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Leadership and uncertainty: complexity and the lessons of history

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Abstract

Problems faced by military leaders will be used to evaluate techniques for dealing with the limits of knowledge. A survey of recent scientific developments will establish that knowledge is limited in principle, and historical examples for coping with limited knowledge in practice will then be analyzed. The convergence between the science of complexity and successful cases of social evolution indicates that the limits of knowledge extend the frontiers of understanding. Concluding sections will briefly explore some ethical implications potentially useful to political and social leaders.

1. Introduction

Military planning affords a challenging case for studying how well social systems operate with limited knowledge. The future challenges military planners must anticipate can be life threatening, and they cannot afford to guess wrong on any count. In periods of dynamic change, like the present, planners face heavy responsibilities, for they must make decisions about so uncertain a future that projecting political, military, or technological trajectories is virtually impossible. Planners must even consider the possibility that military organizations will be asked to deal with situations other than war e.g., policing drug traffic, building nations, or defending the ocean ecology—which have never been thought of as military responsibilities before. Moreover, in changing times it is hard to identify enemies, since they may be in forms that are qualitatively new. Since no society can afford to prepare for every conceivable threat, it is agonizingly difficult to decide what

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to do. But recent developments in contemporary science provide insights into symmetry-breaking evolutionary processes that should help planners better understand their situation and more effectively prepare for the future [40].

Applying scientific models to societies is almost as risky as long-range planning. However, translations from one domain to another can prove useful, so long as 1:1 correlations between chemical, biological, and ecological models and military problems are not expected. In addition, we should not have unrealistic expectations about the predictive power of the new science. Side effects can always occur which fall outside the purview of modeling constraints [54]. However, because the new science more closely approximates nature than the artificial idealizations of the past 300 years, its predictions can be wrong and still be useful. The real world which models simulate, after all, evolves by surprising. It feeds some slight variation through an incompletely known environment laced with nonlinear relations and amplifies results unexpectedly.

Planning has traditionally sought to avoid surprises by controlling events and suppressing variations. Science was expected to provide planners with perfect knowledge. With LaPlace, science claimed to have learned the deterministic laws governing behavior and the techniques for gathering knowledge objectively. Predictions could be guaranteed, according to this model, because all that was necessary to know the future was to observe the present, accurately describe it, fit the data collected into the applicable laws, and crank out the incontrovertible conclusions.

Work in various scientific realms undermined the authority of scientific claims from the beginning of the last century. In particular, the quantum theory of Bohr, Heisenberg, and Born discovered that instrumental observations could not provide complete and perfect knowledge. Quantum theorists found that observing nature changed it, leaving an inevitable ‘uncertainty’ about scientific knowledge. Meanwhile, evolutionary biologists learned that genetic mutations had an inescapable air of randomness about them. Moreover, they concluded that the evolutionary steps from species to species were not smoothly mechanical transitions but short, sudden bursts of untrackable turbulence. Evolution rewrites the laws of nature when brief, surprising periods of change punctuate millennia of equilibrium [19].

Until recently scientists and laymen viewed these developments with considerable unease. Challenging the claims of modern science left them without any authority. Physicists and philosophers lamented reaching the ‘limits of science’ [57] or ‘the end of the road’ [47–48]. But complaints that a scientific paradigm could not accomplish all it had promised left unquestioned the premises on which that paradigm rested. Physicists and philosophers still assumed a world obeying deterministic laws existed externally to and independently of science. They just begrudgingly conceded that their method proved itself an obstacle to gaining complete and perfect knowledge of that world. Working physicists went right on researching, of course, confident that they could solve these conundrums were they free for five minutes to think about them [8]. Developments have come mostly from other spheres, like thermodynamics, biology, and computer modeling [29]. These developments suggest that a science capable of being wrong is actually a rich instrument for thinking about the future. It forswears the claim to omniscience which previously encouraged excess confidence, and it brings science out of the laboratory, where circumstances are rigidly controlled and differences averaged out, into closer approximation of reality, where contingencies arise and exceptions prevail.

A handful of scientists started speculating about a new paradigm [58] in the 1950s. In their view, nature was not once and forever given, nor was it reducible to matter in motion. Quantum physics and evolutionary biology suggested that nature had to be treated holistically and understood as a process [52]. In this paradigm, imperfect information is not just the limit of scientific knowledge but an inherent part of reality. In fact, it was because nature's knowledge of itself was as imperfect as scientific observations that an irreversible nature grew and changed. With this insight the limits of knowledge extended the frontiers of understanding [51].

The old paradigm could track the deterministic trajectory by which material particles changed position and momentum. But it stumbled badly discussing questions about, say, the emergence of life [55,39]. It had no way to explain how the qualities of particles changed in different circumstances. The new paradigm makes the obstacles of science the attributes of nature. It suggests that thermodynamic flows in nature interact with elements and transform them [50], just as scientific instruments aimed at existing reality alter it and produce data embedded in the structure of the observing apparatus. Energy flowing from hot, concentrated spots toward cold, empty spaces bounces and jiggles everything in its path, and the resulting interactions are as creative as quantum physics experiments. Material objects interacting with energy flows can be transformed, and when, through self-organization, interactions stabilize the embedded transformations endure. Information created through interactions is captured in emergent structures, making self-organization the vehicle for evolution in nature. With the new paradigm, a deeper understanding of how nature works is achieved, although science might no longer be able to say precisely what nature is or, where it is going. Nature is now seen as a process of 'becoming', whose evolution science tracks through successive levels of reality. Thus, 'nature is too rich to be described in a single language' [49:53]. Emergent levels of reality require different descriptive laws, and none could be 'reduced' to a privileged dimension.

