DARWINIAN SELECTION IN ASYMMETRIC WARFARE: THE NATURAL ADVANTAGE OF INSURGENTS AND TERRORISTS

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I've killed them by the tens of thousands, scoured their countryside at will, pried their allies away, and humiliated them day after day. I have burned their crops and looted their wealth. I've sent a whole generation of their generals into the afterworld ... Have I changed nothing? They are stronger now than before. They are more than before. They fight more sensibly than before. They win when they used to lose.

—*Hannibal* in David Anthony Durham's "Pride of Carthage"

Never engage the same enemy for too long, or he will adapt to your tactics.

—*Clausewitz*

Abstract

Models of human conflict tend to focus on military power, predicting that—all else equal—the stronger side will prevail. This overlooks a key insight from the evolutionary dynamics of competing populations: the process of *adaptation by natural selection*. Darwinian selection weeds out poor performers and propagates good performers, thus leading to a cumulative increase in effective adaptations over time. The logic of selection applies not only to biological organisms but to any competing entities, whether strategies, technologies, or machines—as long as three conditions are in place: variation, selection, and replication. Applied to asymmetric warfare, Darwinian selection predicts that, counter-intuitively, *stronger* sides may suffer a *disadvantage* across all three conditions: (1) *Variation*—weaker sides are often composed of a larger diversity of combatants, representing a larger trait-pool and a potentially higher rate of "mutation" (innovation); (2) *Selection*—stronger sides apply a greater selection pressure on weaker sides than the other way around, resulting in faster adaptation by the weaker side; (3) *Replication*—weaker sides are exposed to combat for longer (fighting on the same home territory for years at a time), promoting experience and learning, while stronger sides rotate soldiers on short combat tours to different regions. In recent years, many civilian and military leaders have noted that US counterinsurgency and counterterrorism forces are adapting too slowly to match the insurgents in Iraq, the Taliban in Afghanistan, or Al Qaeda worldwide. A Darwinian approach suggests that this is exactly what we might predict: *Weaker* sides adapt *faster* and *more effectively*. Understanding the causes and consequences of Darwinian selection offers insights for how to thwart enemy adaptation and improve our own.

Introduction

ACCORDING TO GENERAL ANTHONY ZINNI, former commander of US forces in the Middle East, a primary failing in current military campaigns has been a failure to *adapt*. As he observed early on in the Iraq conflict: "This is the first war where we've faced an enemy that's adapted better than we have at a tactical and operational level. We had IEDs [Improvised Explosive Devices] from Day 1 … What have we done to adapt? Nothing" (Eisler, 2007). Zinni identified a key problem in counterinsurgency efforts and in the "Global War on Terror" in general: How can we adapt faster to match or overtake the enemy's own shifting tactics and innovation? The obvious place to look for an answer is among the evolutionary principles first introduced 150 years ago by Charles Darwin, whose life's work distilled the stunning diversity of life on Earth into a single phenomenon: adaptation by natural selection.

2009 is the 200^{th} anniversary of Darwin's birth, and the 150^{th} anniversary of the publication of his masterpiece, the *Origin of Species*. The intervening years have seen steady and solid vindications of his insight into the simple but powerful forces underlying evolution. What is surprising is that it has taken so long for people to take seriously the idea that competition and adaptation in nature may provide important lessons for understanding our own efforts to compete and adapt effectively. This is changing. Evolution is becoming an increasingly common framework to understand modern human phenomena ranging from engineering to leadership to economics (Barkow, 2006; Benyus, 2002; Burnham, 2005; King, Johnson, & Van Vugt, in press; E. O. Wilson, 1999).

As one topical example, the recent financial crisis has raised deep questions about the stability of the global financial system and how and why some banks survive while others fail. Many commentators have reverted to evolutionary metaphors such as the "survival of the fittest"—but the idea and implications are being taken seriously. Both the New York Federal Reserve Bank and the Bank of England have consulted with biologists to glean ideas from biology, evolution and ecology on how to manage the complex global "ecosystem" of finance (May, Levin, & Sugihara, 2008; Tett, 2009). Niall Ferguson argues that selection effects shape how the financial world changes over time: "Left to itself, 'natural selection' should work fast to eliminate the weakest institutions in the market, which typically are devoured by the successful" (Ferguson, 2007).

More importantly for this paper, other work suggests that evolution offers important lessons for *international security* (Sagarin, 2003; Sagarin & Taylor, 2008). For much of history, war was a matter of opposing state's armies clashing in open battle. By contrast, contemporary security threats in the 21st century are dominated by unpredictable and rapidly changing threats from "rogue" states or non-state actors, such as terrorism, insurgency, ethnic violence, WMD proliferation, pandemic disease, and climate change. We therefore face a unique challenge that is unprecedented in history for two reasons: (1) never before has international security been so seriously and globally threatened by unconventional threats and unconventional actors (Rosenau, 2007); and (2) never before has the United States had such a complete monopoly on military power (Wohlforth, 1999). It is therefore an environment of both threat and opportunity—lethal forces threaten international security and the US homeland, and yet it is not clear how even the United States, despite being the global military hegemon, can effectively defend itself or even engage the "enemy."

