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Generalizing the core design principles for the efficacy of groups

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ABSTRACT

This article generalizes a set of core design principles for the efficacy of groups that was originally derived for groups attempting to manage common-pool resources (CPRs) such as irrigation systems, forests, and fisheries. The dominant way of thinking until recently was that commons situations invariably result in the tragedy of overuse, requiring either privatization (when possible) or top-down regulation. Based on a worldwide database of CPR groups, Ostrom proposed a set of principles that broadly captured the essential aspects of the institutional arrangements that succeeded, as contrasted to groups whose efforts failed. These principles can be generalized in two respects: first, by showing how they follow from foundational evolutionary principles; and second, by showing how they apply to a wider range of groups. The generality of the core design principles enables them to be used as a practical guide for improving the efficacy of many kinds of groups.

1. Introduction

Hardin's (1968) classic paper "The Tragedy of the Commons" provides a vivid parable of a social dilemma. In an imaginary village, he posits that farmers are free to graze their cows in a commonly owned pasture. The pasture can only support so many cows, but each farmer can gain by adding more of *their* cows to the herd, resulting in the tragedy of overuse. The import of Hardin's article needs to be understood against the background of the times. Many economic theorists were guided by the metaphor of the invisible hand, which asserts that individual self-interest typically promotes the common good. We cannot improve upon Hardin's wording (Hardin, 1968, p. 1244):

> In economic affairs, *The Wealth of Nations* (1776) popularized the "invisible hand", the idea that an individual who "intends only his own gain," is, as it were, "led by an invisible hand to promote. . .the public interest". Adam Smith did not assert that this was invariably true, and perhaps neither did any of his followers. But he contributed to a dominant tendency of thought that has ever since interfered with positive action based on rational analysis, namely, the tendency to assume that decisions reached individually will, in fact, be the best decisions for an entire society.

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In other words, the very concept of individual self-interest leading to societal dysfunction occupied a marginal position in the thought of many economic theorists. When this possibility was acknowledged, privatization (when possible) or top-down regulation were envisioned as the only solutions.

Hardin's field of ecology also had a history of naïve expectations that evolution results not only in individual-level adaptations, but also well-regulated populations, efficient ecosystems, and a harmonious balance of nature. During the same period in which Hardin published his article, these expectations were in the process of being severely challenged by evolutionists such as George C. Williams, whose book *Adaptation and Natural Selection* was published in 1966. According to Williams, adaptations that are "for the good of the group" are seldom selectively advantageous within groups and require a process of group-level selection to evolve. Moreover, Williams claimed that between-group selection is seldom strong enough to counteract within-group selection, so that tragedies of the commons should be the most common state of nature. Hardin and Williams were thus part of a movement within the biological sciences questioning the very existence of higher-level functional organization (Sober and Wilson, 1998).

Given the importance attached to the conclusions presented by Hardin (1968) and the historical influence of neoclassical economics in policy dialogs, the work of Elinor Ostrom and her associates was considered groundbreaking and eventually earned her the Nobel Prize in economics in 2009 (Ostrom, 1990, 2010). The main import of Ostrom's work was to show that *when certain conditions are met, groups of people are capable of sustainably managing their common resources*. Moreover, the tragedy of overuse can be avoided without privatization or top-down regulation. Ostrom's entire career embodied this theme, starting with her thesis research on a group of stakeholders in southern California that eventually managed to regulate groundwater pumping, preventing a tragic incursion of seawater into the water table. Later, Ostrom and colleagues at the Workshop in Political Theory and Policy Analysis were instrumental in the creation of a worldwide database of groups that attempted to manage a variety of common-pool resources (CPRs) such as irrigation systems, forests, pastures, and fisheries. Drawing from empirical cases and guided by the emerging field of game theory, Ostrom identified eight design principles that enable CPR groups to effectively manage their resources, which can be briefly described as follows (see Cox et al., 2010 for the most recent in-depth discussion of the principles).

(1) *Clearly defined boundaries*. The identity of the group and the boundaries of the shared resource are clearly delineated.
(2) *Proportional equivalence between benefits and costs*. Members of the group must negotiate a system that rewards members for their contributions. High status or other disproportionate benefits must be earned. Unfair inequality poisons collective efforts.
(3) *Collective-choice arrangements*. Group members must be able to create at least some of their own rules and make their own decisions by consensus. People hate being told what to do but will work hard for group goals that they have agreed upon.
(4) *Monitoring*. Managing a commons is inherently vulnerable to free-riding and active exploitation. Unless these undermining strategies can be detected at relatively low cost by norm-abiding members of the group, the tragedy of the commons will occur.
(5) *Graduated sanctions*. Transgressions need not require heavy-handed punishment, at least initially. Often gossip or a gentle reminder is sufficient, but more severe forms of punishment must also be waiting in the wings for use when necessary.
(6) *Conflict resolution mechanisms*. It must be possible to resolve conflicts quickly and in ways that are perceived as fair by members of the group.
(7) *Minimal recognition of rights to organize*. Groups must have the authority to conduct their own affairs. Externally imposed rules are unlikely to be adapted to local circumstances and violate principle 3.
(8) *For groups that are part of larger social systems, there must be appropriate coordination among relevant groups*. Every sphere of activity has an optimal scale. Large scale governance requires finding the optimal scale for each sphere of activity and appropriately coordinating the activities, a concept called polycentric governance (McGinnis, 1999). A related concept is subsidiarity, which assigns governance tasks by default to the lowest jurisdiction, unless this is explicitly determined to be ineffective.

These core design principles were described in *Governing the Commons* (Ostrom, 1990). A recent review of studies that had accumulated since the original study provides strong empirical support for the efficacy of the core design principles with a few suggested modifications that differentiate between the resource system and those authorized to use it (Cox et al., 2010).

In this article, we show that the design principles can be generalized in two respects: First, they follow from the evolutionary dynamics of cooperation in all species and the evolutionary history of our own species. Second, because of their theoretical generality, we argue that the principles have a wider range of application than CPR groups and are relevant to nearly any situation where people must cooperate and coordinate to achieve shared goals. For both of these reasons, the principles can be used as a practical guide for increasing the efficacy of groups, although local tailoring is usually required for their implementation.

2. The commons situation from an evolutionary perspective

2.1. The basic problem of conflicts between levels of selection

Although neoclassical economic theory does allow for the existence of faulty information through externalities and other market failures, it is centered on the notion that, by and large, the decisions of individuals with self-regarding preferences result in the best global outcomes. In contrast, sociobiology, the study of social behavior in all species from an evolutionary perspective, stresses that as a basic matter of tradeoffs, maximizing relative fitness within a group seldom maximizes the fitness of the group. In other words, sociobiology is centered on the "tragedy of the commons" situation identified by Garrett Hardin in his famous essay.