Science was liberated by being limited. Ultimate reality was neither dead matter nor immutable laws, since matter changed and laws were created. Ultimate reality now seemed to be the patterned processes of self-organization applicable to chemistry, biology, and ecology. Those same patterns may apply to the evolution of human social systems, as well. If so, planners will still be uncertain about the present and incapable of predicting the future. But having a better understanding of how societies change, they can more effectively prepare for inevitable surprises. Military examples may prove the easiest way to test how well scientific models can be transferred to human social systems, for, despite their intensity, military activities tend to be less complicated than political or economic ones.

2. The evolution of social systems

Military societies regularly have to evolve or perish, and their evolutionary punctuations have been dramatic [45]. Experiences as extensive and intense as those shaping military societies have, no doubt, left legacies about how to operate complex dynamical systems. But it is also likely that the military's hard-earned wisdom is buried in institutional traditions rather than consciously articulated. In an interactive universe, all information does not have to be stored in conscious agents, for much of what emerges depends on information stored externally [16]. This is true of life, where DNA depends on environments to produce organisms [32]. It is also true of our social identities, which depend as much on culture as genetics to produce behavior [5]. So it should not surprise us to learn that, like Moliere's bourgeois gentleman speaking prose, military leaders live complex systems without knowing it.

This paper will test how effective applications of the new scientific paradigm to social evolution are by examining two naval leaders, Lord Nelson and Admiral Moffett. The results will show they anticipated much that the new science advises. Finding that military systems are typical examples of natural processes should not be taken as a claim that war is part of 'human nature', however. An evolutionary view of society implies war has not always been inherent to the human condition and may change radically from time to time. The new scientific paradigm assimilates Ortega's notion that 'man has no nature; what he has is history' [43]. 'War' is an emergent attribute, a function of social systems that have reached the civilized level. Modeling societies using complexity concedes violence existed in archaic societies but shows how war differs from it. Archaic violence was disorganized, individual, generally emotional in origin, and usually short-lived. People fought for the immediate satisfaction of some personal need or desire. Fighters were 'warriors,' like their archetype, Homer's Achilles. In civilized societies, however, violence is organized, collective, often rational, and frequently enduring [20,42]. People fight for strategic goals. Fighters are 'soldiers,' trained specialists who like Hector subordinate biological survival to collective goals. They diverge from the natural inclination to fight only for immediate interests when complex societies harness natural propensities to emergent moral laws [4].

War exemplifies the interactive processes typical of both nature and Post-Modern science. This leads to another conclusion: Civilization emerges as a consequence of interactions between ever more organized groups, which interactions create information that complex self-organized social systems store in themselves [59]. War, like the Hindu deity, Shiva, and the Second Law of Thermodynamics, is both a creator and a destroyer. War created or helped create any number of admired social institutions—democracy in Ancient Greece [22] and the nation-state in Modern Europe [11] being two obvious examples. Of course, war also helped create unattractive social forms, such as female victimization and male supremacy [14].

War creates because organized systems observe each other by exchanging energy, matter, and information. What and how much energy, matter, and information is exchanged, and for what reasons, varies radically over time. But, at bottom, war is simply an example of how nature reduces gradients. In war opposing structures introduce energy, matter, and information into each other in types, forms, and rates they cannot assimilate [15]. Then one combatant's structure endures while the other is smashed or dismembered. Either way, the goal of maximizing universal entropy is satisfied. Biological and social structures, similarly, purchase local order at the expense of cosmic entropy. They self-organize and survive by drawing resources from their environments and dumping waste into them. But social systems interacting through war may also integrate more complex systems that mutually transform their components. Emergent societal forms reflect general evolutionary patterns. They are born amidst entropy bursts and expel entropy into the outside world at greater rates, for the more internal order a structure produces and maintains the more work it must do and the more energy it must dissipate. Civilized societies are not caused by war, for they are organizational responses to over-taxed natural resources. Organized around agriculture, social systems solve problems individuals cannot solve for themselves. War, however, catalyzes the self-organization of civilized societies [9], because it favors state structures able to coerce naturally lazy and self-protecting human beings into working hard and long, in specialized tasks, at grave risk to themselves, for benefits most will never savor.

Like biological evolution, war involves a selection process in which the fitness of a military organization is tested by its environment, another military organization. But, and here is where limited knowledge is so threatening, because the environment measuring military fitness is an organized body of thinking, imaginative, frightened, and, often enough, angry human beings, it is the most insulting environment in the world. Thus, military organizations must compute solutions posed by environments that are actively trying to select against them.

Past science proposed that Planners should anticipate the needs of organizations by reducing the military art to a finite body of axioms. Strategy and tactics could then be deduced with logical necessity and applied with confidence. Sophisticated theorists still spoke of ‘friction’. But all they meant was that axioms might be applied on the basis of imperfect information or commands communicated through noisy networks. These were essentially technical problems, and as soon as tools were developed adequately, perfect knowledge of the battlefield would be available, accurate communication insured, and outcomes guaranteed. Some military leaders still think this way [44]. They believe advanced electronic sensors give commanders complete knowledge and total dominance.

3. Building adaptive systems

The best example of the belief that formal rules can guarantee military outcomes is the ‘Permanent Fighting Instructions’ (PFI) which directed operations in the Royal Navy from the Stuart Restoration to the French Revolution. In that period, the rules imposed on ship actions were equivalent to the deterministic laws controlling natural bodies. Captains were prohibited from exercising initiative, and complete information about each ship was stored by positioning them in-line. Fleets were controlled by Laplacean admirals, authorized to command every movement top–down. Thus, commanders could know with absolute certainty what ships should do to produce desired outcomes. The intended state of a fleet at the end of an encounter is analogous to long-range planners designing solutions to predicted future problems.

