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EDITORIAL

In light of evolution: interdisciplinary challenges in food, health, and the environment

''*Nothing in biology makes sense except in the light of evolution*''

Theodosius Dobzhansky (1973)

History plays a fundamental role in biology. Theodosius Dobzhansky's now famous quote can be viewed not only as a claim for the explanatory power of the evolutionary process, but also as a proclamation of the importance of recognizing the deep history of life itself. But history plays another, eminently pragmatic, role. The human histories of the various subdisciplines of biology have strongly shaped their progress and practical implementation. Combining these perspectives, it is apparent that while evolution itself is widely regarded as a uniting principle in biology, its lessons and utility have often arisen repeatedly but at different times and in different forms in various subdisciplines. Climate change, emerging disease, biotic invasion, and food security are central concerns facing humankind, each with important evolutionary dimensions. Evolutionary expertise and strategies in these areas have arisen largely independently - sometimes quickly, with considerable support and effectiveness, and sometimes gradually, with hesitation and mixed success.

Regardless, the authors of the present volume hold a shared perspective that, like our own history, the history of life is still being written and an evolutionary perspective is as relevant to our future as it is to our past. This special issue is inspired by a desire to both overcome and monopolize upon the largely independent histories of evolutionary perspectives in various applied fields and in so doing foster a common dialog of applied evolution. What are the underlying evolutionary commonalities and differences of such diverse challenges as:

1 Immigration and invasions of pests and pathogens?
2 The emergence of genotype–environment mismatch and its influence on individual and population health?
3 Evolution of virulence and of antibiotic and pesticide resistance?
4 The sustainability of exploited populations and biologic diversity?

How might these evolutionary challenges themselves interact in the context of broader global change? What strategies and lessons can be co-opted to foster successes across disciplines?

Faced with such complex challenges and interdependencies, a strategic first step toward the long-term management and resolution of these biologic issues is to bring leading researchers together from these traditionally disparate fields to share insights into the problems, successes, failures, and new directions of one another's disciplines.

Toward this goal, we convened a scientific summit at Heron Island, Australia in January 2010, drawing academics, professional researchers, postdoctoral scholars, and graduate students from five continents. The meeting, entitled 'Interdisciplinary Solutions to Evolutionary Challenges in Food, Health and the Environment', built upon the contributors' shared conviction that an evolutionary perspective can provide a unifying foundation for addressing humanity's pressing biologic concerns and that it is imprudent to ignore these productive approaches when educating new practitioners (e.g., Nesse et al. 2010).

Two main evolutionary perspectives emerged that appeared to have the most leverage. The first is a retrospective view and considers how past evolution contributes to modern functional 'mismatches' of organisms' traits to rapidly changing environments (Gluckman et al. 2009). The second focuses on contemporary evolution (sensu Hendry and Kinnison 1999) and emphasizes the lability of life in the face of current and future changes (Carroll et al. 2007). Both of these perspectives are important and complementary within an eco-evolutionary framework (*sensu* Fussmann et al. 2007; Kinnison and Hairston 2007; Pelletier et al. 2009) that considers reciprocal feedbacks between evolutionary processes, genetic variation, individual performance, and ecological dynamics. Hence, although fields like conservation, human health, and agriculture have often shifted between the historical and the contemporary, it was clear that in many cases practitioners would benefit from viewing circumstances from both perspectives.

The summit was very successful in fostering new interactions between practitioners, who were asking similar types of questions but in very different fields. For example, the environmental biologists quickly embraced the concept of 'evolutionary mismatch', which was introduced by medical participants. Likewise, we considered how resistance management strategies for crops, which

involve retaining 'refuges' of susceptible individuals, relate to whether and how we might shield threatened wild populations from the evolutionary consequences of anthropogenic selection, how we weigh individual versus group benefits in public health, and even how we might manage competing cell populations to curtail resistance evolution in tumors under chemotherapy. The papers resulting from the summit, published here, carry forward our shared momentum to demonstrate the importance and utility of addressing global problems using evolutionary biology as a common framework. There are illuminating parallels across food, health, and environment, and novel insights ripe for transfer among them. The outcomes from the Heron Island Summit show that applied evolutionary biologists have a great deal to gain from actively sharing with one another rather than continuing on in more specialized isolation.

More illumination is to be expected when the lights of applied evolution shine in common.

Organization of the special issue

The 16 articles of this special issue (13 organized by attendees and three by invitees who were unable to attend) are presented from broad to specific. An opening synthesis paper by Hendry et al. (2011) systematically considers the application of evolutionary axioms on variation, selection, connectivity, and eco-evolutionary dynamics to the domains of food, health, and environment. This is followed by a perspective piece that examines evolutionary management of permanently invaded biotic systems across these domains (Carroll 2011). For each domain, we then provide a more discipline-specific synthesis, followed by a series of topical articles.