Like sociobiology, game theory is centered on situations in which cooperative strategies are vulnerable to more self-serving strategies and the outcome of individual choice does not necessarily maximize the public good. Although game theory was originally framed in terms of the decisions of narrowly rational actors, it is now framed by many theorists as a Darwinian process in which alternative strategies compete against each other and the most successful strategies increase in frequency in the population. The underlying mechanism of replication is conceived in abstract terms and can include genetic inheritance, blind imitation, operant conditioning, or conscious thought. Any mechanism that causes the most successful strategies to increase in frequency results in the same outcome. In this sense, game theory is strongly related to evolutionary theory (Gintis, 2007, 2009).

2.2. Multilevel selection theory

A theoretical framework called multilevel selection (MLS), which includes evolutionary game theory as a special case (Okasha, 2006; Sober and Wilson, 1998; Wilson and Wilson, 2007; Wilson, 2011a), is useful for studying the commons situation in general terms. MLS theory assumes that an evolving population of individuals is subdivided into groups within which social interactions occur. Within each group, natural selection favors the strategies that maximize the fitness of individuals, relative to other members of the same group. The metric is relative fitness, not absolute fitness. A strategy that increases the fitness of everyone in the group to an equal degree, at no cost to the individual provider, is neutral from the standpoint of within-group selection. If there is any cost to providing the public good, then the individual provider is at a relative disadvantage, no matter what its net absolute fitness gain. The logic of maximizing relative fitness within groups is captured by a folk tale in which a genie offers a man a wish, with the provision that his neighbor will get double. "Put out one of my eyes", the man replies.

If a strategy that is "for the good of the group" does not maximize relative fitness within the group, can it nevertheless evolve in the total population? Yes, but only by adding another level to the process of natural selection. Groups of public good providers will survive and reproduce better than groups of free-riders, even if public good providers are less fit than free-riders within any mixed group. Whenever within-group selection and between-group selection favor different strategies, what evolves in the total population depends upon the relative strength of the two levels of selection, which in turn depends upon a number of factors. Sometimes one level prevails, resulting in a homogenous population of public good providers (when between-group selection prevails) or free-riders (when within-group selection prevails). In other cases, frequency-dependent effects cause a mix of types to coexist in the total population. In these cases, the public good providers are always at a relative fitness disadvantage within their own groups and the only way to explain their persistence in the total population is by increasing the scale of the comparison to the level of groups. When social interactions result in multiple locally stable equilibria, then group-level selection can favor the most group-functional equilibrium, resulting in a final outcome that is both "for the good of the group" and internally stable (Boyd et al., 2011).

MLS theory can be used to examine a wide range of population structures that vary in their particular assumptions about how groups form, how long they persist, the particular form of competition among groups, and so on. All evolutionary models of social behavior embody the logic of multilevel selection, insofar as they assume that social interactions take place in groups that are small compared to the total population. In a typical N-person evolutionary game theory model, for example, the total population consists of many groups of size N that form at random. Social interactions take place within each group, sometimes for a number of iterations, before the members (or their descendents) disperse to form new groups. Cooperative strategies typically have a relative fitness disadvantage within groups and evolve only by virtue of groups with more cooperators differentially contributing to the total population. At a larger spatial and temporal scale, Turchin (2005) has used MLS theory to explain the rise and fall of empires. Extreme between-group competition acts as a crucible for the cultural evolution of cooperative societies, which expand to become empires. Then cultural evolution within the empires favors self-serving strategies that eventually result in collapse. MLS theory can also be extended from two levels to multiple levels. It can be extended downward to explain the evolution of cooperation and exploitation among genes within organisms (Burt and Trivers, 2006), and upward to include the evolution of coalitions among groups (Richerson and Boyd, 1999, 2005) or the selection of multispecies ecosystems (Day et al., 2011; Swenson et al., 2000).

2.3. Factors that favor group-level adaptations

Williams (1966) was right when he pointed out that group-level adaptations seldom maximize the relative fitness of individuals within groups and therefore require group-level selection to evolve. He was wrong when he claimed that between-group selection is seldom strong enough to counteract within-group selection. Today we know that the balance between levels of selection can be influenced by a large number of factors. Group-level selection is frequently a significant evolutionary force and can even become the dominant force when certain conditions are met (Sober and Wilson, 1998; Wilson and Wilson, 2007; Frank, 2012a,b). The question then arises, what are some of the factors that cause between-group selection to trump within-group selection?

One set of factors involves the partitioning of genetic variation within and among groups. Consider a model in which altruism and selfishness are coded by two alleles at a single locus, with the altruistic allele at a frequency of p in the total population. Imagine distributing the individuals into groups of size N such that the frequency of the altruistic allele within every group is also p. Since there is no variation between groups, within-group selection is the only evolutionary force and selfishness will evolve. Now imagine distributing the individuals into the groups such that p groups are composed entirely of altruists and $(1-p)$ groups are composed entirely of selfish individuals. Because there is no variation within groups, between-group selection is the only evolutionary force and even extreme altruism will evolve. The partitioning of genetic variation in actual multi-group populations falls between these two extremes. Random variation creates a partitioning dictated by the binomial distribution. A number of factors can create above-random variation among groups, including genealogical relatedness and selective partner choice. Groups of aphids that grow by asexual reproduction from single founding females reach the extreme of within-group homogeneity and between-group variation. In mobile species that are capable of partner choice, when individuals are allowed to choose (and refuse) their social partners and are provided with enough information, behavioral sorting can approach the extreme of clonal reproduction (Aktipis, 2004; Pepper, 2007; Wilson and Dugatkin, 1997).

A second set of factors involves the severity of the conflict between levels of selection. In cases where benefitting the group requires extreme self-sacrifice, then between-group selection must be strong enough to counteract strong within-group selection. At the opposite extreme, behaviors that benefit the whole group at no cost to the individual provider are neutral with respect to within-group selection and will evolve given any variation among groups. Large group-level benefits at small individual cost can evolve with modest variation among groups that characterize many group-living species (Wilson, 1990).

A third set of factors involves complicating the genotype-phenotype relationship. Virtually all of the classic evolutionary models of social behavior assume that behaviors are coded directly by genes, if only as a simplifying assumption. A consequence of this assumption is a strong correlation between *genetic* variation among groups and *phenotypic* variation among groups. When real groups of organisms are created under carefully controlled laboratory conditions, the amount of phenotypic variation among groups is often much greater than one would expect on the basis of these models. The reason is because the phenotypic traits are not coded by single genes but by numerous genes, which code for component traits that interact with each other and the environment in a non-linear fashion. These complex interactions cause groups that vary only slightly genetically to become much more variable phenotypically (the same is true for variation among individuals, where a single genetic mutation can be amplified by development to have a large phenotypic effect). Moreover, when groups are selected for their phenotypic properties in the laboratory, there is typically a response to selection and heritability for group-level traits can be even greater than for individual-level traits (Bijma and Wade, 2008; Goodnight and Stevens, 1997; Wilson, 2005). For this reason, group selection has become a proven method in animal and plant breeding for traits such as egg productivity in hens and low stress in pigs under high density conditions (Muir et al., 2010; Turner, 2011).