Most striking of all, empirical data suggest that powerful states are increasingly likely to lose conflicts against weaker opponents. In the past, stronger sides tended to both initiate and win the wars they fought. But since 1945, this logical prediction no longer holds, and stronger sides are actually *less* likely to win (Arreguín-Toft, 2005; Wang & Ray, 1994). Weaker sides appear to have intrinsic advantages that allow them to punch above their weight. Some of this may be explained by higher commitment or morale (Mack, 1975), the use of barbaric tactics (Arreguín-Toft, 2005; Pape, 2003), or the fact that "victory" is becoming harder for democratic states to achieve because wars must be fought along stricter ethical guidelines and supported by an increasingly informed and demanding public (Johnson & Tierney, 2006; Mandel, 2006; Martel, 2006). Finally, powerful states are often overconfident, enamored with their military power, technology, and ideology and enter into wars they are unlikely to win (Johnson, 2004).

This article, however, suggests that there may be something else going on in the dynamics of asymmetric conflict that counter-intuitively gives an edge to the weaker side. Humans differ from other organisms in many ways, but the struggle to defeat insurgents and terrorists has many characteristics that would be familiar to Darwin, or to any modern ecologist studying the dynamics of competing populations. I apply the logic of Darwinian selection to examine its effects on asymmetric conflicts—who has the upper hand in the arms race of adaptation? I argue that selection effects favor weaker sides, such as insurgents and terrorists, because they are more varied, are under stronger selection pressure, and replicate successful strategies faster than the larger forces trying to defeat them, such as the US Army in Iraq. To put it simply, large “predatory” forces cause their “prey” to adapt faster that they do themselves. The rabbit is running for its life, but the fox is only running for its dinner (Dawkins & Krebs, 1979).

Running to Stand Still: Evolutionary Arms Races

Adaptation has been a key feature of the insurgency in Iraq. As one journalist put it, “it has been a rapid and brutal evolution of attack and counter-measure” (Hider, 2005). Initial attacks following the 2003 invasion were scattered and unorganized, but quickly morphed into car bombs at checkpoints, ramming convoys on the roads, and IEDs. American vehicles became more heavily armored, with makeshift metal plates bolted onto existing Humvees. Insurgents began using shaped-charge IEDs that could penetrate armor, and then the US introduced new vehicles with V-shaped hulls to deflect charges. Insurgents became organized enough to shoot down helicopters, so helicopters started flying at night—and so on, in a continual arms race of innovation, selection and adaptation. Small adaptations can make a big difference. A 2005 Pentagon study found that 80% of US Marines killed by upper body injuries could have survived if they had been equipped with newer body armor to prevent shrapnel hitting their shoulders, sides or torso (Moss, 2006). Better armor had been available since 2003 but took time to get to the field. Adaptation was too slow.

Many senior military commentators have highlighted the central importance of adaptation in today’s counterinsurgency and counterterrorism campaigns, including Anthony Zinni, John Nagl (Nagl, 2002), David Kilcullen (Kilcullen, 2006, 2009), Nigel Aylwin-Foster (Aylwin-Foster, 2005), and US Secretary of Defense Robert Gates, who remarked at a congressional hearing in March 2007 that “as soon as we … find one way of trying to thwart their efforts, [the insurgents] find a technology or a new way of going about their business” (Eisler, 2007). In 2005 US Army Chief of Staff General Peter Schoomaker ordered copies of Nagl’s book, *“Learning to Eat Soup with a Knife”*—which focused heavily on adaptation in Malaya and Vietnam—for every serving 4-star general (Aylwin-Foster, 2005, p. 8).

This continual arms race of adaptation and counter-adaptation suggests similarities with Darwinian selection in nature. As noted by Rafe Sagarin, “a fundamental tenet of evolutionary biology is that organisms must constantly adapt just to stay in the same strategic position relative to their enemies—who are constantly changing as well. For example, to protect its DNA against viruses, a host organism must continually change the access code to its genetic material” (Sagarin, 2003, p. 69). Meeting the Red Queen in *Alice in Wonderland*, Alice finds that however fast she runs, she always stays in the same place. The “Red Queen” concept has become widely used in evolutionary biology to describe how competing individuals can become locked in an “arms race” of strategies, machinery, or weapons. However impressive one side becomes, it may never come any closer to defeating its opponent.

There is some evidence for a Red Queen phenomenon in human conflicts. If there is anything we have learnt over the last few decades, it is that “body counts” are of limited use in understanding or winning counterinsurgency campaigns—political, economic, and social factors may be much more important to success (Galula, 1964; Gartner, 1995; Lynn, 2005; Metz & Millen, 2004; Nagl, 2002). Nevertheless, soldiers killed in lethal competition with each other illustrate the point. Figure 1 shows that during the Vietnam War, enemy body counts were increasing over time, and this was infamously used as an indicator of success by certain elements of the US government and military (Gartner, 1997).

However, Figure 2 shows that if you look at the *ratio* of enemy soldiers killed *per* US soldier killed, there is no clear trend over time at all. In other words, the US military was not getting better at eradicating the enemy. This is particularly remarkable given that, during this period, there was an enormous escalation in the number of US troops sent to Vietnam (as well as resources and machines). The Red Queen phenomenon—enemies adapting to each other over time—may help to explain why even massively *increasing* effort fails to win. The harder you try, they more resilient the enemy becomes.

