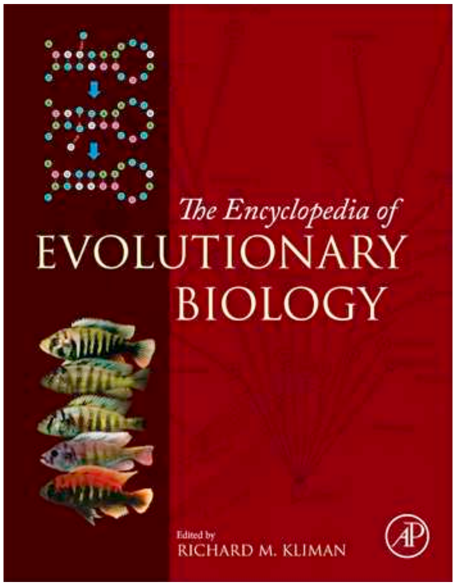

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Security, Evolution and

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Key Definitions

Escalation An evolutionary process where enemies are the predominant selective agents.
Evolutionary security (synonyms: natural security, Darwinian security) Field of study that applies the principles of evolutionary biology to problems in human security.
Operational adaptation Research on how to achieve effective adaptation in war.

Introduction

Security affairs in human society are often discussed in the context of geopolitics, religious and ideological conflict, and human history. Conflicts and the resulting security challenges they create also may have environmental drivers, though conclusive evidence is mixed (Homer-Dixon, 1994; Stewart, 2002; Barnett and Adger, 2007; United Nations Environment Programme, 2009; Forsyth and Schomerus, 2013). Although there have been scattered efforts in the past, since the 9/11 attacks, there has been more concerted and interrelated attempts to examine human security within an evolutionary context. These efforts come from a vast range of fields and viewpoints and accordingly this review cannot be exhaustive but attempts to highlight key areas and to provide a general framework to organize the body of evolutionary security works and illustrate how they might be applied to address human security concerns.

Evolution provides a potentially valuable framework for looking at security for several reasons. From a practitioner standpoint, there is a feeling that the old methods and lenses with which to look at security had either failed (e.g., the 9/11 attacks) or were inadequate to address the complexities and nuances of today's security environment (Sagarin and Taylor, 2008). Evolution provides a lens to look at security broadly and across a number of different gradients. For example, evolution provides insights into the relative role of technology (phenotypic trait variation) and tactics (behaviors) in adapting to security threats. Evolution helps us consider the origin and maintenance of offensive weaponry vs. defensive structures or behaviors. Evolution helps us think about the relative role of cooperation vs. conflict. And, a functional and historical approach can help us think about ways to better prevent and respond to security breaches.

Individual scholars from within and outside biology have raised parallels between security in natural and human systems for many years. Most notably Warder Clyde Allee applied his studies of cooperation among organisms to questions about international conflict and cooperation, including the nascent idea of a United Nations, in several works (Allee, 1943, 1951). Ecologist Ed Ricketts (a student of Allee) frequently referred to evolution and ecology in his essays (Rodger, 2006), and he attempted to apply his studies to the intelligence efforts of the US in World War II, with disappointing results (Steinbeck, 1986). Economist Kenneth Boulding has described his 1962 book *Conflict and Defense* as the 'beginning of an evolutionary theory of conflict, seeing conflict as merely one element in the vast process of evolutionary and ecological interaction' (Boulding, 1962 [1988], p. ix). Paleobiologist Geerat Vermeij created a grand synthesis of paleobiological research suggesting that increasing capacities of organisms to obtain resources leads to increasing dangers in the environment, thus driving an escalation of offensive and defensive capacities for all organisms that interact strongly with their environment (Vermeij, 1987). Later, Vermeij applied this synthesis to human military escalation, making a pointed criticism of missile defense programs in noting that the inevitable evolutionary escalation of weaponry obviates the "false claim that weapons provide absolute security in the event they are used" (Vermeij, 2004, p. 300).

These and other individual efforts have been augmented in recent years through interdisciplinary collaborations and working groups dedicated to evolutionary security studies. Sagarin, for example, convened in 2005 a 'Darwinian Security' working group comprised of biologists and security experts at the National Center for Ecological Analysis and Synthesis. Dominic Johnson convened in 2010 an international workshop on 'Operational Adaptation' featuring biologists, anthropologists, civilian and military security experts and informed by evolutionary models, which was sponsored by the US Office of Naval Research Global. These efforts have resulted in books, collaborative papers and briefings to security agencies, although their ultimate effect on security policy is unknown (see below).