Top–down command and control was so severe that no British captain dared move his ship from the line, nor did admirals attack except with the wind behind their enemies. When British fleets outnumbered enemies the smallest ships simply cruised along at the tail end, firing nary a shot throughout whole battles. To escape, wounded enemies needed only to turn away from the British and head back to port, for victorious captains were not allowed to pursue the defeated for fear control would be lost. Tactical effectiveness was so limited that, in thirteen sea battles, not a single ship was sunk. For nearly 150 years the British were content with such results, because after wounded enemies returned to port, British maritime dominance was preserved [48]. Success controlling the sea makes the seemingly absurd implications of the PFI reasonable.

The French Revolution and Napoleon posed a new challenge, however, and Lord Horatio Nelson developed different tactics for dealing with it [33]. Revolution in France integrated ‘the Nation in arms’, making France a more complex and dynamic society than it had been before. It could access more diverse resources in greater quantities and process them more efficiently than any other Continental state. In Napoleon’s hands, all that power could be used to conquer England. All he needed was control of the Channel for twenty-four hours. In that window of time he could transport the new French conscript armies, invade England, live off the land until the tiny British Army was crushed, and make the country his own [23]. It was not enough, therefore, to periodically re-establish British dominance. As long as a French fleet existed it could, on a moment’s notice and at a time of its own choosing, set out into the Channel, keep a lane to England open for a day, and accomplish the total destruction of Britain. Any freak event—accidents, storms, miscommunications, or mistaken policies—could temporarily remove or restrict the Royal Navy’s presence and allow a French attack.

To secure England, Nelson had to destroy the French ability to invade. His self-appointed task was to decimate, not frighten or discourage, the French fleet [26]. Ever vigilant, Nelson had to be prepared to fight whenever the French, with their Spanish allies, decided to make their play [31]. Months, even years of patrol time were spent blockading ports, since there was no way to anticipate Allied maneuvers and any proactive initiative might leave Nelson just out of range at the critical moment. He was in a position comparable to the world described by chaos theory, where the slightest error in measuring initial conditions may cascade exponentially through a series of bifurcation points until all knowledge of an observed system is lost [13]. Nelson had to find a way to make his small, weary, weather-beaten fleet effective in competition with the Allies, regardless of when they acted or what they planned [25]. His leadership revolution abandoned the effort to predict what the Allies would do—he would not depend on correctly anticipating Allied movements. Effectively conceding that a commander’s knowledge is always limited, Nelson was wise enough to realize fleets knew more than he. So he created a fleet able to successfully deal with surprises—with whatever decision the enemy made.

Ironically, the measure of Nelson’s achievement is a victory won without his active participation—which was also the case in his earlier triumph at Aboukir Bay. At Trafalgar, Nelson was fatally wounded just as the fleets engaged. For the rest of the battle he was below decks, sometimes unconscious and unable to command. Up to that point he had issued only two orders: ‘Engage the enemy more closely’ and the famous ‘England expects every man to do his duty’. Neither order gave any concrete direction, and the latter, he said, was merely ‘to amuse the fleet’. As far as the second in command, Collingwood, was concerned, however, Nelson’s issuing orders was not the least bit funny since ‘we all know what to do’. Nelson went beyond avoiding specific directions, actually giving the young captain commanding the sloops authority to issue, in the Admiral’s name, any order he, the junior captain, thought proper [35].

Nelson was not abdicating responsibility. By the artfulness of his leadership in the months preceding Trafalgar he had built a Fleet he did not have to command and control; Nelson's fleet could fight itself. Spontaneously and bottom-up, its captains ignored conventional maneuvers and sailed their ships directly into the Allied fleet. That 'the order of sailing' would be 'the order of battle' was Nelson's 'intent'. But it was not, in any normal sense, a 'plan' for fighting the Allied fleet. It simply said waste no time positioning ships. Rather, upon sighting the enemy, attack immediately. Immediately attacking implied the battle was to be viciously fought, for total destruction was Nelson's goal. Sailing directly into the Allied line reveals Nelson also intended to break it, so that the larger fleet could be fragmented and then dealt with in isolated units, where British supremacy momentarily existed [35]. Nelson brought tactics from Revolutionary land warfare—especially, the concentration of force—to operations at sea.

4. Bottom-up solutions

Nelson did not plan in detail because he knew 'nothing is sure in a sea fight' and that communications break down once the guns belched black smoke. Yet it is reasonable to ask why Nelson's fleet was successful when its commander was mortally wounded, no centralized command existed, and no advance plan promulgated. The answer shows that information can be stored in social systems which far exceeds the knowledge available to leaders in real time. It also makes Lord Nelson, an eighteenth century admiral with little formal education but a life rich in experience, virtually prescient. He intuitively designed systems capable of surviving in rapidly changing environments, of evolving the ability to continue evolving. That is, his strategy is an analog version of complexity theory, an anticipation of Darwinian evolution, and a demonstration of how any structure successfully survives.

Understanding how a one-eyed, one-armed popinjay who flaunted convention, hated Frenchmen, and despised Spaniards accomplished so much requires a diversion into language theory. This may seem irrelevant. But language is the evolutionary system of which we have the most direct knowledge, so much can be learned from it. Language begins in confusion, said Saussure, for words are initially just noises. However, arbitrary in origin, words nevertheless communicate information because people agree to associate specific sounds with certain referenced parts of their environment. The sounds can be anything—'dog' or 'chien' or 'hund'—and it is only by convention that people in different places agree to use one of these noises to refer to certain domesticated animals.

