INSTITUTIONAL EVOLUTION IN THE HOLOCENE: THE RISE OF COMPLEX SOCIETIES

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Summary: The evolution of complex societies began when agricultural subsistence systems raised human population densities to levels that would support large scale cooperation, and division of labor. All agricultural origins sequences postdate 11,500 years ago probably because late Pleistocene climates we extremely variable, dry, and the atmosphere was low in carbon dioxide. Under such conditions, agriculture was likely impossible. However, the tribal scale societies of the Pleistocene did acquire, by gene-culture coevolution, tribal social instincts that simultaneously enable and constrain the evolution of complex societies. Once agriculture became possible, a competitive ratchet drove further improvements in subsistence and in scale of social organization . Those societies that grew and became better organized were advantaged in individual wealth and economic and military power, and tended to conquer, absorb, or be imitated by smaller and less well organized societies. Internal competitors for power espousing useful social innovations could deliver improved returns when their quest was successful. Notwithstanding the ratchet, social complexity increased only slowly in the first half of the Holocene and even afterwards few periods except the past two centuries saw changes that were dramatic on the scale of individual lifetimes. We attempt a taxonomy of the processes that regulate rates of institutional evolution, cause reversals of complexity against the ratchet, and impose historical contingency on institutional evolution.[i]

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INTRODUCTION

Human societies are much larger and more complex than the societies of other social mammals. This fact creates an evolutionary puzzle: Five million or so years ago, our ancestors lived in small groups with limited cooperation organized around kinship and reciprocity. Today, we live in vast societies, organized and regulated by many complex institutions. In this paper, we argue that this transition occurred in two stages: First, over the last several hundred thousand years, humans evolved the capacity for cumulative cultural evolution, which in turn, lead to the gene-culture coevolution of larger and more cooperative societies. By the late Pleistocene, hominids evolved the social instincts necessary to create societies on the tribal scale, a level of social organization absent in other primates and, indeed, entirely unique to our species. These instincts and the social institutions that they underpinned were the preadaptations to complex sociality that followed. Second, the Pleistocene-Holocene boundary, about 11,500 years ago, marks a major transition point in human social evolution. Institutional evolution in the late Pleistocene was limited by a regime of highly variable environments under which agricultural subsistence systems were *impossible*. The climate of the Holocene has been very much less variable, and agriculture is *possible* over a large fraction of the earth's land surface. Indeed, the greater efficiency of agricultural production means that agricultural populations can generally out-compete hunter-gather populations. Thus once agriculture became possible, competitive forces made it *compulsory*, in the long run at least. We hypothesize that a similar dynamic drove the evolution of social institutions. Societies with more cooperation, coordination, and division of labor can generally out-compete societies with less.

Since the Pleistocene-Holocene transition was a rapid, globally synchronous, event, variations in the rate of institutional evolution in different parts of the world represent natural experiments that should yield clues pointing to the processes that limit the rate of evolution of institutions. That is, since the progressive trend toward more complex societies characterizes almost all parts of the world, we know that the equilibrium degree of complexity has not been reached until quite recently at least. (We make no attempt to speculate about such questions as how much more complex societies can become or if industrial use of non-renewable resources has created an unsustainable overshoot of equilibrium.) Thus we can conceive of the problem as discovering the main limiting factors that slow the competition driven progressive trend toward greater social complexity. A number of plausible candidates exist, permitting a dim outline of the large-scale dynamics of institutional evolution.

Darwinian models of cultural evolution

Two rather different approaches to the use of Darwinian theory are current in the contemporary social sciences. One is to apply the substantive results of Darwinian theory to human behavior. This field was pioneered by Alexander (1974) and Wilson (1975) and was given a somewhat different twist by Symons (1989) under the heading of "evolutionary psychology." Since natural selection is the most important directional force in organic evolution, these scholars use fitness optimizing models to generate testable hypotheses about human behavior (Borgerhoff Mulder et al., 1997). Typically, such work

endorses a number of common dogmas current in evolutionary biology, for example the generalization that group selection is seldom a strong force. The weakness of this approach is that it may not do full justice to the unique features of human behavior.

We advocate a different strategy pioneered by Campbell (1965) and first put in mathematical form by Cavalli-Sforza and Feldman (1973). The work starts with the idea that culture is a system of inheritance. We acquire culture by imitating other individuals much as we get our genes from our parents. The existence of a fancy capacity for high-fidelity imitation is one of the most important derived characters distinguishing us from our primate relatives, who have only relatively rudimentary imitative abilities (Tomasello, 1999). We are also an unusually docile animal (Simon 1990) and unusually sensitive to expressions of approval and disapproval by parents and others (Baum, 1994: 218-219). Thus parents, teachers, and peers can shape our behavior rapidly and easily compared to training other animals using more expensive material rewards and punishments. Finally, once children acquire language, parents and others can communicate new ideas quite economically to those who don't know them. This economy is only relative; although we get our genes all at once at the moment of conception, acquiring an adult cultural repertoire takes some two decades. Humans ultimately acquire a repertoire of culture that rivals the genome in size.

The existence of cultural transmission means that culture has what evolutionary biologists call "population level properties." Individuals' behavior depends on the behaviors common in the population from whom they acquire beliefs just as individuals' anatomy is dependent on the genes common in the population from whom they acquired their genes. The diversity of cultural traits across cultures is great, but for the most part we are limited to learning those extant in our culture in our time. However, in the long run, the commonness or rarity of genes or culture in the population is a product of what happens to the individuals who reproduce or not, and are imitated or not. The analogy is more than a curiosity because population biologists have developed a formidable kit of empirical and theoretical tools to analyze this intricate interplay between the individual and population level. In the terms sociologists often use, population biologists have the means to make the macro-micro problem (Alexander et al. 1987) tractable. Several theorists, but fewer empiricists have raided the population biologists' cupboard for these tools (Cavalli-Sforza and Feldman 1981, Lumsden and Wilson 1981; Boyd and Richerson 1985; Durham 1991).

In this exercise, we think it best to wear the analogy between genes and memes most lightly. For example, we have resisted using the term "meme" to describe the "unit" of cultural transmission (Boyd and Richerson 2000). Who knows if the structure of cultural inheritance is anything like the neatly particulate gene? We do know that culture is most un-gene-like in many respects. Culture has the principle of inheritance of acquired variation (what one person invents another can imitate). We are not entirely blind victims of chance imitation, but can pick and choose among any cultural variants that come to our attention and creatively put our own twist on them. We don't have to imitate our parents or any other specific individuals but can always be open to a better idea. The innovative part of the Darwinian analysis of cultural evolution has been to

explore the impact of such differences on the cultural evolutionary process, letting model results and the existing empirical facts not substantive analogies guide the research. Substantively, cultural evolution turns out to have its own unique adaptive properties and its own unique suite of characteristic maladaptations, some examples of which we discuss here.

Maladaptations are epistemologically more interesting than adaptations. The trouble with adaptations is that the competing theories—creationism, genetic fitness optimizing, cultural evolution, macrofunctionalism, rational choice theory—all predict that adaptive behavior will be common. Each theory's predicted maladaptations are much more distinctive. For example, Hamilton (1964) deduced from the principles of natural selection acting on genes that organisms should engage in altruistic acts only when the benefit to the recipient exceed the costs to the provides by a factor greater than the reciprocal of the relatedness by descent between them, his famous $b/c > 1/r$ rule. Since in most animal species, individuals have only few relatives with appreciable r Hamilton's theory predicts that altruism will be massively undersupplied compared to a perfectly group-selected case where altruism within groups should be supplied whenever $b/c > 1$. Every individual in a group would be better off if every other followed the $b/c > 1$ rule instead of the $b/c > 1/r$, but natural selection on genes cannot favor such acts. With the exception of humans and a few other special cases, Hamilton's rule predicts the maladaptively low amount of animal cooperation quite well. Human societies are a theoretical puzzle because they typically include much cooperation between distantly related and unrelated people. We have adaptively evaded a rule that otherwise seems to have nearly the law-like force of a physical principle. We argue below that cultural evolution is likely the source of our capacity to pull off our defiance of Hamilton's rule.