A fourth set of factors involves the evolution of rewards and punishments that alter the costs and benefits associated with a given social strategy. Rewarding altruism can make it individually advantageous and punishing selfishness can make it individually costly. Given the existence of such a social control system, the presence of altruism and absence of selfishness become easy to explain—but we still must explain how the social control system evolves. In most cases, the rewards and punishments are themselves public goods provided at private expense, requiring between-group selection to explain *their* evolution (Boyd and Richerson, 1992; Fehr and Gächter, 2002; Sober and Wilson, 1998).

Given so many factors that influence the balance between levels of selection, the categorical statement that lower-level selection invariably trumps higher-level selection appears naïve in retrospect. Instead, the balance between levels of selection needs to be determined on a case-by-case basis.

2.4. Major evolutionary transitions

The balance between levels of selection is not static but can itself evolve. When between-group selection sufficiently dominates within-group selection, groups become so cooperative that they qualify as higher-level organisms in their own right. This outcome is called a major evolutionary transition and was first proposed by cell biologist Lynn Margulis to explain the evolution of nucleated (eukaryotic) cells as symbiotic communities of bacterial (prokaryotic) cells (Margulis, 1970). It was generalized by Maynard Smith and Szathmary (1995, 1999) to explain the first bacterial cells, multicellular organisms, eusocial insect colonies, and perhaps even the origin of life itself as groups of cooperative molecular interactions. The fact that individual organisms are highly regulated social groups, whose members previously led a more independent existence, is one of the most important discoveries in the history of evolutionary thought.

There are three hallmarks of a major evolutionary transition. First, it is a rare event. Eusociality is estimated to have originated in insects only about a dozen times (Wilson and Hölldobler, 2005; Hölldobler and Wilson, 2009). Second, it has momentous consequences once it occurs, as the new super-organism becomes ecologically dominant. After they originated, eusocial insect species diversified and became so ecologically dominant that they comprise over half the biomass of all insects on earth. Third, a major transition is never complete. Within-group selection is only suppressed, never entirely eliminated, and it is suppressed only by virtue of an arsenal of mechanisms that keep it under control.

2.5. Human biocultural evolution as a major transition

It is becoming increasingly clear that the human species qualifies as a major transition (Boehm, 1999, 2011; Haidt, 2012; Richerson and Boyd, 2005; Steffen et al., 2011; Turchin, 2005; Wilson, 2011b, 2012b). We are distinctive among primates in our degree of cooperation among nonrelatives, in our capacity for symbolic thought, and in our capacity to transmit learned information across generations. The latter two capacities are themselves forms of cooperation. Thus, the entire package of distinctive human traits can be attributed to a shift in the balance between within- and between-group selection, causing groups to be selected primarily for their degree of teamwork.

All of the hallmarks are present: It was a rare event, occurring only once among primates. It had momentous consequences once it occurred; we are the dominant species on the planet, for better or for worse. It is far from complete; within-group selection still operates and anti-social behaviors are suppressed to the degree that they are only by virtue of an arsenal of social control mechanisms that keep them under control.

Unlike eusocial insect colonies, which appear to have originated as single families and therefore had a high degree of genetic variation among groups, the human major transition probably began with groups that consisted of a mix of relatives and non-relatives (Hill et al., 2011). Between-group selection became strong relative to within-group selection primarily on the basis of social control mechanisms that suppressed within-group selection and cultural mechanisms that amplified phenotypic variation among genetically similar groups. For example, in a species that is psychologically adapted to adopt and enforce behavioral norms, groups can become phenotypically completely different (by adopting different norms) even when they are genetically identical (Boyd and Richerson, 1992; Wilson and Kniffin, 1999).

The human capacity for cooperation, including the cultural transmission of learned information, enabled our ancestors to spread out of Africa and colonize the entire planet, adapting to all climatic zones and hundreds of ecological niches. With the advent of agriculture, the scale of cooperative human groups increased by orders of magnitude, largely by a process of between-group cultural evolution. Genetic and cultural evolution have influenced each other throughout our history as a species, making us a product of biocultural coevolution (Richerson and Boyd, 2005).

Based on this brief summary of MLS theory, we can now return to the core design principles identified by Ostrom and her associates for CPR groups.

3. The core design principles from an evolutionary perspective

When viewed from a multilevel evolutionary perspective, the core design principles identified by Ostrom and her associates for CPR groups provide an ideal social environment for the evolution of group-level adaptations in any social species and for a wide range of contexts in our own species. Let's examine each design principle in turn.

(1) *Clearly defined boundaries*. All examples of major evolutionary transitions involve groups with clear boundaries, such as the cell wall for cells and nests for eusocial insects. Wilson (2012b) has conjectured that the campfire provided the equivalent of a nest for our own species. Regardless of this particular conjecture, ancestral human social interactions were typically conducted in small groups whose membership (e.g., those present), objectives (e.g., hunting, gathering, raiding and migrating), and their actions were obvious to everyone.

The population structure of hunter-gatherer societies described in the ethnographic literature is typically quite fluid, with individuals participating in many groupings depending upon the context (Boehm, 1999, 2011; Hill et al., 2011). This might seem like an absence of clearly defined boundaries, but the important criterion is for the identity of the group and the parameters of the shared endeavor to be clearly delineated *within each context*. The rules, rights, and obligations that apply to one context (e.g., a group of men raiding another village) need not apply to other contexts (e.g., the same group of men hunting). In addition, a fluid population structure can enhance group-level selection, as when cooperators form groups that exclude cheaters. Our species is especially adept at participating in multiple groups simultaneously, with clearly defined parameters for each group.

(2) *Proportional equivalence between benefits and costs*. When costs and benefits are not proportional, some members of the group benefit at the expense of others (within-group selection) and group-level selection must be correspondingly strong for group-level adaptations to evolve. When costs and benefits are proportional, then selection differentials within the group are eliminated and between-group selection is unopposed. People have a sophisticated ability to establish equivalence with the help of social conventions enforced by rewards and punishment. As an example, consider a context in which one person must perform a dangerous activity to benefit the group, a highly disproportional distribution of costs and benefits. The social convention of drawing straws establishes proportionality by equalizing the probably that any particular member will bear the cost. In general, the more proportionality is established within groups, the stronger between-group selection will be, relative to within-group selection.

(3) *Collective-choice arrangements*. Consensus decision-making provides a safeguard against decisions imposed by some members of the group at the expense of others, since group members will not agree to arrangements that place them

at a disadvantage. In addition, when group-level decision-making is structured the right way, it can lead to better outcomes than individual-level decision-making (Van Vugt and Ahuja, 2011; Wilson, 1997; Wilson et al., 2004). Group-level decision-making is itself a group-level adaptation.