Approaches

There are several basic approaches that have been used in applying evolutionary thinking to security issues. Briefly, these include using analogies from nature to illuminate what appear to be similar situations in human security struggles, or the inverse approach in which direct observation of human security situations are contextualized in evolutionary terms.

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An alternative approach is developing models, including but not limited to those previously used in ecological and evolutionary studies, to simulate or elucidate underlying causes of behaviors and patterns in human security. All of these approaches have been used in either an analytic/explanatory sense to shed light on past or ongoing security situations, or in a pro-active/prescriptive sense to make predictions or warnings about potential future security scenarios (examples in Sagarin and Taylor, 2008).

Direct Analogies from Nature

Analogies from nature provide rich ground for examining security in society. While simple 'biomimicry' has turned up numerous 'products' of evolution (e.g., the fusiform shape of a tuna, camouflage mechanisms in cuttlefish) that may be effectively used in security situations (Armstrong and Warner, 2003), there is far richer ground to explore in the 'process' of evolution and the activities of biological organisms, when put into the context of security studies.

Perhaps the most obvious area to look, because it is so apparent in the phenotype of many organisms, is in studies of development and escalation of armaments and defensive structures of conflict. A recent review of this topic, particularly focused on modern fauna and making a number of direct analogies to human weaponry, is Emlen's *Animal Weapons* (Emlen, 2014). Whereas behavioral changes may be an initial, and reversible defense, animals also can add morphological defenses. Thus, the ecological interest in constitutive vs. inducible defenses in plants and animals (Harvell, 1990; Poitrineau *et al.*, 2004) is another potential analogy to human security, regarding to what extent we invest in a baseline level of security vs. maintaining the capacity to quickly ramp up defenses when necessary.

Looking at predator–prey relationships has been used to provide insight into warring sides in conflict. The relative costs of predation can also be examined in societal terms. Applying the 'life-dinner' principle (in which one side is running for its life where the other is merely trying to obtain a single meal) (Dawkins and Krebs, 1979) to conflict can illuminate the relative motivations of terrorists vs. states (Guerra-Pujol, 2012).

These differential benefits and costs relate to a larger and growing field of security studies – that of asymmetric conflict – that have relevant analogies in evolved systems. Parasite–host interactions, for example, resemble many features of asymmetric conflict among human societies where one side at relatively low energetic cost can have enormous effects and even modify the behavior of a typically larger and better-resourced host. The analogy of viruses, in particular, has been used widely to describe the actions of terrorists, the relatively lower cost of terrorist action vs. counter-terrorism by a 'host' country, cybersecurity threats, and surprisingly, the roots of cooperation (Villarreal and DeFilippis, 2000; Stares and Yacoubian, 2005; Lafferty *et al.*, 2008; Villarreal, 2008). Likening crime to an infectious disease and examining spatial and temporal patterns of its spread has also been an effective analogy (Zeoli *et al.*, 2012; NPR, 2015).

Intraspecific competition also has lessons for human security. 'Arms races' among species (particularly due to sexual selection on armaments such as antlers or oversized claws) are apt descriptors of some types of human conflicts and thus can be analyzed for their underlying causes and long-term trends. Fiddler crab males, for example, have been likened to both the posturing of both sides of the cold war, as well as the stability conferred by the concept of 'mutually assured destruction' (Sagarin, 2012; **Figure 1**). Such analogizing is more than descriptive because it allows a mechanistic view of the conditions in which symmetrical conflict can lead to stability or escalation. For example, Emlen (2014) argues that certain conditions, including competition for limited resources, resources that are localized and defensible, and opportunities for face-to-face conflict, make escalation of armaments more likely.

Figure 1 The Cold War arms race between the Soviet Union and the US was similar to male fiddler crabs competing with each other for mates. Crabs wave their oversized claws at each other but actually don't use them in battle, and analogously, superpowers assume that the threat of using strong nuclear weapons against the enemy prevents the enemy's use of those same weapons. https://upload.wikimedia.org/wikipedia/commons/5/5f/Fiddler_crab_4.jpg.

