

# *The Signal*

Monthly newsletter of the W. M. Keck Center for Behavioral Biology  
at North Carolina State University  
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## **Keck Center's Fred Gould Elected to the National Academy of Sciences**



At its 148<sup>th</sup> annual meeting in Washington DC on May 3, 2011, the National Academy of Sciences announced the election of 72 new members and 18 foreign associates, including North Carolina State University's Fred Gould, William Neal Reynolds Professor of Entomology and founding member of the W. M. Keck Center for Behavioral Biology. Gould has been a pioneer in the development of insect resistant crops as an alternative to the use of chemical insecticides by introducing insecticidal proteins expressed by *Bacillus thuringiensis* in genetically modified crops. More, recently Gould has spearheaded a new university initiative in genetic pest management. Gould is also widely known for his basic scientific contributions to understanding the evolutionary tradeoffs between generalist and specialist insect herbivores and the co-evolution of sexual communication systems. His work has made substantial impact in enhancing crops and combating world hunger in third world countries.

His election to the NAS follows a string of honors during the last several years, most recently NC State's Alexander Quarles Holladay Medal, which will be conferred during this year's graduation.

"Fred's election is well deserved and contributes to the reputation and prestige of the Keck Center and our University. We are very proud of him," says Keck Center director, Dr. Robert Anholt.

"This could not be any better news for NC State University," says William Neal Reynolds Distinguished University Professor Trudy Mackay, who was elected to the NAS last year, "It shows that our university is on the rise. Congratulations to Fred!"

Established by Abraham Lincoln on March 3, 1863, the mission of the National Academy of Science is to advise the nation on science, engineering, and medicine. Election to the NAS is considered one of the highest honors bestowed upon a scientist.

Please, congratulate Fred on this exceptional accomplishment.

***The Signal* will not be published during the summer recess.  
The next issue of *The Signal* will appear in September, 2011.  
*The Signal* wishes its readers a pleasant and productive summer.**

# Evolution and Natural Selection in Action: Genetics, Ecology and Behavior of Darwin's Finches

by Rüdiger Riesch

This past April the W. M. Keck Center for Behavioral Biology at NC State had the distinct pleasure of hosting two of the most influential evolutionary biologists of our time: Peter and Rosemary Grant of Princeton University. Both are famous for their lifelong work on Darwin's finches (*Geospiza* spp.), a complex of 14 species of ground finches from the Galápagos archipelago that shared a common ancestor approximately two to three million years ago. During their illustrious careers the Grants have accrued many honors, including being elected as Fellows of the Royal Society, the National Academy of Sciences and the American Academy of Arts and Sciences, as well as being recipients of the prestigious Darwin-Wallace Medal, the Darwin Medal, the Kyoto Prize and the Balzan Prize. In two separate seminars, one at the North Carolina Museum of Natural Sciences and the other at NC State University the Grants shared with us their understanding of the wondrous works of natural and sexual selection in the wild.

Peter Grant began the seminars, entitled "*Evolution of Darwin's Finches: The role of genetics, ecology and behavior*," with a short introduction to biodiversity, accentuated by pictures illustrating the extreme diversity of coloration and morphology in cichlids from the African Great Lakes and dewlap coloration of *Anolis* lizards. "Neither species nor environment are static but are constantly changing", he explained. Humans, however, have changed most ecosystems beyond recognition in a dramatically short amount of time, leading to a striking increase in extinction rates and an irreversible loss in the diversity of life on Earth. Therefore, he pointed out, one of the great challenges of our time will be for "*Homo not-so-sapiens*" to "preserve the environment in a way that organisms and the environment are capable of natural change". But what exactly is natural change, and how can many new species arise out of a single ancestral one? Understanding this in Darwin's finches could help elucidate the mechanisms behind biological diversity in a variety of other organisms.

Darwin's finches primarily differ in beak size and shape and the Grants discovered that weather conditions and the presence or absence of other species (*i.e.*, competitors) are vital to the direction of natural selection on these traits. This is exemplified by the influence wet and dry years have had on beak size in two species (*Geospiza fortis* and *Geospiza scandens*) over the years.



Peter and Rosemary Grant

For example, during a strong drought in 1977 *G. fortis* on Daphne Major were forced to rely more and more on larger seeds for food. However, individuals with smaller beak sizes were not able to exploit this food source and many died, resulting in a dramatic shift of the population mean in beak size. Interestingly, an exceptionally wet year during an El Niño event in 1983 led to an overabundance of small seeds, which led to selection favoring birds with smaller beaks and the population mean shifted towards smaller beaks. Over approximately 40 years the Grants have now followed these finches and have observed strong temporary bouts of directional selection but also oscillating selection on beak traits. Clearly, Peter Grant acknowledged, this demonstrates both the predictability of evolution in the short term (*i.e.*, during droughts or extremely wet years) and the unpredictability of evolution in the long term (*i.e.*, over more than 30 to 40 years).