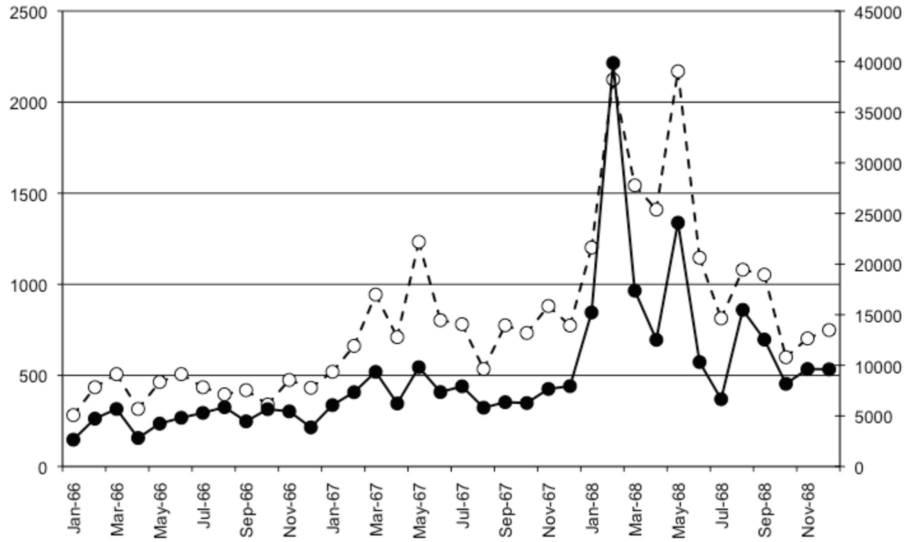

Figure 1. Absolute numbers of enemy combatants (black dots and right-hand axis) and US soldiers (dashed line and left-hand axis) killed in Vietnam 1966-1968. The large spike in 1968 reflects the large-scale battles of the Tet Offensive (data from Gartner, 1997).

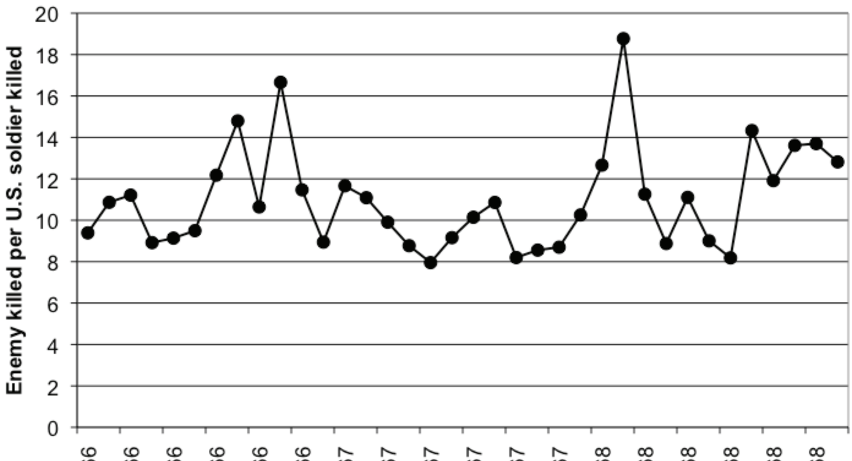

Figure 2. Enemy combatants killed *per* US soldier killed in Vietnam 1966-1968 (data from Gartner, 1997).

Turning to the conflicts of today, we see the same phenomenon. Figure 3 shows the ratio of insurgents killed or captured *per* US soldier killed in Iraq (O'Hanlon & Kamp, 2006). As with Vietnam, there is no indication that over this period US troops are getting better at capturing or killing insurgents. Indeed, given the massive *increase* in US and coalition troops deployments since 2003, if anything the data suggest that the US became *less* effective over time (though see Johnson & Madin, 2008). Only when political, economic and social factors were effectively integrated with focused military operations such as the "surge" of 2007, was there a significant improvement of security in Iraq.

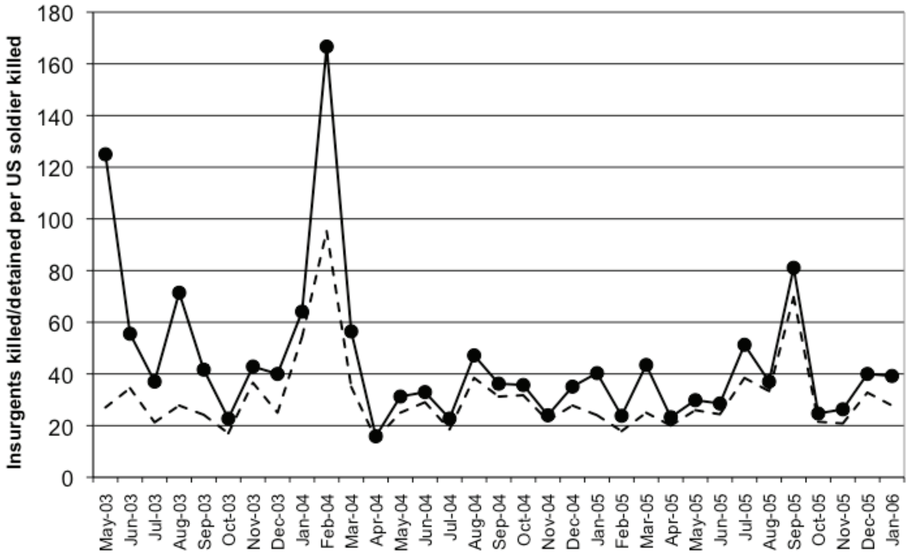

Figure 3. Insurgents killed or captured *per* US soldier killed in Iraq 2003-2006 (solid line). Dashed line shows same ratio if US deaths from non-hostile accidents are included (data from O'Hanlon & Kamp, 2006).