The unique features of the cultural system of inheritance are predictable from the elementary consideration that selection on genes to increase our capacity to learn from each other would surely not have favored this rather costly system if it did only what genes could do for themselves. One important advantage of the cultural system is the linkage of decision-making processes with transmission to create a system for the inheritance of acquired variation. Given that decision rules ultimately derive from the action of selection on genes and hence are adaptive, on average at least, a system that responds both directly to natural selection *and* to adaptive decision-making forces will be able to adapt to varying environments more quickly than can organisms that adapt by genes and non-transmitted learning (Boyd and Richerson, 1985: Ch.4 &5). Plagiarizing the learning of others creates a system that can adapt swiftly to new conditions without a crippling expenditure of effort on individual learning. Secondly, accurate and rapid social learning allows humans, but seemingly not other species, to accumulate innovations so as to build up, historically over many generations—but rather rapidly compared to organic evolution—more sophisticated cultural adaptations than individual people could possibly have invented for themselves (Boyd and Richerson, 1996). Human cultural adaptations are not only dramatically different from place to place and time to time but are also as complex as organic adaptations that would take much longer to evolve. The Inuit adaptation to the Arctic and the San adaptation to the Kalahari are impressively complex and impressively different on a scale that would result in different species if accomplished by organic evolution. In support of these theory-derived conjectures, we

note that humans evolved during the Pleistocene, a period of high frequency climatic variation (Richerson and Boyd, 2000), and we became an unusually widespread animal by middle Pleistocene times. The ability to adapt quickly to a temporarily variable environment is easily put to use adapting to spatial variation as well, adapting a tropical ape to live in temperate and eventually periglacial climates. We became completely cosmopolitan using subsistence strategies tailored to practically every terrestrial and amphibious habitat on the planet. We believe that ability of the cultural system to rapidly create sophisticated adaptations to niches that persisted for a relatively few generations was the main advantage that paid the overhead of our large brain and long learning curve.

The evolution of institutions of complex societies

The evolution of complex societies is one of the most interesting questions in all the social sciences. How can a species long adapted to living in small egalitarian groups evolve revolutionary new social institutions that lead them to live in very large, highly inegalitarian social systems? Tribal people often express shock and contempt at what we put up with in the name of "civilization." Why did the progressive trajectory of increased complexity start around ten thousand years ago, not thirty or five? Why did societies in some parts of the world move down the progressive path more swiftly than others? What processes regulate the tempo of institutional evolution? What gives the progressive trend its multilinear diversity? No two trajectories of complexification are identical, even in closely related societies and sub-societies, much less in remotely connected cases like Western Europe, Western Asia, India, China, and Meso-America, despite many similarities. Why has the pace of change had a tendency to accelerate as we approach the present? Why is the progressive trend punctuated, in every historical case, by more or less abrupt declines and collapses?

These are exceeding complex questions that have defied definitive solution despite much hard work—and much real progress—by social scientists, historians, and political philosophers. The development of Darwinian tools encourages a fresh cut at them. In what follows we lay out an analysis that seems like a sensible series of first steps using Darwinian analysis of Holocene institutional evolution. We beg our readers' indulgence with the inevitable crudities that accompany first steps and hope that you will take them as illustrations prefiguring what a more mature analysis will likely accomplish. The boast of Darwinian biologists is that the power of their theory in that discipline derives first from its correct conception of the processes of evolution and from its inclusive, synthetic, and systemic commitments. Darwinian biology is a big tent housing diverse and often fractious practitioners. Even after a century and a half of work it is a vibrant field full of interesting unsolved puzzles, many of a quite fundamental character. We hope that this paper conveys some vision, however limited it is in the present state of development of our field, of what the social sciences might look like if the use of Darwinian methods became routine in the analysis of culturally determined behaviors.

TRIBAL SOCIAL INSTINCTS HYPOTHESIS

The tribal social instincts hypothesis is based on the belief that group selection plays a more important role in shaping culturally transmitted variation than it does in shaping genetic variation, and, as a result, that humans have lived in social environments

characterized by high levels of cooperation for as long as culture has played an important role in human development. The simplest model of group selection on cultural variation we have made is based on the effects of a conformist bias in cultural transmission (Boyd and Richerson, 1985: chapter 7; Henrich and Boyd, 1998). Conformity is a useful rule to follow in imitating others because many evolutionary forces conspire to make adaptive behavior common. When in doubt, doing as the Romans do when in Rome is an easy and useful rule to follow. Using this rule has the effect of reducing variation within groups and protecting groups against the effects of migration from other groups. Other rules, such as preferring to imitate people of your own symbolically marked group or the practice of social selection against deviants may have similar effects. Group selection does not work on genes for cooperation according to most models because group selection cannot easily build variation between groups as fast as selection against cooperators within groups—and migration between groups—reduces it. Thus, selection on cultural variation is a more likely mechanism for favoring the origins of cooperative institutions than is selection on genes. We have also studied models of the evolution of symbolic marking of group boundaries (Boyd and Richerson 1987, McElreath et al. no date) and moralistic punishment (Boyd and Richerson 1992a).

By the late Pleistocene, 50 kyr B.P., perhaps earlier, human societies were probably possessed tribal scale institutions (Bettinger 1991, Richerson and Boyd 1998). If we define "institutions" as customary rules of behavior that have the effect of creating sociopolitical structures serving collective functions, then hunting and gathering societies of the ethnographic record always have tribal scale institutions, though sometimes rather minimal ones. For example, many of the simplest known hunting societies have well developed systems of egalitarian counter-dominance that prevent individuals from appropriating disproportionate shares of food. These institutions in turn probably allow such societies to act as effective risk-sharing groups that can efficiently exploit high return, high-risk strategies such as the pursuit of big game (Boehm 1993, Wiessner 1996). Ethnographically known hunter-gatherers are quite variable in the scale, sophistication and formality of their institutions (Kelly 1995, Arnold 1996).

The Shoshoni of the American Great Basin are a classic example of socially very simple hunter-gatherers. Steward (1955: Chapter 6) described them as having a family level of sociocultural integration. During most of the year, Shoshoni nuclear families foraged for sparse plant resources alone or in the company of one or two other families. The main resources of the Great Basin did not favor cooperation in subsistence activities and the low productivity of the environment discouraged concentrations of population favorable to other social activities. The Shoshoni lacked a formal tribal political system and had no organized religious activities. Nevertheless, as Steward emphasized, even the Shoshoni had *some* customs regulating social life and *some* routine collective behavior. The kinship system itself regulated social relations between families. Marriage was in the form of a contract between the families involved. A common property system ensured that all families had equal access, first come, first served, to most but not all resources. During the winter, families aggregated into multi-family camps. In such camps *ad hoc* "bosses" organized events such as communal rabbit and antelope hunts, dances and games. Respected men served as regional repositories of information about the

distribution of subsistence resources and so regulated the dispersion and assembly of families during the seasons.

At the opposite extreme, some hunting and gathering societies had much denser populations and much more extensive and formal economic, political, and religious institutions than the Shoshoni. In Western North America, the salmon rich societies of the Northwest Coast are such an example (Kelly 1995: 321-328). Many of these societies were highly ranked and chiefs had much power. Politics, religion, and the economy were highly organized. Between these extremes a great diversity of institutional forms have been recorded among hunter-gatherers. In most of California, for example, people were organized into "tribelets" comprising from a hundred to a few thousand people (Bean 1978). Most ethno-linguistic units were divided into several autonomous tribelets. Tribelets were generally composed of corporate lineages and had formal political leadership, sometimes including ranked chieftainships. Tribelets were generally centered on a principle village where council meetings, religious rituals and collective economic activities took place. Supra-tribelet institutions included regional cult complexes and trade fairs. These brought thousands of people together for annual or more frequent gatherings, often including people from different ethno-linguistic groups.

Did the range of late Pleistocene hunting and gathering societies resemble the ethnographic range? Extrapolating from ethnographic to archaeological cases is of course fraught with problems, especially in the case of hunter-gatherers most of whose material culture, for example dwellings, is poorly preserved (Kelly 1995: Chapter 9, Bettinger 1991). Archaeology is relatively silent about social organization but a good case can be made that at least late Pleistocene societies were toward the complex end of the ethnographic spectrum (Price and Brown 1985).The hunting of big game is a subsistence strategy that generally involves cooperation in hunting, fairly large-scale risk sharing social strategies and hence social institutions considerably more complex than the Shoshonean extreme. Big game hunting was common in the late Pleistocene and almost certainly favored the same relatively complex institutions as it does in ethnographic cases. The personal art that is a conspicuous part of the Upper Paleolithic Transition is similar to craft productions that are incorporated into tribal scale institutions in ethnographic cases (Wiessner 1984). The cave art of France and Spain is the sort of activity associated with fairly large-scale ritual systems in ethnographic cases. Insofar as the archaeological record reflects social institutions it suggests that late Pleistocene societies had institutions on the tribal scale comparable to those observed by ethnographers.

We believe that the human capacity to live in tribes evolved by the coevolution of genes and culture. Simple cultural cooperative institutions favored by cultural group selection would have favored genotypes that were better able to live in groups that at first were only marginally cooperative outside of families and simple schemes of reciprocity. Given marginal genetic changes, cultural evolution could marginally advance the scale of cooperation. These rounds of coevolutionary change then proceeded until capacities for cooperation with distantly related fellow tribals, emotional attachments to symbolically marked groups, and willingness to punish others for transgression of group rules became

quite advanced. Mechanisms by which cultural institutions might exert forces tugging in this direction are not far to seek. Cultural norms affect mate choice and people seeking mates are likely to discriminate against genotypes that are incapable of conforming to cultural norms (Richerson and Boyd, 1989). Men who cannot control their self-serving aggression ended up exiled to the wilderness in small-scale societies and to prison in contemporary ones. Women who are lazy or an embarrassment in social circumstances are unlikely to find or keep husbands. We believe that with, at a minimum, tens of thousands of years to work with, natural section on cultural variation could easily have had dramatic effects on the evolution of human genes by this process. Of course, humans are still in part a wild animal; our genetically transmitted evolved psychology shapes human cultures, and as a result cultural adaptations often still serve the ancient imperatives of genetic fitness. But the leash works both ways. Cultural evolution creates new selective environments that cause *cultural imperatives to be built into our genes*.

