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Ecological Metaphors in Organizational Science: An Interdisciplinary Critique

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Abstract: Metaphors are prominent across a wide range of research literatures, serving as imaginative sparks for innovative approaches to complex problems and provocative questions. Research metaphors are very often interdisciplinary in nature, with scholars drawing insight and inspiration from disciplines outside of their own. Yet, research metaphors are rarely developed through interdisciplinary collaborations between scholars in the disciplines in which content is sourced and those in the disciplines in which the content targets. Consequently, the meaning of research metaphors is often left underdeveloped or is fundamentally misaligned with the concepts and principles that are being drawn from source disciplines. Here, we as a social scientist and ecologist come together to review the ecological principles of hierarchy and interactions, and the application patterns of said principles within the organizational science literature. The review provides a case example of the conceptual complexities associated with research metaphor development and application. We illustrate divergences from and convergences with ecological sources, as well as inconsistencies in the ways in which organizational scientists define and apply the source content to the study of human organization phenomena. In doing so, we model the impact of interdisciplinary collaboration on the development and application of richer, more trustworthy research metaphors.

Keywords: interdisciplinary research, interdisciplinary collaboration, metaphor development, ecological metaphors, organizational metaphors

Introduction

For centuries, metaphor was just the place where poets went to show off.
Michael Chorost (2005, p. 2), technology theorist

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Research metaphors are often lauded for their capacity to excite the imaginations of researchers, especially when they are seeking new explanatory approaches to complex findings or generating new angles from which to approach especially perplexing problems (Biscaro & Comacchio, 2018; Klein, 2023; Lakoff & Johnson, 1980; Picart, 1997). This value proposition has rung true for us throughout a more than decade-long interdisciplinary exploration of the patterns associated with the development and application of ecological metaphors to human organizations and systems (Mars et al., 2012; Mars & Bronstein, 2018, 2020). We are truly an interdisciplinary team. One of us is a sociologist who researches community and organizational innovation. The other of us is an ecologist who studies interactions within and among non-human species.

We have observed throughout our work together that research metaphors are rarely developed and applied through interdisciplinary collaborations that include scholars in the disciplines in which content is sourced and the disciplines in which the content targets. We are often reminded of the saying in academia that scholars know a lot about very little. That is, discipline-based research is almost always very narrow in scope, with depth of examination and exploration being the hallmark of rigor. Consequently, researchers become rigidly "fixed on certain approaches, and less flexible in novel situations or situations outside their domain of expertise" (Keestra, 2017, p. 121). In this article, we model how interdisciplinary collaboration can bring greater rigor to research metaphor development. We do this via an interdisciplinary critique of ecological metaphor applications in the organizational science (OS) literature. Our goal is to model a collaborative process for developing and applying more purposeful and precise metaphors during integrative interdisciplinary research (Nagatsu & MacLeod, 2018; Repko & Szostak, 2021). The underlying assumption is that interdisciplinary collaboration enables the rigorous tracing of the meaning of research metaphors back to original source content, clarifying and strengthening, or altering and refining (or even abandoning), metaphorical assertions. To this end, we model how interdisciplinary partnerships can productively challenge and refine existing metaphors, as well as develop new ones in ways that lead to deeper, richer intellectual contributions and practical outcomes. For instance, we have shown elsewhere how the rigorous application of natural ecosystem and population ecology metaphors can reveal important nuances in the organizational structures and counter-intuitive patterns of development that characterize innovative organizational systems (Mars, 2020; Mars & Bronstein, 2018, 2020).

The interdisciplinary partnership we model throughout this essay aligns with the ongoing discussion of integrative interdisciplinary research (Nagatsu & MacLeod, 2018; Repko & Szostak, 2021). More specifically, metaphors can be useful devices for making sense of and communicating the knowledge and theoretical insights generated from research that involves the integration of concepts, principles, methods, and in essence languages from otherwise disparate disciplines (Klein, 2023; Repko & Szostak, 2021). The rigorous conceptualization of interdisciplinary research metaphors, such as that which we model here, can aid in the integrated treatment of the phenomena being studied as opposed to taking "an assembly of approaches [from multiple disciplines] which divide problems along disciplinary lines" (Nagatsu & MacLeod, 2018, p. 8).

Scholars outside of ecology have long drawn upon ecological language to describe how humans assemble, function, flourish, and perish (Gaziano, 1996; Levine, 1995; Swedberg, 2020). This work has inspired a host of ecological metaphors that imply parallels between natural interactions and systems and those that occur between humans and the many organizational forms they assume. Examples of ecological concepts and principles that are applied to human and societal contexts include models that explain human connectivity and dynamics associated with activism (Treré & Mattoni, 2016), mass communication (Scolari, 2012), organizational development (Hawley, 1950), human assemblages of various types (e.g., creative ecosystems, educational ecosystems, entrepreneurial ecosystems) (Mars et al., 2012; Cavallo et al., 2019; de Bernard et al., 2022), and human-to-human interactions that resemble ecological mutualism, commensalism, and symbiosis (e.g., Gurrieri et al., 2023; Mars & Bronstein, 2020; Walker et al., 2011).

While pervasive, the application of ecological metaphors to human and societal phenomena is sometimes critiqued for being insubstantial, serving only to provide creative riffs that lack intellectual rigor and theoretical power (Andriessen, 2006; Contractor, 1999; Inns, 2002). From this critical perspective, ecological metaphors serve only to distract from potential contributions and breakthroughs, increasing the likelihood of underdeveloped, fragmented arguments and ideas that fall short of being cohesive theoretical and/or empirical advancements (Pinder & Bourgeois, 1982; Carr & Leivesley, 1995). As Chorost implies in the opening quote above, scholars, knowingly or not, often use metaphors as clever anecdotes and intellectual grandstands that do little to advance their disciplines (Inns, 2002; Rosenthal, 1982).

Nevertheless, we retain confidence in the promise of ecological metaphors to serve as explanatory devices and powerful vehicles for deeper, more cohesive exploration into interdisciplinary theory building. To affirm and advance this promise, we provide a) a primer on a set of ecological concepts that explain hierarchy classifications within, versus among, defined entities (species, populations, communities, populations) and interaction-type classifications (interactions that are mutually beneficial, unilaterally beneficial, or mutually detrimental) and b) an overview of how these principles have been mapped onto human and societal phenomena. We turn to the use of ecological metaphors in a specific field of the social sciences—organizational science (OS)—to demonstrate the explanations and observations that guide the primer. In doing so, we illustrate a conceptual mapping process aimed at bringing conceptual depth and theoretical power to the interdisciplinary development and application of research metaphors.