More subtle linkages between evolution and human security have been elucidated within the behaviors and life histories of organisms. Threat detection and alarm calling are particularly apt areas of study. On this question, a concern for the natural and human social realm is how can threats be detected accurately, and alarms about these threats be conveyed clearly and with enough urgency to get a population to react appropriately. The issue of habituation to alarm calls (or ignoring false alarms) is particularly worrisome in the human security realm (Blumstein, 2008), where it has been estimated that 21 million Americans don't keep batteries in their smoke detectors and even residents of areas hard hit by the 2005 Boxing Day tsunami soon dismantled newly installed tsunami warning alarms because of the high rate of false alarms (Sagarin, 2012). Accordingly, analogies from the natural world tend to focus on 'honest signaling,' which is expected to be costly when used (Blumstein *et al.*, 2012). Yet we should expect many situations where honest signaling is rare and individuals are trying to provide mis-information to modify the behavior of another individual. Understanding the value of information is key and to properly interpret information, knowledge about the signaler's reliability is often essential. For instance, Blumstein revealed that some individuals in-groups of marmots make alarm calls only when there is a clear and present danger, whereas others make abundant alarm calls, even to non-consequential threats (Blumstein and Armitage, 1997; Blumstein, 2008). Marmots use their estimates of caller reliability when making decisions about how to respond to these vocalizations.

Observing human conflict, cooperation, and other security-related behaviors and then reaching back for evolutionary causation represents the inverse approach of using evolutionary analogies. The field of evolutionary psychology attempts to identify ultimate drivers of human behavior (Barkow *et al.*, 1992) and may be useful in helping to explain seemingly irrational or maladaptive behaviors (such as suicide bombing or the inability to properly weigh the relative risk of terrorism relative to other more common threats) which may have been adaptive (or neutral) in humans' ancestral environments (Liddle *et al.*, 2011). Nonetheless, because our own deep evolutionary history is intertwined with a more modern social evolution that itself may feedback on our evolution, seminal works in the areas of evolutionary psychology, 'sociobiology' (Wilson, 1975), and 'biopolitics' (Somit and Peterson, 1997) have generated considerable controversy that continues to be debated (e.g., Wilson, 1998; Corning, 2001; Somit and Peterson, 2001; Goetze and James, 2004).

Much aggressive and cooperative behavior among humans has been linked to human cultural biases, including deep seeded ethnocentrism (Hammond and Axelrod, 2006) and favoring in-group members against out-group members, which are reinforced through cultural norms and religion, as portrayed in a rich evolutionary literature (Henrich and McElreath, 2003; Ehrlich and Levin, 2005; Sosis and Alcorta, 2008). Villarreal examined the deep evolutionary roots of in-group/out-group biases, suggesting they are a human manifestation of self/non-self recognition systems that date back to the earliest bacterial and viral interactions (Villarreal and DeFilippis, 2000; Villarreal, 2008). Hatemi and colleagues (2013) links this out-group bias directly to fear of out-group members and discuss the conflict it creates in a political context. Because many of these biases are expressed through religious identification, global assessments of common features of religion can helpfully point out likely development-related points of entry and exit from radical religious beliefs (e.g., adolescence) (Sosis and Alcorta, 2008).

Peeling back a layer from strong out-group biases in humans reveals that cooperation among in-group members is an essential and somewhat enigmatic process (Henrich and Henrich, 2006) when contrasted to self-interest, and this is particularly debated in the context of altruism. Altruism in humans has been explained through basic evolutionary mechanisms such as kin selection (Davis, 1997; West *et al.*, 2011) as well as more nuanced explanations such as the role of empathy (which likely goes back deeper than the human lineage; de Waal, 2008), costly displays that reinforce group identity (Henrich, 2009), potential for group punishment of defectors (Fehr and Gachter, 2002) and even 'supernatural' punishment (acknowledged in a religious sense) of defectors (Johnson and Kruger, 2004).

Dominance hierarchies are a particular set of behaviors that have been viewed for many years of having direct linkages between human and nonhuman analogs. Allee (1938), for example, carefully considered the 'pecking order' in hen houses as a direct lesson for human cooperation and conflict. Silk (2002) used studies of primates to suggest that random acts of aggression may effectively discourage subordinates from defecting in a hierarchical society. More recently, the work of Robert Sapolsky and colleagues has linked dominance hierarchies in primates to factors that maintain cooperation or foment conflict, with commensurate lessons for humans (Sapolsky, 2006). Individuals (or nations) may have special roles in stabilizing societies. For instance, Flack *et al.* (2006) showed that the removal of especially powerful dominant male pigtail macaques (*Macaca nemestrina*) led to increased conflict and group fragmentation. Especially powerful entities can have a stabilizing effect on groups. Related to dominance hierarchies, with important implications for warfare and peace building, are studies on the evolution of leadership (King *et al.*, 2009).