Almost everyone agrees that human cultures were essentially modern by the Upper Paleolithic, 50,000 years ago. So even if the cultural group selection process began as late as the Upper Paleolithic, human behavior has been selected for 2,000 generations in social environments in which the innate willingness to recognize, aid, and if necessary, punish fellow group members was favored by social selection acting on genes. We suppose that the resulting tribal instincts are something like principles in the Chomskian linguists' "principles and parameters" view of language (Pinker 1994). The innate principles furnish people with basic predispositions, emotional capacities, and social skills that are implemented in practice through highly variable cultural institutions, the parameters. People are innately prepared to act as members of tribes but culture tells us how to recognize who belongs to our tribes, what schedules of aid, praise, and punishment are due to tribal fellows, and how the tribe is to deal with other tribes—allies, enemies, and clients. Richerson and Boyd (2001) review the empirical evidence supporting the tribal social instincts hypothesis.

Because the tribal instincts are of relatively recent origin, they are not the sole regulators of human social life. The tribal instincts are laid on top of more ancient social instincts rooted in kin selection and reciprocal altruism. These ancient social instincts conflict with the tribal. We are simultaneously committed to tribes, family, and self, even though the conflicting demands very often cause us great anguish such as Freud (1930) described in *Civilization and Its Discontents* or Graham Greene portrayed in novels such as *The Honorary Consul*. The existence of ancient instincts significantly constrains the evolution of institutions.

Competing Hypotheses

We have not the space to review in detail all the competing hypotheses to explain the evolution of human social organization. Broadly speaking, however, these fall into two classes: those that emphasize individual level processes and those that emphasize group functionality. Methodological individualists in the social sciences are deeply skeptical about the group-functional picture of human behavior, and wish to ground the social sciences on the postulate of self-interested rational choice (e.g. Coleman 1990). Evolutionary biologists by and large follow Williams' (1966) lead in rejecting group

selection as an important force in nature. In the case of humans, not to mention other animals, selfish behavior and very small scale altruism, for example among close relatives, is common and in accord with methodological individualists' theoretical models. Following Axelrod and Hamilton (1981) and Alexander (1987), individualists reckon that the logic of small-scale reciprocity can be scaled up to explain human cooperation on the large scale without violating any of the standard assumptions of methodological individualism, such as postulating a strong role for group selection.

The relationship between rational choice theory and cultural evolution theory is complex because we assume that individual choice exists and acts as a force shaping cultural evolution (Boyd and Richerson, 1993). We hold, however, that choice is marginal and does not normally follow the canons of formal rationality. That is, people form their repertoires of behavior mostly by imitation of others, making somewhat biased choices among the cultural variants they observe, and sometimes independently inventing new adaptive behaviors. When the results of such myopic decision-making are accumulated over a population of people and many cycles of imitation and decision-making they indeed become potent evolutionary forces. However, we also suppose that they are not sufficiently powerful to obviate the effects of natural selection *on cultural variation*. Our social instincts hypothesis requires that cultural group selection be strong enough to counter individualistically motivated selfish decision-making in order to favor tribal-scale cooperation. Then, once a social instinct favoring prosocial behavior toward ingroup members exists, it will not only affect everyday behavior, but also the kinds of decisions people make about what new cultural variants to adopt. People will tend to bias their "vote" in favor of new prosocial institutions, as indeed seems to be the case in American voting patterns (Sears and Funk 1990). Humans seem to be moved by selfish and prosocial arguments both. Which wins, and to what extent, in any given case is problematical. Our ancestors lacking the tribal social instinct had not even our ambivalent commitment to ingroup cooperation and in the end our societies come to differ dramatically from theirs.

Group functionalism was once very prominent in sociology and anthropology. Most functionalist hypotheses have been silent about evolutionary origins and so are not of interest to us here. Several evolutionary hypotheses have been proposed since Darwin (1874: 179) articulated a clear group selection argument to account for human cooperation: "A tribe including many members who, from possessing in a high degree the spirit of patriotism, fidelity, obedience, courage, and sympathy, were always ready to aid one another, and to sacrifice themselves for the common good, would be victorious over most other tribes; and this would be natural selection." One possibility is that humans are genetically group selected. Several prominent modern Darwinians [W.D. Hamilton (1975), E.O. Wilson (1975: 561-2), R.D. Alexander (1974), and Eibl-Eibesfeldt (1982)] have given serious consideration to group selection as a force *in the special case* of human ultra-sociality. They are impressed, as we are, by the organization of human populations into units that engage in highly organized, lethal competition with other groups, not to mention other forms of cooperation. Direct group selection on genes is a process that could give human groups a degree of functional integration. A second view

is that processes peculiar to culture are prone to group selection. This idea is the root of our tribal instincts hypothesis.

A third possibility is that human propensities to cooperate are a byproduct or accident of some other process. Simon (1990) proposed that human cooperation is a byproduct of our docility and that docility is necessary to take advantage of cultural transmission. We worry that this hypothesis can be true at the margin. Selfish and manipulative individuals do not seem to be automatically handicapped in their acquistion of culture. Van den Berghe (1981) argued that in small-scale societies cultural similarity in dialect, clothing, and so forth was used as a sensitive marker of genetic relatedness. The relative isolation of families and bands set up sharp cultural gradients that would measure genetic distance more effectively than innate characters for which the gradient at the small scale is likely to be very small. In the much larger, denser societies made possible by agriculture, the number of people with very similar culture might reach thousands and, with mass media, millions. Such cultural similarity may trigger kin selected social instincts so that we treat our fellow tribals as close kin. The problem with this hypothesis is that in many circumstances we still recognize our kin and behave as if our innate propensity to favor real kin is quite intact. For example, blood relatives tend to be spared homicide relative to non-kin, such as step-children in the same household (Daly and Wilson 1988).

WORK-AROUND HYPOTHESIS

Contemporary human societies differ drastically from those under which our social instincts presumably evolved. Until a few thousand years ago humans lived in relatively small, egalitarian societies with a modest division of labor. After the domestication of plants and animals, beginning about 11,500 years ago, human densities rose substantially and the potential for an expanded division of labor grew. Beginning about 5,000 years ago, complex societies began to emerge. Hierarchical states arose to administer the increasingly minute division of labor. Families became dependent on the products of strangers for routine subsistence. Leaders came to have great and sometimes quite arbitrary authority to coerce common citizens. Complex systems also universally develop social stratification in which objective material well-being and culturally defined prestige vary greatly by social role. Those in high positions in the command and control system seemingly inevitably acquire a more or less disproportionate share of society's rewards. There is every evidence that humans' Pleistocene evolutionary experience did not prepare us to tolerate more than the most minimal command and control institutions (Boehm 1993). Nor were we prepared to tolerate much inequality. The cultural evolution of complex societies in the Holocene will have had to *work around* these awkward realities of our ancient and tribal instincts, drawing upon the prosocial elements in them while finessing the elements not suited to large scale social systems.

If our social instincts hypothesis is correct, complex societies will have evolved under the constraints and possibilities offered by our evolved social psychology (Salter, 1995). The rapid social changes of the last few thousand years should throw our social instincts into high relief. For example, one of the most striking features of complex societies, including modern societies, is the persistence of tribal scale social institutions

and the elaboration of institutions such as nationalism that utilize mass media to simulate tribes on a larger scale. Business organizations, schools, religions, and government bureaucracies generally contain features that tap or respond to our propensity to grant loyalty to tribes or reasonable facsimiles. The persistence of ethnic sentiments in a large-scale modern world that would seem to make them obsolete is an example (Glazer and Moynihan 1975). The ancient social instincts also retain important functions in the modern world. Families and personal friendships are important in every human social system.

The work-around hypothesis asserts that social instincts are part building blocks and part constraints on the evolution of complex social systems. To evolve large scale, complex social systems, culturally evolved strategies take advantage of whatever support the instincts offer while coping as well as possible with the difficulty of raw material evolved for life in quite different sorts of societies. Families willingly take on the essential roles of biological reproduction and primary socialization. Appropriate larger scale institutions can acceptably regulate their tendency to narrow loyalties and nepotistic subversion of group favoring rules. Tribal scale loyalties put deep emotion behind group enterprises, though the small scale of "natural" tribes requires careful management if larger scale objectives are not to be sacrificed. Large national and international (e.g. great religions) institutions develop ideologies of symbolically marked inclusion that often fairly successfully engage the tribal instincts on a much larger than tribal scale. The existence of contemporary societies handicapped by few loyalties outside the family (Banfield 1958) or by excessively powerful loyalties to small tribes (West 1941) remind us that work-arounds are awkward compromises that are difficult to achieve and easy to lose.