Four main elements are woven throughout this article: a) a review of ecological principles of hierarchy and interactions, b) the mapping of these principles within their applications in the OS literature as a case example, c) an illustration of the conceptual complexities and limitations associated with metaphorical developments and applications that *lack interdisciplinary collaboration*, and d) a demonstration of the efficacy of interdisciplinary collaboration in the development, adaption, and application of theoretically rich and powerful metaphors. Readers will gain a thorough understanding of the parallels and divergences between ecological principles of hierarchy and species interaction and their applications to human organizations and systems. Equally important, readers are provided with a compelling example of the power of interdisciplinary collaboration and extension to the conceptualization and mapping of research metaphors.

In the following section, we discuss how our analysis is informed by prior work on metaphorical development and application to include interdisciplinary perspectives. We then introduce the ecological meaning of each key principle, hierarchy classification, and interaction-type classification. Throughout these sections, we illustrate the convergences, divergences, and inconsistencies in how the ecological principles have been applied to a range of human organization and system phenomena to include, as examples, entrepreneurial networks, industrial sectors, and even school systems. Our concluding remarks begin with a set of questions for organizational scientists to consider as pathways to more intentionally developing and realizing the theoretical potential of ecological metaphors. We close with commentary on the value of interdisciplinary collaboration and extension when developing and advancing metaphorical concepts and models that are expressively rich and heuristically deep—metaphor qualities that we interpret in the next section.

Interdisciplinarity and Principles of Metaphorical Development and Application

Interdisciplinary research allows scholars to address complex ideas and problems in ways that single disciplinary approaches would not allow (Klein & Newell, 1997). Additionally, theorists can use research metaphors to help present complex or abstract ideas in more accessible, comprehendible ways (Klein, 2021; Silber, 1995). Bowdle and Gentner (2005) state, “in spite of (or perhaps because of) the semantic distance between their terms, metaphors are often more effective instigators of conceptual change than are their literal counterparts” (p. 193). The transformative potential and epistemological impact of interdisciplinarity is heavily dependent on the transference and adaptation of concepts and principles across disciplinary boundaries (Faber & Schepper, 1997; Jacobs & Frickel, 2009). Interdisciplinary collaboration is especially conducive to the rigor and success of such transference and adaptation (Hübenthal, 1994; Keestra, 2017; Klein, 2004, 2021a, 2023).

There are two forms of metaphorical value: heuristic and expressive (Swedberg, 2020). The *heuristic value* of a metaphor is realized when it fosters new learning or advances existing understanding of complex concepts. The *expressive value* of a metaphor is the degree to which it effectively conveys the meaning of new and complex ideas and concepts. We pull a metaphor from evolutionary biology to illustrate these two forms of value. As far back as the 18th century, the diversity of life has been described as a tree: a complex, bifurcating entity tracing back along a single stem to a single common ancestor. While evolutionary biologists and ecologists alike now see this "Tree of Life" (ToL) as oversimplified or outright inaccurate, it has entered common usage as a metaphor for life's complexity. Mindell (2013) describes the *heuristic value* of this metaphor when stating, "Practical effects of the ToL as a heuristic device include stimulating development of new questions, new analytical tools, and new evolutionary knowledge, particularly for distinguishing and integrating evolution of organismal and molecular lineages" (p. 487). In the same paper, Mindell points to the expressive value of the ToL metaphor in its capacity for sharing complex evolutionary processes with both scientific and public audiences.

Scholars have been encouraged to be more systematic and attentive to the original disciplinary meaning of concepts when developing and applying research metaphors (Cornelissen et al., 2008; Maasen, 2000). Cornelissen (2005), an organizational theorist, recommends that social scientists begin their systematic approach to metaphor development and application by conceptually aligning the meaning of the source concept(s) (e.g., ecological meaning) onto that of the target concept(s) (e.g., organizational phenomena). In doing so, social scientists can identify conceptual connections between source and target content that have potential heuristic and/or expressive value. Researchers are then better able to sort, explore, and develop theoretical connections in ways that lead to deeper insights, novel questions, and/or clearer communication of the more abstract and complex elements of their work. Consequently, unexpected connections among otherwise disparate principles and concepts can be made, and new and richer insights into phenomena can be revealed (i.e., heuristic value is increased) (Katz, 1992; Tourangaue & Sternberg, 1982; Swedberg, 2020). Likewise, rigorous metaphorical development and application can help social scientists better explain the abstractions and complexities that inform their arguments and characterize their discoveries (i.e., expressive value is increased) (Gibbs & Gerrig, 1989).

The following sections form a brief primer on hierarchy and interactions within and among individuals and groups in nature, stemming from ecology. To clarify, ecology is a subfield of biology that focuses on the scientific study of organisms in relation to their environments. Woven throughout the primer is the mapping of ecological principles to corresponding metaphors used within the organizational science (OS) literature. We selected the OS example for two reasons. First, there is a rich tradition in the OS literature of drawing on ecological metaphors, especially those dealing with hierarchies and interactions. Second, this example provides ample opportunity to explore the conceptual consequences of metaphorical application that did not emerge from interdisciplinary partnerships (with a few exceptions, e.g., Mars et al., 2012, Mars & Bronstein, 2018; Shaw & Allen, 2018). With these points in mind, our work serves as a template for researchers in all fields to transfer to their own interdisciplinary collaborations involving metaphorical applications and developments.

We first review hierarchical concepts starting with organisms, progressing to populations, then to interactions between species pairs, and finally to communities and ecosystems. We then focus in on interactions according to whether they take place between similar entities or among entities that have quite different features and interests. Thereafter, we further divide interactions by whether they benefit both entities, one entity only, or neither entity.

A cautionary statement is warranted regarding the application of any ecological concept to human behaviors. Humans have cognitive processes that allow them to predict the consequences of their actions, plan, make choices, try out multiple options, contemplate the advantages of cheating, envision the costs of being cheated, and enforce cooperation to prevent or punish it. While such actions are not necessarily efficacious, the abilities they involve are critical to understanding human behavior (Raihani, 2021). The science of ecology, however, generally focuses on species *other than humans*, ranging from bacteria to plants to mammals. Most of these species lack most or all the aforesaid cognitive processes. Hence, when we look, for instance, at cooperation within a beehive or ant nest and use it to take away lessons for how humans should behave, as the ancient Greeks did (Bronstein, 2015: Ellison & Gotelli, 2021), it is critical to remember that the activities of these insects were shaped over millions of years of evolution. At this point, they generally lack the ability to *not* cooperate as a family unit. Further, evolution favors those that help themselves in the short term, often by exploiting others, behaviors that we believe humans mostly do not wish to emulate. The ability to predict the long-term consequences of behaviors is unique to humans. Further, as a rule, non-human organisms have limited ability to detect imminent changes in their environment and make strategic switches in behavior. It is critical, then, to keep in mind that, even though humans cooperate, compete, and destroy their local surroundings as other species do, there are limitations to how much we can take away from nature when we try to understand the causes and consequences of these behaviors (Raihani, 2021).

