Chapter 23. MACROEVOLUTION: MICROEVOLUTIONARY PROCESSES AND THE HISTORY OF THE HUMAN SPECIES

> We view *Homo* as an evolving genus that beat the odds. It overcame the resistance to advanced cognitive evolution by the cosmic good fortune of being in the right place at the right time."
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> C. Lumsden and E.O. Wilson
> *Genes, Mind, and Culture* (1981)

O. Introduction to part IV of the course, "Evolutionary Transformations of Human Ecological Patterns"

Human evolution is a great saga: How did the human species and our component cultures arise from a chimp-like ape to become, ultimately, modern humans? The first three parts of the course have described the ecological/evolutionary typology of human societies, the basic evolutionary mechanisms that operate on human populations, and some of the systemic environmental interactions of human populations. In the last part of the course, we want to turn back to the main types of human societies and ask how each one might have evolved. That is, how and why might humans have evolved from apes in the first place? Why did hunting societies eventually give rise to horticultural ones, etc.? Can we use the science we have described in the previous chapters to inform our understanding of human history?

This last, seemingly innocent, question gives rise to the fascinating, fiercely debated issue of the relationship between historical and scientific explanation. Both evolutionary biologists and social scientists are confused and uncertain about what kind of answer we can give to these most interesting questions. Recall the discussion of Steward's failure to connect his ecology and evolution described in Chapter 2. Problems like his are still important. This is one of those easy-to-visit frontier areas of science where you can see fairly clearly for yourself how we scholars struggle for new knowledge on the edge of the sea of ignorance!

Part of the problem is conceptual. Science is about general "laws," explanations that cover many cases. But humans are members of one, unique, historical lineage. Can science say much of anything about solitary cases? Are historical and scientific explanations either conflicting or even opposed modes of explanation?

Part of the problem is practical. Historical events happened a long time ago, and most of the evidence is lost. A powerful theory would help us fill in the gaps of incomplete data. Students of biological and cultural evolution do indeed have a a fairly powerful set of theoretical tools derived from observation and experiment. However, of course the best data come from short-term experiments and observations in the lab and field. Thus we understand *microevolution* (events on the time scale of a few years) fairly well. *Macroevolution* is a more problematic phenomenon. Large-scale historical changes take place on time scales of thousands to millions of years, far beyond the direct reach of experiments and observation. If there are any macroevolutionary phenomena that are hard to detect with microevolutionary experiments, we are in trouble with gaps.

In this chapter, we outline the issues involved in trying to extrapolate from a micro theory to a macro account. We tentatively conclude that a scientific micro-based account of macroevolutionary historical phenomena is probably possible, but that scientists have to admit that history offers real and special problems.

In the subsequent chapters, we will apply the basic models developed in the course to explanations of the basic macroevolutionary transformations in human history. You will see that there are some fascinating hypotheses around, though none that meet demanding tests. On the other hand, many hypotheses can be eliminated using current theory and data.

***Microevolution*: The processes of evolution as observed through direct observation and experiment. The microevolutionary time scale is from one to a few generations or cycles of cultural transmission.**

***Macroevolution*: The process of evolution as observed through paleontology, archaeology, and history. The more dramatic events of evolution (new species, new technological systems) occur rarely and slowly and are not directly observable in the present. The time scales involved are tens to hundreds or many more generations or cycles of cultural transmission.**

I. Conflict Between Scientific and Historical Explanation

The conflict between "scientists" and "historians" has a long tradition in the social sciences. Two of the most important founding documents in human ecology, Peter Vayda and Roy Rappaport (1968) and Donald Campbell (1975) are explicitly critical of merely descriptive historical approaches to human history. Other very prominent social scientists, such as Marshall Sahlins (1976) and Clifford Geertz (1973), started their careers as "scientific" human ecologists, but later wrote very critical accounts of such studies from the historical side. More recently, Misia Landau (1991) has analyzed scientists attempts to give an account of human origins and argues that all the classical accounts have the structure of folk hero myths. Attempts to do "science" seems to have resulted in mere mythologizing; a very tart accusation as you can appreciate from our standard scientists' condemnation of mythologizing in Chapter 2!

Historians ask: Aren't explanations of human social life necessarily interpretive and particularistic? Any given unique evolutionary trajectory has to be explained by events unique to that trajectory, not by general laws that apply to every case. Aren't present phenomena are best explained mainly in terms of past contingencies, not ahistorical processes like function or adaptation that would erase the trace of history if they really were important? Like other "scientific," antihistorical explanations of human cultures, the argument goes, Darwinian models cannot account for the lack of exact, complete correlation of environmental and cultural variation, nor the long term trends in cultural change.