(4) *Monitoring*. Earlier we stated that within-group selection is suppressed only by virtue of an arsenal of mechanisms that keep it under control. Monitoring is an essential part of the arsenal.
(5) *Graduated sanctions*. One reason that we are a highly group-selected species is because group members can impose extreme costs on miscreants at low cost to themselves. A miscreant can be expelled from the group, for example (a virtual death warrant during earlier times), merely on the basis of a consensus decision. Given such power of the group over each member, gentle reminders can be extremely effective, although more potent sanctions must be waiting in the wings.
(6) *Conflict resolution mechanisms*. As with proportional equivalence and collective-choice arrangements, fair conflict resolution mechanisms act as a safeguard against exploitation within groups.
(7) *Minimal recognition of rights to organize*. This design principle only becomes relevant in large-scale societies composed of subgroups. For the vast stretch of our evolutionary history, all groups were small groups responsible for their own organization. In a modern context, relations among groups are a matter of multi-tier cultural evolution.
(8) *For groups that are part of larger social systems, there must be appropriate coordination among relevant groups*. This design principle is also restricted to large-scale societies and can be best understood in terms of multilevel selection operating on a multi-tiered population structure.

To summarize, when a group possesses the core design principles, the opportunities for some members to benefit at the expense of others become extremely limited. Succeeding as a group becomes the only remaining option. This is the basic requirement for a major evolutionary transition in any species. There is a striking correspondence between the principles derived by Ostrom for CPR groups and the conditions that caused us to evolve into such a cooperative species in the first place.

3.1. Clarifying the concept of core design principles

Earlier we described four sets of factors that can cause between-group selection to trump within-group selection. The core design principles identified by Ostrom for CPR groups are a subset of these factors. The core principles are not required for between-group selection to operate strongly, as long as other factors intervene. For example, groups whose members are closely related genealogically, or who have amply demonstrated their altruistic tendencies to each other, are likely to cooperate without requiring monitoring, sanctions, and so on. Emergency situations that result in huge benefits of cooperation and trivial incentives to cheat likewise do not require some of the core design principles. The most comprehensive guide for understanding and constructing cooperative social environments is MLS theory as a whole (or an equivalent theoretical framework; see Wilson, 2008). Nevertheless, we think that the core design principles are still useful to keep in mind because they apply to most human groups whose members are not close relatives, proven friends, or coping with a dire emergency. In many human social situations, the core design principles are required to accomplish shared objectives.

The general capacity to cooperate does not specify how to achieve any particular shared objective, such as hunting, childcare, or warfare in an ancestral context or managing an irrigation system, a business, a classroom, or a government in a modern context. The specific objectives of a group will require auxiliary design principles in addition to the core design principles, as we will show in the next section.

3.2. The distinction between design principles and their implementations

Any design principle, core or auxiliary, can be potentially implemented in more than one way. For example, monitoring can be accomplished by hiring a person to monitor, by taking turns, by installing surveillance cameras, and so on. The distinction between a design principle and its implementation is equivalent to the distinction between ultimate and proximate causation in evolutionary theory (Wilson and Gowdy, 2013). Ultimate causation explains why a trait evolves in functional terms, while proximate causation explains the specific mechanism that evolves in any particular case. Just as there are many ways to skin the proverbial cat, ultimate and proximate causation exist in a one-to-many relationship.

The importance of distinguishing between design principles (ultimate causation) and their implementations (proximate causation) is illustrated by a problem that Ostrom encountered while analyzing her database of CPR groups (Ostrom, 1990). At first she tried to correlate the performance of the groups with specific implementations, without success. The reason is easy to understand in retrospect: If there are 10 successful ways to monitor (for example), then the correlation between any one way and group performance will be weak. Only when she combined different implementations into functional categories was she able to demonstrate a strong association between the design principles and group performance.

Another reason to distinguish between design principles and their implementation is that while the design principles can be specified in general terms, the specific implementations cannot. For example, most groups will require monitoring but groups will probably vary in the particular form of monitoring that works best for them, depending upon local circumstances.

For this reason, the design principles cannot be implemented in a cookie cutter fashion but require a process of local adaptation to find the best implementations.

4. Using the core design principles to improve the efficacy of groups

The generality of the core design principles suggests that they can be used as a practical guide to improve the efficacy human groups. Any group whose members must work together to achieve shared goals could potentially benefit. Before providing examples, we need to address a paradox: The core design principles are easy to understand without formal theoretical justification. They have comprised the human social environment for most of our evolutionary history. One might think that human groups would spontaneously adopt them, but this is not the case.

The CPR groups studied by Ostrom and her associates *varied* in the degree to which they employed the design principles, with corresponding variation in their ability to govern their commons. The failure of some groups to employ the design principles allowed Ostrom to demonstrate their efficacy. In addition to variation among existing groups, some groups fail so badly that they cease to exist altogether and aren't available to be studied. Even groups that adopted the design principles often did so by a trial and error process, converging on the same functional solutions in different ways. They were doing the right thing, but did not necessarily know why it was right.

When we survey other kinds of groups, such as governments, businesses, schools, neighborhoods, and volunteer organizations, we also see enormous variation in how well they work and the degree to which they employ the core design principles. A formal analysis would be required to understand the relationship between the design principles and the performance of these groups, comparable to what Ostrom and her associates undertook for CPR groups. The main point that we are trying to establish here is that the design principles are not so obvious or instinctive that all groups quickly converge upon them. As a result, there is enormous room for improvement in the efficacy of groups of all sorts, based upon an explicit consideration of MLS theory in general and the core design principles in particular.

We will now describe how the design principles can be applied to two contexts that go beyond CPR groups; education and urban neighborhoods.

4.1. Educational contexts for the core principles

A class is a group of people with the objective of learning a body of information. A school is a larger group with the objective of organizing a curriculum of classes. A state or a nation is a still larger group with the objective of providing a quality education for its citizens, among many other objectives. Each group in the nested hierarchy can perform well or poorly, depending upon how it is structured. A systematic study of educational groups, comparable to what Ostrom and her associates accomplished for CPR groups, is an ambitious task for the future. Here we will present a sample of case studies indicating that the same core design principles are involved, along with auxiliary principles required for the specific context of education.

We begin by observing that many classroom social environments are deficient in the core design principles. Especially when viewed from the perspective of low-performing students, there is not a strong group identity, the purpose of the group is poorly understood and does not engage interest, consensus decision-making is lacking, good behavior is poorly monitored and enforced, even the teachers are unable to organize their own activities, and the classroom is often embedded within a dysfunctional larger educational social environment.

The situation is not entirely bleak. As with CPR groups, classrooms *vary* in their efficacy, with stunning successes in addition to miserable failures. One of the best validated classroom management programs is called The Good Behavior Game (GBG), which has been refined and assessed over a period of decades and is currently employed in several thousand classrooms worldwide (see review by Embry, 2002). It includes most of the core design principles and other features that are congruent with MLS theory. The GBG begins by establishing norms of good behavior by consensus. Even first graders are able to list the appropriate dos and don'ts, but the important fact is that they are creating *their* lists and not lists arbitrarily imposed upon them by the teacher and school. Once the norms of good behavior have been established and suitably displayed in the classroom, the class breaks up into groups that compete to be good while doing their schoolwork. Groups that manage to avoid a certain number of misbehaviors receive a small reward, such as picking from a prize bowl or activities like singing a song or dancing for a minute. At first they play the game for brief periods with immediate rewards. Gradually the game lengthens and is played without being previously announced. The rewards are also gradually delayed until the end of the day or week, until the norms of good behavior become the culture of the classroom.