Emergent Properties

The most intriguing and complex view of evolution in security comes through examining the widespread or in some cases emergent properties of evolutionary systems. Chief among these properties is that of adaptability – the capacity of a biological system to cope with (adapt to) the unexpected disturbances of the environment, internal or external. Especially after 9/11, many security agencies and advisors talked of the need to be more adaptable, and the process and outcomes of adaptable biological systems likewise became a unifying theme of evolutionary security work (Sagarin and Taylor, 2008).

While adaptability is an attractive conceptual framework for security, it needs to be broken down into processes that can be emulated if it is to be useful in an applied security context. One such process is symbiosis, which is both universal and emergent in evolutionary systems (Margulis, 1998). Symbiosis can be seen as an appropriate model for the kinds of partnerships necessary in security practice because in nature it is not a simple *quid pro quo*, and it includes relationships between unlikely partners including partners that once had an antagonistic relationship (Allee, 1951; Margulis, 1998). Corning (2005) suggested that synergistic (cooperative) effects have played an important role in the emergence of more complex natural and social systems and conversely that a global security system might emerge through the selective advantages of cooperative interactions. Analogous symbioses in human affairs have resulted in health provisioning partnerships between Israeli, Palestinian, and Jordanian health practitioners (Gresham *et al.*, 2009), and likely led to a rapid reduction in deaths due to improvised explosive devices in Iraq for US forces (Sagarin, 2012).

Redundancy is another general feature of adaptable systems that appears universal in biology (Vermeij, 2004). At the upper end of biological complexity, redundancy (of functional types) seems to provide resiliency to ecosystems (Levin, 1999). In human terms, redundancy can provide a 'hedge' against the uncertainty of unpredictable security situations. Indeed, individuals often seek to reduce uncertainty about the true risk of predation and using different modalities of stimuli to assess risk is likely favored in noisy, dynamic, and uncertain situations (*sensu* Munoz and Blumstein, 2012).

Finally, adaptable systems often rely on decentralized abilities to sense change in the world (Vermeij, 2008). The adaptive vertebrate immune system is an exemplar, wherein immune cells search for, identify, and neutralize invading pathogens throughout a body with very little contact with the central nervous system. In the realm of human security, the last decade has seen an explosion of decentralized sensory systems – particularly those facilitated by cell phone networks – aimed at security-related concerns such as mapping disease outbreaks or areas needing immediate assistance following a natural disaster.

Evolutionary and Ecological Models

The descriptive approaches above have been augmented by modeling approaches that capitalize on the enormous body of existing evolutionary and ecological models made for situations analogous to those that are found in human security concerns. Examples of models used in studies of conflict are especially rich in game theory with Axelrod's *The Evolution of Cooperation* being a key early contribution (Axelrod, 1984, 2006). Many games focus particularly on the conditions under which cooperation between people or groups arise. Interpretations of games have relied on both economic and evolutionary models, which may lead to conflicting conclusions about root causes for the observed behaviors (Hagen and Hammerstein, 2006), suggesting that there is still need to reconcile the relative roles of cultural and biological evolution in determining peoples' willingness to cooperate with or punish other people.

Ecological models stemming from various levels of biological complexity have been used to draw light on terrorism and conflict. Turchin and collaborators (2003) have used various spatial ecological models of animal movement and population cycles to draw conclusions about seemingly synchronous events in economics and international relations. Drapeau *et al.* (2008) used heuristics of predator–prey and competition models to outline potential counter-terrorism strategies. Bohorquez and colleagues (2009) developed models that treat insurgent populations as part of an ecology of dynamically evolving, decision-making groups to identify commonalities in the timing and size of violent events within conflicts. Keohane and Zeckhauser (2003) used an ecosystem model of stocks and flows to examine how individuals might respond to terrorism.

More recently, food web and network models have been manipulated for use in security studies. For example, using the medium of TED talks, Eric Berlow applied food web theory to an overly-complex map of the US war strategy in Afghanistan and showed that it could be simplified to just a small number of key actions. Ferenc Jordan used network theory to analyze the July 7, 2005 London subway terrorist attacks and determined that terrorists chose the second-most destructive combination of stops to attack (out of 3.2 million possible combinations) (Jordan, 2008).

Finally, natural selection models can be used to study conflict. Johnson (2009), for example, studied coalition vs. insurgency success across several years of combat in Iraq using the three pillars of natural selection theory (variation, selection, replication) as metrics. He found that insurgent organizations had several characteristics favoring faster rates of adaptation under all three of these components of selection. However, the battlefield creates strong selective forces and the creation of 'hillbilly armor' illustrates that even coalitionary forces can adapt (Figure 2).