Here, Rosemary Grant took over the presentations. She focused on the question of how two or more populations of a species diverge to the point of becoming separate species. This question is exemplified best by the curious case of one subspecies of the sharp-beaked ground finch (*Geospiza difficilis*), in the literature often simply called the Vampire finch (*G. d. septentrionalis*). This finch not only feeds on nectar, but also breaks open seabird eggs and is known to even pierce the skin of masked boobies (*Sula dactylatra*) to drink on fresh blood. According to Rosemary Grant, the current theory is that this behavior evolved from the pecking behavior these finches show when cleaning parasites from the plumage of the booby and other birds. However, at first sight the question arises as to how this type of finch could have evolved from the seed-eating ancestral finches that originally colonized the Galápagos archipelago? Rosemary Grant explained that the

# Epigenomics in Asheville

by Katharine Jordan

prevailing hypothesis is that these finches diverged due to prolonged periods of allopatry that arose when individuals colonized new island. The islands of the Galápagos archipelago are highly diverse and not at all uniform. Therefore, food availability differs greatly between islands, and the finches needed to adapt to the individual environment experienced on each island. If populations on different islands spent long enough separated from one another, they might not be able to recognize each other as members of the same species on secondary contact. Obviously, this calls for reproductive isolation barriers, and the Grants have identified two barriers to interbreeding on secondary contact: song and morphology. Playback experiments and experiments with dummies have demonstrated that individuals are able to distinguish between conspecifics and heterospecifics based on song and morphology.

Clearly, song and morphology function as premating isolation barriers, but do they leak? The short answer, Rosemary Grant informed us, is yes. Different *Geospiza* occasionally interbreed resulting in introgressive hybridisation. How can this happen if interbreeding is usually prevented by song differences? The Grants discovered that occasionally, a young finch is imprinted on the wrong song or learns the wrong song due to the nest having been taken over by a different finch species. Under these unusual circumstances, males of one species would sing the song of another species and, thus, end up mating with heterospecific females, or females of one species would actually prefer males of another species that sing the song these females were imprinted on. To date, there is no indication of postmating isolation due to genetic incompatibilities, because these hybrids survive and are often successful breeders themselves. In fact, the Grants recently witnessed the rise of a new lineage of finches that arose through hybridisation. These hybrids were unusually large, sang an unusual song and were genetic hybrids of *G. fortis* and *G. scandens*. But even more astonishing, they completely ignore the parental species and only breed with one another, while also being completely ignored by the two parental species. So far, the Grants have not been able to detect any negative effects of this massive inbreeding in these hybrid finches, probably due to hybrid vigor.

Here, the remarkable scientific journey Peter and Rosemary Grant took us on ended, but their scientific discoveries surely will continue far into this still-young century. Their meticulous work over these past decades highlights the importance of long-term studies if we ever want to fully understand the interplay between micro- and macroevolution. Clearly, evolution over short periods of time is much more predictable than evolution over long time periods. Hence, their investigation of the effects of droughts and extremely wet years caution us from over-interpreting the strong effects of rare events, which in the larger scheme of evolution might turn out to be merely ephemeral.

The Keystone Symposium on Epigenomics and Disease Susceptibility was held in Asheville, North Carolina. It boasted experts in epigenetics, genomics, and stem cell research from 23 countries and 6 continents, and over 300 participants.

As the genome sequencing era has vastly increased the knowledge of genomes, and GWA studies have not produced many associations with large relative risk for disease phenotypes as once hoped, many in the field have turned to variation in transcription regulation as a possible cause for disease phenotypes. Compelling human epidemiological and animal experimental data indicate that the risk of developing adult-onset complex diseases and neurological disorders is influenced by persistent epigenetic adaptations in response to prenatal and early postnatal exposures to environmental factors. Epigenetics refers to heritable changes in gene function that occur without a change in the sequence of DNA. The main components of the epigenetic code are DNA methylation, histone modifications, and non-coding RNAs. Epigenetic programs in cells are normally reproduced in mitosis, and can be maintained during meiosis, resulting in epigenetic trans-generational disease inheritance. The objective of this conference was to provide evidence that environmental exposures during early development can alter the risk of developing medical conditions, such as asthma, autism, cancer, cardiovascular disease, diabetes, obesity, and schizophrenia later in life by modifying the epigenome.

