

# Towards an Evolutionary Theory of Nongenetic Effects

09 – 13 December 2013 @Snellius

Evolutionary theory provides a mathematical description of the gradual change of organisms over time, due to natural selection and the retention and inheritance of phenotypic variation. Evolutionary insights are widely used throughout the life sciences, and applications range from genetic algorithms, through breeding programs to the study of antibiotic resistance. However, at the heart of evolutionary theory lies the crucial assumption that inheritance is exclusively governed by the transmission of DNA-basepair variations, which contrasts with growing evidence that there are other ways in which phenotypic variation can be inherited: for example, through the inheritance of epigenetic or structural modifications of the DNA, the transmission of maternal hormones and antibodies, or social learning. While some progress has been made to map the consequences of these nongenetic effects, we are yet unable to make detailed predictions about their evolution, strength and nature in a range of ecological and social contexts. The workshop set out to address this question by developing novel theoretical models of the evolution of nongenetic effects.

To enrich evolutionary theory with insights on nongenetic effects, a team of evolutionary biologists, ecologists and mathematicians got together to work on the following questions:

- What ecological conditions (e.g. what type of environmental fluctuations) favor the evolution of nongenetic effects?
- How does intergenerational conflict (such as genetic conflicts of interest between parents and offspring) affect the evolution of nongenetic effects?
- How do nongenetic effects affect long-term adaptation?

Overall, hard work in all of the subgroups paid off and a number of studies were initiated that we hope will lead to publishable outputs: foremost, we are currently working on a collaborative perspectives paper that summarizes conceptual progress on the three questions listed above, which we aim to submit to *Trends in Ecology & Evolution* (impact factor 18.9) or *BioEssays* (impact factor 5.8). In addition, each subgroup explored one or more specific projects dealing with one of the three questions. For example, one project focused on the evolutionary dynamics of epigenetic modifiers in fluctuating environments - this led to a model being finalized during the workshop, forming the basis of a manuscript that is now being written.

Perhaps the biggest 'aha moment' came from a subgroup that included a mix of developmental and theoretical biologists, who modeled epigenetic effects in developmental networks. Using this network approach yielded a rich range of features, and may explain the common pattern of developmental re-emergence, in which an ancestral traits may be lost, but re-appear in phylogenetically younger taxa after a disturbance. This project has sparked a new collaborative venture for which grant proposals are being written to share PhD students between the University of Arizona and the University of Pierre et Marie Curie in Paris.

Other tangible outcomes resulting from the workshop are models dealing with long-term effects of birth order and the evolution of sex determination dependent on maternal effects, which we hope will lead to submission of manuscripts for publication in the coming year.

All participants very much appreciated the format of the workshop, in which participants worked together in a number of small subgroups to address specific problems over the course of the five days - this was felt to be more productive than conventional meetings which are dominated by talks and lectures. Needless to say, the configuration of the Snellius site at the Lorentz Center greatly facilitated such an arrangement. We would recommend the Lorentz Center@Snellius venue as a venue for other biologists who aim to bring together empiricists and theoreticians; and we are eager to come back ourselves.

Possible improvements that we might suggest mainly concern the workshop format: we scheduled all plenary talks during the first three days, to leave more time for actual hands-on work later. In hindsight, however, it would have been good to spread talks more evenly over the full five days.

**Rufus Johnstone** (Cambridge, United Kingdom)  
**Bram Kuijper** (Penryn, United Kingdom)  
**Ido Pen** (Groningen, Netherlands)