The "scientists'" answer is classically that when one ignores scientific theory, all that is left is a descriptive narration of historical events using informal folk categories. Each case of an evolutionary history may be unique, but the cases as a whole fall into patterns underlain by understandable processes. The patterns and common processes then tell us much about why each case behaved as it did. Certainly, many historical patterns are complex and the facts are few, but to give up on science is to give up on the only truly powerful set of investigative tools we have. No matter how difficult the problem is, we can always do better using science than if we don't. To the "scientist," the "historians'" arguments are just a disguised way of avoiding the hard task of real understanding in favor of easy but completely unsatisfactory story-telling that is hardly different from writing fiction.

In this chapter we argue that the attempt to make a fight out of "history" versus "science" is a mistake. (1) The historians are correct to point out that there are many examples of real historical change in human macroevolution. Scientific human ecologists have sometimes tried to ignore historical patterns of change, and have been guilty of oversimplifying the connection between micro and macroevolution. (2) Modern evolutionary models in fact have several basic mechanisms that can generate historical macroevolutionary patterns. "Historians" cannot claim that observed historical patterns are inexplicable from the "scientific" point of view.

If these points are correct, when we remove the quotes science and history really are one approach. Darwinian theory is both scientific and historical. The history of any evolving lineage or culture is a sequence of unique, contingent events. Similar environments often give rise to different evolutionary trajectories, even among initially similar societies. Anglo-Americans travelling abroad find the British somewhat strange and the Germans decidedly foreign, and not just in matters of language either. Somtimes very long run trends in features such as size occur. Human societies have tended to increase in size in a more or less steady manner for the past 10,000 years. Nonetheless, these historical features of organic and cultural evolution can result from a few microevolutionary processes.

Our aim is to catalog the kinds of microevolutionary processes that can give rise to historical patterns of change in both the organic and cultural cases. There are number of microevolutionary processes that can generate historical macroevolutionary patterns that can bridge the conceptual gap between scientists and historians. Once the conceptual gap is gone, the harder task of using scant data to infer the causes of macroevolutionary events is a doable enterprise.

II. What Makes Change Historical?

Our first problem is give an usable definition of "history." The above debate is pretty abstract until the we describe more precisely that makes historical change is. The historians' argument is (e.g., Trigger 1978) that history involves unique, contingent pathways from the past to the future that are strongly influenced by unpredictable, chance events. For example, as we'll discuss in Chapter 28, capitalism arose in Europe rather than China, perhaps because Medieval and Early Modern statesmen failed to create a unified empire in the West (McNeill 1980). Several times popes and kings almost succeeded in taming the politically fractious West, but they never quite did it. If one of these "almost" initiatives had been implemented, Europe might have become a continent-wide, conservative, Catholic, Empire, dominated by a rural landed elite. Such an empire would have sharply controlled merchants and manufacturers. Thus Europe after the Middle Ages could have moved into something like the later Austro-Hungarian Empire on a large scale. The rise of capitalism and the industrial revolution might not have happened at all, or might have happened in another place at another time.

In contrast, it is argued, scientific explanations involve universally applicable laws.

In evolutionary biology and in anthropology, these often take the form of functional explanations, in which only knowledge of present circumstances and general physical laws (e.g. the principles of mechanics) are necessary to explain present behavior (Mitchell and Valone 1990). For example, long fallow horticulture is commonly used in tropical forest environments, presumably because it is the most efficient subsistence technology in such environments (Conklin 1969; Chapter 5). The fact that similar subsistence techniques are used in similar environments is an example of the sort of patterns that scientists invokd in the face of historians' claims that everything is the accident of history.

It has often been argued that this dichotomy is false. Eldredge (1989:9) forcefully defends a common objection: all material entities have properties that can change through time. Even the simple entities like molecules are characterized by position, momentum, charge, and so on. If we could follow a particular water molecule, we would see that these properties changed through time -- even the water molecule has a history according to Eldredge. Yet, everyone agrees that we can achieve a satisfactory scientific theory of water. Historical explanations, Eldredge argues, are just scientific explanations applied to systems that change through time. We are misled because chemists tend to study the average properties of very large numbers of water molecules.