The arbitrary origins of words and the systematic convention of their references vividly illustrate a fundamental aspect of all natural processes: what something is and what it means are not the same. What something is depends on its source; what something means depends on its context. What something is, existentially, is its raw Being; what something means varies with its effects. Thus, the same thing can perform many different functions, depending on the contextual relationships in which it is entangled. In any decent human conversation, for instance, a sentence will emerge no one has ever spoken before. Yet everyone present understands its meaning, and it is the ability to surprise without confusing that makes language successful. This is accomplished because language, to be shared, must have publicly agreed upon meanings for the words used and publicly stated grammatical rules for constructing sentences. That is, language does not evolve because 'anything goes' [21]—if that were the case what was said would not be understood and language, having no selective advantage, would disappear. But language would be almost as useless if it were limited to a list of previously authorized statements, in the manner of the PFI. Language survives and evolves because it constrains how we speak without prescribing what we say. Obliging lower level activities to follow rules preserves a linguistic system. But liberating expression permits it to evolve to higher levels, to utter sounds in which new meanings are referenced or emerge.

Successful evolutionary systems behave similarly. The components constituting all self-organized systems, for example, become something different when the contexts in which they act change and new rules are written. Every biological organism on our planet has carbon in it, which is the same atom in coal, diamonds, and graphite. But if a suitable weight of carbon from one or all of these latter sources were placed in a beaker with proper amounts of the other atoms making up human beings and briskly shaken, not stirred, no General Patton pops up to show young men how to get others to die for their country. It is not the material stuff of which our bodies are constituted that makes us human but the way that stuff is contextualized. Moreover, it is a fundamental axiom of the new science that what emerges when interactions transform components is not determined by the components but by the contexts their interactions create. That is why courage and honor and selflessness cannot be reduced to genetics. The people who behave well in military situations owe as much to their organizations as they owe to themselves. Members of wholes greater than the sums of their parts, people acquire attributes like selflessness and dutifulness when social systems self-organize.

Now there are at least two fundamental lessons here, one negative and one positive. The negative lesson is that, once again, the future is unpredictable, for even if leaders get right what the next step in evolution is they cannot determine what that step will mean. They may, for instance, correctly assess a threat, anticipate when it will materialize, and plan how to deal with it. But they can never know how those actions might alter the web of domestic or international relations. This may be why military leaders rarely like going to war—they realize that even if war solves a known problem, larger, less tractable problems might result from victory. Winning the Cold War is a classic example, for the end of a bi-polar world poses the ill-formed problems now faced.

The positive lesson is that, to succeed, planners do not need to know the future. Their continuous guidance is no more necessary than direct orders were for Nelson's fleet. Nelson created a system that could read its own environment, detect threats and opportunities, and quickly respond with local initiatives. No one needed to know in advance, where the Allies would be, which way they would be going, what ships were in their line, what the weather was, or any of a million other details about initial conditions that could alter outcomes. Nor was a plan for dealing with every contingency needed. Relying on the initiatives of individual captains to confront problems at the local level, Nelson's fleet out-smarted its selecting environment. Victory resulted from his creating an organization in which individuals were transformed by membership in a community. His fleet really was a whole greater than the sum of its parts, and, doing the duty England expected, the men in it transcended their limitations. Their bold actions forced the Allies, whose command and control structure mimicked the PFI, to make choices at rates beyond their processing capacity. But why did not Nelson's fleet fly apart, as each captain taking 'his own bird' made individual decisions? Why was chaos not introduced when Nelson fell mortally wounded?

Organization was preserved even as individual captains acted opportunistically because Nelson's 'band of brothers' was bound by grammar-like rules which made their actions meaningful to each other no matter what they individually did. Duty constrained how the captains acted without determining what they did. They had not planned in advance to do certain things regardless of the situation. Nor were they obliged to inform Admiral Nelson of their actual circumstances and wait for him to decide what action was 'best'. Having talked for hours and hours over various possibilities and shared among themselves a concept of battle, individual captains could react instantly to their immediate conditions, knowing full well that the ships behind and around them would figure out what challenges or opportunities had appeared and that they would, out of love, respond in ways calculated to help adventuresome comrades. The fleet thus solved its own problems, as they arose, in real time. Changing structure faster than the environment, Nelson's fleet survived the test of battle and the death of its commander.

Fear of failure makes learning this counter-intuitive lesson difficult. It urges leaders and planners to match future forces to specific threats and to have 'zero-tolerance' for deviations. Training encourages leaders and planners to equate preparedness with perfection and to plot ideal solutions to predicted challenges. But perfection extracts a dangerous price, for perfectly fit organisms are adapted to exceptionally narrow niches [3]. Perfect fitness means an organism and environment have complete and total knowledge of each other. Complete and total knowledge is only conceivable if the organism and its environment are at equilibrium, where there is no flow across the organism's frontier. Perfectly adapted structures are either crystals which may be shattered by a single blow—or they are dead.

5. Naval aviation and the battleship paradigm

The US. Navy of the 1930 s, which was 'ever more efficient at less and less' [7], typified the dangers of perfection. That Navy was hard to criticize, for it appeared exceptionally fit. But although ever more ready to steam across the Pacific in mighty battleships looking for a decisive victory over Japan, it was caught anchored and then devastated in a morning. The raid on Pearl Harbor, of course, was an 'observation' made by releasing energy and matter in ways that maximized entropy. But the raid also created information, for the US Navy that resulted was an embedded 'phenomenon' shaped by the attacking instrument. After 1942, the US deployed a carrier Navy that showed its meaning at Coral Sea and Midway, the first battles between fleets which never saw each other [24].