Undoubtedly, bees will not read this essay and then pursue new metaphors to better understand colony management strategies. While tongue in cheek, this self-evident statement reminds social scientists that human agency marks a clear distinction between us as a species and our non-human counterparts. Implications of this distinction center on human capacities to intentionally forecast, weigh, design, and moderate intended and unintended consequences relative to agendas and goals. The notion that human interactions are intentionally designed and orchestrated is a marked divergence from how we know other organisms behave, whose interactions and systems emerge via natural selection in unplanned, unintentional ways (Mars et al., 2012). While ecological metaphors provide powerful insights into how humans can and do intentionally structure interactions, they are limited when it comes to actual decision making and strategy development.

Biologically speaking, of course, humans are all a single species, making the use of between-species metaphors in any research field technically incorrect. Regardless, we take it as a starting point that between-species language can be profitably used to describe phenomena that take place among humans. The groups of individuals that organizational scientists focus on typically have varying agendas, conflicting interests, and differentiated functions, strengths, and needs that largely mimic between-species interactions in nature. Our backgrounds as an ecologist and social scientist lead us to believe that this makes the adoption of between-species language not entirely inappropriate. Differences in the agendas, interests, and functions of human organizations that interact constitute an inter-organizational dynamic that makes the metaphorical use of the interspecific interaction-types insightful (and heuristically and expressively valuable). Regarding interactions, our key focus will be on the underlying meaning of concepts such as mutual benefit and conflict of interest: a) what ecologists mean by these kinds of terms, b) the extent to which OS is aligned with ecology in this respect, and c) how greater ecological understanding of these concepts may further inform research that is aimed at developing deeper understandings of the complexities that shape the structures and performance of human organization and systems.

Our focus on how greater ecological understanding of interactions in nature can enhance the understanding of human organization and system complexities illustrates the interdisciplinary research technique of extension (Repko & Szostak, 2021). This technique entails "extending the meaning of an idea beyond the domain of the discipline into the domain of another discipline" (Newell, 2007, p. 258). A key element of the extension technique is finding common ground between disciplines where conceptual interdisciplinary alignments can be accentuated and departures from the original meaning of source content can be calibrated in collaborative and precise ways. Our engagement in the extension technique is ongoing with us continually deliberating and scrupulously reconciling our different perspectives as a sociologist and ecologist. By rigorously illustrating the extension technique by way of our interdisciplinary critique of ecological metaphors within the OS literature, we contribute to the growing narrative on how integrated interdisciplinary research is performed (Szostak, 2013, 2015).

Hierarchies of Life and Organization

Hierarchical Classifications in Nature

Life is often viewed as fundamentally hierarchical in nature (Wu, 2013). Cells are made up of individual components that interact to generate a functional unit. Cells themselves differentiate and interact to generate multicellular organisms. Moving upwards are the levels of the hierarchy of life commonly studied by ecologists (see Figure 1). Within a single locale are individual organisms; groups of organisms of the same species that may or may not interact, termed *populations*; associations between pairs of species; associations among larger groups of species, termed *communities*; and associations among different communities as well as their nonecological environment (e.g., air, water, sunlight), which are termed *ecosystems*.

Concepts from population ecology (e.g., the forces leading groups to grow and shrink) have been profitably applied to OS research for decades

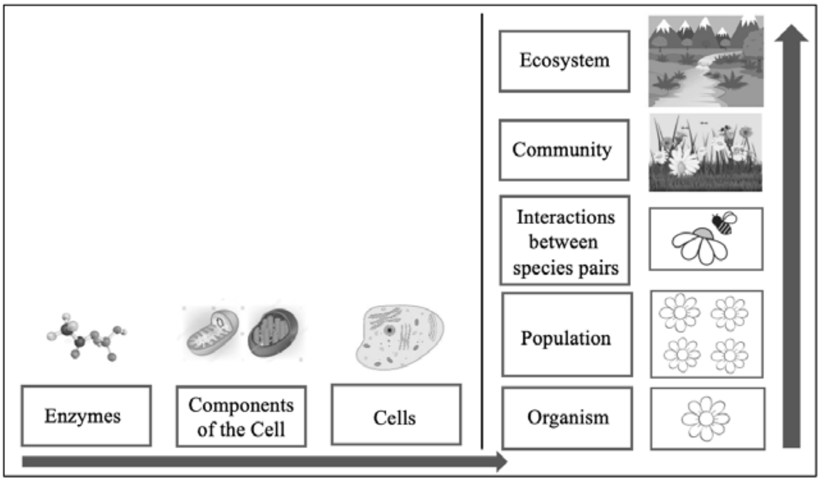

Figure 1. Hierarchical Organization in Nature
Note. The column of boxes on the right-hand side are the domains studied by ecologists.

(Boeker, 1991; Hannan & Freeman, 1977; Morgan, 1986; Mars & Bronstein, 2020). Further, as we and others have discussed elsewhere, ecosystem concepts (e.g., how large groups of differentiated entities are networked) have been heavily drawn upon recently in the social sciences, with somewhat more variable success (Mars et al., 2012, Mars & Bronstein, 2018; Shaw & Allen, 2018). Note again that the differentiated entities within ecological communities and ecosystems will be distinct species, whereas differentiated entities in human communities and ecosystems will be groups and networks of single species, humans, characterized by differentiated functions, skills, interests, resources, etc.

Here, we focus on the level between populations and ecosystems: interactions between pairs of entities. The differentiated entities in this case are, to an ecologist, pairs of individuals of either the same or different species. To a social scientist, they will always be the same species: humans. From an ecological perspective, interactions within single species and between different species share many features. For example, in both cases an interaction can benefit both, only one, or neither of the participants. Both within- and between-species interactions can lead groups to form, allowing all participants to fare better than they would in isolation; but they can also lead groups to dissolve, as individuals come into conflict. In fact, as we will discuss, conflicts of interest between partners are a fundamental characteristic of all interactions between pairs of entities—whether in nature or human contexts. Any interaction, whether within species or between species, embodies a balance between cooperation and conflict – even with mutualistic dynamics in which all involved species gain some benefit.