It is common knowledge within the military community that successful counterinsurgency campaigns require much more than military might. However, at least at the beginning of the Iraq conflict, many believed that the most effective strategy was to kill or capture insurgents. The Pentagon's 2006 *Quadrennial Defense Review* on Irregular Warfare found that, of 127 US "pacification operations" in Iraq from May 2003 to May 2005, most were "reactive to insurgent activity—seeking to hunt down insurgents" (cited in Aylwin-Foster, 2005, p. 5). An evolutionary approach concurs with classical counterinsurgency wisdom that the "kinetic" approach of offensive military operations does not provide a lasting solution. Russian troops and police were unable to defeat the rebels in Chechnya even though they outnumbered them by more than 50 to 1 (Kramer, 2004), and according to David Galula, the French could not have defeated the insurgency in Vietnam "even if they had been led by Napoleon" (Galula, 1964, p.32). Could Darwinian selection of combatants, strategies and technologies help to explain why?

Natural and Unnatural Selection

Natural selection is a very *powerful* process—it has led to all the diversity of life on Earth, perhaps 100 million species, complex machinery such as eyes and immune systems and brains, and to a stunning array of defensive and offensive adaptations for survival. However, natural selection is also a very *simple* process. In one recent definition: "Selection is the nonrandom differential survival or reproduction of phenotypically different individuals" (Kingsolver & Pfennig, 2007, p. 561).

> "Thus, selection requires variation, whereby individuals differ in some of their characteristics, and differential reproduction, whereby some individuals have more surviving offspring than others because of their distinctive characteristics. Those individuals that do have more surviving offspring are said to have higher fitness (note that fitness is a relative, not an absolute, measure). When the characteristics under selection show heredity (*i.e.*, when parents pass on some of their characteristics to their off-spring), selection will lead to evolutionary change in these characteristics. Indeed, when populations exhibit variation, heredity, and differential reproduction for a trait, evolution by natural selection will occur. Because these three conditions are met for many traits in many populations, evolution by natural selection is widespread.
>
> The factors in the environment that exert selection—both the biological ones, such as an individual's competitors, predators, and parasites, and the nonbiological ones, such as the weather—are called agents of selection. Traits on which agents act are termed targets of selection" (Kingsolver & Pfennig, 2007, pp. 561-562).

To clarify, all that is needed for Darwinian selection are three simple conditions: (1) some amount of *variation* in characteristics ("phenotypically different"); (2) a process of *selection* such that some characteristics survive better than others ("differential survival"); and (3) some means of *replication* so that successful characteristics are passed on to subsequent generations ("survival or reproduction"). How natural selection works in nature is straightforward—there is clear variation in traits (*e.g.* body size), a clear process of selection (*e.g.* starvation, predation), and a clear mode of replication (sexual or asexual reproduction producing offspring that share genes and thus characteristics with the parents).

Selection can be "artificial" instead of "natural"—as when humans breed dogs or horses to exaggerate certain desired traits. The underlying process is the same, but the selection pressure is imposed by humans *choosing* who should reproduce with whom, instead of nature.

It may be less clear how selection could apply to non-biological contexts, but recall the three necessary conditions: variation, selection and replication. *Any* entity that varies, experiences differential survival, and replicates copies of itself will be subject to selection. Once we look harder we realize selection is going on all around us. The designs of cars, say, vary enormously, experience differential survival depending on how efficient they are, and successful features are copied in future generations while bad ones are discarded. The hand of selection is humankind, not nature, but it is a process of selection nevertheless. Cars evolve over time and their features betray an ancestry of incremental adaptation. Most famously, Richard Dawkins pointed out that even ideas ("memes") are subject to evolution by natural selection—they vary, can be favored or disfavored, and are replicated among different people's minds (Dawkins, 1976). Adaptation by natural or unnatural selection has been identified in a wide range of entities spanning genes, individuals, groups, cultures, machines, organizations, and even states (Burt & Trivers, 2006; Dawkins, 1976, 1982; Dietl, 2008; Richerson & Boyd, 2004; Thayer, 2000; Thompson, 2001; Viola & Snidal, 2006; D. S. Wilson, 2002).

The main *difference* between natural and artificial contexts in fact makes selection effects *all the more* important for our purposes. In biological contexts, natural selection can be relatively powerful. Field studies have found that natural selection in the wild can cause a change in a given trait of 1 standard deviation in 16 generations (Hoekstra *et al*., 2001). However, natural selection is still relatively slow because it depends on the death and reproduction of individual organisms, so it can take weeks, months, years or decades for each new generation to appear. In human contexts, by contrast, selection can be: (a) extremely *fast* because replication can occur via imitation and learning, which operates on timescales of days, hours or seconds; and (b) extremely *powerful* because successful traits can be transmitted to multiple individuals through demonstration, speech, or writing. "Cultural" evolution can therefore be rapid and substantial—many times more so than genetic evolution (Richerson & Boyd, 2004).

The power of selection is already being harnessed in fields outside biology. For example, Darwinian "genetic algorithms" have long been used by pharmaceutical companies to breed useful molecules, by engineers to design aircraft wings, ship hulls, and car shapes, and by traders to analyze stock markets. Genetic algorithms create and test millions of possible variations in a cumulative evolutionary process of trial and error, in which design elements that perform well are selected, recombined, and replicated. Over many generations of this process, genetic algorithms "evolve" effective designs. Many designs derived by the blind process of genetic algorithms would never have even been thought of by a human designer, and they frequently outperform human alternatives.