The most important cultural innovations required to support complex societies are command and control institutions that can systematically organize cooperation, coordination, and a division of labor in societies consisting of hundreds of thousands to hundreds of millions of people. Command and control institutions lead to more productive economies, more internal security, and better resistance to external aggression. Note that command and control are separable concepts. Command may aim at quite limited control. For example, a predatory conquest state may use command almost exclusively for the extraction of portable wealth, not for prosocial projects. Institutions often exert control without personal commands. Markets most famously control behavior by price signals from a diffuse world of anonymous buyers and sellers. Market enthusiasts do sometimes forget that command systems are generally needed to make markets function, ranging from mandatory use of calibrated weights and measures to central banks (Dahrendorf 1968: chapter 8). The main types of work-arounds seem to us to be the following:

Coercive Dominance

The cynics' favorite mechanism for creating complex societies is command backed up by force. The conflict model of state formation has this character (Carneiro 1970). A society successful in war upon a neighboring group can impose itself as a ruling class on the defeated if the defeated cannot flee, as farmers often cannot.

Elements of coercive dominance are no doubt necessary to make complex societies a going concern. Tribally legitimated self-help violence is a limited and expensive means of prosocial coercion. Complex human societies have to supplement the moralistic solidarity of tribal societies with formal police institutions. Otherwise, the large-scale benefits of cooperation, coordination, and division of labor would cease to exist in the face of selfish temptations to expropriate them by individuals, nepotists, cabals of reciprocators, organized predatory bands, and classes or castes with special access to means of coercion. At the same time, the need for organized coercion as an ultimate sanction creates roles, classes, and subcultures with the power to turn coercion to narrow advantage. Social institutions of some sort must police the police so that they will act in the larger interest to a measurable degree. Such policing is never perfect and, in the worst cases, can be very poor. The fact that leadership in complex systems always have at least some economic inequality shows that narrow interests, rooted in individual selfishness, kinship, and, often, the tribal solidarity of the elite, always exert an influence. The use of coercion in complex societies offers excellent examples of the imperfections in social arrangements traceable to the ultimately irresolvable tension of selfish and prosocial instincts.

While coercive, exploitative elites are common enough, there are two reasons to suspect that no complex society can be based purely on the coercion. The first problem is that coercion of any great mass of subordinates requires that the elite class or caste be itself a complex, cooperative venture. The second problem with pure coercion is that defeated and exploited peoples seldom accept subjugation as a permanent state of affairs without costly protest. Deep feelings of injustice generated by manifestly inequitable social arrangements move people to desperate acts, driving the cost of dominance to levels that cripple societies in the short run and often cannot be sustained in the long run (Kennedy 1987). Insko et al.'s (1983) experimental evolutionary analysis of coercive versus more prosocial leadership in laboratory micro-societies illustrates the degree to which dominated groups will chafe and rebel at their oppression. Durable conquests, such as those leading to the modern European national states, Han China, or the Roman Empire leaven raw coercion with more prosocial institutions. The Confucian system in China, and the Roman legal system in the West, were far more sophisticated and durable institutions than the highly coercive systems sometimes set up by predatory conquerors and even domestic elites.

Segmentary Hierarchy

Late Pleistocene societies were undoubtedly segmentary in the sense that supraband ethnolinguistic units served social functions, although they presumably lacked much formal political organization. The segmentary principle can serve the need for more command and control by hardening up lines of authority without disrupting the face-to-face nature of proximal leadership present in egalitarian societies. The Polynesian ranked lineage system illustrates how making political offices formally hereditary according to a kinship formula can help deepen and strengthen a command and control hierarchy (Kirch 1984; Sahlins 1963). A common method of deepening and strengthening the hierarchy of command and control in complex societies is to construct a formal nested hierarchy of

offices, using various mixtures of ascription and achievement principles to staff the offices. Each level of the hierarchy replicates the structure of a hunting and gathering band. A leader at any level interacts mainly with a few near-equals at the next level down in the system. New leaders are usually recruited from the ranks of sub-leaders, often tapping informal leaders at that level. As Eibl-Eibesfeldt (1989:314) remarks, even high-ranking leaders in modern hierarchies adopt much of the humble headman's deferential approach to leadership.

The hierarchical nesting of social units in complex societies gives rise to appreciable inefficiencies. In practice, brutal sergeants, incompetent colonels, vainglorious generals, and their ilk in other bureaucracies degrade the effectiveness of social organizations in complex societies. Squires (1986), elaborating on Tullock (1965), dissects the problems and potentials of modern hierarchical bureaucracies to perform consistently with leaders' intentions. Leaders in complex societies must convey orders downward, not just seek consensus among their comrades. Only very careful attention to detail can make subordinates responsive to the hierarchy's leaders without destroying their sense that these same leaders would have arisen by natural consensus without imposition from above. The chain of command is necessarily long in large complex societies, and remote leaders will not normally be able to exercise personal charisma over a mass of subordinates deeper down the hierarchy. Devolving substantial leadership responsibility to sub-leaders far down the chain of command is necessary to create small-scale leaders with face-to-face legitimacy. However, it potentially generates great friction if lower-level leaders either come to have different objectives than the upper leadership or are seen by followers as equally helpless pawns of remote leaders. Stratification often creates rigid boundaries so that natural leaders are denied promotion above a certain level, resulting in inefficient use of human resources and a fertile source of resentment to fuel social discontent.

Exploitation of Symbolic Systems

The high population density, division of labor, and improved communication made possible by the innovations of complex societies increased the scope for elaborating symbolic systems. The development of monumental architecture to serve mass ritual performances is one of the oldest archaeological markers of emerging complexity. Usually an established church or less formal ideological umbrella supports a complex society's institutions. At the same time, complex societies extensively exploit the symbolic ingroup instinct to delimit a quite diverse array of culturally defined subgroups, within which a good deal of cooperation is routinely achieved. Military organizations generally mark a set of middle-level, tribal scale units with conspicuous badges of membership. A squad or platoon's solidarity can rest on bonds of reciprocity reinforced by prosocial leadership, but ship's companies, regiments, and divisions are made real by symbolic marking. Ethnic group–like sentiments in military organizations are often most strongly reinforced at the level of 1,000–10,000 or so men (British and German regiments, U.S. divisions) (Kellett 1982:112–117). Typical civilian symbolically marked units include regions (e.g., Swiss cantons), organized tribal elements (Garthwaite 1993), ethnic diasporas (Curtin 1984), castes (Gadgil and Guha 1992; Srinivas 1962), large economic enterprises (Fukuyama 1995), and civic organizations (Putnam 1993).

Many problems and conflicts revolve around symbolically marked groups in complex societies. Official dogmas often stultify desirable innovations and lead to bitter conflicts with heretics. Marked subgroups often have enough tribal cohesion to organize at the expense of the larger social system, as when lower-level military units arrange informal truces with the enemy or when ideologies of elite superiority support excessively exploitative institutions. A major difficulty with loyalties induced by appeals to shared symbolic culture is the very language-like productivity possible with this system. Language itself is a classic badge of an ethnic group. Dialect markers of social subgroups emerge rapidly along social fault-lines (Labov 1972). Charismatic innovators regularly launch new belief and prestige systems, which sometimes make radical claims on the allegiance of new members, sometimes make large claims at the expense of existing institutions, and sometimes grow explosively. Or, contrariwise, larger loyalties can arise, as in the case of modern nationalisms overriding smaller scale loyalties, sometimes for better, sometimes for worse. The ongoing evolution of social systems can evolve in unpredictable, maladaptive directions by such processes. Gibbon (1776–1788) attributed the decline and fall of Rome in part to the rise of Christianity (a timid and pacifistic ideology unsuited to empire, according to his notorious hypothesis). The worldwide growth of fundamentalist sects that challenge the institutions of modern states is a contemporary example (Marty and Appleby 1991; Roof and McKinney 1987). The contemporary Chinese state fears *Falun Gong*, with reason or not is hard to say. Resurgent ethnic loyalties recently wrecked Yugoslavia. The rise of the various "isms" in some of the most powerful nation-states of the world made parts of the 20th Century a sanguinary hell. Ongoing cultural evolution is impossible to control, at least impossible to control completely.

Legitimate Institutions

At their most functional, symbolic institutions, together with effective leadership and smooth articulation of social segments, create a sense of living under a regime of tolerably fair laws and customs. Rationally administered bureaucracies, lively markets, the protection of socially beneficial property rights, widespread participation in public affairs, and the like provide public and private goods efficiently, along with a measure of protection of individual liberties. Individuals in modern societies typically feel themselves part of culturally labeled tribal-scale groups, such as local political party organizations, that have influence on the remotest leaders. In older complex societies, village councils, local notables, tribal chieftains, or religious leaders often hold courts open to humble petitioners. These local leaders in turn represent their communities to higher authorities. As long as most individuals feel that existing institutions are reasonably legitimate and that any felt needs for reform are achievable by means of ordinary political activities, there is considerable scope for collective social action.