To be sure, the 'Gun Club' members who had shaped the fleet bombed at Pearl Harbor were not instantly converted. They repeatedly urged Congress to build more and newer battleships [42]. The Japanese attackers were themselves so captivated by the dominant paradigm that they promptly divided their carriers and used them as off-shore bombardment platforms [37]. Yet the USN had the wherewithal with which to fight a new kind of war. So is it not reasonable to suppose that planners had actually foreseen developments and successfully prepared for them? And if so, ought we not to honor and imitate these leaders?

Admiral William Moffett was the father of the American carrier Navy, and his most ardent admirers, judging from the outcomes, hold him up as the paragon of clear, forward-looking vision. But historians who have carefully studied his actions as the first commander of the Bureau of Aeronautics appraise Moffett's leadership in less adoring terms [12]. It was clear, in any case, that he was no Billy Mitchell—he was no fanatical prophet intending to transform the fleet. Early in his career he had actually urged young pilots to get out of aviation before killing themselves. Nor is there any evidence that Moffett ever radically changed positions, like Admiral William F. Fullum, who had a conversion experience as hundreds of planes passed repeatedly over his anchored ships on Armistice Day, 1918.

Moffett saw naval aviation as a hand-maiden to Mahanian battle fleets. Within this paradigm, navies existed to 'command the seas,' which was achieved by decisive battles fought by capital ships concentrated in fleets. Airplanes could be added to Mahanian fleets. Launched from battleships, airplanes could be their 'eyes,' searching beyond the horizon for enemies. Later Moffett realized planes could help direct naval gunfire, flying over enemy fleets and 'spotting' for battleships. He quickly realized spotter planes would be threats and that an enemy would defend against them. So he endorsed building carriers to bring more scouts and spotters into service and provide them with protection against similar weapons in the hands of opponents. Finally, like Bradley Fiske, he even defined airplanes as 'guns with 200 mile ranges' and imagined an offensive role for them.

This is the sort of 'linear' thinking which 'unpacks' an existing paradigm and projects its logical implications into the future. Laplace would have been proud; but neither Moffett nor Fiske nor any other responsible Navy leader predicted Coral Sea or Midway. That was beyond their ken. Like all rational leaders, they were trapped within the cognitive constraints of their society. Every society is constituted by a set 'social roles', which perpetuate dependable individual behaviors and make cooperation in an environment possible. The information structuring social roles is stored in symbolic form in the Values, Ethics and Morals (VEMs) shared by members of societies. VEMs are social constructs communicating the 'meaning' of actions to individuals.

The meaning of local actions is their system-level effects, and VEMs symbolize meaning. VEMs do not reference what people do but the effects actions have on societies. Their emergence indicates social systems have self-organized, for they would have no selective advantage in *natural* environments. In nature, individuals act through their biologically endowed senses, computing what serves their interest best through sensations of pleasure and pain. VEMs superimpose higher-level constraints on behavior, for they compute solutions in terms of 'good' and *evil*. Good and evil map global states in terms of their desirability. Through the mediation of VEMs, which act like periscopes, individuals rise above their status as component parts and glimpse societal wholes. Equipped with a sense of how social systems will respond to different options, individuals can anticipate which actions will be rewarded and which punished. Since people experience rewards and punishments as pleasure and pain, VEMs build on biology even if they cannot be reduced to it.

In societal systems, like navies, VEMs are reinforced by experiences with available technologies. Tools incarnate purposes and propensities. Their use habituates people to certain regularized actions, which are rewarded by rank and honors. Regularized cooperative actions constitute social roles, the performance of which is evaluated at the social level. Of course, people judge themselves by the same VEMs, and when expectations raised by VEMs are compared to resources accessed, the semantic loops constituting systems are closed [6]. Through the emotional commitments engendered by VEMs, people 'lock-in' to the behaviors appropriate to social systems.

Planners raised in social systems tend to think within the boundaries that experience has conditioned, and the leaders who made a carrier Navy possible did not 'think outside the box'. Their VEMs were Mahanian strategies; their skills made them effective line, gunnery and engineering officers; and service aboard battleships poised for fleet engagements won them promotions. But Moffett, Fiske, and the rest kept an option open, which was something just as valuable as leaping their intellectual traces. They had no real idea of what air power would mean to twentieth century navies. They did not even know what form of air power would turn out to be useful, which is why Moffett fought for blimps and dirigibles, built water- and carrier-based airplanes, and endorsed storing planes in dirigibles and capturing them with trapezes. It was not his prescient genius that saved the day. It was his willingness to make mistakes, to tolerate errors that proved invaluable. Moffett was the variation who kept the demonstrably fit battleship navy from replicating itself perfectly. He 'wasted' money on a new, frail, untried and untested technology, which allowed the Navy to express a new idea. He did not have to create a new Navy; he had only to maintain the ability of the existing Navy to grow and change. A 'steward' [53] Moffett 'preserved the sources of renewal', as the ecologist Buz Holling might put it.

The Navy Moffett left upon his death in the crash of the airship *Akron* confronted its future as a 'cloud of possibilities' [1]. Unlike those of his contemporaries whose lives were devoted to perfecting the battleship fleet by relentlessly tuning their every thought and action to its needs, Moffett, like nature and Post-Modern science, was 'error-friendly' [60]. He did not anticipate and solve all problems but prodded and cajoled authorities to risk experimentation, to perch the Navy on what Chris Langton calls 'the edge of chaos' [30].