Not only can the GBG have a transformative effect on classroom behavior over the short term, but it has long-term effects that extend into adulthood. In a longitudinal study that began in the 1980s in the Baltimore City School District, the GBG was implemented in the first and second grades for some classrooms but not others in a randomized controlled design. No intervention took place after the second grade. By the sixth grade, students from the GBG classrooms were less likely to be diagnosed with conduct disorder, to have been suspended from school, or to be judged in need of mental health services. During grades six through eight, they were less likely to use tobacco or hard drugs. In high school, they scored higher on standardized achievement tests, had a greater chance of graduating and attending college, and had a reduced need for special education services. In college, they had a reduced risk for suicidal ideation, lower rates of antisocial personality disorder, and lower rates of violent and criminal behavior. The GBG was exceptionally effective at achieving these outcomes for boys

(Bradshaw et al., 2009; Kellam et al., 2008). Thus, at least some of the same core design principles that enable a group of farmers to effectively manage an irrigation system can cause children to embark upon a more successful trajectory through their lives.

A more radical educational success story is the Sudbury Valley School, which was founded in 1968 and has become a model for several dozen other schools worldwide (http://www.sudval.org). The governance of the school is scrupulously democratic, with students taking part in all of the major decisions, including hiring and firing of faculty. Norms of good behavior are agreed upon by consensus, monitoring is efficient, and conflicts are resolved by a judicial committee that all students and staff members are expected to take turns serving upon. Within this strong democratic and normative environment, students have complete freedom to learn what they want, without any formal courses or examinations. The adult staff facilitates the self-motivated learning by the students and provides explicit instruction when asked. A careful study tracking the alumni of the Sudbury Valley School shows that it compares very favorably to conventional schools at a fraction of the cost of a public school education, not to speak of an elite private school education (Gray and Chanoff, 1986).

In addition to embodying the same core design principles that make CPR groups efficacious, the Sudbury Valley School includes auxiliary principles that are relevant to the specific objective of education—including mixed age interactions. Learning and teaching in hunter-gatherer and many traditional societies takes place largely without formal education (Gray, 2009; Hewlett and Lamb, 2005). Instead, children spend most of their time in mixed age groups. The older children are strongly motivated to become adults and the younger children are strongly motivated to become like the older children. Learning the skills and roles of the society takes place in the context of self-motivated practice and play. The powerful effects of mixed-age interactions within a normative environment that prevents bullying and other harmful behaviors is subverted by the modern educational practice of grouping children into same-age classes instructed by adults, but used to full effect at the Sudbury Valley School.

Our third case study is a program for at-risk 9th and 10th grade high school students called the Regent Academy in Binghamton, New York, which was designed explicitly with the core and auxiliary design principles in mind (Wilson et al., 2011). To qualify for admission into the Regent Academy, students must have failed three or more classes during the previous year. Wilson and Kauffman worked with the principal (Purdy) and teachers of the academy to implement the core design principles as much as possible, given the modest resources available to the program. For example, a sense of group identity was established by housing the program at a single location (as opposed to students traveling to classes at different locations), by group identity-building activities, and by insuring that every staff member interacts with every student every day. Norms of appropriate behavior were discussed and displayed in the same fashion as the Good Behavior Game. The principal was a daily presence in the lives of the students and quickly addressed misbehaviors and conflicts using the principle of graduated sanctions. Students were involved in decision-making as much as possible, including the selection of activities during a Friday afternoon "fun club". The principal and teachers were given considerable leeway designing the program by the school district, in accordance with design principle 7. Some of the implementations were conceived at the beginning of the program, while others were worked out on the basis of experience, illustrating the importance of adapting the implementations to local circumstances.

Auxiliary design principles included establishing a safe and secure social environment and structuring activities so that long-term learning objectives were also rewarding over the short term. Fear and anxiety are important motivators for escaping harmful situations over the short term, but learning over the long term, in addition to positive personal and social development, requires a feeling of safety and security that is especially lacking in the lives of at-risk students (Frederickson, 2009). Learning seldom takes place in any species when all the costs are in the present and the benefits are in the future. Even gifted children develop their talents primarily when they enjoy what they are doing on a day-to-day basis (Csikszentmihalyi et al., 1993). The Regents Academy was therefore designed to be enjoyable on a daily basis as much as possible.

The performance of the Regent Academy students was compared to a matched sample of at-risk students in a randomized control design and to the average performance of all students in the school district. The students quickly responded to the social environment provided by the Regent Academy and greatly outperformed the comparison group by the first quarter marking period. At the end of the year, not only did the Regent Academy students greatly outperform the comparison group on the state-mandated exams, but they performed on a par with the average high school student. The Regents Academy students also improved on a number of non-academic measures, such as personal assets and family support (Kauffman and Wilson, in preparation). Very few programs for at-risk high school students succeed this well without expensive measures such as extending the school day and year.

To summarize, although more systematic study is needed, the core design principles appear to be as relevant for the context of education as for the management of common-pool resources.

4.2. Neighborhood contexts for the core principles

A neighborhood is a relatively small group of people who live close to each other and share all the common concerns that come with spatial proximity. As with CPR groups and classrooms, neighborhoods vary in how well they function as social units. The best have a strong identity, degree of trust, and a sense of what needs to be managed at the neighborhood level. One of the most consistent results of sociological research is that the ability to monitor and police activities in a neighborhood is at least as important as liking and socializing with one's neighbors (Sampson, 2004). The worst neighborhoods are not perceived as cooperative social groups at all by their residents, but rather as dangerous social environments in which one must fend for oneself. In short, while systematic study is needed, the core design principles are likely to be as relevant to neighborhoods as to schools and CPR groups.

We will describe two case studies in which the core design principles are being used as a framework for improving the quality of neighborhoods. The first is called the West Side Community Collaborative (WSCC) in Buffalo, New York (Oakerson and Clifton, 2011). Since the late 1990s, several of the neighborhoods on the West Side of Buffalo near the Niagara River were characterized by substantial deterioration of the housing stock and the invasion of drug dealers, prostitutes, and substantial decline of property values. The WSCC elected not to tackle all of the deteriorating areas at once, but instead organized individual block clubs where local residents could meet regularly, help clean up vacant lots, put in gardens, identify housing structures that substantially violated local housing codes, and work directly with city inspectors to document the most flagrant problem properties (including inspecting these properties and taking photographs). An important factor in the success of their effort was a Buffalo Housing Court judge who was willing to take strong action, if necessary, against property owners who did not take remedial actions when charged.

By acting together, neighbors living in the threatened neighborhoods, slowly reversed "the tragedy of the commons" that they faced and created a vibrant neighborhood over a period of years. They adopted most of the core design principles in this effort, as discussed below.