Hierarchical Classifications and Human Organizations

The meaning and nuances of the terms we use to explore the parallels of interactions between pairs of ecological entities and those between human organization entities are clarified in Figure 2. As we highlighted earlier, organizational scientists rarely attempt to align their use of hierarchical terminology with underlying ecological meanings, weakening the conceptual power of the resulting metaphors. This threat of dilution motivates our current call for interdisciplinary collaboration in the development and application of ecological metaphors across research literatures.

Nevertheless, alignment patterns can be pieced together from the existing OS literature. These patterns are summarized in Table 1 as a companion to Figure 2 and segue to the detailed descriptions presented in the passages that follow. These descriptions provide the background needed to rigorously explore and compare interactions between entities in nature with those within human organization contexts.

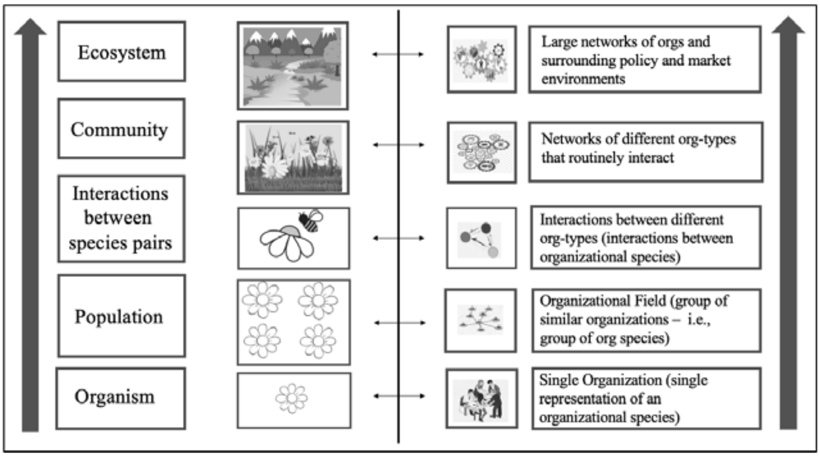

Figure 2. Parallel Interactions Between Pairs of Ecological Entities and Those Between Human Organization Entities

Table 1. OS Application of Ecological Hierarchy Terms Shown in Figures 1 and 2

Ecological Terms	Human Organizational Applications
Ecosystem	Organizational community (or network of communities) *plus* the non-organizational environment that influences interactions and overall systemic functioning and persistence (e.g., policy environments and economic conditions and arrangements) (Mars et al., 2012; Cavallo et al., 2019; Shaw & Allen, 2018)
Community	Organizational network of different species that interact within a common environment and according to shared norms (Bertoni et al., 2019; Gaba & Meyer, 2008; Monge et al., 2008; Romanelli, 1991)
Among-species interactions	Different organizational species that interact in ways that involve cooperation or competition (Dobrev & Kim, 2006; Shaw & Allen, 2018; Simons & Ingram, 2004)
Population	A group of organizational species that may interact based on compatible features and the exchange of differentiated resources (Mars & Bronstein, 2020; Baum & Singh, 1994; Gaba & Meyer, 2008; Gibbons, 2004; Reydon & Scholz, 2009)
Organism	Single representation of an "organizational species," that is, an organization made up of actors (e.g., employees) with common purpose and involves the sharing of resources within in pursuit of the common purpose and self-replication over time (Demers, 2007; McKelvey, 1982; McKelvey & Aldrich,1983; Shaw & Allen, 2018)

Early descriptions of organizational *species* accentuate individual organizations that, despite having similar structures and purposes, operate independently based on observable and measurable variations in competencies. Taking a more connective view, Shaw and Allen (2018) have suggested that organizational species share (metaphorical) *genomes* (e.g., specializations, business models, *umwelts* or "self-worlds") that encourage collaboration on the "recycle[ing] of scarce customer-related resources" (p. 90). In this usage, organizations that are similar in function and rely on common sets of resources, regardless of differences in size, performance capacities, and operational structures, represent a common species (Abbott et al., 2016; Baum & Singh, 1994; Gaba & Meyer, 2008; Hannan & Carol, 1992).

Organizational scientists use *population* as an ecological metaphor to identify and conceptualize organizational species of a similar type that become connected based on common functions and resource constraints. According to Gibbons (2004), organizational populations consist of organizations (or species) "that occupy the same or interrelated environmental niches . . . produce related out puts, use related resources, and rely on similar technologies" (p. 938). Likewise, Gaba and Meyer (2008) and others (e.g., Abbott, et al.,2016; Mars & Bronstein, 2020; Hannan & Carroll, 1992; Reydon & Scholz, 2009) indicate that networks of similar organizations make up industries or sectors that in ecological terms represent "populations." Returning to Shaw and Allen's (2018) genome perspective, populations form when organizational species with shared genomes connect relative to common purpose and resource constraints.

Moving further up the ecological hierarchy, organizational scientists routinely identify *organizational communities* as two or more populations of distinct species that become networked through complementary functions and compatible resource needs and supplies (Aldrich & Ruef, 2006; Gaba & Meyer, 2008). For instance, Hannan and Freeman (1987) examine the interplay between industrial and craft unions by treating each union-type as a distinct species and thus a stand-alone population. Industrial unions are industry-wide collectives that do not specialize membership according to worker skill areas, whereas craft unions are smaller collectives within industries that confine membership to a specific skill area. The two populations became initially connected by a shared purpose: collective agency over working conditions. The rise of industrial unions over time stifled the growth of craft unions. It becomes clear that interactions within communities can be positive or negative and over time create conditions of organizational homogeneity (e.g., more industrial unions, fewer craft unions) followed by new organizational forms emerging to exploit resources that went unused within established communities (Romanelli, 1991). As illustrated by this example, organizational communities form, change, persist, and fail according to population networks, variations in resource niches, and interaction dynamics (Bertoni et al., 2019; Monge et al., 2008).

The application of the *ecosystem* metaphor to human organizations and systems has been especially popular in the past two decades (Mars et al., 2012). Studies within this body of work focus on various contexts ranging from entrepreneurship (Cavallo et al., 2019) to innovation (Autio & Thomas, 2014) to education settings (Mars & Bronstein, 2018). Organizational scientists, as well as social scientists more generally, view an ecosystem as an organizational community (or network of communities) plus the non-organizational environment that influences interactions and overall systemic functioning and persistence (e.g., policy environments and economic conditions and arrangements) (Mars et al., 2012). This interpretation is consistent with the ecological view of ecosystems as a set of diverse ecological populations (i.e., communities) and the abiotic physical environment in which they live and interact (Wu, 2013).