Moffett's actions, considered within the context of his public testimony and private statements, show that for military organizations, as for nature, error-making is vital. As examples, consider the carriers *Lexington* and *Saratoga*, built during Moffett's career. In 1928, they were the biggest ships in the Navy, they steamed at 34 knots, and carried 88 planes a piece [41]. But these prototypes of future forces were not deduced by Cartesian logic. They come closer to being products of agents Allen calls 'Stochasts', people who embrace change consciously [2]. The *Lexington* and *Saratoga* were virtually accidents—they owed their magnificent size and attack capacity to international diplomacy and domestic politics not long-range planning. More battleships could not be built because of the Washington Naval Treaty, while bureaucratic inertia resisted General Billy Mitchell's zealous attempts to consolidate all air forces into a single new service. Yet after 1941 the cruiser hulls with flat tops from which Navy planes flew proved to be the variants around which a new species evolved and a new set of doctrines emerged.

6. Living with the limits of knowledge

Ethical implications arise from combining complexity theory and the limits of knowledge. Complexity tells us that, at bifurcations, nonlinear systems can leap to unpredictable new organizational levels, influenced by random individual acts. Thus, it is possible for individuals to have profound effects on the future states of systems. But if the limits of knowledge leave individuals incapable of predicting the future state of social systems, can they be held responsible for what their actions cause? If systems really are complex, how can the word *cause* even be used, and without it what is left of the Western ethical tradition [27] Military examples reflect this situation, for battles are won and lost, with greater or lesser casualties, because of unpredictable individual acts. In fact, the most familiar consequence of a nonlinear reaction is the kingdom lost for want of the nail in the shoe of the horse unprepared for the battle.

We all know that kingdoms are only lost because whole companies of blacksmiths, iron mongers, horse-breeders, and so on make a tangled web of interacting choices. Thus, while it is clear actions have consequences, if consequences are determined on system levels, of which agents never have full knowledge, then every act must be a shot in the dark, the effects of which are beyond the agent's control. Individuals may be responsible for what they do, but, at least on the historical level, they rarely accomplish what they intend. Complexity theory would seem to render ethical considerations moot.

But we must remember our starting point - the search for a science able to map a world of becoming rather than being, of processes rather than things, of change rather than stasis. If the world is a more or less continuous process of change, then one thing we should expect is for different kinds of information to be created as new systems self-organize. The emergence of VEMs exemplifies this, for it maps the symmetry-break between organisms mapped by genes and societies mapped by symbols. If VEMs emerge, there is no reason to suppose they are any less prone to evolutionary change than everything else in the world. VEMs emerged when social systems needed to correlate the behaviors of large numbers of people separated by great distances. The first societies to do that, 'civilizations' had specific far-from-equilibrium states to maintain if specialized farmers, soldiers, artisans, and clerks were to act as if they knew what one another were doing. These states could be described in highly moralized terms, for civilizations had created well-defined environmental niches.

But over time societies became more complex, with ever larger numbers of specialized roles being developed. Each new role meant that social systems had found new resources to access or new ways to process resource flows. The more resources flowed into social systems and the more efficiently resources were processed, the more dynamically unstable they became. Eventually, societies reached points comparable to military systems, in which any perturbation was potentially fatal. Finding ways for people to fit themselves into highly specialized roles and for the roles to fit into societies then became problematical. Destabilization constantly threatened, for any mis-fit in networks of interacting agents could lead to collapse.

Traditional civilizations put themselves into positions comparable to fleets obeying the PFI. They were command and control systems rigidly held in place by centralized authorities. Order was to be maintained by issuing commandments from on high, often describing behaviors narrowly. But slight improvements in social roles often led to increased resource flows, which meant the environments in which social systems were embedded became more dynamic. After 1500 these changes added up, until too many things were happening too fast for centralized commands to process. At this point social evolution faced a new punctuation, one as dramatic as the rise of civilizations had been. For now societies had released such resource flows that they could only survive by embracing a policy of decentralization. By modifying VEMs a way was found for processing to be massively distributed.

Affecting how brains work, VEMs are like operating programs. Present in many brains, they provide individuals with the ability to simultaneously process flows from their immediate environments. But for individual processors to cooperate the operating code had to be rewritten, which is an effective but dangerous reform. VEMs now concentrated on how decisions were made rather than on describing right decisions. Essentially, this meant making self-control the most prized individual attribute. When individuals can be trusted to act with an eye to society as well as themselves, they can be empowered. Societies need not wait upon central command to learn of a situation and decide on a policy. Nor need they commit to a single solution to every problem. Like captains in Nelson's fleets, self-controlling individuals can be liberated to explore environmental opportunities and initiate actions using their own judgments. Rather than moralize particular states and enjoin people to stay in them, which was the way traditional societies maintained stability, more complex societies emphasize ethics. If morals represent the rules describing desirable and undesirable states, ethics represent the rules for deciding how states are to be achieved or avoided. Ethics are rules for making rules. Complex societies favor ethics over morals because they cannot know in advance exactly which states will be stable but must educate individuals to act reasonably.

Systems guided by rules for making rules are much more flexible than formal systems. Their leaders need not know everything in advance because the organizations themselves are learning systems, as the military examples demonstrate nicely. Nelson's fleets arranged themselves as solutions to the problems their enemies posed [17]. Nelson accomplished this, in the first place, by establishing a common core of understanding among his captains. They met weekly for lunches aboard H.M.S. *Victory* and, munching mutton and sipping Port, they discussed the 'concept of battle'. Nelson argued that battle should be 'decisive' and should 'annihilate' the enemy. But he did not lecture his captains on what to do in advance. Rather, he got them to repeatedly share their sense of what behavior was appropriate in various circumstances. That mutually shared understanding was like a dictionary, for it enabled each of them to deduce overall battle conditions by decoding the actions taken by others. They knew each other so well that when one saw another wheel or lunge he could well imagine what the other was seeing, although distance and smoke might have made that part of the arena quite invisible. Actions successively taking advantage of unseen opportunities reflected much more information than senses provided. Working together, everything that was discovered separately was globalized quickly. Nelson's captains exceeded the limits of knowledge by, effectively, thinking in one another's brains.

