Integration between ecological and genealogical patterns:
Where are we?

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Genealogical patterns are those that can be followed and fully captured by following ‘bloodlines’, related lineages, and their common ancestry.

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Genealogical patterns are those that can be followed and fully captured by following ‘bloodlines’, related lineages, and their common ancestry.
“By ecology we mean the body of knowledge concerning the economy of nature, the total relations of the animal to both its inorganic and organic environment; including its friendly and inimical relations with those animals and plants with which it comes into contact. In a word, all the complex relationships referred to as the struggle for existence.”
It has been pointed out by Boltzmann\(^1\) that the fundamental object of contention in the life-struggle, in the evolution of the organic world, is available energy.\(^2\) In accord with this observation is the principle\(^3\) that, in the struggle for existence, the advantage must go to those organisms whose energy-capturing devices are most efficient\(^4\) in directing available energy into channels favorable to the preservation of the species.

The first effect of natural selection thus operating upon species will be to give relative preponderance (in number) to those most efficient in guiding available energy in the manner most favorable to the preservation of the species. Primarily the path of the energy flux through the system will be determined by the devices which nature and chance have provided.

But the species possessing superior energy-capturing and directing devices may accomplish something more than merely to divert available energy for which others are competing with it. They are presented, capable of supplying available energy in excess, actually being tapped by the entire system of living organisms.
Population genetics “models”

Loci, alleles, frequencies  
zygotes  

\[
[(1-q)a + qA] = 1
\]

mutation

\[
\Delta q = -uq + v(1-q)
\]

selection

\[
q = \frac{v}{u + v}
\]

Hardy-Weinberg eq.

\[
[(1-q)a + qA]^2
\]

\[
\Delta q = \frac{sq(1-q)}{[1 - s(1-q)]}
\]

complication

intractability

1866
Haeckel

1881
Darwin's worms

1859
Origin

1890 – 1900
Warming, Schimper, Drude

1900

1905

1910 – 1930
neo-Darwinian Synthesis

1930 – 1935
Modern Synthesis

1935
Tansley: concept of ecosystem

1940

1944
David Lack

1953
Odum

1959

1962
Hutchinson & MacArthur

1965
Orians

1967
Lovelock, birth of Earth System

1972

1973
van Valen: Red Queen hp

1975

1980

1983
Odling-Smee: niche construction

1985

1988

1995
Unfinished Synthesis

1999

2003
The sloshing bucket

2050

I have already given my reasons for rejecting the terms “complex organism” and “biotic community.” Clements’ earlier term “biome” for the whole complex of organisms inhabiting a given region is unobjectionable, and for some purposes convenient. But the more fundamental conception is, as it seems to me, the whole system (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome—the habitat factors in the widest sense. Though the organisms may claim our primary interest, when we are trying to think fundamentally we cannot separate them from their special environment, with which they form one physical system.

It is the systems so formed which, from the point of view of the ecologist, are the basic units of nature on the face of the earth. Our natural human prejudices force us to consider the organisms (in the sense of the biologist) as the most important parts of these systems, but certainly the inorganic “factors” are also parts—there could be no systems without them, and there is constant interchange of the most various kinds within each system, not only between the organisms but between the organic and the inorganic. These ecosystems, as we may call them, are of the most various kinds and sizes. They form one category of the multitudinous physical systems of the universe, which range from the universe as a whole down to the atom. The
“It is becoming increasingly apparent that a complete answer to any question should deal with physiological, adaptational and evolutionary aspects of the problem. The evolutionary process of becoming yields the most profound understanding of biological systems at all levels of organization. The non-evolutionary answer to the question of why an animal is abundant in some parts of its range and rare in others is of necessity incomplete.”
“It is becoming increasingly apparent that a complete answer to any question should deal with physiological, adaptational and evolutionary aspects of the problem. The evolutionary process of becoming yields the most profound understanding of biological systems at all levels of organization. The non-evolutionary answer to the question of why an animal is abundant in some parts of its range and rare in others is of necessity incomplete.”

"Ecology [...] has its descriptive generalizations, such as the principle of competitive exclusion, but as in other fields, evolution would seem to be the only real theory of ecology today. Even if one strongly believes in the action of natural selection it is exceedingly difficult, as Darwin pointed out, to keep it always firmly in mind. Neglect of natural selection in ecological thinking is, therefore, understandable though regrettable. However, its deliberate exclusion in these years following the Darwin centennial would seem to be exceedingly unwise."
80-60 Kya

"organisms seem to be both energy conversion machines and reproducing ‘packages’ of genetic information. As such they are integrated simultaneously into two largely separate, but interacting kinds of general systems" (1986, p. 351)
Fig. 4 The sloshing bucket theory of evolution
Eldredge 2003

Fig. 4 The sloshing bucket theory of evolution
Fig. 4 The sloshing bucket theory of evolution

The Sloshing Bucket: How The Physical Realm Controls Evolution

Fig. 4 The sloshing bucket theory of evolution
Ecological Hierarchy

- Biosphere
- Regional Ecosystems
- Local Ecosystems
- Populations ("avatars")
- Organisms (as ecological interactors)

Evolutionary Hierarchy

- Larger Groups of Species
- Species
- Populations ("demes")
- Organisms (as reproducers)

Natural Selection

Fig. 3 The two hierarchies and natural selection

The evolutionary consequences of niche construction: a theoretical investigation using two-locus theory.

