genetic background on female meiotic crossover rates in *Drosophila melanogaster*. *Evolution* **68:** 2718-2726.

Of note…

Robert Anholt and **Trudy Mackay** presented invited seminars at the Department of Ecology at Lund University, Sweden, on "The genotype-phenotype map: lessons from Drosophila" and "The Genetic architecture of behavior in Drosophila."

John Godwin presented a TED-style talk on stress coping styles and their evolutionary history at Shaw University (Raleigh, NC).

Lisa McGraw gave a talk at Shaw University (Raleigh, NC) entitled "Lessons in love from a garden pest".

Heather Patisaul and her colleagues, Alana Sullivan, Elsworth, Stetzik, Perry, D'Addezio, and Cushing, presneted a poster on "Impact of postnatal bisphenol A exposure on exploratory behaviors and related neuroendocrine pathways in prairie voles (*Microtus ochrogaster*)." at the 8th International Congress of Neuroendocrinology in Sydney, Australia.

David Tarpy gave invited seminars at Durham Technical College, Arizona State University School of Biological Sciences and an on-line presentation for the RNAi for Bee Health symposium.

David Tarpy and colleagues, Hamm, Raynor, **Simone-Finstrom**, Linksavyer, George, and Lubkin, presented a poster on "Evaluating queen quality of in vitro reared queen bees via digital image processing" at the MBI conference in Columbus, OH. **Michael Simone-Finstrom** and **David Tarpy** also presented a poster on "Unruly mates: no evidence for behavioral control or effort assessment in honey bee queen mating" at the International Society of Behavioral Ecology, New York, NY. **David Tarpy** and colleagues, Rogers and Burrack, presented a poster on "Flower morphology influences pollinator community with implications for cross-pollination: observations in rabbit eye blueberry (*Vaccinium ashei Re*ade) at the NABREW Meeting, Atlantic City, NJ. **Michael Simone-Finstrom** and **David Tarpy** also presented a poster on "Social context of disease resistance: Interactions among social and individual immune defense mechanisms in honey bees" at the Society for Evolution Conference in Raleigh NC.

David Tarpy and colleagues, Rueppell, **Simone-Finstrom**, Huang, Collazo, Smith, Yousefi and Strand presented a poster on "The relation of stress and social behavior to mortality in honey bee workers" at the AGE Conference, San Antonio, TX. J. J. Keller and **David Tarpy** gave a poster on "Biocontrol strategies for Small Hive Beetle (SHB) control in honey bee colonies." at the Bayer Bee Care Center, Research Triangle Park, NC.

Michael Simone-Finstrom and **David Tarpy** with colleages, Huang, Rueppell and Strand presented a poster on "Effects of migratory beekeeping on longevity and oxidative stress" , and **David Tarpy** and colleagues, Steinhauer, Rennich, Wilson, Caron, E. J. Lengerich, Pettis, Rose, Skinner,Wilkes, and vanEngelsdorp gave a presentation on "A national survey of managed honey bee 2012-2013 annual colony losses in the USA: results from the Bee Informed Partnership" at the ABRC Symposium, San Antonio TX.

To contribute to The Signal, to be placed on our mailing list or for information about the W. M. Keck Center for Behavioral Biology, contact Dr. Robert Anholt, Department of Biological Sciences, Box 7614, North Carolina State University, Raleigh, NC 27695-7614, tel. (919) 515-1173, anholt@ncsu.edu.

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