But it is not enough for members of military units to understand each other. In addition they need a binding commitment to each other that can only be called 'love'. Love might seem a strange virtue for people bent on killing. But in military units people are not asked to love their enemies, only their comrades. If a leader can, as Nelson did, produce a 'band of brothers', then each can act fearlessly to exploit opportunities, confident that all the rest will rush to aid in whatever action is initiated. Social systems cannot build brotherhood by words alone, and Nelson often went to great lengths to demonstrate his love. For instance, although out numbered by the Allies, Nelson sent his predecessor home in the second largest ship under his command. Admiral Calder was facing charges, and Nelson felt he should meet his judges with the dignity his rank warranted. Risking death and defeat for his nation as well as himself testifies to how deeply Nelson cherished his comrades. He could be almost as generous to inferiors, for when he noticed a seaman had failed to include his own letter in pouches being mailed before Trafalgar began, Nelson ordered the sloop back to pick it up. These gestures bound seamen together through their shared love for Nelson, and, in the 1790s when British fleets were at their most mutinous, Nelson's sailors swore to shed every drop of their blood on whatever course he set them [36].

Perhaps, then, we need not have clear and certain knowledge to solve problems. Our ancestors missed the point, partly, no doubt, because our concepts of nature are framed by our social experiences [18]. Traditional civilized societies were rigid and seemingly eternal, and traditional VEMs guided behaviors along lines that were assumed permanently useful. Based on such structures, philosophers set an absolute standard for behavior that leaves us feeling morally inferior—all our choices are between shades of gray and seem to shift with every occasion. But we live in more complex systems, whose survival we actually threaten when we cling to archaic VEMs. If we try to preserve a moralized societal state in dynamic environments we will make societies more vulnerable to perturbation and lose the ability to adapt competitively. For that reason, the new science of complexity suggests that nature avoids catastrophes by organizing sloppy but robust systems. A behavior based on ethical rules for making rules reflects that knowledge as it matches our realities.

7. Complexity and ethics

Knowing that the cosmic consequences of our deeds are unpredictable may inhibit action, which can be just as dangerous as rigidity far from equilibrium. But paralysis need not follow from the limits of knowledge. To begin with, we should recall just how much damage 'true believers' characterized by their unique hold on Truth have done [46]. Any science that qualifies moral hubris is desirable in itself because it is likely to spare lives. Meanwhile, a science that provides a model of how nature works as a guide to action has the advantage of being realistic. Yet it would seem that a nature which cares only to increase universal entropy and blindly looks for ever more efficient ways to reduce gradients has little ethical guidance to offer. But that is because we are still trapped within the confines of traditional VEMs, expecting that what is natural is what has always existed. If nature evolves, then there are new things in it—such as ethics—and we can use knowledge of how ethics emerged to guide behavior. Ethics are no less natural for being created rather than discovered and eternal, and no less real for being relative rather than revealed and absolute. It is wiser, dealing with the limits of knowledge, to live by a schema based on natural processes than commands or moral laws.

Natural processes generate complexity. Increased complexity involves qualitative change, measured, in part, by the emergence of new attributes gained when components self-organize into new systems. We represent precisely such evolved components, both in our biological forms and our psychological dimensions. In the latter category are most of the attributes we consider species-specific, including our rationality, self-awareness, and morality. These attributes are historical products, but that does not make them illusory. They are valuable to ourselves, but that does not make them subjective.

It follows that, despite the limits of knowledge, sustaining the evolutionary process that generated our human attributes provides an ethical guide to action. We must admit that the evolutionary process has no ultimate or final end. Most moralists think life must have an end to be meaningful and that the end must be derived from some source external to it. However, the extranatural sources of meaning proffered have a very distinct limitation: they make no measurable improvement in the quality of life. As the Catholic philosopher Karl Lowith recognized amidst the bombed rubble of World War II, 2000 years of Christian morality has not made the world more peaceful [34]. But the emergence of rational, self-conscious, moral individuals as the product and vehicle of evolution not only represents qualitative change; its scientific explanation may offer guidance for future action. Knowing that we have become more fully human through evolution does not tell us what to do next. But it provides a criterion for selecting between options: Choose to act, the new science implies, so that the act of choosing remains possible.

When people are free to choose the future remains open and the search for more efficient ways to reduce gradients continues. Admittedly, the Second Law does not care how universal entropy is increased, so misery and slaughter are acceptable to it. But by respecting the humanity that nature has already created, a complexity-based stance allows for distinctions between quantitatively similar paths to the future. In an evolving nature, the products of history are what makes history valuable. A complexity-based ethic is justified naturally, for rational, self-conscious, moral individuals sustain social systems at the edge of chaos, where evolution continues. Thus the seemingly neutral conclusion that the goal of the process is the process, or its continuance, is ethical after all. To fulfill this goal would take a true humanity, full, rich, ripe, and displaying the whole panoply of creative possibilities.

8. The social dimension

Survival in dynamic environments depends on more than individuals, who, by definition, have too limited knowledge to survive. Communities are equally important. As the naval aviation example showed, complex societies solve their own problems—frequently before the people leading them even realize the problems exist. Systems approaching the world as clouds of possibilities succeed by individuating their parts and liberating individuals to act on the basis of their environmental knowledge. But free individuals are highly vulnerable. Vulnerability makes them socially valuable, for free individuals are sensitive to nuanced environmental change. When societies are far-from-equilibrium even slight environmental variations can be threatening, and, of course, environmental opportunities must be exploited. So sensitized individuals scurrying about are socially valuable.