Ecological Interaction Types Within Populations, Communities, and Ecosystems

We now turn to an ecological perspective on the mechanisms underlying hierarchical interactions that take place between pairs of entities within populations, communities, and ecosystems. Pairs of entities can interact in highly diverse ways, with outcomes for each that range from positive to neutral to negative. Beginning in the 1950's, a tradition began in ecology for interactions involving two different species to be named according to pairs of signs (plus [+], minus [–], and zero [0]) that capture their net outcomes for each (Bronstein, 2015) (see Table 2). Whether an interaction has a positive or negative outcome for each partner is, however, not rigid; rather, it can shift with local conditions. Ecologists term this feature context-dependency (Chamberlain et al., 2014). For instance, ants aggressively protect some aphids from their predators, in exchange for sugar-rich excretions ("honeydew"). However, under certain conditions—for example, when ants have plenty of sugar but lack protein—the ants turn on the aphids and devour them (Sakata, 1994). Thus, this interaction shifts, depending on context, from benefiting aphids to harming them, while remaining good for the ants.

In this section, we summarize current ecological understanding of three prominent types of between-species interactions: mutualism, commensalism, and symbiosis. Staying with the OS example, we conclude each summary with a synopsis of how each interaction-type has been used to analyze and understand human organizational behaviors and strategies. Competition is a fourth interaction-type that is referenced throughout this main section. Competition is a minus/minus interaction (Table 2). That is, it is detrimental

Table 2. The Grid of Species Interactions

Effect on Species One	Effect on Species Two	Interaction Type
+	+	Mutualism
–	+	Predation/Parasitism
–	–	Competition
0	+	Commensalism
0	–	Amensalism
0	0	Neutralism

Note. In this scheme, in common use in ecological science, interactions are named in accordance with the effects experienced by each of two species.

to both partners, although the magnitude of this effect can be quite different on the two sides. The notion of competition as the struggle for existence through access to scarce resources is well-established in both the ecological and social sciences. The ecological notion of competition followed, rather than preceded, its development in the human domain; it remains a topic of debate and continued revision among ecologists (McPeek, 2022). In the social sciences, competition is considered a deeply engrained human trait and is widely recognized as a reality when it comes to individual and group interactions (Flinn et al., 2005; Molina et al., 2017). We have chosen not to address competition as a stand-alone interaction-type in this article, opting instead to weave it in as factor that influences the viability and stability of the other three types.

Mutualism

Mutualisms are mutually beneficial (+/+) interactions between two different species (Bronstein, 2015; see Table 2). Pollination offers a familiar example of mutualism. In plant-pollinator interactions, a plant can move its pollen between flowers—which is essential for it to reproduce—by producing a food reward (usually sugar-rich nectar) that entices certain animals. In feeding at and then moving between flowers, the consumers (e.g., bees and hummingbirds) spread the pollen. The basics of pollination and of many other mutualisms were known to humans long before scientists began to study them. One finds, for instance, alabaster reliefs depicting Assyrian deities shaking pollen onto date palm flowers, capturing one of the earliest documented efforts to increase agricultural yields (Giovino, 2007).

Mutualisms range from completely specialized to quite generalized, and from complete mutual dependence to one-sided dependence, and to interactions that are helpful but not necessary. A well-studied example of a mutually dependent, highly specialized mutualism takes place between fig trees and tiny wasps that pollinate the trees and can only reproduce within the fruits that result from their actions. The edible fig, *Ficus carica*, and its pollinator are only one of more than 700 such species pairs (Bronstein, 1992). Apple trees also require pollination to reproduce, but many insect species provide good service; each of those insects, in turn, visits the flowers of many other plant species. The comparison between edible fig trees and apple trees illustrates the difference between specialized and generalized mutualisms.

The scientific study of mutualism is relatively young. It began to flourish only in the 1970's (Bronstein, 2015). Although Darwin did write about mutualisms in some depth, these interactions did not yet have a name, and ecologists, and biologists more broadly, long discounted their significance. For many decades, following on an older (pre-Darwinian) natural history tradition, mutualisms were considered to be "friendships" between species that are motivated to help each other. Such notions have been definitively set aside, with ecologists now interpreting mutualisms as "reciprocal antagonisms" (Bronstein, 2015). Each species uses its partner to get something it requires for survival or reproduction; the interaction is mutualistic because these exploitative effects are offset by the benefits the exploiter delivers (i.e., I am exploited, but I get something I require in return). In the pollination example, plants offer nectar to get their own pollen moved between flowers, not out of an interest in keeping pollinating animals healthy. Further, there is a distinct advantage for plants to produce nectar that is as scanty and made as cheaply as possible. Producing as little nectar as cheaply as possible reduces the energy spent by plants while retaining the benefits of pollination. Reciprocally, animals visit flowers not to move pollen for the benefit of plants, but because they are hungry and are not satiated by what a single flower provides. The availability of mutualistic partners is limited, and this leads to competition (Johnson & Bronstein, 2019). For example, apples must compete with sunflowers for pollinators, who choose which plant species to associate with based on their relative amounts of nectar; on the other side, hummingbirds and bees sometimes fight for access to the most nectar-rich flowers.

Mutualisms are fundamentally based on self-interested exchange. An important consequence is that mutualisms are almost always subject to cheating (Bronstein, 2001). For example, some flowers appear to offer nectar, but have none; they dupe pollinators into visiting. Consequently, their pollen is moved at no cost to themselves. On the other side of the interaction, some nectar-feeders access food by chewing holes through the flowers, bypassing pollen entirely, a behavior that benefits themselves (they can potentially feed faster this way) but not the plants. Organisms have evolved a dazzling array of adaptations to deter or punish cheaters and keep their partners honest.[1] For example, bees quickly learn and abandon plants that offer little or no nectar in their flowers; flowers, in turn, exhibit shapes that force pollinators to brush against pollen on their route to hidden rewards whose quantities cannot be easily assessed.