Eldredge's argument explains too much. Not all change with time is history in the sense that historically oriented biologists and social scientists intend. To see this consider an electrical circuit composed of a voltage source, a capacitor and an fluorescent light. Under the right conditions, the voltage will oscillate through time, and these changes can be described by simple laws. Are these oscillations historical? On Eldredge's view they are; the circuit has a history, a quite boring one, but a history nonetheless. Yet such a system does not generate unique and contingent trajectories. After the system settles down one oscillation is just like the previous one. The period and amplitude of the oscillations are not contingent on initial conditions. They are not historical in the sense of "one damn thing after another" (Elton 1967:40) leading to cumulative and divergent, if haphazard, change.

What then makes change truly historical? We think that two requirements capture much of what is meant by "history," and that they pose an interesting and serious challenge for reconciling history with a scientific approach to explanation. A pattern of change is historical if:

A. Trajectories are not stationary on the time scales of interest.

History is change that does not repeat itself. On long enough time scales, the oscillations in the circuit become statistically monotonous or "stationary" (see definition box for a discussion of this important but simple and little known concept). Similarly, random day-to-day fluctuations in the weather do not constitute historical change if one is interested in organic evolution because on long evolutionary time scales the there will be so many days of rain, so many days of sun and so on. By choosing a suitably long period of time, we can construct a scientific theory of stationary processes using a statistical rather than strictly deterministic approach. In the case of nonstationary historical trajectories, a society or biotic lineage tends to gradually become more and more different as time goes by. There is no possibility of basing explanation on, say, a long-run mean about which the historical entity fluctuates in some at least statistically predictable way, because the mean calculated over longer and longer runs of data continues to change significantly. One of the most characteristic statistical signatures of nonstationary processes is that the variance they produce grows with time rather than converging on a finite value as time increases. The definition box and Figure 23-1 elaborate the concept of stationarity.

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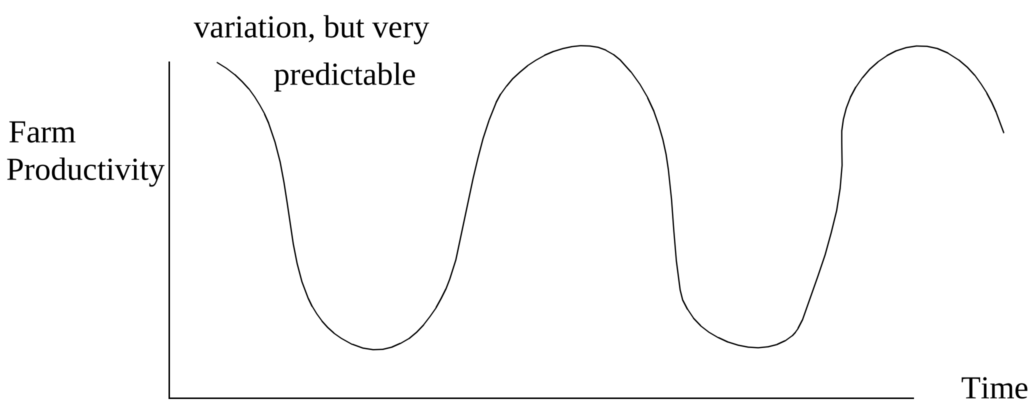
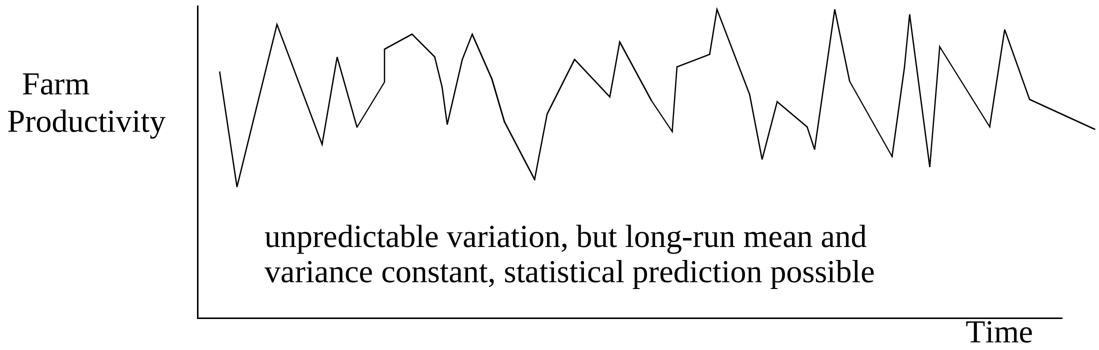
Figure 23-1. Illustrations of (a) deterministic, (b) noisy, but stationary, and (c) non-stationary change with time.