Keywords: Evolution; niche construction; adaptation; two-locus theory; organism-environment coevolution; frequency-dependent selection.
The evolutionary consequences of niche construction: a theoretical investigation using two-locus theory

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References:
- Odling-Smee: niche construction
- Evolutionary Ecology journal
- Unfinished Synthesis
- Vrba: turnover pulse
- van Valen: Red Queen hypothesis
- Punctuated Equilibria
- Lovelock, birth of Earth System
- Hutchinson: ecological stage
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**Evolutionary Ecology journal**

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Introduction

Eco-evolutionary dynamics

F. Pelletier\textsuperscript{1,2,*}, D. Garant\textsuperscript{2} and A. P. Hendry\textsuperscript{3}

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Evolutionary ecologists and population biologists have recently considered that ecological and evolutionary changes are intimately linked and can occur on the same time-scale. Recent theoretical developments have shown how the feedback between ecological and evolutionary dynamics can be linked, and there are now empirical demonstrations showing that ecological change can lead to rapid evolutionary change. We also have evidence that microevolutionary change can leave an ecological signature. We are at a stage where the integration of ecology and evolution is a necessary step towards major advances in our understanding of the processes that shape and maintain biodiversity. This special feature about ‘eco-evolutionary dynamics’ brings together biologists from empirical and theoretical backgrounds to bridge the gap between ecology and evolution and provide a series of contributions aimed at quantifying the interactions between these fundamental processes.
Introduction

Eco-evolutionary dynamics

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**Picante: R tools for integrating phylogenies and ecology**

Steven W. Kembel\(^1\),\(^*\), Peter D. Cowan\(^2\), Matthew R. Helmus\(^3\), William K. Cornwell\(^4\), Helene Morlon\(^5\), David D. Ackerly\(^2\), Simon P. Blomberg\(^6\) and Campbell O. Webb\(^7\)

\(^1\)Center for Ecology and Evolutionary Biology, University of Oregon, Eugene, OR, \(^2\)Department of Integrative Biology, University of California, Berkeley, CA, USA, \(^3\)Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Kunming, Yunnan, China, \(^4\)Biodiversity Research Centre, University of British Columbia, Vancouver, BC, Canada, \(^5\)Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA, USA, \(^6\)Faculty of Biological and Chemical Sciences, University of Queensland, Brisbane, Australia and \(^7\)Arnold Arboretum of Harvard University, Cambridge, MA, USA

Associate Editor: David Posada

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A special feature about ‘eco-evolutionary dynamics’ brings together biologists from empirical and theoretical backgrounds to bridge the gap between ecology and evolution and provide a series of contributions aimed at quantifying the interactions between these fundamental processes.
The contribution of evening primrose (*Oenothera biennis*) to a modern synthesis of evolutionary ecology

Marc T. J. Johnson
Toward an integration of evolutionary biology and ecosystem science

Abstract
At present, the disciplines of evolutionary biology and ecosystem science are weakly integrated. As a result, we have a poor understanding of how the ecological and evolutionary processes that create, maintain, and change biological diversity affect the flux of energy and materials in global biogeochemical cycles. The goal of this article was to review several research fields at the interfaces between ecosystem science, community ecology and evolutionary biology, and suggest new ways to integrate evolutionary biology and ecosystem science. In particular, we focus on how phenotypic evolution by natural selection can influence ecosystem functions by affecting processes at the environmental, population and community scale of ecosystem organization. We develop an eco-evolutionary model to illustrate linkages between evolutionary change (e.g. phenotypic evolution of producer), ecological interactions (e.g. consumer grazing) and ecosystem processes (e.g. nutrient cycling). We conclude by proposing experiments to test the ecosystem consequences of evolutionary changes.