On the other hand, individuals who do not trust the current institutional order's justness are liable to band together in revolutionary organizations, such as the terrorist groups of the contemporary world. Trust varies considerably in complex societies, and variation in trust is the main cause of differences in happiness across societies (Inglehart and Rabier 1986). Even the most efficient legitimate institutions known are prey to

manipulation by small-scale organizations and cabals, the so-called special interests of modern democracies.

A test

Elsewhere we have used the differential performance of armies in WWII as a specific test of the work-around hypothesis (Richerson and Boyd 1999). We chose military organizations as a test because the extreme demands for personal sacrifice expected of modern soldiers in wartime exaggerates the conflict between individual interest (and loyalty to kin) and altruistic motivations to act on behalf the larger society. In summary, the more successful institutions of complex societies go quite far toward simulating the social institutions of simple societies. The German Army in WWII outperformed Allied armies (on a man-for-man basis, controlling for the advantage of Russians in numbers and the Western Allies' superior supply system and control of the air). 100 Germans could accomplish the same tasks that would require about 120 British or American troops or 200 Russians. This superiority, military analysts believe, came from the Germans' meticulous concern for the social-psychological needs of soldiers. German divisions were recruited on a territorial basis so that recruits shared their dialect and other symbols of regional identity. Thus care was taken to furnish soldiers with a tribal identity via identification with their regiments and divisions. Interestingly, although at least some soldiers were motivated by Hitler's bent ideological mission to "save" Europe from the Jews and Bolsheviks, the army put little trust in the sustaining power of such sentiments and took care create strong loyalties to divisions and regiments of a truly tribal scale. German training emphasized building solidarity with comrades, so personal bonds of loyalty were exploited. Unlike the American Army, those who trained together fought together. German face-to-face leaders were expected to minimize social distance from their men and to look out for their welfare at every turn. They gave orders in the form of objectives to be met, leaving the means of meeting them up to individuals. Physical coercion by leaders was common only in the Russian army. The German army placed its best leaders in the front lines, whereas the American managerial approach demanded much talent in rear areas to organize the flow of supplies. German officers and noncoms were thus more like the informal natural leaders of hunting and gathering societies than was the case in Allied armies. In several relatively small but symbolic ways the German army expressed its concern for the welfare of individuals. Medals were awarded promptly for real combat accomplishments, an efficient field postal system kept soldiers in touch with their families, and hardship leaves were frequently granted, for example to help ones family if they were bombed. By making individual soldiers feel well cared for as individuals and as participants in a tribal enterprise, the German army sustained their morale and exemplary performance even under the horrifying conditions of the Eastern Front.

THE ORIGINS OF AGRICULTURE EXPERIMENT

Several independent trajectories of subsistence intensification, often leading to agriculture, began during the Holocene (Richerson et al. 2001). By intensification we mean a cycle of innovations in subsistence efficiency per unit of land leading to population growth that in turn leads to denser settlement per unit area of land. No plant-rich intensifications are known from the Pleistocene. Subsistence in the Pleistocene

seems to have depended substantially on relatively high-quality animal and plant resources that held human populations to modest densities. Recent data from ice core climate proxies show that the last glacial climates were extremely hostile to agriculture—dry, low in atmospheric CO_2, and extremely variable on quite short time scales (Broecker 1995; Bradley 1999). We believe that these data suggest that agriculture was impossible under last-glacial conditions. Human populations appear to have been biologically quite modern in behavior in most respects from Upper Paleolithic times forward (40-50 kyr B.P, Klein 1999). Population growth is a rapid process on time scales shorter than a millennium. Cultural evolution is a rapid process on time scales of ten millennia. If agriculture had been possible in the Pleistocene, it should have appeared before the Pleistocene-Holocene transition. The quite abrupt final amelioration of the climate at the onset of the Holocene 11,500 yr B.P. was followed immediately by the beginnings of plant intensive resource use strategies in some areas, although the turn to plants was much later elsewhere. Almost all trajectories of subsistence intensification in the Holocene are progressive and eventually agriculture became the dominant strategy in all but the most marginal environments. The Polynesian expansion of the last 1,500 years and the European expansion of the last 500 years pioneered agriculture in the Pacific Islands, Australia and large parts of Western North America, the last substantial areas of the earth's surface favorable to it.

Two distinctive regimes for institutional evolution

Thus, evolution of human subsistence systems during the career of anatomically modern humans seems to divide quite neatly into two regimes, a Pleistocene regime of hunting and gathering subsistence and low population density, and a Holocene regime of increasingly agricultural subsistence and relatively high and rising population densities.

The dispersed resources and low mean density of populations in the Pleistocene meant that relatively few people could be aggregated together at any one time and place. The lack of domestic livestock meant that movement of goods on land would be limited to what humans could carry. No evidence of extensive use of boats to transport goods appears in the archaeological record of the late Pleistocene although some significant water crossings were necessary for people to reach Australia. Low density, logistically limited human populations have small (but far from negligible as we saw above) scope for exploiting returns to scale in cooperation, coordination and division of labor and their institutions remain comparatively simple.

Intensified subsistence and higher population densities multiply the number of people and volume of commodities that societies can mobilize for economic and political purposes. Expanded exchange allows societies to exploit an expanded division of labor. Larger armies are possible to deal with external threats or to coerce neighbors. Expanding the number of people sharing a common language and customs will accelerate the spread of useful ideas. *Given appropriate institutions*, the denser societies made possible by agriculture can realize considerable returns to better exploitation of the potential of cooperation, coordination, and the division of labor. Corning (1983) elaborates the advantage of large scale and greater complexity of social organization along these lines under his synergism hypothesis. Thus, in the Holocene, the origins of agriculture and its

rising productivity over succeeding millennia at least permit the evolution of more complex societies.

A competitive ratchet

Intra- and inter-society competition put a sharp point on the potential for more complex societies. Holding the sophistication of institutions constant, marginal increases in subsistence productivity per unit land will lead to denser or richer populations that can out-compete societies with less intensive subsistence systems. Holding subsistence productivity constant, societies with marginally more sophisticated social organization will also out-compete rivals. Within groups, contending political interests with innovations that promise greater rewards for altered social organization can use either selfish or patriotic appeals to advance their cause. Successful reformers may entrench themselves in power for a considerable period. Malthusian growth will tend to convert increases in subsistence efficiency and security against depredations to greater population density, making losses of more complex institutions painful and further advance rewarding. Richerson et al. (2001) show that the rate limiting process for intensification trajectories must almost always be the rate of innovation of subsistence technology or subsistence related social organization. At the observed rates of innovation, observed rates of population growth will always be rapid enough to sustain a high level of population pressure favoring further subsistence and social-organization innovations. Competition may be economic, political/military, or for the hearts and minds of people. Typically all three forms will operate simultaneously. In the Holocene, agriculture and complex social organization are, in the long run, compulsory. Thus, from the 16th through the 19th Centuries, European populations settled many parts of the world and overwhelmed native populations with less efficient subsistence and less complex social organization. In regions such as Asia where disparities of subsistence and social organization with West were less striking, societies like China, Japan and India retained or reclaimed their political independence at the cost of humiliating exposure to Western power and of borrowing many technical and social-organizational techniques from the West.

The tendency of population to grow rapidly and for knowledge of advanced techniques to be retained somewhere act as pawls on the competitive ratchet. Even during the European Dark Ages, when the pawls slipped several cogs on the ratchet, the slide backward was halted and eventually reversed in a few hundred years.

Replications of the experiment

Agricultural subsistence evolved independently at least seven times in the Holocene and many more societies have acquired at least some key agricultural innovations by subsistence (Richerson et al. 2001). Although none of these origins are earlier than the early Holocene, many are much later. The trajectory of institutional evolution is similar. To take one benchmark, the origin of the state level of political organization began in Mesopotamia around 5,500 B.P., but most are later, some much later (Service 1975, Feinman and Marcus 1998). For example the Polynesian polities of Hawaii and Tonga-Samoa became complex chiefdoms on the cusp of the transition to states just before European contact (Kirch 1984). Pristine states evolved independently, perhaps ten or so

times, in several parts of the world and traditions of statecraft in various areas of the world evolved in substantial isolation for significant periods.

If our basic hypothesis is correct, the climate shift at the Pleistocene-Holocene transition removed a tight constraint on the evolution of human subsistence systems and hence on the institutional evolution. On the evidence of the competitive success of modern industrial societies, subsistence evolution has yet to exhaust the potential for more efficient subsistence inherent in agricultural production and ongoing increases in the complexity of social institutions suggests that institutional evolution is still discovering more synergistic potential in human cooperation, coordination and division of labor. The out-of-equilibrium progressive trend in human evolution over the last 11 millennia means that we can achieve a certain conceptual and probably empirical simplification of the problem of the evolution of institutions in the Holocene. We can assume a strong, worldwide tendency, driven by the competitive ratchet, toward societies at least as complex as current industrial societies. We can assume that changes in climate and similar non-social environmental factors play a small role in the Holocene. Granted these assumptions, we are left with three questions about subsistence and institutional evolution. (1) Why are rates of change so rapid in some areas (Western Eurasia) and slow in others (Western North America)? The competitive ratchet seems to have been routinely cranked faster in some places than others. What are the factors that limit the rate of cultural evolution in some cases relative to others? We shall argue that several processes can retard the rate of cultural evolution sufficiently to account for the observed rates of change. (2) How do we explain the multi-linear pattern of the evolution of institutional complexity? Although an upward trend of complexity characterizes most Holocene cultural traditions, the details of the trajectory vary considerably from case to case. The operation of the ratchet is very far from pulling all evolving social systems through the same stages; only relatively loose parallels exist between the cases. (3) Why does the ratchet sometimes slip some cogs? In no particular cultural tradition is progress even and steady. Episodes of temporary stagnation and regression are commonplace.