Mutualism Among Human Organizations

Returning to the OS example, the conflicts described above, involving misalignments of the interests of the two partners, competition for mutualistic partners, constant risk of being cheated, etc., are generally absent in the conceptualization of mutualism in the OS literature. Examples of OS studies that overlook these mutualistic dynamics are Barnett's (1990) examination of the telephone industry and Simons and Ingram's (2004) analysis of Israeli agricultural cooperatives. In both instances, the +/+ nature of mutualistic interactions are emphasized without attention to exploitative intentions or the potential for "cheating."

The exclusive emphasis on +/+ dynamics between mutualistic organizations is incomplete. Specifically, organizational leaders and actors are unlikely to engage in +/+ interactions to help *both* themselves and others. Likewise, organizations function "selfishly" according to agendas and strategic goals, cultures and routines, stakeholder needs and demands, and so on (Mintzberg et al., 2002). That is, just as in non-human systems, human mutualisms as seen in and between organizations are motivated by the pursuit, exploitation, and competition for resources, not a sense of altruism or loyalties (Ajates, 2020; Kauppila, 2010). The idea that mutualistic partners in nature are fundamentally driven by self-interest is a more critical view of mutualistic interactions between humans and the organizations they form and operate. For instance, patterns in nature can further inform how organizational scientists analyze and predict temporal trajectories of mutually beneficial interactions between organizations. Forecasting points in time when conflicts of interest are likely to emerge and better understanding the vulnerability of organizations and sectors to shifts in external conditions and environments is one such potential application. The expanded understanding of the dynamics of mutualistic interactions in nature could also help organizational science scholars (and social scientists more generally) identify and characterize otherwise overlooked behaviors and strategies, such as cheating and the prevention of and/or response to cheating.

1 Ecologists commonly refer to behaviors within nature using anthropomorphic terms such as "cheating" and "honesty" (e.g., Bronstein, 2001; Jones et al., 2015; Riehl & Frederickson, 2016). In natural settings, these terms characterize behavioral outcomes and do not assert any notions of ethics or morals within the species themselves.

Organizational scientists mostly use the concept of mutualism to study arrangements and interactions between organizations of similar type and function, as well as between those that operate along shared supply and value chains (e.g., Baum & Singh, 1994; Greve & Rao, 2012). In nature, mutualistic pairs are usually very different from each other, such that they get something from their partner that would not otherwise be obtainable (Bronstein, 2015). While the application of the mutualism metaphor to inter-organizational interactions often involves some variation between organization-types, connectiveness is typically based on similar functions, resource needs, etc. For example, consider Walker et al.'s (2011) research on member and non-member advocacy organizations or Mair and Hehenberger's (2014) examination of interactions between philanthropic firms that primarily use scripted strategies and those who rely more heavily on unscripted strategies. In both cases, there are variations in the structures and approaches of organizational types, though they share purpose, resource needs, and stakeholder targets. Such commonalities are more likely to push inter-organizational competition over time, given the mutual pursuit of the same resources and outcomes—yet this insight goes overlooked. In nature, species in the same populations are more likely to compete for a mutualistic partner, than overexploit that partner over time to gain the needed resources more efficiently.

New directions in ecology show non-human mutualistic interactions can over time become exploitative to include, for instance, cheating behaviors (Wechsler & Bascompte, 2022). Organizational scholars and other social scientists have yet to integrate this more fluid perspective with their work that uses the mutualism metaphors to study and explain the dynamics that shape individual and collective interactions. It is challenging for researchers to stay current in their own fields, as well as in the disciplines from which they source metaphorical perspectives. Interdisciplinary collaborations such as ours can help make sure that the understanding of a concept from a different disciplinary area is understood in the context of the most recent scholarship.

Commensalism

Commensalisms are +/0 interactions in which one partner benefits and the other is neither benefited nor harmed (recall Table 2). Commensalism is much more poorly understood than mutualism, probably far more common in nature, and generally dismissed (with minimal justification) as being rather trivial. Mathis and Bronstein (2020) identify two different forms of commensalism. In the first form, "no-effects commensalism," the unaffected party experiences neither costs nor benefits from associating with a partner. A familiar example is represented by vines that twine up trees to reach the sunlight: The vines benefit, whereas the trees they need for support are neither benefited nor harmed. The second form is "balanced-costs-and-benefits commensalism." Here, the unaffected partner does experience costs and benefits from associating with another species, but these exactly balance each other out. For example, some plants produce costly food rewards for ants, which in return attack small herbivores such as caterpillars, protecting the plants from damage. When herbivores are relatively rare, the cost to the plant of producing food for the ants and the benefit the ants provide to the plant in return can be equal but opposite in direction; in this situation, the ants experience a benefit from the interaction (they get food), but the plants are neither benefited nor harmed (Chamberlain & Holland, 2008).

Ecologists recognize the difficulty of distinguishing between mutualisms and commensalisms in nature. To do so requires quantifying the effects of an interaction on both partners, an approach that is surprisingly rare (Bronstein, 1994; Mathis & Bronstein, 2020). More commonly, the effects on one partner are measured, while the effects on the others are simply estimated. There are many cases in which interactions once thought to be mutualisms were subsequently shown to be commensalisms, and vice versa. Furthermore, under some ecological conditions an interaction can be mutualistic while in other conditions it can be commensal. In the example above, the frequency of caterpillars might determine whether the ant-plant interaction is a mutualism or commensalism. The key point here is that it can be very difficult to confidently assign an ecological interaction a single name. Interactions are highly dynamic.

Commensalism Among Human Organizations

The ecological definition of commensal interactions as embodying a +/0 outcome is rarely, if ever, reflected in the OS literature that uses this term. The etiology of this disjuncture begins with Hawley's (1950) foundational work on human ecology, in which commensalism is characterized as humans, whether as individuals or organizations, "eating from the same table" (p. 39). The term commensalism derives from the Latin *cum mensa* ("at the table of"). It was used as early as the Middle Ages to refer to individuals who ate at the king's table but provided him no service in return; it entered the ecological literature in the 1870's to mean an interaction that benefited one of two partners only, in explicit contrast to mutualism (Mathis & Bronstein, 2020). Following Hawley (1950), however, the OS literature has interwoven the terms commensalism and mutualism in a variety of idiosyncratic ways. For example, Audia et al. (2006) show a positive association between entrepreneurial firm populations that are formed and sustained by mostly commensal relations and new start-up activities. In their interpretation of this finding, the authors directly associate commensalism with "mutualistic effect(s)" (p. 391). Such conflation of commensalism and mutualism is repeated or implied elsewhere in the OS literature (e.g., Barnett & Carroll, 1987; Dobrev et al., 2006; Haveman et al., 2001; Kuilman & Li 2009; Ruef, 2000; Xu et al., 2014).