The meeting commenced with the Keynote Address by Eva Jablonka from Tel Aviv University titled "Fetal Origins of Disease Susceptibility: Being Fit in Four Dimensions", where she gave an overview of the history and exponential growth of the field. The birth of the field, during 1900 to 1950s, spurred scientists like Conrad Waddington, Robin Holliday, Tracy Sonneborn, David Nanney, and Boris Ephrussi to coin the word "epigenetics" and postulate other mechanisms of phenotypic variation that are not due to DNA variation. Building on the early hypotheses during the 1980-90s, medical epigenetics became a hot field, mainly focused on cancer and aging mechanisms. Currently, since the late 1990s, we are experiencing an epigenetic explosion. As molecular tools and technology have vastly improved, so has the exponential growth of the medical epigenetics field with the integration of psychobiology and molecular biology. As a result of this explosion many hypotheses are now generally accepted. Epigenetic mutations can affect population dynamics. Adaptation can occur through selection of heritable "epi-alleles." Genetic and epigenetic changes following genomic hybridization or

ecological stresses mobilize epigenetic control mechanisms. Epigenetic differences can initiate reproductive isolation. Heritable induced non-DNA variation can influence selection, and evolution of ontogeny is partially shaped by constraints and affordances imposed by epigenetic inheritance. Epigenetics will be a bridge between sociology, psychology, ecology, molecular biology, and, ultimately, medicine.

The first session of the conference focused on fetal origins of adult disease susceptibility. Ezra Susser from Columbia University spoke about effects of prenatal exposures and links to adult disease, specifically an increase in schizophrenia during the Dutch Famine (1945) and The Chinese Bitter Years (1959-1961). He thinks that there is a link between folic acid intake and IGF2 expression. Marcus Pembrey from University College in London is investigating how environmental exposures in one generation produce a measurable outcome to subsequent unexposed generations. He found trans-generational behavioral manifestations on longevity, cardiovascular disease, obesity, and diabetes from environmental exposures such as famine, onset of smoking, and betel nut chewing. Gudrun Moore, also from University College in London, investigates the importance of proper regulation of imprinted genes and their effects on birth weight. Her talk stressed the importance of combining genetic and epigenetic factors to understand complex diseases. Claudine Junien from INRA discussed sexual dimorphism in gene expression using rats and mice reared on different diets. Martha Susiarjo from the University of Pennsylvania looked at effects of Bisphenol A (BPA) on genomic imprinting in mice and concluded that BPA causes a disruption of imprinting patterns. Ruijun Han from the University of Minnesota demonstrated that stress during gestation increased obesity and glucose intolerance in mice through expression of NPY.

The theme of the evening session was epigenetic mechanisms of gene regulation. Ian Wood discussed a mechanism for histone deacetylase activity through the transcription repressor Rest, whose misexpression has been associated with several diseases. Joe Ecker gave an update on epigenomics of plants, where a large collaboration has been undertaken to sequence the "methylomes" of *Arabidopsis thaliana* to understand mechanisms of gene methylation. Victor Lobanenko discussed different mechanisms for CTCF, a zinc finger protein, expression and its incidence with cancer. Sonja Prohaska gave a short talk on analytical analysis and modeling the dynamic epigenome.

The third session of the conference dealt with in vitro fertilization, cloning, and stem cells. James Thomson gave a great talk on the differences in human stem cells, (ES and IPS). The methylomes of the two types of cells are globally the same but there is some epigenetic memory of tissue origin and the overall

mean epigenetic state of human IPS and ES cells are different. Louise Laurant discussed the Stem Cell Matrix Database and its applications, strengths, and consequences in cell therapy, drug toxicity and efficacy of predictions, and human disease modeling. Wolf Reik talked about how epigenetic reprogramming in germ cells and early embryos interacts with programming and affects epigenetic marks during aging. Rosanna Weksberg gave a short talk on loss of methylation in maternal imprinted genes associated with Beckwith Weidmann Syndrome. Toshi Shiodi's short talk was about mechanisms of specific erasures of hypermethylation in mouse pluripotent stem cells.