WHAT REGULATES THE TEMPO AND MODE OF INSTITUTIONAL EVOLUTION?

The overall pattern of subsistence intensification and increase in social complexity is clearly consistent with the hypothesis that agriculture, and hence complex social institutions, were impossible in the Pleistocene but eventually mandatory in the Holocene, but the real test is whether or not we can give a satisfactory account of the variation in the rate and sequence of cultural evolution. Work on this project is in its infancy, and what follows is only a brief sketch of the issues involved.

Geography May Play a Big Role

Diamond (1997) argues that Eurasia has had the fastest rates of cultural evolution in the Holocene because of its size and to a lesser extent its orientation. Plausibly, the number of innovations that occur in a population increases with total population size and the flow of ideas between sub-populations. Since we know that the original centers of cultural innovation were relatively small compared to the areas to which they later spread, most societies acquired most complex cultural forms by diffusion. Societies isolated by

geography will have few opportunities to acquire innovations from other societies. Contact of isolated areas with the larger world can have big impacts. The most isolated agricultural region in the world, Highland New Guinea, underwent an economic and social revolution in the last few centuries with the advent of American sweet potatoes, a crop that thrives in the cooler highlands above the malaria belt of lowland New Guinea (Wiessner and Tumu 1998). The Americas, though quite respectable in size, are oriented with their major axis north-south. Consequently innovations have to mainly spread across lines of latitude from the homeland environment to quite different ones, unlike Eurasia where huge east-west expanses exist in each latitude belt. The pace of institutional change in Eurasian societies mirrors this region's early development of agriculture and the more rapid rate of subsistence intensification.

Climate Change May Play a Small Role.

The Holocene climate is only invariant relative to the high frequency, high amplitude oscillations of the last glacial (Lamb 1977). For example, seasonality (difference between summer and winter insolation) was at a maximum near the beginning of the Holocene and has fallen since. The so-called "Climatic Optimum," a broad period of warmer temperatures during the middle Holocene, caused a wetter Sahara, and the expansion of early pastoralism into what is now forbidding desert. The late medieval onset of the Little Ice Age caused the extinction of the Greenland Norse colony (Kleivan 1984). Agriculture at marginal altitudes in places like the Andes seems to respond to Holocene climatic fluctuation (Kent 1987). The fluctuating success of state-level political systems in the cool, arid, Lake Titicaca region is plausibly caused by wetter episodes permitting economies that support states, while they collapse or fade during arid periods. While the effect of Holocene climate fluctuations on regional sequences must always be kept in mind, the dominance of the underlying monotonic tendency to increase subsistence intensification and evolve more complex institutions seems likely to be driven by other processes.

Coevolutionary Processes Probably Play a Big Role

The full exploitation of a revolutionary new subsistence system like agriculture requires the evolution of domesticated strains of plants and animals. Human social institutions must undergo a revolution to cope with the increased population densities that follow from agricultural production. Human biology changes to cope with the novel dietary requirements of agricultural subsistence.

Agriculture requires pre-adapted plants and animals. In each center of domestication, people domesticated only a handful of the wild plants that they formerly collected, and of this handful even fewer are widely adopted outside those centers. The same is true for domesticated livestock. Zohary and Hopf (1989) have listed some of the desirable features in plant domesticates. California has so many climatic, topographic, and ecological parallels with the precocious Fertile Crescent that its very tardy development of plant-intensive subsistence systems is a considerable puzzle. Diamond (1997), drawing on the work of Blumler (1992), notes that the Near Eastern region has a flora that is unusually rich in large-seeded grasses. California, by contrast, lacked large seeded grasses, having not a single species that passed Blumler's criterion. Aside from obvious

things like large seed size, most Near Eastern domesticates had high rates of self-fertilization. This means that farmers can select desirable varieties and propagate them with little danger of gene flow from other varieties or from weedy relatives. Maize, by contrast, outcrosses at high rates. Perhaps the later and slower evolution of maize compared to Near Eastern domesticates is due to the difficulty of generating responses to selection in the face of gene flow from unselected populations (Diamond, 1997: 137). Smith (1995) discusses the many constraints on potential animal domesticates.

Even in the most favorable cases, the evolution of new domesticates is not an instantaneous process. Blumler and Byrne (1991) identify the rate of evolution of domesticated characters like non-dehiscence as one of the major unsolved problems archaeobotany. Coevolution theorists like Rindos (1984) imagine a long drawn out period of modification leading up to the first cultivation, whereas Blumler and Byrne conclude that the rate of evolution of domesticates *may* be rapid, while stressing the uncertainties deriving from our poor understanding of the genetics and population genetics of domestication. Hillman and Davies' (1990) simulations indicate that the evolution of a tough rachis (the primary archaeological criterion of domestication) in inbreeding plants like the wheats and barley could easily be so rapid as to be archaeologically invisible, as, indeed, it so far is. Their calculations also suggest that outcrossed plants, such as maize, will respond to cultivator selection pressures on the much longer time scales that Rindos and Diamond envision.

Humans have to adapt biologically to agricultural environments. While the transition from hunting and gathering to agriculture resulted in no genetic revolution in humans, a number of modest new biological adaptations were likely involved in becoming farmers. The best-documented case is the evolution of adult lactose absorption in human populations with long histories of dairying (Durham, 1991). To some extent the relatively slow rate of human biological adaptation may act as a drag on the rate of cultural innovations leading to subsistence intensification and on institutional advances.

Diseases limit population expansions, protect inter-regional diversity. McNeill (1979) and Crosby (1986) draw our attention to the coevolution of people and diseases. The increases in population density that resulted from the intensification of subsistence invited the evolution of epidemic diseases that could not spread at lower population densities. One result of this process is possibly to slow population growth to limits imposed by the evolution of cultural or genetic adaptations to diseases. For example, a suite of hemoglobins have arisen in different parts of the world that confer partial protection against malarial parasitism and these adaptations may have arisen only with the increases in human population densities associated with agriculture (Cavalli-Sforza, et al. 1994). Cavalli-Sforza et al. estimate that it would take about 2,000 years for a new mutant hemoglobin variant to reach equilibrium in a population of 50,000 or so individuals (see also Gifford-Gonzales 2000). Serious epidemics also have direct impacts upon social institutions when they carry away large numbers of occupants of crucial roles at the height of their powers. In such epidemics significant losses of institutional expertise could occur, directly setting back progressive evolution. Regional suites of

diseases handicap immigrants and travelers, thus tending to isolate societies from the full effects of cultural diffusion.

Cultural evolutionary processes play a decisive role

The processes of cultural evolution may generally be more rapid than biological evolution, but cultural change often takes appreciable time. We (Boyd and Richerson 1985) view cultural evolution as a Darwinian process of descent with modification. Evidence about characteristic rates of modification is important for understanding the relative importance of various processes in cultural evolution. In one limit, the conservative, blind, transmission of cultural variants from parents to offspring, the main adaptive force on cultural variants would be natural selection, and rates of cultural evolution would approximate those of genes. At the other extreme, humans may pick and chose among any of the cultural variants available in the community and may use cognitive strategies to generate novel behaviors directly in light of environmental contingencies (Borgerhoff Mulder et al. 1997). In the limit of economist's omniscient rational actors, evolutionary adjustments are modeled as if they are instantaneous. We believe that for many cultural traits human decisions have relatively weak effects in the short run and at the individual level, although they can be powerful when integrated over many people and appreciable spans of time. Archaeological and historical data on the rates of change in different domains of culture will be some of the most important evidence to muster to understand the tempo and mode of cultural evolution. Much work remains to be done before we understand the regulation of rates of cultural evolution, but some preliminary speculation is possible.

New technological complexes evolve with difficulty. One problem that will tend to slow the rate of cultural (and organic) evolution is the sheer complexity of adaptive design problems. As engineers have discovered when studying the design of complex functional systems, discovering optimal designs is quite difficult. Blind search algorithms often get stuck on local optima, of which complex design problems often have very many. Piecemeal improvements at the margin are not guaranteed to find globally optimal adaptations by myopic search. Yet, myopic searches are what Darwinian processes do (Boyd and Richerson 1992b). Even modern engineering approaches to design, for all their sophistication, are more limited by myopic cut and try than engineers would like.