Organizational scientists at times interpret commensalism in ways that subsume interactions that involve either competition or cooperation. As such, commensalism is used interchangeably to describe interactions in which both sides either benefit or lose, departing from the ecological definition of commensalism, in which one side gains from an interaction and the other side experiences no effects. Astley and Fombrun (1983) capture the spirit of this usage when stating, "Commensalism is exhibited both in competitive interaction, as when chickens rival for food thrown into their pen, and in cooperative interaction, as when antelopes herd together to increase their immunity from attack by enemies" (p. 578). Other examples in which organizational scientists apply the term commensalism to interactions in which each side either gains or loses include Oliver's (1988) study of isomorphic tendencies among volunteer social service agencies and Dobrev and Kim's (2006) examination of sector shifts in the American auto industry.

The use of the commensalism concept in the OS literature once again implies intentionality. Phrases that connote intentionality include "similar organizations work together [commensalistically] in concerted political action" (Barnett & Carroll, 1987, p. 401), "collectively reinforce the boundaries around the shared resource space [through commensalistic relations]" (Dobrev & Kim, 2006, p. 236), and "a commensal collective is the perception of the benefits of pooled action and the decision to act as one for them" (Carney, 1987, p. 346). These phrases imply intention via the motivation to create a collective good (or at least the perception of a collective good). Such motivation and strategy would not be observed in nature nor considered in a strictly ecological analysis. Accordingly, the ecological contribution to the metaphor in these examples is diluted to accommodate a key difference between human and non-human species—acting with strategic intent.

Symbiosis

Recapping, ecologists commonly divide up pairwise interactions according to whether the effects on each species are positive, negative, or neutral. Categorizations like this serve to highlight similarities between interactions that might not otherwise be thought to resemble each other. There are other ways to partition the universe of possible interactions, however. Another common approach is to divide interactions according to whether an organism is so dependent upon a partner that survival apart from it is impossible, or alternatively, whether each organism can survive without the other. The former interactions (for example, humans and the bacteria found in our guts) are termed *symbioses*; the latter interactions (for example, plants and their pollinators) are non-symbiotic or free-living (Bronstein, 2015). But symbioses are not simply highly specialized, obligatory interactions. Rather, they are also distinguished by the feature that symbionts live inside their partner species (their "hosts").

Note that the term "symbiosis" is not present in the classic grid of pairwise interactions (see Table 2)—it is a term that describes a *lifestyle*, not an *interaction outcome*. Symbioses always benefit the symbiont, but the host can benefit, be harmed, or be entirely unaffected. Thus, it could fit into any of the categories in the top row or the first column of Table 2. With that said, "mutualism" and "symbiosis" have been confused almost since the two terms were coined in the 1870's (Bronstein, 2015). In nature, some mutualisms are symbiotic whereas others are not, and some symbioses are mutualistic whereas others are not.

Symbiosis Among Human Organizations

Organizational scientists loosely use the symbiosis concept at several levels. At the organization (or species) level, individuals are depicted as symbionts who develop their identities and support their activities using the resources made available to them from through the organizations in which they work (Kaplan et al., 2017). At the population level, organizations that create strategic connections with similar entities that have access to the resources needed to fend off competitive threats have also been referred to as symbionts (Astley & Fombrun, 1983; Carney, 1987). At the ecosystem level, symbiosis is sometimes used to depict relationships between various firms positioned along a shared supply chain who exchange resources in ways that create and maximize opportunities within a shared geographic proximity and marketspace (Ashton, 2008). None of these and similar usages is consistent with the ecological meaning of these terms.

Like some ecologists, organizational scientists have used "symbiosis" and "mutualism" interchangeably (Carroll, 1981; Abrahamson & Fombrun, 1994; Hannan & Freeman, 1977). In a study of environmental strategy in the U.S. brewery sector, Boeker (1991) contrasts competition as a +/– interaction with symbiosis as a +/+ interaction. Moreover, the association between symbiosis and mutual benefit leads organizational scientists to repeatedly suggest that symbiotic interactions are in opposition to those that involve competition, rather than—as the ecological literature documents—competition shaping symbiosis itself. In a study of national education systems, Carroll (1981) suggests that systemic-level competition compromises the potential for symbiosis between different types of schools within a shared system. In a later essay that reviewed the organizational ecology literature of the time, Carroll (1984) again drew a clear distinction between symbiosis and competition, with the former being limited to +/+ relations and the latter –/– relations. In a study of hospital federations, D'Aunno and Zuckerman (1987) similarly argued that symbiotic linkages are limited to relations that are mutualistic in nature, and thus devoid of competition. These three examples illustrate a past tendency of organizational scientists to use symbioses as another name for mutually beneficial interactions. Missing here is the ecological reality that competition can take place between symbionts associated with the same host, or less commonly between a host and symbiont (Ghosh et al., 2022). Likewise, mutual benefit is not a universal characteristic of symbiosis in nature with some symbioses producing benefits for only one of the two partners.

In nature, symbioses often, although not always, involve dependency between hosts and symbionts with the degree of dependency varying greatly between partners and across systems (Fisher et al. 2017). Dependency (either unilateral or bilateral) as a central element of symbiotic interactions is sometimes acknowledged in the OS literature, though not always in alignment with ecological understanding. In a study of direct foreign investments in emerging market firms, Xia et al. (2014) indicate that mutual dependency is a fundamental trait of symbiosis, which is an ecologically flawed assertation (as we have clarified above). As an example, consider the negative effects of algorithm changes by such social media marketing platforms as Amazon and Facebook (i.e., hosts) on small businesses (i.e., symbionts) whose online presence becomes lost within newly refined search engines (Nambisan et al., 2018).

There are instances in which organizational scientists frame organization-centered strategies and conflicts of interest as indicators of competition within symbioses. For instance, Martin and Siehl (1983) characterize the oppositional dynamic between dominant cultures and countercultures within organizations and sectors as "an uneasy symbiosis" (p. 54). Similarly, in a study of leadership roles in collaborative innovation, Davis and Eisenhardt (2011) raise the potential for conflict between otherwise collaborative (and thus symbiotic) firms due to the power and influence of distinct, contradictory processes within each firm. As these two examples show, organizational scientists do sometimes draw on the concept of symbiosis in ways consistent with the ecological meaning of the term: Specifically, the potential for conflict and competition is explicitly acknowledged. Nevertheless, these interactions neither take place between different species nor are physiologically intimate. "Pairwise interaction" would be a ecologically more appropriate term for what these authors otherwise effectively capture in ecological terms.