(1) *Clearly defined boundaries*. By limiting the range of the actions to single block, and then moving on to neighboring blocks, the WSCC was able to make use of well understood boundaries to produce collective efforts.

(2) *Proportional equivalence between benefits and costs*. The property owners on each block were able "to realize benefits commensurate with the costs of their property maintenance of re-investment. The result was a shared benefit or common good enjoyed by all property owners on the block. Those who failed to cooperate—holdouts—"profited little and were forced to exit" (Oakerson and Clifton, 2011, p. 19).

(3 and 4) *Collective choice arrangements and monitoring*. The block residents in the Buffalo neighborhoods did not have the authority to make their own rules and had to abide by city-wide building codes. "They did, however, closely monitor compliance with those rules and played a critical role in invoking the rules in court. . .it was a rule-enforcement process responsive to neighborhood initiative and highly sensitive to neighborhood participation" (Oakerson and Clifton, 2011, p. 19).

(5) *Graduated sanctions*. Neighbors reserved strong sanctions (e.g., calling in city inspectors who could cite owners into Housing Court) for those cases where property owners resisted their efforts and used mild sanctions (mostly persuasion) to try to get those who were at first unwilling to comply to do so without having to invoke strong sanctions immediately.

(6) *Conflict resolution mechanisms*. Mild disagreements could be settled in the block clubs, which met regularly, and by discussion among neighbors. The availability of the Housing Court was, however, a substantial advantage for the neighbors. "Recourse to an independent, authoritative third-party to resolve disputes among neighboring property owners clearly facilitated the ability of the neighborhood to constrain property owners who permitted highly subtractive uses and functioned as holdouts in the process of collective action" (Oakerson and Clifton, 2011, p. 20).

(7) *Minimal recognition of rights to organize*. The block clubs created by this effort were recognized as legitimate organizations by the City Hall's Board of Block Clubs so long as each one followed the general rules for frequency of meetings, election of leaders, and adoption of bylaws.

(8) *Coordination among relevant groups*. The city of Buffalo (as is the case for most cities) is a complex, layered entity "in which small-scale effects (confined to a single block) are nested within larger scale effects (a city district, such as the West Side). Adjacent blocks and streets do affect one another; this is the basis for the block-by-block strategy of neighborhood restoration pursued by the WSCC. The layered nature of the urban commons requires more than a single level of collective organization" (Oakerson and Clifton, 2011, pp. 20–21).

Our second case study is a program called the Design Your Own Park (DYOP) Competition in Binghamton, New York (Wilson, 2011c). It uses the opportunity to design and create a neighborhood park as the equivalent of a common-pool resource for residents of a neighborhood. Groups that form to create a park are coached to adopt the core and auxiliary design principles. Once they start working effectively in the context of the park, they can also begin addressing other common needs. The park itself provides a safe, secure, and esthetically pleasing environment for mixed-age social interactions. When the park becomes well used by neighbors with a sense of ownership, monitoring and graduated sanctions take place spontaneously.

DYOP includes two auxiliary design principles in addition to the core principles. First, the groups that form to create a neighborhood park are likely to experience a higher turnover of members than CPR groups and therefore must be designed to accommodate this. Second, most CPR groups attempt to function well as groups but are not concerned about replicating at other locations. DYOP is designed with replication in mind, which requires an additional set of design principles. It is too early to formally measure the success of DYOP, but early indications are encouraging. Not only are the parks becoming a positive focus and physical location for neighborhood interactions, but planning groups are also beginning to address other needs of their neighborhoods, including relief efforts following the worst flood in Binghamton's history in 2011.

Both of these case studies illustrate the importance of coordinating interactions across social scales, with lower scales (neighborhoods) and larger scales (the city) each playing an essential role. For the Buffalo project, the block clubs were essential for taking charge in the improvement of their neighborhoods, but the city was also essential for granting (limited) authority to the block clubs and providing assistance when needed, especially in the form of strong sanctions against residents who did not respond to milder sanctions from their own neighbors. In the case of the Binghamton project, the whole point is to create neighborhood groups capable of managing their own affairs, but this requires an infrastructure at the scale of the whole city with the help of the Mayor's Office, City Council, and Parks department. Coordination among groups and across social scales illustrates the importance of the eighth core design principle—polycentric governance—as discussed in more detail below.

5. Discussion

The main purpose of this article is to show how a set of design principles derived by Ostrom and her associates for CPR groups can be generalized to include many kinds of groups. Generalization is possible because the design principles follow not only from political theory (Ostrom's home discipline), but from the evolutionary dynamics of cooperation in all species and the biocultural evolution of our own species. Once the core design principles are understood from an evolutionary perspective, their application to most human groups whose members must cooperate to achieve shared goals becomes clear.

The role of theory in either clarifying or obfuscating the importance of the core design principles warrants comment. Neoclassical economic theory is centered upon a set of assumptions about individuals and their social environment. Given the assumptions, the maximization of individual utilities also maximizes the common good. The basic conflict between levels of selection does not exist within the parameter space defined by the assumptions of the theory. The existence of externalities and market failures are recognized to a degree, but they do not occupy center stage and are considered to be exceptions instead of ubiquitous features of social life. The disconnect between economic theory and Ostrom's work is so great that on the day after she was awarded the Nobel Prize, economist Steven Levitt commented on his New York Times blog that most economists probably had not heard of her or knew what she did—and that he was chagrinned to count himself among them. In short, the core design principles identified by Ostrom and her associates become nearly invisible against the background of mainstream economic theory.

When we move away from economics to other policy arenas such as education, there is no single mainstream theory but rather dozens of theories that are poorly integrated with each other. Each has a surface logic that makes the core design principles appear reasonable, unreasonable, or invisible depending upon the background assumptions. A practice such as age segregation can become widespread without any awareness that it might interfere with the way that learning and teaching has taken place for thousands of generations.

Theories of urban governance are similarly diverse, and frequently obfuscate rather than clarifying the core design principles. Most academic disciplines related to the study of urban government have assumed, on the basis of theoretical assumptions rather than evidence, that allowing large numbers of small-scale as well as medium and large-scale governmental units is chaotic. Academics have participated in a massive effort to consolidate urban governance in the US and much of Western Europe. Alternative views make the core design principles appear reasonable, even obvious. Vincent Ostrom, Charles Tiebout and Robert Warren presented a view in 1961—a polycentric view—that analyzed the importance of governance arrangements at small, medium and large scales in most urban areas (Ostrom et al., 1961). The work of Jacobs (1961) and Kotler (1969) also called for governance at small urban levels nested within a larger governance system. Scholars at the Workshop for Political Theory and Policy Analysis pursued two decades of careful empirical research on urban police arrangements in diverse metropolitan areas and found that the most effective police systems combined diverse service providers of small and large scale rather than organizing all police services at a metropolitan level (see papers contained in McGinnis, 1999).