Parallel problems are probably rife in human subsistence systems. The shift to plant-rich diets is complicated because plant foods are typically deficient in essential amino acids, and vitamins, have toxic compounds to protect them from herbivore attack, and are labor intensive to prepare. Finding a mix of plant and animal foods that provides adequate diet at a feasible labor cost is not a trivial problem. For example, New World farmers eventually discovered that boiling maize in wood ashes improved its nutritional value. The hot alkaline solution breaks down an otherwise indigestible seed coat protein that contains some lysine, an amino acid that is low in maize relative to human requirements (Katz, et al. 1974). Hominy and *masa harina*, the corn flour used to make tortillas, are forms of alkali treated maize. The value of this practice could not have been obvious to its inventors or later adopters, yet most American populations that made heavy use of maize employed it. The dates of origin and spread of alkali cooking are not known.

It has not been reinvented in Africa even though many African populations have used maize as a staple for centuries.

New social institutions evolve with difficulty. An excellent case can be made that the rate of institutional innovation is more often limiting than the rate of innovation of technology. As anthropologists and sociologists such as Julian Steward (1955) have long emphasized, human economies are social economies. Even in the simplest human societies, hunting and gathering is never a solitary occupation. At the minimum, such societies have division of labor between men and women. Hunting is typically a cooperative venture. The unpredictable nature of hunting returns typically favors risk sharing at the level of bands composed of a few cooperating families because most hunters are successful only every week or so (Winterhalder 1986). Portions of kills are distributed widely, sometimes exactly equally, among band members.

The deployment of new technology requires changes in social institutions to make best use of innovations, often at the expense of entrenched interests, as Marx argued. The increasing scale of social institutions associated with rising population densities during the Holocene have dramatically reshaped human social life. Richerson and Boyd (1998, 1999) discuss the complex problems involved in evolutionary trajectory from small-scale, egalitarian societies to large-scale complex societies with stratification and hierarchical political systems. For example, even the first steps of intensification required significant social changes. Gathering is generally the province of women and hunting of men. Male prestige systems are often based on hunting success. A shift to plant resources requires scheduling activities around women's work rather than men's pursuit of prestige. Using more plants will conflict with men's preferences as driven by a desire for hunting success; it will require a certain degree of women's liberation to intensify subsistence. Since men generally dominate women in group decision-making ("egalitarian" small scale societies seldom grant women equal political rights), male chauvinism will tend to limit intensification. Bettinger and Baumhoff (1982) argue that the spread of Numic speakers across the Great Basin a few hundred years ago was the result of the development of a plant-intensive subsistence system in the Owens Valley. Apparently, the groups that specialized in the hunt would not or could not shift to the more productive economy to defend themselves, perhaps because males clung to the outmoded, plant poor, subsistence. Winterhalder and Goland (1997) use optimal foraging analysis to argue that the shift from foraging to agriculture would have required a substantial shift in risk management institutions, from minimizing risk by intraband and interband sharing to reducing risk by field dispersal by individual families. Some ethnographically known Eastern Woodland societies that mixed farming and hunting, for example the Huron, seemed not to have made this transition and to have suffered frequent catastrophic food shortages.

Institutional evolution no doubt involves complex design problems. For example, Blanton (1998) describes some of the alternative sources of power in archaic states. He notes that archaic states differ widely in time and space as their evolution wanders about in a large space of alternative social institutions.. Thus, the Classical Greek system of small egalitarian city-states with wide participation in governance was a far different

system from those like Egypt with divine royal leaders from near its inception as a state or the bureaucracies that were common in Western Asia. Philip, Alexander, and their successors substantially rebuilt the Greek state along Western Asian lines in order to conquer and administer empires in Asia. Much of the medium-term change in archaic and classical state institutions seems to involve wandering about in a large design space without discovering any decisively superior new institutional arrangements (Marcus 1998; Feinman 1998).

The spread of complex social institutions by diffusion is arguably more difficult than the diffusion of technological innovations. Social institutions violate four of the conditions that tend to facilitate diffusion (Rogers 1983). Foreign social institutions are often (i) not compatible with existing institutions, (ii) complex, (iii) difficult to observe, and (iv) difficult to try out on a small scale.

Thus the evolution of social institutions rather than technology will tend to be the rate limiting step of the intensification process. For example, North and Thomas (1973) argue that new and better systems of property rights set off the modern industrial revolution rather than the easier task of technical invention itself. A major revolution in property rights is likely also necessary for intensive hunting and gathering and agriculture to occur (Bettinger 1999). Slow diffusion also means that historical differences in social organization can be quite persistent, even thought one form of organization is inferior. As a result, the comparative history of the social institutions of intensifying societies exhibits many examples of societies getting a persistent competitive advantage over others in one dimension or another because they possess an institutional innovation that their competitors do not acquire. For example, the Chinese merit-based bureaucratic system of government was established at the expense of the landed aristocracy, beginning in the Han dynasty (2,200 B.P.) and completed in the Tang (1,400 B.P.) (Fairbank 1992). This system has become widespread only in the modern era and is still quite imperfectly operated in many societies.

To the extent that games of coordination are important in social organization, changes from one coordination solution to another may by greatly inhibited. Games of coordination are those, like which side of the road to drive on, for which it matters a lot that everyone agree on a single solution and less on which solution is chosen (Sugden 1986). Notoriously, armies with divided command are defeated. A poor general's plan formulated promptly and obeyed without question by all is usually superior to two good generals' plans needing long negotiations to reconcile or leaving subordinates with choices of whose plan to follow. We care less whether gold, silver, or paper money are legal tender than we care that we have a single standard. Many if not most social institutions probably have strong elements of coordination. Take marriage rules. Some societies allow successful men to marry multiple wives while others forbid the practice. One system may or may not be intrinsically better, but everyone is better off playing from one set of rules. Since the strategies appropriate for one possibility are quite different from the other, marriage partners would like agreement on the ground rules of marriage up front to save costly negotiation or worse later on. Hence many institutions are in the form of a socially policed norm or standard contract ("love, honor, cherish and obey until

death do us part") solving what seems like it ought to be a private coordination problem. However, except in pure cases, different coordination equilibria will also have different average payoffs and different distributions of payoffs than others. Even if most agree that a society can profitably shift from one simple pure coordination equilibrium to another (as when the Swedish switched from driving on the left to the right a couple of decades ago to conform to their neighbors' practices) the change is not simple to orchestrate. One of our universities voted recently not to switch from the quarter to the semester system despite a widespread recognition that a mistake was made 30 years ago when the quarter system was instituted. Large, uncertain costs that many semester-friendly faculty reckoned would attend such a switch caused them to vote no. Larger scale changes, such as the Russian transition from a soviet to capitalist economy, face huge problems that are plausibly the result of the need to renegotiate solutions to a large number of games of coordination as much as any other cause.

The design complexity, importance of coordination, slow evolution, limited diffusion, and difficulty of coordination shifts probably conspire to make the evolution of social institutions highly historically contingent. The multilinear pattern of evolution of social complexity could result from two causes. Societies might be evolving from diverse starting points toward a single common optimal state surrounded by a smooth "topography" which optimizing evolutionary processes are climbing toward the summit. Or, societies may be evolving up a complex topography with many local optima and many potential pathways toward higher peaks. In this case, even if societies start out at very similar initial points, they will tend to diverge with time. We believe that at least part of the historical contingency in cultural evolution is due to slow evolution on complex topographies (Boyd and Richerson 1992b).

Ideology May Play a Role. Nonutilitarian processes may strongly influence the evolution of fads, fashion, and belief systems. Such forces are susceptible to feedback and runaway dynamics that defy common sense (Boyd and Richerson 1985: Chap. 8). The links between belief systems and subsistence are nevertheless incontestably strong. To build a cathedral requires an economy that produces surpluses that can be devoted to grand gestures on the part of the faithful. The moral precepts inculcated by the clergy in the cathedral underpin the institutions that in turn regulate the economy. Arguably, ideological innovations often drive economic change. Recall Max Weber's classical argument about the role of Calvinism in the rise of capitalism.

Complex social systems are vulnerable. We suggest that the fragility of institutions derives from compromises and tradeoffs that are caused by conflicts between the functional demands of large scale organizations and the trajectory of small-scale cultural evolution often driven by psychological forces rooted in the ancient and tribal social instincts. The evolution of work-arounds seldom results in perfect adaptations. Resistance to the pull of the ratchet can increase sharply when external pressures such as competition from other societies, demographic catastrophes, or internal processes such as the evolution of a new religion put weak work-arounds in jeopardy. All complex societies may have weak work-arounds lurking among their institutions. As we noted above, each of the major types of institutional workarounds has defects that lead to intra-societal

conflict. Small-scale societies have appreciable crudities at least in part deriving from conflicts, both intra-psychic and political, between individual and kinship interests and the larger tribe (Edgerton 1992). If our argument is correct, larger scale societies do not eliminate these conflicts but add to them manifold opportunities for conflict between different elements of the larger system. Even the best of such systems current at any one time are full of crudities and the worst are often highly dysfunctional. A considerable vulnerability to crisis, change without progress, setback and collapse is inherent in an evolutionary system subject to strong evolutionary forces operating at different levels.