One example closer to human conflict is the use of genetic algorithms to design effective combatants in computer war games. In one recent project with *Quake 3*, initial players were given random mutations, and then fought standard computer opponents. Those that performed well "reproduced" with each other, and their successful strategies blended together to form a new generation, while losers were discarded (New Scientist, 2006). This process was repeated over many generations to "evolve" super-characters that could consistently beat the computer, and were much harder for human players to defeat as well. Curiously, some early versions never emerged from their hiding places, but over time evolved players developed some counter-intuitive and unexpected tactics, such as following very closely behind their opponents whilst constantly dodging from side to side. In a subsequent twist, evolved players are able to copy real human players' tactics and share them among their robot teammates.

Selection Effects in War

Selection effects are likely to be especially significant in human conflict. There is considerable variation (*e.g.* alternative weapons and tactics), strong selection pressure (massive and immediate costs of failure in casualties and dollars), and rapid means of replication (weapons and tactics that perform well will be copied quickly while those that fail will be scrapped)—fertile ground for adaptation. In principle, selection effects help both sides of a conflict, but the Red Queen phenomenon suggests that even if both sides improve in absolute terms, relative to each other they may remain in stalemate (F16s offer no relative advantage over Spitfires if the opponent now has Mig 29s instead of Messerschmitt 109s). Selection effects may apply to a range of *entities* in war: soldiers, weapons, tactics, techniques, procedures, technologies, strategies, machines, leadership, organizations *etc*. The basic logic holds in all cases, but below I focus on individual soldiers for clarity (similar arguments can be made for alternative entities). Now let us consider the individual roles of each condition for selection: variation, selection, and replication.

Variation

In any conflict, each side's soldiers will have considerable variation in skill, strength, stamina, physiology, training, intelligence, discipline, knowledge, experience, morale, incentive, weapons, armor, and so on. (A similar list can be constructed for any of the other possible entities under selection noted above—*e.g*. machines will vary in speed, armor, maneuverability, *etc*). Thus, even a military unit trained in the same place for the same mission by the same people will exhibit significant variation in the combat effectiveness of its individual soldiers.

A crucial additional concept here is *mutation*, which goes above and beyond the natural variation found in a given trait. In biology, genetic mutations occur from time to time via mistakes in copying DNA, many of which may turn out to be detrimental to the organism, but some of which will increase fitness and spread. In modern human contexts, mutation has a parallel in *innovation*—new ideas that offer something genuinely novel. Innovations may offer a step change in effectiveness that goes above and beyond the normal sources of variation outlined above.

Finally, *recombination* is another crucial source of variation. The phenomenon of sexual reproduction is thought to have evolved precisely because of the advantages it brought in recombining (mixing up) the genes of the two parents (*e.g*. promoting resistance to disease). Although no *new* genes are introduced in this process (unlike mutation), existing genes are recombined in novel combinations, which can give rise to serendipitous variation. In modern human contexts, recombination may be just as important—*e.g*. two people swapping ideas that gel to generate something greater that the sum of its parts, or that lead to something unexpected or cheaper or more effective.

Selection

All else equal, poor soldiers (*e.g*. poorly trained, undisciplined, poor marksmen), are more likely to be "selected out" (killed or captured) than good soldiers (*e.g*. well trained, disciplined, good marksmen). Therefore, during the course of a conflict, an army should experience an *increase in the proportion of effective soldiers*. On average, the survivors are the better soldiers (unless killing is somehow completely random, such as through indiscriminate bombardment).

Replication

If bad soldiers are killed or captured, however, then the population as a whole is decreasing in size, so the stronger side can win even if its (dwindling) enemy is getting better on average—because there are ever fewer of them to fight. However, adaptation occurs when new recruits replenishing the army learn from, imitate, or copy the *good* soldiers (the survivors), not the bad soldiers (who are dead). This replication of good soldiers and strategies means the population will *increase in combat effectiveness over time*.

Predictions

If the three conditions above are fulfilled, and selection occurs, then we can expect three principle *results* of selection (which could be quantified and tested):

1. The total *number of individuals decreases* because some have been killed, until replaced by new recruits.
2. *Variation decreases* because selection removes traits at the extreme ends of the distribution (*e.g.* the *slowest* soldiers or vehicles; notwithstanding unusual mechanisms such as "disruptive" selection, or frequency dependence).
3. The average *magnitude* of the trait changes (*e.g*. average speed increases as slow soldiers or machines are selected out of the population).

The punch line here is very simple: variation, selection and replication "grow" a better army. But since *both* opponents are subject to these effects, whichever side experiences *more* variation, *stronger* selection, or *faster* replication will adapt *more quickly* and/or *more effectively* than its opponent. We should be particularly concerned with selection effects, therefore, when we are fighting asymmetric wars.

Selection Effects in Asymmetric Conflicts

Here I argue that selection: (1) *favors weaker sides in general* because they tend to have greater variation, experience stronger selection, and replicate faster; and (2) *favors insurgents and terrorists in particular* because they exhibit especially high variation, selection, and replication.

"Antagonistic interactions between organisms have driven much of evolution," notes Sagarin (2003, p. 68). "These battles have taken a variety of forms, including symmetric conflicts, pitting closely matched competitors that fight for dominance but seek to avoid deadly clashes; and far more lethal asymmetric conflicts involving unequal opponents, in which the weaker combatant resorts to unanticipated, often insidious tactics."

When opposing divisions of Red Army and Wehrmacht clashed in World War II, selection effects might be expected to be roughly similar because they were both large conventional forces employing broadly similar tactics and weapons. In such cases, selection effects will tend to cancel out on either side, leaving the outcome of the battle under the greater influence of leadership, strategy, morale and the raw numbers of men or machines thrown into the fight.