Figure 2 Operational adaptation on the battlefield. When US forces were caught off-guard by the development of improvised explosive devices (IEDs) in Iraq, active duty personnel up-armored their vehicles with whatever spare parts and scrap metal was available. It took years for the military to develop and deploy better-armored vehicles, but such hillbilly armor provided an interim solution. https://en.wikipedia.org/wiki/Improvised_vehicle_armour#/media/File:HillbillyArmor5tonCargo.jpg.

Targets and Prospects

There is always a concern that analogies from nature can be overstretched or inappropriately applied and most recent works on evolution and security acknowledge this directly. For example, Ehrlich and Levin (2005) explicitly discuss differences between human social evolution and biological evolution *via* natural selection. Likewise, a discussion of the ethics of applying evolutionary models to societal concerns graces most extended works on this topic (e.g., Vermeij, 2004). The misuse of 'social Darwinism' and adoption by proponents of eugenics has left scars on the academic community that are still felt today.

There are numerous fields of security studies and practice that have been examined from a functional and historical perspective, including crime analysis and policing strategies, homeland security, and natural disaster prevention (Felson, 2006; Sagarin, 2012; Roach and Pease, 2013). Cyber and information security, which already commonly uses the biological language of viruses, still suffers from a relatively static, firewall-based approach to security (Wulf and Jones, 2009), a situation that may benefit from an evolutionary treatment (Sagarin and Taylor, 2012; Sagarin, 2013).

Conflict between states might also be examined in an evolutionary context. From a behavioral point of view, Thayer attempted to reexamine various theories in international relations with an evolutionary lens and then applied this viewpoint to warfare and ethnic conflict (Thayer, 2004). Dietl, taking a macro-level approach, used concepts from selection theory to strengthen the idea that structural changes in world politics can be viewed in evolutionary terms (Dietl, 2008). While scholars have debated the role of environmental conditions in leading to conflict or hampering peace building (Crocker *et al.*, 2014), actual applications of evolutionary theory to peace building have been limited (Sagarin, 2014).

Likewise, an area of security that would seem to most naturally lend itself to lessons from adaptable natural systems is the growing field of climate change adaptation, but thus far this field has primarily focused on social sciences approaches to stakeholder engagement (Willows and Connell, 2003), rather than viewing adaptation as a biological process. One of the key lessons from nature here is to understand whether there is sufficient adaptive flexibility (i.e., phenotypic plasticity) in a particular system or whether evolutionary changes are necessary. While there is extensive work studying the phenotypic plasticity of plants and animals, we need to know much more about human societal plasticity, its drivers, and the adaptive consequences of it.

While we can retrospectively identify the logic of evolution being applied to security policy, it is hard to identify particular cases where evolutionary approaches have been used at the outset to solve a security problem. A renewed focus on identifying both security problems amenable to applying evolutionary logic as well as identifying mechanisms underlying potential evolutionary responses may be helpful in developing concrete case studies of successful natural security.

There is a worry that although evolutionary approaches to security have been relatively welcome within academic circles, the pathway to incorporating them in practice may follow the delayed and incomplete application of 'Darwinian Medicine' to the practice of medicine (Armbruster, 2008). Indeed, one lesson from Darwinian Medicine is that it may take decades to develop an effective change model that becomes widely adopted. Thus, we should not be too concerned that it may take time to develop a catalog of successful natural security case studies.

Certainly, government and military officials have been briefed by some scientists in these works through individual meetings, staff briefings, seminars at military and homeland security departments and research academies (e.g., Sagarin lectured in evolutionary security at the Naval Postgraduate School) and conferences. There have also been calls for proposals from military organizations specifically looking at biomimetic technologies. How influential these inroads have been on policy remains to be seen and may never be fully quantifiable as policy arises from a complex mix of underlying science and research (which may come from many different fields), ideological struggles, and the particularly political environment surrounding law makers.

Regardless of the pathway to application, there is abundant basic research to be done in this field, which is very much in its infancy. Identifying key security questions that are amenable to an evolutionary approach will be a needed step in properly evaluating the tremendous potential of applying lessons from 3.5 billion years of successful life on Earth to increase the security of its diverse set of global citizens.

See also: Antagonistic Interspecific Coevolution. Intraspecific Coevolutionary Arms Races

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