In the session on epigenetics and complex diseases, Maria Berdasco talked about her genome-wide methylation array to look for biomarkers of cancer expression patterns. Frederica Perera discussed effects of exposure to polycyclic aromatic hydrocarbons and BPA on neurodevelopment and asthma related symptoms in children. Dana Dolinoy also is looking at effects in methylation due to exposure to BPA in mice and humans, and has found that both hypo- and hyper-methylation occur as a result of BPA exposure. Cheryl Walker looked at fetal and postnatal environmental exposures of phytoestrogens and their effects on female reproductive health in mice developing uterine cancer through methylation changes. Robert Lyle from Oslo University gave a short talk on discordance between monozygotic twins and several immune mediated disorders, such as, psoriasis. Carrie Breton from the University of Southern California discussed air pollution exposure effects on children's health that are correlated with methylation changes in nitric oxide synthase that lead to asthma.

The evening session on epigenetic trans-generational inheritance began with a talk by Emma Whitelaw from the Queensland Institute of Medical Research in Australia. She look modeled the effects of fetal alcohol syndrome in mice, specifically facial dysmorphology, birth weight, and anxiety disorders. Michael Skinner of Washington State University discussed effects of endocrine disruptors in developing rats just before the sex determination period with effects that have affected four subsequent generations.

In the session on epigenetics and neurological disorders, Art Petronis discussed the implications of epigenetic misregulation in complex disease using twin studies to try to elucidate disease predisposition, sex effects, and age effects as well as SNP effects in the increase in prevalence of psychiatric disorders. Janine Lasalle described epigenetics and autism spectrum disorders. She is looking at risk factors as well as protective mechanisms that influence DNA methylation associated with human diseases. Farah Lubin talked about histone methylation in memory formation and aging, specifically the histone marks which are altered during memory formation and aging

in mice and that are correlated with rearing environments and exposure to pharmacological agents.

The final session of the conference focused on mammalian evolution and disease susceptibility. David Haig spoke about the evolution of human life history including mathematical formulas to try to determine selfish and altruistic acts at the age of sexual maturity based on observations of physical, behavioral, and socioeconomic trends in onset of menarche in females. Christopher Badcock delved into his imprinted brain theory and the balance between autism and psychosis disorders and the role of maternal and paternal imprinted gene regulation.

The conference was geared mostly toward human and mouse studies, but regardless of what organism you work with, it was thought provoking. The recurring themes are that complex diseases are not just caused by DNA variation, but most likely a combination of DNA variation and epigenetic regulation through methylation and histone modification. These epigenetic effects can occur through environmental chemical exposures and nutritional environment in both prenatal and postnatal periods, which can manifest in adult phenotypes as well as exhibit transgenerational effects.

## **The 52<sup>nd</sup> Annual *Drosophila* Research Conference**

*by Yazmin Serrano*

The 52<sup>nd</sup> Annual *Drosophila* Research Conference was held in beautiful San Diego. More than 1600 research scientists who study *Drosophila* attended the conference. There were over 900 poster presentations covering 16 different topics, including evolution and quantitative genetics, *Drosophila* models of human diseases, and neurophysiology and behavior.

The conference began with a historical retrospective presented by a panel of speakers which included Leslie Griffith and Michael Rosbash from Brandeis University. The first plenary session began with an image award presentation (the images that won awards are available on line for viewing at <http://www.drosophila-images.org/2011.shtml>),

followed by presentations on *Drosophila* developmental biology. Topics were wide-ranging and included signaling pathways that play an evolutionary conserved role in aging, sensory transduction in the detection of noxious reactive chemicals, immunological determinants of defense against infection in *Drosophila*, pathogenesis of Alzheimer's disease and its effects on axonal transport of amyloid precursor protein, patterns and divergence in the evolution of gene expression, and chromosomal organization of the *Drosophila melanogaster* genome.

Following the morning plenary session, the conference broke into concurrent platform sessions

with presentation on cell division and growth control, RNA biology, neurogenetics and neural development, evolution and quantitative genetics, *Drosophila* models of human disease, pattern formation, cell cycle and cell death, neurophysiology and behavior, chromatin and epigenetics, cell biology and cytoskeleton, gametogenesis and organogenesis, regulation of gene expression, immunity and pathogenesis, physiology and aging, techniques and functional genomics, stem cells and cell biology and signal transduction. I represented North Carolina State University and presented a poster on how variation in startle behavior can be analyzed using a panel of wild-derived advanced intercrossed second chromosome substitution lines. The conference attendees were treated to an immense variety of information, and could choose from among 140 talks, over 950 posters, and 11 workshops. Additionally, FlyBase, FlyMine, and other databases presented demonstrations of new software and improved information content.

The closing plenary talks featured an interesting presentation by Kami Ahmad from Harvard University, who examined the importance of nucleosome dynamics for gene regulation, chromosome function, and the heritability of chromatin states. Her exciting research focused on characterizing the machinery and mechanisms that assemble nucleosomes. Another highlight was the talk by Therese Markow (University of California, San Diego), who discussed the natural ecology of flies, focusing on reproduction, diet, and the implications of field observations on genetic and evolutionary studies of laboratory populations.