By contrast, when we apply the logic of selection to *asymmetric* conflicts where one side is more powerful than the other—such as counterinsurgency and counterterrorism—it gives rise to a perverse result. Selection effects (imposed by side A) serve to evolve a *more effective* enemy (side B)—*stronger* sides may suffer a *disadvantage* across all three conditions: (1) *Variation*—weaker sides are often composed of a larger diversity of combatants, representing a larger trait-pool and a potentially higher rate of "mutation" (innovation); (2) *Selection*—stronger sides apply a greater selection pressure on weaker sides than the other way around, resulting in faster adaptation by the weaker side; (3) *Replication*—weaker sides are exposed to combat for longer (fighting on the same home territory for years at a time), promoting experience and learning, while stronger sides rotate soldiers on short combat tours to different regions. I now compare each of these three conditions for the weaker and stronger sides in turn, using examples from the ongoing conflicts in Iraq and Afghanistan.

Variation in Iraq and Afghanistan

Insurgents in Iraq infamously come from diverse backgrounds. One analysis found that 10% originated from entirely different countries (Krueger, 2006). It is therefore unsurprising that they employ a multitude of methods and approaches. An Air Force officer working on electronic counter-measures in Afghanistan suggests that foreign fighters were "generally more effective and lethal that indigenous forces. I would argue that the path these fighters took to wage jihad in Afghanistan, and live within a diverse network of other fighters, forced them to be more adaptable on many levels, which translated to their effectiveness" (pers. comm.). Weaker sides are also more able and willing to "break the rules" to stand up to a stronger enemy (hence the origin of guerilla and terrorist strategies of warfare), allowing strategies simply not available to counterinsurgency forces.

By contrast, US soldiers are issued with similar weapons and follow standardized doctrines (which insurgents can learn and work around), rules of engagement, and political constraints. This problem is perpetuated because the Iraqi security forces are duplicating many of these same approaches. These are problems for any Army, but according to one commentator (admittedly a British one), the US Army in Iraq was especially "weighed down by bureaucracy, a stiflingly hierarchical outlook, a pre-disposition to offensive operations, and a sense that duty required all issues to be confronted head-on … Commanders and staff at all levels … rarely if ever questioned authority, and were reluctant to deviate from precise instructions. Staunch loyalty upward and conformity to one's superior were noticeable traits" (Aylwin-Foster, 2005, p 3, 7). Aylwin-Foster also argued that while US commanders differed, "if there was a common trend it was for micro-management," and "the net effect was highly centralized decision-making" which "tended to discourage lower level initiative and adaptability" (Aylwin-Foster, 2005, p. 6-7). A degree of overconfidence in parts of the US administration and military also appeared to reduce the perceived need to adapt (Aylwin-Foster, 2005; Fallows, 2004, 2005; Johnson, 2004; Woodward, 2005). Overall, insurgents appear to be more varied in the first place and to operate in conditions more conducive to subsequent experimentation—key promoters of variation, mutation and ultimately adaptation.

Selection in Iraq and Afghanistan

In both Iraq and Afghanistan many more—orders of magnitude more—insurgents are killed than US soldiers per unit time (*e.g*. see Figure 3), and this higher turnover leads to a stronger selection pressure acting on the insurgents than on US troops.

Replication in Iraq and Afghanistan

Insurgents are fighting indefinitely and on familiar ground—it's their life and home, not a tour of duty in a foreign country—so they will acquire greater local experience than US soldiers. Even if they give up fighting themselves, they can still pass on (replicate) valuable knowledge to others in the area.

Today, information sharing is a key objective among insurgents. In Iraq, "Insurgent attacks are regularly followed with postings of operational details, claims of responsibility, and tips for tactical success" (Kilcullen, 2006, p. 114, citing A. Cronin). Such replication of strategies and technologies extends much more widely, however:

> "In the field today we see real-time cooperation and cross-pollination among insurgents in many countries ... Al-Qaeda operatives pass messages between and among Pakistan, Afghanistan, Iran and Iraq. Improvised explosive devices that first appear in Chechnya proliferate to Iraq and Afghanistan. Iranian improvised-explosive technology appears in Iraq, and Pakistani extremists operate in Afghanistan. Insurgents in Iraq mount operations in response to events in Lebanon, and conduct attacks in Jordan. Southeast Asian insurgents apply methods developed in the Middle East, which circulate via the Internet or on CD-ROMs. This transnational pattern is part of a deliberate al-Qaeda strategy, but there is evidence that non-al-Qaeda groups are also noting and copying these methods" (Kilcullen, 2006, p. 114).

By contrast, US soldiers are deployed on limited tours. Of course, many servicemen have now spent multiple tours in Iraq, but even multiple tours amounts to much less time in theatre than resident insurgents. In any case, rotations meant that personnel "may be sent back to Iraq, but probably on a different assignment in a different part of the country. The adviser who has been building contacts in a village or with a police unit is gone, and a fresh, non-Arabic-speaking face shows up" (Fallows, 2005, p. 70).