Concluding Remarks

So, how does our exploration of ecological metaphor applications in the organizational science literature inform interdisciplinary studies? Lord Ernest Rutherford, a Nobel laureate in physics, states, "all science is either physics or stamp collecting." This perspective highlights a disciplinary pecking order that drives scholars in less established, more fluid disciplines to seek credibility and grounding from better established, more substantial counterparts (Gallagher & Appenzeller, 1999; Urbanska et al., 2019). In the case presented here, OS falls in the latter camp as a body of scholarship positioned at the intersection of a variety of more "pure" social science disciplines (e.g., economics, psychology, sociology), resulting in a remarkable range of conceptual and methodological creativity and experimentation (Biscaro & Comacchio, 2018; Tsoukas, 1991; Zahra & Newey, 2009). While often celebrated, these same characteristics threaten to stunt scientific progress and theoretical maturation, with scholars opting to pursue creativity and interesting conjectures and provocations over deeper, more interdisciplinary dives into existing theoretical propositions and lines of inquiry (Pfeffer, 1993). Equally concerning, biases held within disciplines with higher perceptions of prestige and status (i.e., "hard sciences") against what are thought to be their less prestigious counterparts (i.e., "soft sciences") work against productive interdisciplinary collaborations such as what we have demonstrated here (Urbanska et al., 2019).

Consistent with Klein's (2021b) call for breaking down disciplinary boundaries that so often hinder productive interdisciplinary collaborations, we ourselves, one of whom is a sociologist and the other an ecologist, see more up sides than down sides to interdisciplinary metaphor development and adoption. On the one hand, the expressive value of metaphors can make complex and/or abstract concepts and principles more accessible and engaging to wider audiences (Swedberg, 2020). On the other hand, these figurative tools, like interdisciplinary research more generally (Zahra & Newey, 2009), have the potential to open fresh perspectives, raise new questions, and refine existing lines of inquiry, that is, heuristic value (Darbellay, 2012). Recall the example of the Tree of Life metaphor discussed above.

Interdisciplinary heuristic value depends on deliberately integrating the original meaning of the source concept(s) with the theories and models being used to study target phenomena, and clarifying and articulating the conceptual adaptations being made during a synthesis. Researchers must willingly and openly extend their thinking beyond their own individual disciplinary boundaries to find and intellectually capitalize on common ground (Newell, 2007). Indeed, conceptual clarity and articulation is far more important than literal interpretation and the quest for rigid parallels. Such clarity and articulation, in our experience and consistent with the views of others (Hübenthal, 1994; Keestra, 2017; Klein, 2004, 2021a, 2023), depends largely on interdisciplinary collaboration and extension. In our own work, we have spent many hours identifying, debating, and refining synergies with the shared intent of making the application of biological metaphors to human organization and system contexts more meaningful and productive. As an example, the distinction between the instincts of non-human species in nature and the intentions of humans within organizations and systems has been a recurrent point of debate, discussion, and negotiation. It would be relatively easy for an ecologist to quickly dismiss the appropriateness of biological metaphors given species in nature do not act with strategic purpose. Conversely, it may be tempting for a sociologist to overlook or brush aside the instinct-over-intention dynamic in nature to accommodate current, albeit shallow applications of biological metaphors. Resisting both tendencies, we have come together as interdisciplinary colleagues to productively confront and work through the stickiness of this intellectual task. In doing so, we have discovered and pursued deeper questions (heuristic value), such as how competitiveness actually influences more than it hinders collaboration between organizations (Mars & Bronstein, 2018). We have also been able to simplify and more clearly explain abstract and opaque dynamics (expressive value), such as how the entanglement of various organizational types bring resiliency to systems as nestedness does within natural ecosystems (Mars et al., 2012; Mars & Bronstein, 2018).

Nevertheless, change can be very challenging in any human context, with scholarly research, in the broadest sense, being no exception. Researchers often become gatekeepers who protect conventional wisdoms rather than stewards of knowledge creation and theoretical progress (Crane, 1967; DeGrazia, 1963; Keestra, 2017). Yet, conceptual paradigms and theoretical understanding can and do change over time (Darbellay, 2012). Agreeing with Kuhn (1993), we see promise in the role of metaphors as constructive mechanisms of scholarly imagination that "lie at the heart theory change and transmission" (Ortony, 1993, p. 14). This perspective reinforces one of the two goals we set out to reach at the onset of the essay—to inspire more rigorous development and applications of metaphors by modeling rigorous interdisciplinary collaboration and extension.

In summary, we call for more collaboration among those who study human organizations and those in otherwise isolated disciplines—such as the effort we have put forward here as a sociologist and ecologist. Our experiences collaborating on this essay and working together on earlier projects convince us that the understanding and meaningful application of ecological metaphors to human phenomena are best pursued through true interdisciplinary partnerships. We are recommending the formation of mutualistic interactions between researchers in otherwise isolated fields with the mutual benefits being the reframing of persistent questions and the development of exciting new lines of inquiry within one or more of the representative disciplines. Of course, interdisciplinary collaborations may be commensal in nature, with one discipline benefiting and the other neither gaining nor losing from the collaboration. The intellectual stimulation that we have both experienced through our collaborative work leads us to believe that +/+ outcomes are more likely than +/o ones, and certainly far more likely than +/–.

Biographical Notes

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Judith L. Bronstein, PhD, is University Distinguished Professor of Ecology and Evolutionary Biology at the University of Arizona and a Member of the American Academy of Arts and Sciences. Dr. Bronstein's research focuses on the ecology and evolution of interspecific interactions, particularly on the poorly-understood, mutually beneficial ones (mutualisms). Using a combination of field observations, experiments, and theory, Dr. Bronstein's lab examines how population processes, abiotic conditions, and the community context determine net effects of interactions for the fitness of each participant species. Specific conceptual areas of interest include: (i) conflicts of interest between mutualists and their consequences for the maintenance of beneficial outcomes; (ii) the causes and consequences of "cheating" within mutualism; (iii) context-dependent outcomes in both mutualisms and antagonisms; and (iv) anthropogenic threats to mutualisms. Dr. Bronstein's recent empirical work has focused on exploited pollination mutualisms in deserts, desert grasslands, and montane habitats in Arizona and Colorado. More generally, she works towards developing a strong conceptual foundation for the very young study of mutualistic interactions. She is also engaged in an interdisciplinary collaboration that explores the development and application of ecological metaphors within social science literatures.

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