The 53<sup>rd</sup> Annual *Drosophila* Research Conference will be held in March 2012 in Chicago, Illinois.

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## Seminars

The W. M. Keck Center announces a Canopy Workshop for Biologists.

The Canopy Workshop for Biologists, organized by the NCSU Department of Biology and the NC Museum of Natural Sciences, will take place May 12-14 on the NCSU campus. In this workshop, biologists and educators will learn how to safely and effectively climb trees for biological research and for teaching. The course will culminate with a guided climb for local 5<sup>th</sup> graders at a county park. Several lectures in association with the workshop at NCSU will be open to the general public:

On Wednesday, **May 11**, at 3:00 pm, Dr. Steve Yanoviak will give a presentation on the ecology and behavior of arthropods in tropical forest canopies – directed gliding, parasitic interactions, and influence on habitat structure. The lecture will be in 3503 Thomas Hall.

On Thursday, **May 12**, at 12:00 pm, Dr. Meg Lowman will give a presentation on Canopy Biology, evolution of the high frontier. The lecture will be in the first floor lounge of Caldwell hall.

On Friday, **May 13**, at 8:00 am, Dr. Meg Lowman will give a lecture on conservation of the church forests of Ethiopia. The lecture will be in Park Shops 200.

On Friday, May 13, at 12:00 pm, Dr. Steve Yanoviak will give a presentation on bringing your best science into the canopy. The lecture will be in the first floor lounge of Caldwell hall.

On Friday, **May 13**, at 12:00 pm, Dr. Bonnie Blaimer will give a presentation on canopy ants in Madagascar. The lecture will be in Park Shops 200.

On Saturday, **May 14**, at 8:00 am, Dr Andrea Lucky will present a seminar on citizen science and canopy sampling. The lecture will be in Park Shops 200.

## Publications

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

Morozova, T. V., Mackay, T. F. C. and Anholt, R. R. H. (2011) Transcriptional networks for alcohol sensitivity in *Drosophila melanogaster*. *Genetics* **187**: 1193–1205.

Losa, S. M., Todd, K. L., Sullivan, A. W., Cao, J., Mickens, J. A., and Patisaul, H.B. (2011) Neonatal exposure to genistein adversely impacts the ontogeny of hypothalamic kisspeptin signaling pathways and ovarian development in the peripubertal female rat. *Reprod. Toxicol.* **31**: 280-289.

Merrill, R. M., Gompert, Z., Dembeck, L. M., Kronforst, M. R., McMillan, W. O. and Jiggins, C. D. (2011) Mate preference across the speciation continuum in a clade of mimetic butterflies. *Evolution* **65**: 1489–1500.

Lucky, A. (2011) Molecular phylogeny and biogeography of the spider ants, genus *Leptomyrmex* Mayr (Hymenoptera: *Formicidae*). *Mol. Phylogenet. Evol.* **59**: 281-292.

## Of note

**Robert Anholt** attended the annual meeting of the National Academy of Sciences in Washington, DC.

**Susan Harbison** presented seminars on systems genomics of sleep in *Drosophila* to the Nutrition and Obesity Research Center at the University of Alabama, Birmingham, AL, and the Division of Intramural Research at the National Heart, Lung, and Blood Institute, Bethesda, MD.

**Jiri Hulcr** gave an invited seminar at Ohio State University at Wooster, OH, titled “Ambrosia beetle-fungus symbiosis: Incest, symbionts theft, and a catastrophic future for naïve tree species.”

**Jim Hunt** presented a seminar at Iowa State University and participated in a working group on organizational systems in insect and human societies at Arizona State University.

**Brain Langerhans** gave seminars at McGill University (Montreal, Canada), Duke University, and the North Carolina State University College of Veterinary Medicine.

**Trudy Mackay** gave invited lectures in the Department of Biology at the University of Rochester, Rochester, NY, and the NIEHS Laboratory of Molecular Genetics, Durham, NC. She also delivered the A. B. Chapman Lectures in the Department of Animal Science at the University of Wisconsin, Madison, WI. She attended the annual meeting of the National Academy of Sciences in Washington, DC, where she signed the registry book following her 2010 election to the Academy.

**Yazmin Serrano** presented a poster at the *Drosophila* Research Conference in San Diego, CA.

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 Biology, Box 7617, North Carolina State University, Raleigh, NC 27695-7617, tel. (919) 515-1173, anholt@ncsu.edu.