The Air Force officer working in Afghanistan noted that peak insurgent successes seemed to coincide with the experience of US ground units: "The longer a unit has been in theater, the more effective they are at decreasing casualties due to IEDs" (pers. comm.). He identified a "14-day adaptation cycle for a given area of operations; that is, the enemy took only 14 days to adapt to one of our new TTPs (tactics, techniques and procedures) and attack us in a new way." As a comparison, French Army conscripts in Algeria stayed 28 months after training, becoming "seasoned soldiers who understood rebel tactics" (Martin, 2005, p. 56). Interestingly, these units even *adopted enemy soldiers and methods*: "Each battalion … benefitted from a hunter unit, often composed of harkis [Muslim soliders in the French Army] and former rebels, which tracked the local katibas [150-man resistance units] and practiced guerilla tactics against them" (Martin, 2005, p. 56). Although they ultimately lost the war, this strategy was deemed highly successful.

The rapid turnover of diplomats and other civilian officials in Iraq, as well as soldiers, has been argued to have "slowed efforts to rebuild the country, disrupted key relationships with Iraqis and led to frequent and abrupt shifts in US policy" (Richter, 2005). The problem was exacerbated in Iraq because of the heavy use of contractors, who would stay just a few months—or less if a Federal pay ceiling of $180,000 was reached (often very quickly, due to overtime). Such changes led to "institutional amnesia" (a direct failure of replication). Many admitted that it took "several months, and in some cases a year, to become proficient in their jobs." Military commanders are rotated in and out fairly rapidly as well. Lt. General David Petreaus, for example, was widely seen as the ideal man for the job of commanding general in Iraq, with a decorated career, a Ph.D. in counterinsurgency from Princeton, and lauded leadership of the 101st Airborne Division in Northern Iraq. Yet even he was only in charge for 14 months. One retired colonel remarked that: "history is pretty darn clear that if you've got an exceptional commander, you ought to keep them in the theater as long as you can."

Information sharing and lesson learning is not absent on the US side. For a start, US soldiers undergo significant counterinsurgency training before and between tours of duty, drawing on experienced instructors who have recently fought in Iraq or Afghanistan. Furthermore, there are means of improving learning in near real time in the field as well as at home:

> "Every brigade in Iraq and Afghanistan now has a secure intranet page, which soldiers are encouraged to fill with observations and queries. Early this year a secure online chat-room, the Battle Command Knowledge System, appeared. Besides circulating thousands of tactical questions and answers, it can help soldiers find technical experts, learn foreign languages, contact counterparts in the war zone, or squint through the web camera of an armored vehicle in Iraq. At Fort Leavenworth, the rather wonderfully named Center for Army Lessons Learned (CALL) has catalogued 6,200 battlefield and training-ground observations in the past four years and produced 400 reports on them. Its staff has tripled. 'They've been pumped full of steroids,' says Lieutenant-General David Petraeus, Fort Leavenworth's commander, who has recently returned from Iraq" (Economist, 2005, p. 23).

Effective replication of ideas and tactics is also evident among terrorist organization (Jackson, 2005). Robert Pape found that, "looking at the trajectory of terrorist groups over time, there is a distinct element of experimentation in the techniques and strategies used by these groups and distinct movement toward those techniques and strategies that produce the most effect. Al Qaeda actually prides itself for a commitment to even tactical learning over time—the infamous 'terrorist manual' stresses at numerous points the importance of writing 'lessons learned' memoranda that can be shared with other members to improve the effectiveness of future attacks" (Pape, 2003, pp. 350-351).

To summarize this section, the three conditions for Darwinian selection—variation, selection, and replication—are *systematically higher for insurgents than for counterinsurgent forces* (see Table 1). Therefore, the situation is even worse than a Red Queen "arms race." Both sides may be evolving and adapting, but all the conditions are in place for insurgents to evolve *more* rapidly and *more* effectively. The US counterinsurgency effort may be expected not just to hold its own, but to fall behind. Insurgencies are complex events, with numerous political, social, economic, geographic and historical influences (Beckett, 2001; Clark, 2003; Galula, 1964; Gilbert, 2002; Nagl, 2002). However, this does not detract from the idea that selection effects may be another important factor—yet one that has received hardly any attention.

Table 1. Comparison of conditions for selection among weaker and stronger sides in Iraq and Afghanistan

Condition	Insurgents	United States
1. Variation	• Multinational • Innovative • Ad hoc methods • Decentralized	• American • Doctrinal • SOPs, law, ethics • Centralized
2. Selection	• Many killed/captured	• Few killed/captured
3. Replication	• Unlimited tours • Stay in local territory • Free information use	• Short tours • Varied deployments • Top-down strategies

"Adaptability": Preparing for the Unexpected

Even good adaptation is not good enough. By definition, you are "adapting" to something that has already happened—*i.e.*, too late. The Holy Grail, therefore, is to find a way to generate *adaptability*, the ability to react immediately and effectively to rare, unpredictable, or even unknown threats.

There is no foresight in nature. However, there are some tricks we may learn from the biological world that make organisms better equipped to deal with rare or unpredictable threats. One way biological organisms maintain flexibility is through "phenotypic plasticity," which is "the ability of an organism to express different phenotypes [characteristics] depending on the biotic or abiotic environment. Single genotypes [*i.e.* despite having identical genes] can change their chemistry, physiology, development, morphology, or behavior in response to environmental cues" (Agrawal, 2001, p. 321). "Plasticity" is highly adaptive, because it means that organisms can quickly adjust to widely different situations within its own lifetime—even to completely novel problems it has never experienced before. Another method found in nature is to trigger new adaptations; "under stressful conditions organisms can produce DNA polymerases (mutases) that replicate faulty or mutated DNA, potentially introducing solutions in an environment where novelty is required" (Agrawal, 2001, p. 325). Transposons and mutases have themselves evolved by natural selection—Darwinian selection for the very *ability* to adapt. Over evolutionary time, the tools to generate innovation have been built into successful organisms. Ideally, we would build such features into human institutions as well.