Most theorists in economics, education, urban government, or any other sphere of public policy assume that their ideas are consistent with other branches of knowledge and ultimately with evolutionary theory (if they think about evolutionary theory at all), but this is often not the case. Mainstream economic theory provides an example. Its assumptions about human abilities and preferences, which are often labeled by the term *Homo economicus*, as if a description of a biological species, are famously at odds with actual human abilities and preferences (Thaler and Sunstein, 2008). Efforts to explain how a theory can be right when its assumptions are wrong (e.g., Friedman, 1953) do not pass muster when scrutinized carefully (Wilson, 2012a).

Theories become a house of mirrors when they lack unity to this degree. The fact that the core design principles derived by Ostrom for CPR groups can be placed on a strong evolutionary foundation, congruent with other branches of knowledge, is therefore an important milestone, even before the hard work of empirical research on real-world groups begins.

The database that Ostrom and her associates created for CPR groups provides a model for how to synthesize a diffuse literature on a given context. A comparable effort for other contexts, such as educational groups, neighborhood groups, or business groups, would be very worthwhile. Our examination of a few case studies for the contexts of education and neighborhoods only scratches the surface, but supports the notion that the core design principles can be generalized. In addition, an extensive literature on human social behavior in the laboratory can be related to the core design principles, if only in retrospect, and broadly supports their generality. Examples include minimal group experiments in social psychology demonstrating the importance of social identity (Berreby, 2008) and cooperation games in behavioral economics demonstrating the importance of monitoring and sanctions (Gintis et al., 2005).

Given such a strong foundation of theoretical and empirical support, the core design principles can potentially serve as a practical guide for increasing the efficacy of groups in real-world settings. Some groups already work well and do not need improvement; after all, our species evolved by genetic and cultural evolution to function well as groups. There is a sense in which it is instinctive and comes naturally to us. The core design principles are easy to understand intuitively without a lot of formal theorizing. Yet, it is not the case that human groups spontaneously adopt the core design principles, providing much room for improvement. We encourage others to use the principles (and more generally MLS theory) as a practical guide for improving the efficacy of groups, as we are starting to do for schools and neighborhoods.

Part of the generality of the core design principles is that they apply across all social scales, from neighborhoods to the global village. To the extent that nations qualify as corporate units, they employ the same range of social strategies as lower-level organisms. To the extent that nations do not qualify as corporate units, it is often due to dysfunctions caused by conflicts from within. Either way, a sophisticated understanding of the evolutionary dynamics of cooperation in general and the biocultural evolution of our own species is useful for understanding and improving the situation.

It is also important to appreciate the importance of interactions across scales. A modern society consists of countless spheres of activity. Each sphere has an optimal scale that must be determined on a case-by-case basis. Then the spheres must be appropriately coordinated with each other. Anything else will be suboptimal. In other words, there is no viable alternative to polycentric governance. Many spheres of activity that are currently being managed at a large scale would be better managed at a smaller scale, but smaller scale units often rely critically on services that can only be provided at a larger scale, as we have seen in the case of neighborhoods relying upon their city for backup sanctions. We look forward to the day when governance consists of optimizing and coordinating among many spheres of activity from a sophisticated evolutionary perspective.

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References

Aktipis, C.A., 2004. When to walk away: contingent movement and the evolution of cooperation. Journal of Theoretical Biology 231, 249–260.
Berreby, D., 2008. Us and Them: The Science of Identity. University of Chicago Press, Chicago.
Bijma, P., Wade, M.J., 2008. The joint effects of kin, multilevel selection and indirect genetic effects on response to genetic selection. Journal of Evolutionary Biology 21, 1175–1188.
Boehm, C., 1999. Hierarchy in the Forest: Egalitarianism and the Evolution of Human Altruism. Harvard University Press, Cambridge, MA.
Boehm, C., 2011. Moral Origins: The Evolution of Virtue, Altruism and Shame. Basic Books, New York.
Boyd, R., Richerson, P.J., 1992. Punishment allows the evolution of cooperation (or anything else) in sizable groups. Ethology and Sociobiology 13, 171–195.
Boyd, R., Richerson, P.J., Henrich, J., 2011. Rapid cultural adaptation can facilitate the evolution of large-scale cooperation. Behavioral Ecology and Sociobiology 65, 431–444.
Bradshaw, C.P., Zmuda, J.H., Kellam, S., Ialongo, N., 2009. Longitudinal impact of two universal preventive interventions in first grade on educational outcomes in high school. Journal of Educational Psychology 101, 926–937.
Burt, A., Trivers, R., 2006. Genes in Conflict. Harvard University Press, Cambridge, MA.
Cox, M., Arnold, G., Villamayor-Tomas, S., 2010. A review of design principles for community-based natural resource management. Ecology and Society 15 (4), 38 http://www. ecologyandsociety. org/vol15/iss4/art38/
Csikszentmihalyi, M., Rathunde, K., Whalen, S., 1993. Talented Teenagers: The Roots of Success and Failure. Cambridge University Press, Cambridge, UK.
Day, M.D., Beck, D., Foster, J.A., 2011. Microbial communities as experimental units. Bioscience 61, 398–406.
Embry, D., 2002. The good behavior game: a best practice candidate as a universal behavioral vaccine. Clinical Child and Family Psychology Review 5, 273–297.
Fehr, E., Gächter, S., 2002. Altruistic punishment in humans. Nature 415, 137–140.
Frank, S., 2012a. Natural selection. III. Selection versus transmission and the levels of selection. Journal of Evolutionary Biology 25, 227–243.
Frank, S., 2012b. Natural selection. IV. The Price equation. Journal of Evolutionary Biology 25, 1002–1019.
Frederickson, B., 2009. Positivity: Groundbreaking Research Reveals How to Embrace the Hidden Strength of Positive Emotions, Overcome Negativity and Thrive. Crown Archetype, New York.
Friedman, M., 1953. Essays in Positive Economics. University of Chicago Press, Chicago.
Gintis, H., 2007. A framework for the integration of the behavioral sciences. Behavioral and Brain Sciences 30, 1–61.
Gintis, H., 2009. Game Theory Evolving, 2nd ed. Princeton University Press, Princeton, NJ.
Gintis, H., Bowles, S., Boyd, R., Fehr, E. (Eds.), 2005. Moral Sentiments and Material Interests: The Foundations of Cooperation in Economic Life. MIT Press, Cambridge, MA.
Goodnight, C.J., Stevens, L., 1997. Experimental studies of group selection: what do they tell us about group selection in nature? American Naturalist 150, S59–S79.
Gray, P., 2009. Play as the foundation for hunter-gatherer social existence. American Journal of Play 1, 476–522.
Gray, P., Chanoff, D., 1986. Democratic schooling: what happens to young people who have charge of their own education? American Journal of Education 94, 182–213.
Haidt, J., 2012. The Righteous Mind: Why Good People are Divided by Politics and Religion. Pantheon, New York.
Hardin, G., 1968. The tragedy of the commons. Science 162, 1243–1248.
Hewlett, B., Lamb, M.E. (Eds.), 2005. Hunter-gatherer Childhoods: Evolutionary, Developmental, and Cultural Perspectives. Transaction, New Brunswick.
Hill, K.R., Walker, R.S., Bozicevic, M., Eder, J., Headland, T., Hewlett, B., Hurtado, A.M., Marlowe, F., Wiessner, P., Brian Wood, B., 2011. Co-residence patterns in hunter-gatherer societies show unique human social structure. Science 331, 1286–1289.
Hölldobler, B., Wilson, E.O., 2009. The Superorganism: The Beauty, Elegance and Strangeness of Insect Societies. W.W. Norton, New York.
Jacobs, J., 1961. The Death and Life of Great American Cities. Vintage, New York.
Kauffman, R.A., Wilson, D.S. Effects of a program for at-risk high school students on non-academic variables, in preparation.