Maynard Smith and Szathmáry (1995) treat the rise of human ultra-sociality as analogous to other major evolutionary transformations in the history of life. As with our tribal social instincts and work-around proposals, the key feature of transitions from say cellular grade organisms to multicellular ones is the improbable and rare origin of a system in which group selection works at a larger scale to suppress conflict at the smaller and eventually to perfect the larger scale superorganisms. Actually, "perfect" is too strong a word, distinct traces of conflict remain in multicellular organisms and honeybee colonies too. We suggest that human societies are recently evolved and remain rather crude super-organisms, heavily burdened by conflict between lower and higher level functions and not infrequently undone by them. Outside of the realm of utopian speculation and science fiction, there does not appear to be an easy solution. Muddle along is the rule, pulled on the trajectory toward more social complexity by the competitive ratchet.

Changes in the rate of cultural evolution and the sizes of cultural repertoires. Rates of social and technical evolution appear to be rising towards the present. Modern individuals know more than their ancestors, and social complexity has increased. The cultural evolution in the Holocene began at a stately pace. Not for some 6,000 years after the initial domestication of plants and animals in southwestern Asia did the first state level societies finally decisively transcend tribal scale roots of human sociality. Tribes, city-states and empires competed to govern Eurasia for another 4,500 years while the first states emerged in the New World and Africa. The rise of the West over the last millennium has brought revolutions in subsistence and social organization, particularly during the last half millennium. Even in Eurasia, the last pastoral and hunting tribes of the interior were only defeated by Chinese and Russian firearm armies a couple of centuries ago. Only for the last century or two has cultural evolution been sufficiently rapid so that almost everyone is aware of major changes within their lifetime. Malthus, writing around the turn of the 19th Century still regarded technical innovation as quite slow, on quite sound empirical grounds. Only a couple of decades after his death would cautious empiricists have good grounds to argue that the industrial revolution was something new under the sun (Lindert 1985). The accelerating growth of the global population is a product of these changes and the curve of population growth is one reasonable overall index of cultural change. Another is the increasing division of labor. Innovations on the subsistence side at first rather gradually, and then lately very rapidly, reduced the personnel devoted to agricultural production and shifted labor into an expanding list of mercantile, manufacturing, government, and service occupations.

The reasons for the accelerating rate of increase are likely several. First, the sheer increase in numbers of people must have some effect on the supply of innovations. Second, the invention of writing and mathematics provided tools for supplementing memories, aiding the application of rationality, and for the long distance communication of ideas. Scribes in small numbers first used their new skills to manage state supply depots, tax roles, and land mensuration. Only gradually did procedures in different fields become written and mathematics come to be used to solve an expanding array of problems. Third, books ultimately became a means of both conserving and communicating ideas, at first only to an educated elite. Fourth, quite recently, the mass of people in many societies became literate and numerate, allowing most people to take up occupations dependent upon prolonged formal education, policy and procedure handbooks, technical manuals, reference books, and elaborate calculations. Fifth, the rise of cheap mass communication, beginning with the printed book, has given individuals access to ever-larger stores of information. The internet promises to give everyone able to operate a workstation access to all the public information in the world. Donald (1991) counts the spread of literacy and numeracy as a mental revolution on the same scale as the evolution of imitation and spoken language. Sixth, institutions dedicated to deliberately promoting technical and social change have grown much more sophisticated. Boehm (1996) argues that even acephalous societies usually have legitimate, customary institutions by which the society can reach a consensus on actions to take in emergencies, such as the threat of war or famine (see also Turner 1995: 16-17).

Institutions organized as a matter of social policy to further change continue to increase perceptibly in scope and sophistication. Institutions like patents that give innovators a socially regulated property right in their inventions ushered in the industrial revolution. Private companies invest in new technology, under the eye of government regulators beginning about the turn of the 20th Century. Government bureaucracies conduct useful research from the public purse beginning in a small way in the 19th Century. Research universities recruit some of the best minds available, place them in an intellectual hothouse, and reward scholars for new ideas of whatever kind they are prepared to pursue. Masses of young people are educated by such innovators and their students, especially during the last 50 years. The military's general staffs, modeled on the impressively effective Prussian/German General Staff developed by Scharnhorst, Gneisenau and their students like Clauswitz, drove military modernization at impressive rates in the 19th and 20th Centuries. Dupuy (1977) argues that the effectiveness of German soldiers in WWII was in largest part a product of the German General Staff drawing more appropriate lessons from WWI and implementing more thorough reforms than competing general staffs. Development institutions like agricultural extension services and teaching hospitals move innovations in some fields from the university to the farm or doctor's office at a smart pace. Think-tanks ponder public policy in the light of research, national academies of science craft white papers based on elaborate searches for expert consensus, legislatures hold hearings trying to match the desires of constituents with the findings of the experts in order to produce new policies and programs.

WE HAVE A SHADOWY OUTLINE OF THE TEMPO AND MODE OF THE EVOLUTION OF INSTITUTIONS

The large, rapid change in environment at the Pleistocene-Holocene transition set off the trend of subsistence intensification and institutional complexity of which modern industrial innovations are just the latest examples. If our hypothesis is correct, the reduction in climate variability and, increase in CO_2 content of the atmosphere, and increases in rainfall rather abruptly changed the earth from a regime where agriculture was everywhere impossible to one where it was possible in many places. Since groups that utilize efficient, plant-rich subsistence systems and deploy the resulting larger population more effectively will normally out-compete groups that make less efficient use of land and people, the Holocene has been characterized by a persistent tendency towards subsistence intensification and growth in institutional sophistication and complexity. The diversity of trajectories taken by the various regional human sub-populations since ? 11,600 B.P. are natural experiments that will help us elucidate the factors controlling the tempo and mode of cultural evolution leading to more efficient subsistence systems and the more complex societies these systems support. A long list of processes interacted to regulate the trajectory of subsistence intensification, population growth, and institutional change that the world's societies have followed in the Holocene. Social scientists are in the habit of treating these processes as mutually exclusive hypotheses. They seem to us to be competing but certainly not mutually exclusive. Many are not routinely given any attention in the historical social sciences. At the level of qualitative empiricism, tossing any one out entirely leaves puzzles that are hard to account for and produces a caricature of the actual record of change. If this conclusion is correct, the task for historically minded social scientists is to refine estimates of the rates of change that are attributable to the various evolutionary processes and to estimate how those rates change as a function of natural and socio-cultural circumstances. We lack a quantitative understanding of the burden of flawed work-arounds and other features of complexity that retard and locally reverse tendencies to greater complexity. We only incompletely understand the processes generating historical contingency.

The present very high rates of technical and institutional evolution are a problem of immense applied importance. While some observers are complacent about current trends (Fukuyama 1992), others worry. For example, our headlong quest for increased material prosperity that guides so much current calculated institutional change not only takes great risks of environmental deterioration and a hard landing on the path to sustainability, but seems flawed from the point of view of satisfying human needs and wants (Frank and Cook 1995; Easterlin 1995).

THE END OF COMPLEX SOCIETIES?

Those who are familiar with the Pleistocene often remark that the Holocene is just the "present interglacial." The return of climate variation on the scale that characterized the last glacial is quite likely if current ideas about the Milankovich driving forces of the Pleistocene are correct. Sustaining agriculture and complex societies under conditions of much higher amplitude and more frequent environmental variation than farmers currently cope with would be a very considerable technical challenge. At the very best, lower CO_2

concentrations and lower world average precipitation suggest that world average agricultural output would fall considerably.

In one sense, though, the Holocene is not just another interglacial. Petit et al. (1999) suggest that it may be uniquely long, although decidedly cooler than the maximum temperatures of the previous four interglacials, at least in continental Antarctica. Current anthropogenic global warming via greenhouse gasses threatens to elevate world temperatures to levels that in past interglacials apparently triggered a large feedback effect producing a relatively rapid decline toward glacial conditions. The Arctic Ocean ice pack is currently thinning very rapidly (Kerr 1999). A dark, open Arctic Ocean would dramatically increase the heat income at high northern latitudes, and have large, difficult to guess impacts on the Earth's climate system. No one can yet estimate the risks we are taking of a rapid return to colder, drier, more variable environment with less CO_2, nor evaluate exactly the threat such conditions imply for the continuation of agricultural production. Nevertheless, the intrinsic instability of the Pleistocene climate system, and the degree to which agriculture is dependent upon the unusually long Holocene stable period, should give one pause (Broecker 1997).

Of course, our sophisticated understanding of the natural world and our ability to turn that understanding into purposive collective action must not be underestimated. Human societies are perhaps indeed a major transition in evolution as Maynard Smith and Szathmáry (1995) argue, but to our way of thinking this transformation is still a work in progress. Given the manifest remaining crudities of our social systems, the power of our own destructive inventions, and potential of glacial climates and other forces of nature to weak havoc on human plans, completing the human transition promises to be a near run thing.

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