For food, Thrall et al. (2011) lead off with a synthesis of directions and constraints for the evolutionary management of agro-ecosystems.[1] They focus on pest and pathogen management as exemplars for integration of agronomic, ecological, and evolutionary thinking. They advocate the use of predictive frameworks based on evolutionary models as pre-emptive management tools and identify specific research opportunities to facilitate this. This is followed by Denison's (2011) proposition that some classes of evolved developmental and performance tradeoffs in crops that constrain meeting production goals may in fact be reversible. With diverse examples from whole-crop production, crop–fungal symbioses, and human developmental and life cycle responses to food quality, Denison's broad perspective extends from leaf to lifespan. Agricultural practices exert extreme selection over vast landscapes, and everyday evolution in the enzyme systems of insects and bacteria in response to pesticides is the topic of the study by Russell et al. (2011). In response to insecticide-induced mortality, insects have evolved a relatively narrow scope of detoxification systems, whereas bacteria, which exploit pesticides as nutrients, have evolved a variety of highly efficient enzymes. The comparative findings of this review simultaneously inform pesticide resistant management and suggest prospects for the rapid evolution of bioremediation.

In the health domain, Gluckman et al. (2011) provide an opening synthesis that begins by articulating the principles of evolutionary medicine - that selection acts on fitness, not health; that our evolutionary history does not cause disease, but rather impacts on our risk of disease in particular environments; and that we are now living in novel environments compared to those in which we evolved. These authors then consider eight pathways by which evolutionary processes influence the risk of disease. Improving the utility of evolutionary perspectives for practitioners is of concern in all domains. In a carefully constructed effort to hone evolutionary tools for medicine, Nesse (2011) holds forth on the best paths to take, and the pitfalls to avoid, in the evolutionary study of disease vulnerability.

Vector-borne diseases cause a significant proportion of human mortality, and pathogen virulence evolves in part as response to antiparasitic factors in host immune responses (Long and Graham 2011). Immune responses to malaria pathogens, for example, may undercut parasite transmission in ways that select against virulence, suggesting that medical interventions that limit immunopathology may have the unwelcome side effect of favoring more virulent genotypes and so increase the severity of disease. Another area in which applications are emerging quickly is human–medical evolutionary genomics. Based on his interdisciplinary review, Crespi (2011) suggests four new principals for medical genomics that underscore the field's dependence on evolutionary perspectives and recommends new approaches that consider molecular genetic trade-offs in tandem with inferences based in comparisons to derived versus ancestral human alleles.

Shifting to the environment domain, the introductory synthesis by Lankau et al. (2011) begins by noting that while evolutionary principles have a long history in conservation biology, a necessary next step is to shift the focus to proactive evolutionary management. They articulate means by which evolution-based management can be an efficient and consistent way to foster greater ecological resilience in the face of widespread, rapid, and multifaceted environmental change. Contemporary evolution characterizes many communities of concern, and Sgrò et al. (2011) consider the prospects for incorporating

[1]Complementing the articles in this section are the papers in the September 2010 'Evolution in Agro-Ecosystems' Special Issue of Evolutionary Applications (volume 3, issue 5–6).

evolutionary principles into conservation design for organisms under stress from climate change. They tackle the question of how to permit *in situ* selection while retaining sufficient genetic variation for further evolution in response to continuing environmental change. Lankau and Strauss (2011) then take the mechanistic aspects further, with an original focus on how changes in population size alter density-dependent evolutionary processes. These two papers transition well into an experimental case study of the evolutionary 'rescue effect' in guppy populations following demographic catastrophe (Weese et al. 2011). Ongoing evolution in guppy populations limited migrant contributions, offering empirical verification of what may prove to be a common conservation conundrum: adaptive maintenance of local fitness may come at the cost of increased demographic risk.

In contrast to evolutionary responses to environmental change, phenotypically plastic responses may yield adaptation with fewer demographic costs. Sih et al. (2011) explore how behavioral mediation under change may be crucial for population persistence. Using examples from prospering versus failing taxa, they present a mechanistic framework for predicting interspecific variation in the capacity for behavioral adaptation and suggest that knowing recent evolutionary history may aid in the effort. Presenting a specific case study of evolution in response to anthropogenic influences, Marnocha et al. (2011) provide replicated evidence for morphological evolution of island lizards in response to alterations of habitat structure. Ecological inference and convergence among islands suggest that the responses are adaptive. No genetic differentiation between populations in wild versus disturbed habitats is detectable, indicating that a small degree of genetic change may underlie evident adaptive evolution. Following after this microhabitat-scale analysis, Thomassen et al. (2011) provide a striking contrast with a map-based macroscopic analysis. In populations stranded in habitat islands within formerly continuous biomes, they recommend prioritizing the protection of those with the greatest intraspecific genetic and phenotypic variation and thus the highest potential for adapting in situ to environmental change. Conservation modeling of refuge placement based on this criterion generates very different schemes from those based on species diversity alone and reveals that communities exhibiting high levels of current intraspecific variation are poorly protected.

Together, these 16 papers offer an unprecedented compilation of cutting-edge work on evolutionary applications across the major applied biologic disciplines. While they vary in domains and specific aims, you will note numerous efforts to build and expand links and synergies among fields. As applied evolutionary biology itself emerges as a synthetic discipline, we hope interdisciplinary efforts such as that represented here help to illuminate the path forward.

Related resources

The summit was coordinated through the Institute for Contemporary Evolution. Ongoing programs, meeting follow-up, and addition information are available on the Institute's 'I See Evolution' Web site, (http://www.icEvolution.org). Included are videos of the talks presented at the Heron Island Summit and a 12-minute film about the summit.

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