Kellam, S., Brown, C.H., Poduska, J., Ialongo, N., Wang, W., Toyinbo, P., Petras, H., Ford, C., Windham, A., Wilcox, H., 2008. Effects of a universal classroom behavior management program in first and second grades on young adult behavioral, psychiatric, and social outcomes. Drug and Alcohol Dependence 95, S5–S28.
Kotler, M., 1969. Neighborhood Government: The Local Foundation of Political Life. Bobbs-Merrill, Indianapolis.
Margulis, L., 1970. Origin of Eukaryotic Cells. Yale University Press, New Haven.
Maynard Smith, J., Szathmary, E., 1995. The Major Transitions of Life. W.H. Freeman, New York.
Maynard Smith, J., Szathmary, E., 1999. The Origins of Life: From the Birth of Life to the Origin of Language. Oxford University Press, Oxford.
McGinnis, M.D. (Ed.), 1999. Polycentric Governance and Development: Readings from the Workshop in Political Theory and Policy Analysis. University of Michigan Press, Ann Arbor.
Muir, W.M., Wade, M.J., Bijma, P., Ester, E.D., 2010. Group selection and social evolution in domesticated chickens. Evolutionary Applications 3, 453–465.
Oakerson, R.J., Clifton, J.D.W., 2011. Neighborhood decline as a tragedy of the commons: conditions of neighborhood turnaround on Buffalo's West Side. In: Workshop in Political Theory and Policy Analysis, pp. W11–W26.
Okasha, S., 2006. Evolution and the Levels of Selection. Oxford University Press, Oxford.
Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge, UK.
Ostrom, E., 2010. Beyond markets and states: polycentric governance of complex economic systems. American Economic Review 100, 1–33.
Ostrom, V., Tiebout, C.M., Warren, R., 1961. The organization of government in metropolitan areas: a theoretical inquiry. American Political Science Review 55 (4), 831–842.
Pepper, J.W., 2007. Simple models of assortment through environmental feedback. Artificial Life 13, 1–9.
Richerson, P.J., Boyd, R., 1999. Complex societies: the evolutionary origins of a crude superorganism. Human Nature 10, 253–290.
Richerson, P.J., Boyd, R., 2005. Not by Genes Alone: How Culture Transformed Human Evolution. University of Chicago Press, Chicago.
Sampson, R.J., 2004. Neighborhood and community: collective efficacy and community safety. New Economy 11, 106–113.
Smith, A., 1776 [2010]. The Wealth of Nations. Simon & Brown, Hollywood, FL.
Sober, E., Wilson, D.S., 1998. Unto Others: The Evolution and Psychology of Unselfish Behavior. Harvard University Press, Cambridge, MA.
Steffen, W., Grinevald, J., Crutzen, P., McNeill, J., 2011. The anthropocene: conceptual and historical perspectives. Philosophical Transactions of the Royal Society A 369, 842–867.
Swenson, W., Wilson, D.S., Elias, R., 2000. Artificial ecosystem selection. Proceedings of the National Academy of Sciences 97, 9110–9114.
Thaler, R.H., Sunstein, C.R., 2008. Nudge: Improving Decisions about Health, Wealth and Happiness. Yale University Press, New Haven.
Turchin, P., 2005. War and Peace and War. Pi Press, Upper Saddle River, NJ.
Turner, S.P., 2011. Breeding against harmful social behaviours in pigs and chickens: state of the art and the way forward. Applied Animal Behaviour Science 134, 1–9.
Van Vugt, M., Ahuja, A., 2011. Naturally Selected: The Evolutionary Science of Leadership. HarperBusiness, New York.
Williams, G.C., 1966. Adaptation and Natural Selection: A Critique of Some Current Evolutionary Thought. Princeton University Press, Princeton, NJ.
Wilson, D.S., 1990. Weak altruism, strong group selection. Oikos 59, 135–140.
Wilson, D.S., 1997. Incorporating group selection into the adaptationist program: a case study involving human decision making. In: Simpson, J., Kendricks, D. (Eds.), Evolutionary Social Psychology. Erlbaum, Mahwah, NJ, pp. 345–386.
Wilson, D.S., 2005. Natural selection and complex systems: a complex interaction. In: Hemelrijk, C. (Ed.), Self-organization and Evolution of Biological and Social Systems. Cambridge University Press, Cambridge, UK, pp. 151–165.
Wilson, D.S., 2008. Social semantics: toward a genuine pluralism in the study of social behavior. Journal of Evolutionary Biology 21, 368–373.
Wilson, D.S., 2011a. Instant expert: evolution of selfless behavior. New Scientist, http://dx.doi.org/10.1016/S0262-4079(11)61857-5.
Wilson, D.S., 2011b. The Neighborhood Project: Using Evolution to Improve My City. One Block at a Time. Little, Brown, New York.
Wilson, D.S., 2011c. The design your own park competition: empowering neighborhoods and restoring outdoor play on a citywide scale. American Journal of Play 3, 538–551.
Wilson, D.S., 2012a. A tale of two classics. New Scientist 213, 30–31.
Wilson, E.O., 2012b. The Social Conquest of Earth. Norton, New York.
Wilson, D.S., Dugatkin, L.A., 1997. Group selection and assortative interactions. American Naturalist 149, 336–351.
Wilson, D.S., Gowdy, J., 2013. Evolution as a general theoretical framework for economics and public policy. Journal of Economic Behavior and Organization, http://dx.doi.org/10.1016/j.jebo.2012.12.008.
Wilson, D.S., Kaufman, R.A., Purdy, M.S., 2011. A program for at-risk high school students informed by evolutionary science. PLoS One 6 (11), e27826.
Wilson, D.S., Kniffin, K.M., 1999. Multilevel selection and the social transmission of behavior. Human Nature 10, 291–310.
Wilson, D.S., Timmel, J., Miller, R.R., 2004. Cognitive cooperation: when the going gets tough, think as a group. Human Nature 15, 225–250.
Wilson, D.S., Wilson, E.O., 2007. Rethinking the theoretical foundation of sociobiology. Quarterly Review of Biology 82, 327–348.
Wilson, E.O., Hölldobler, B., 2005. Eusociality: origin and consequences. Proceedings of the National Academy of Sciences of the United States of America 102, 13367–13371.