Keywords
Biodiversity and ecosystem functioning, community genetics, eco-evolutionary dynamics, ecological stoichiometry, ecosystem science, evolutionary biology, feedbacks, natural selection.
Meeting report

Integrating ecology into macroevolutionary research

Lynsey McInnes¹,², *, William J. Baker³, Timothy G. Barracough¹, Kanchon K. Dasmahapatra⁴, Anjali Goswami⁴,⁵, Luke J. Harmon⁶, Héliène Morlon⁷, Andy Purvis¹, James Rosindell⁸, Gavin H. Thomas⁹, Samuel T. Turvey¹⁰ and Albert B. Phillimore¹

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Abstract

At present, evolutionary biology and ecology have a partially disjointed relationship. A biological community is a complex system that creates, maintains, and changes ecosystem processes through feedback and evolitional selection. In particular, ecosystems can be strongly influenced by feedbacks from evolutionary timescales and the forces of macroevolution. We develop a new model of ecosystem organization that integrates evolutionary processes into a single framework. This model is based on the concept of evolutionary dynamics, ecological stoichiometry, and the theory of redundant but necessary interactions.
The Newest Synthesis: Understanding the Interplay of Evolutionary and Ecological Dynamics

Thomas W. Schoener

The effect of ecological change on evolution has long been a focus of scientific research. The reverse—how evolutionary dynamics affect ecological traits—has only recently captured our attention, however, with the realization that evolution can occur over ecological time scales. This newly highlighted causal direction and the implied feedback loop—eco-evolutionary dynamics—is invigorating both ecologists and evolutionists and blurring the distinction between them. Despite some recent relevant studies, the importance of the evolution-to-ecology pathway across systems is still unknown. Only an extensive research effort involving multiple experimental approaches—particularly long-term field experiments—over a variety of ecological communities will provide the answer.
Special Issue: Eco-evolutionary dynamics

Towards a general, population-level understanding of eco-evolutionary change

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Review article – A system for analysing features in studies integrating ecology, development, and evolution

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Key words: Adaptation, Development, Ecology, Evolution, Homology, Morphology, Ontogeny, Phylogeny

Abstract. Ecology is being introduced to Evolutionary Developmental Biology to enhance organism-, population-, species-, and higher-taxon-level studies. This exciting, burgeoning troika will revolutionise how investigators consider relationships among environment, ontogeny, and phylogeny. Features are studied (and even defined) differently in ecology, development, and evolution. Form is central to development and evolution but peripheral to ecology. Congruence (i.e., homology) is applied at different hierarchical levels in the three disciplines. Function is central to ecology but peripheral to development. Herein, the supernumerary form (‘isomorphic’ or ‘allomorphic’), congruence (‘homologous’ or ‘homoplastic’), and function (‘adaptive’ or ‘nonadaptive’) are combined with two developmental mode (i.e., growth) categories (‘conformational’ or ‘nonconformational’) to provide a 16-class system for analysing features in studies in which ecology, development, and evolution are integrated.
Toward an integration of evolutionary biology and ecosystem science

Abstract
At present, the disciplines of evolutionary biology and ecosystem science are weakly integrated. As a result, we have a poor understanding of how the ecological and evolutionary processes that create, maintain, and change biological diversity affect the flux of energy and materials in global biogeochemical cycles. The goal of this article was to review several research fields at the interfaces between ecosystem science, community ecology and evolutionary biology, and suggest new ways to integrate evolutionary biology and ecosystem science. In particular, we focus on how phenotypic evolution by natural selection can influence ecosystem functions by affecting processes at the environmental, population and community scale of ecosystem organization. We develop an eco-evolutionary model to illustrate linkages between evolutionary change (e.g. phenotypic evolution of producer), ecological interactions (e.g. consumer grazing) and ecosystem processes (e.g. nutrient cycling). We conclude by proposing experiments to test the ecosystem consequences of evolutionary changes.

Keywords
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Toward an integration of evolutionary biology and ecosystem science

Abstract
At present, the disciplines of evolutionary biology and ecology have a poor understanding of how the richness of biodiversity affects the flux of energy through ecosystems. The purpose of this article was to review several research themes that integrate evolutionary biology and ecological science, and suggest future directions for research. In particular, we focus on how phenotypic diversity contributes to ecosystem resilience by affecting processes at the ecosystem scale. We develop an eco-evolutionary model of consumer-resource interactions (co-evolution of producer), ecological interactions (competition, predation, and recycling). We conclude by proposing examples to support the above ideas.

Keywords
Biodiversity and ecosystem function, coevolution, stoichiometry, ecosystem science, evolutionary ecology.
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Patterns in the natural world are extremely important. [...] They pose both the questions and the answers that scientists formulate as they seek to describe the world [...]. Science is a search for resonance between mind and natural pattern as we try to answer these questions. (Eldredge 1999, pp. 4-5)

It is this two-way street [...] that together form the resonance between mind and material nature that is the heart and soul of science. The search for more accurate depictions and explanations of phenomena already perceived is where most of the serious day-to-day work of science lies. But it is in the learning of new ways to see phenomena that true novelty and creativity come in. Both are vital and in many ways themselves inseparable. Both involve wrestling with patterns in nature-the explanation of agreed-upon pattern, and the search for new ways of seeing new patterns (Eldredge, cit., p. 16).
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