But facing environmental uncertainties on the basis of limited local knowledge is very dangerous. So systems must promise to support their individualized members when experiments prove mistaken and protect them against threats about which they are ignorant. Rewarding the winners is nice, but in the absence of emotional bonds, which mechanical forces like markets cannot generate, relationships may not adapt to surprising futures [56]. Survival requires societies that stick together, which also implies successful individuals share the credit with the context that made their actions meaningful.

This argument may be less naive than it sounds, for one fundamental tenet of the new science is that everything is contextualized. Outcomes, therefore, are not direct consequences of intentions but results of interactions between intentions and contexts [28] A favored example is the humble fly, which is not smart enough to do what its name denotes. Were it that smart, the fly's brain would be so massive it could not get off the ground. But flies do not have to know how to fly, and their genes do not tell them how to do it [38]. They are genetically programed, but to jump in response to certain stimuli and flap their wings when their feet are not touching anything. The information that transforms jumping and flapping into flying is stored in the atmosphere, and it is accessed by interaction between the insect and the air. Fish are often much more efficient swimmers than they should be because of the way their body movements trigger water currents that propel the fish forward at great speed [10].

In the cases concerning us, it is individual intentions that matter. Individual intentions interact with social systems to produce outcomes. But intentions, at least in part, are shaped by the cultural context in which they are formed. So even our intentions—what we will—are partly the result of interactions between our brains and the symbols that program their processing procedures. The entrepreneur who claims exclusive credit for some successful venture is neglecting the multitude of financial, technological, and whimsical interactions generating success. Like generals claiming to have planned every step of a successful battle—defeats alone depend on forces beyond the commanders' control—entrepreneurial bragging betrays a Modern paradigm characterized by atomism and linear causality. We can forgive it as covering up the anxieties of individual experience. But we should not confuse agents hiding from their sense of vulnerability with realistic analysis. Success, complexity theory demonstrates, depends on agents-in-contexts.

If the preceding is correct we are, under the best of circumstances, choosing and acting with limited knowledge. For that reason, making definitive moral pronouncements is unwise. But the contemporary world is far too dynamic to confront without ethical guidance. Traditionally, we have looked at outcomes and made moral judgments. But moral judgments, again, imply knowledge of what state is desirable. The desirability of states, of course, is context-dependent—the same state can be good or bad depending on the situation. In a dynamic world contexts interact with intentions to produce situations we can only guess at, for we simply do not know enough about surrounding contexts. So it may be fairer, in judging an act, to forgive results that were quite other than reasonably expected and instead evaluate the criteria and tools used in decision-making. In this sense a person can be ethical even when outcomes are immoral. Nelson and Moffett were charged with protecting their nations; they are not responsible for what those nations did. They cannot be blamed for Peterloo or Hiroshima, for which others are responsible.

Similarly, despite the world's complexity and the limits of our knowledge, we cannot proceed without planning. Even accepting the theoretical limits of knowledge arising from quantum theory and complexity, short-term planning should be possible. Systems tend to be stable, if for no other reason than all the variations occurring cancel one another out most of the time. Moreover, if we are looking toward the near-term, our observations need not be intrusive and the number of iterations separating elements whose initial conditions were imperfectly known is few. So in the short term surprises should be rare.

But short-term planning often proves problematical nevertheless, for it is in the short term that existing rationality works best. The existing rules are clear and the information to which they apply is known. So planned improvements—incremental increases in efficiencies—can be achieved. The result is that systems guided by effective plans tend to more and more perfectly fit themselves into narrower and narrower niches, until they are vulnerable to even minor environmental shifts. Loosening moral constraints allows variations which sustain the cloud of possibilities, despite incremental improvement.

On the other hand, the odds against getting long-term predictions about future states of complex systems correct are prohibitively high. So if knowing what to do is impossible, the next best thing is to prepare systems that can discover threats and generate solutions to them spontaneously. Preserving the capacity of systems to save themselves gives substance to Post-Modern ethics. It says value the self-conscious individuals that have emerged over time by choosing actions that preserve freedom and diversity in community. Do not, in other words, act to make communities utopian in any sense—do not act to achieve particular goals by imposing moralities top–down. Particular moral goals imply God-like knowledge of The One Right Thing. No individual, regardless of rank, has such knowledge.

Yet individuals in all positions affect environmental conditions, whose feedback can transform dynamically unstable systems. But exactly how unknown conditions will affect intentions is unpredictable. Just as we do not know in advance what people in a discussion will say, the global effects of actions in complex systems can never be perfectly predicted. But we can understand what discussants say provided they obey the rules of grammar and stick close to the established dictionary. Similarly, we can act ethically even when we do not know the moral outcomes of our actions, which are equivalent to the meaning of linguistic expressions. No Shakespeare can defend against misinterpretation, any more than individuals in complex societies can guarantee the beneficial results of their actions.

Perhaps the best we can do is the ethical equivalent of speaking grammatically. If we choose policies that respect individual freedom and preserve community, then we can face futures together, no matter how surprising. Our individuality will help us locate threats and opportunities. By the same token, however, we need societies that protect free speech, for none of us can tell in advance what expression will excite growth or warn of dangers. Thus 'safety nets' are as important as rights and liberties, and unless communities provide security and support, selfish pursuit of material rewards will tear communities apart. An evolutionary ethic thus suggests a covenant between whole and part. Aiming to heighten individuality as community evolves, it recognizes that in an interactive, dynamic world both individual and societies owe their existence and survival to each other.

Such rudimentary guidance will not protect us from errors but reduce the chances of catastrophes. Geared to preserving an open future, the ethics of complexity suggest that we need not legislate for perfection and eternity but only for fair play and participation. If we are free to correct mistakes we can live with limited knowledge.

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