The advantages of adaptability can be seen most clearly when looking over long stretches of evolutionary time—which traits and strategies have endured across long time periods and even survived major extinction events? Analyzing the entire span of biological evolution paleontologist Geerat Vermeij (Vermeij, 2008) identified seven broad strategies that tended to be most successful in the face of novel security threats: (1) tolerance; (2) active engagement; (3) increase in power or lifespan; (4) unpredictable behavior; (5) quarantine and starvation of the threatening agent; (6) redundancy; and (7) adaptability. He finds that "the most successful attributes of life's organization—redundancy, flexibility, and diffuse control—are also the characteristics of human social, economic, and political structure that are best suited to cope with unpredictable challenges." Nature may therefore offer invaluable lessons for how we design our own defensive and offensive strategies (Sagarin, 2003).

Vermeij's key insight is that some adaptations to *everyday* threats also turn out to be effective adaptations to *rare, novel* or *unpredictable* threats. The owners of these serendipitous adaptations will be more likely to avoid or withstand disasters. There are numerous examples in human history in which "everyday" adaptations were effectively used to deal with entirely *novel* threats instead. For example, when Soviet tanks escorting convoys in Afghanistan discovered they could not elevate their guns high enough to engage hostile forces high on the mountainsides, the Soviet Army resorted to using self-propelled anti-aircraft artillery instead (Beckett 2001). Armies that accumulate diverse and flexible technologies or strategies over time are more likely to be able to fall back on a broader range of alternatives in unusual circumstances. This should be a goal for the constantly changing challenges of counterinsurgency.

Conclusions

Competing populations are subject to Darwinian selection effects whenever three conditions are in place—variation, selection, and replication. When conflict is asymmetric, *weaker sides have an intrinsic advantage* because they tend to be more *varied*, under greater *selection pressure*, and to *replicate* successful strategies rapidly. This would explain the empirical observation that weaker sides—such as insurgents and terrorists—appear to adapt more quickly and more effectively than their stronger foes.

Both sides can use this knowledge to their advantage. Weaker sides can capitalize on their intrinsic advantages, promoting innovation, adapting to strong selection pressure, and replicating effective strategies. Stronger sides have the harder task of turning the tide in their favor, but counterinsurgency and counterterrorism forces can exploit insights from evolution to (a) *reduce enemy adaptation* and (b) *improve their own adaptation.* This can be achieved by a three-pronged attack on all three elements of selection—variation, selection, and replication, which must be maximized on one's own side, and minimized on the side of the enemy.

In this paper I have simply outlined why selection effects may be important, especially in counterinsurgency and counterterrorist campaigns. The next step is to apply the quantitative tools of evolutionary biology to measure and compare selection effects in war. The idea of using biological models to study modern counterinsurgency has been specifically proposed by researchers within the defense community (Drapeau, Hurley, & Armstrong, 2008), and some preliminary models have been completed (Johnson & Madin, 2008; Turchin, 2005). Using simple assumptions and basic data, novel predictions can be derived, tested, and used to forecast the effects of alternative strategies.

One goal for future analyses is to explore whether insurgencies are best modeled as predator-prey systems, host-parasite systems, or some other alternative (Drapeau et al., 2008; Johnson & Madin, 2008; Lafferty, Smith, & Madin, 2008; Turchin, 2003). All are possible given certain assumptions, and each may offer unique insights despite having pros and cons. Host-parasite systems would emphasize the Red Queen type of "co-evolution" discussed earlier and apparent in Iraq—in which specific new adaptations by one side are continually met with specific counter-adaptations by the other side. By contrast, predator-prey tend to emphasize *asymmetries* in the adaptation of predators and prey. While both accumulate adaptations over time, prey tend to develop more specialized defenses than predators have specialized means of countering them, thus better conceived of as an arms race or "escalation" rather than reciprocal co-evolution (Vermeij, 1987, 2008). Escalation "places primary emphasis on the role of enemies (predators, competitors, and dangerous prey) as the most important selective agents among individual organisms" (Dietl, 2003). Predator-prey systems support the idea that weaker sides—if weaker sides can be considered "prey"—will adapt *more* effectively. For example, the "life/dinner principle" mentioned earlier implies there will be stronger selection on more committed or threatened sides (rabbits) than on the predators (foxes). Finally, most predators prey on several species, making it difficult to develop specialized adaptations for each one. An analogy might be that although insurgents in Iraq can focus exclusively on adapting to US soldiers, US soldiers have to adapt to many theatres of operation.

Natural selection may appear too simplistic to apply to the complexity of modern war. However, many complex processes are based on simple underlying principles (Jervis, 1997; Levin, 1999). Perhaps the most complex system of all is biology itself—yet DNA, the fundamental ingredient of all life, is made up of a handful of simple molecules, and evolution proceeds with just three simple rules (variation, selection, replication). From so simple a beginning, to paraphrase Darwin, arose the incredible complexity of life on earth that gave rise to Earth's biodiversity, ecosystems, and the human brain. As one author put it recently, "Darwinism was revolutionary not because it made arcane claims about biology but because it suggested that nature's underlying logic might be surprisingly simple" (Orr, 2009). War may be complex but so is nature. If they share common underlying principles then we should at least explore them in case they offer novel ways to win the conflicts we are currently losing.

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