(a) Deterministic change

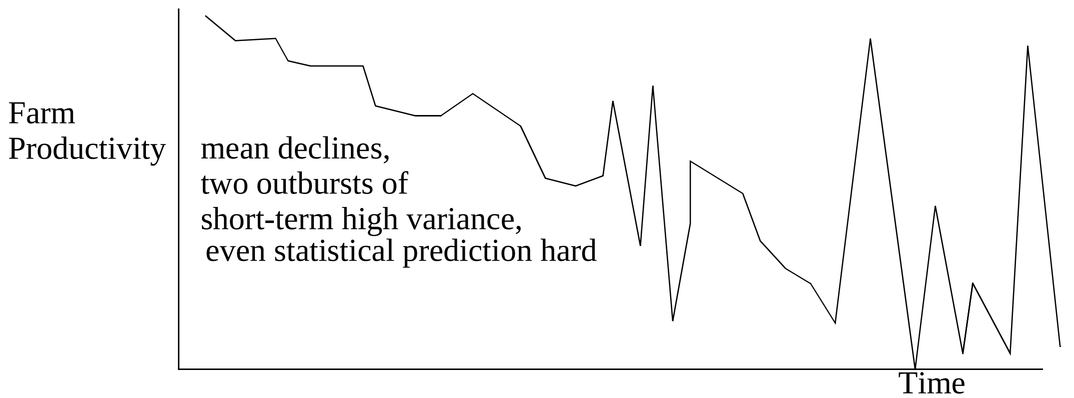


Exact prediction possible if we know the law describing the process of change

(b) Random, but stationary, change



(c) Non-stationary change



B. Similar initial conditions give rise to qualitatively different trajectories.

Historical change is strongly influenced by happenstance. This requires that the dynamics of the system must be path dependent; isolated populations or societies must tend to diverge even when they start from the same initial condition and evolve in similar environments. Thus, for example, the spread of a favored allele in a series of large populations is not historical. Once the allele becomes sufficiently common it will increase at first exponentially, and then slowly, asymptotically approaching fixation. Small changes in the initial frequencies, population size, or even degree of dominance will not lead to qualitative changes in this pattern. In separate but similar environments, populations will converge on the favored allele. Examples of convergence in similar environments are common--witness the general similarity in tropical forest trees and many of the behaviors of the long fallow cultivators who live among them the world over. On the other hand, there are also striking failures of convergence--witness the many unique features of Australian plants, animals, and human cultures. The peculiar hanging leaves of eucalypts, the bipedal gait of kangaroos, and the gerontocratic structure of Australian Aboriginal societies make them distinctively different from the inhabitants of similar temperate and subtropical dry environments on other continents.

> ***Time Scales*:**
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> **This term refers to some characteristic measure of how fast or slow a process normally is. To use the term formally, we have to define a measure of the speed of the process. For exponential processes like malthusian growth, the doubling (or halving) time is a convenient measure. For more complex processes, with large changes in rate in different parts of the curve, a more complex measure is required. For example, for the increase of a favorable innovation due to natural selection or bias, the time to get from 5% to 95% of the population would be a good formal measure (refer back to fig. 9-1). If, historically, the time scale for the malthusian growth of populations far from carrying capacity is has a time scale of a two or three generations, and the time scale for the spread of a favorable innovation is a few tens of generations, we would say that malthusian growth has a shorter time scale than the diffusion of innovations.**

Note that a process that is historical in one spatio-temporal frame may not be in another. If we are not too interested in a specific species or societies in given time periods, we can often average over longer periods of time or many historical units to extract ahistorical generalizations. Any given water molecule has a history, but it is easy--necessary without a Maxwell's demon--to average over many of them and ignore this fact.

It is important not to blur the distinction between simple trajectories and true historical change. it is easy to see how evolutionary processes like natural selection give rise to simple, regular change like the spread of a favored allele or subsistence practice. However, it is not so easy to see how such processes give rise to unique, contingent pathways. Scientists take the approach to steady states and convergence in similar situations as evidence for the operation of natural "laws," so it *seems* natural to conclude that failures of stationarity

***Stationary vs. nonstationary processes*:**

This is an important conceptual distinction in the statistical study of "time series" (historical data). A stationary process is one that is varies in a statistically predictable way. Even if there is change, the statistical variables that describe the pattern of change don't themselves change with time. If we record the number of "heads" in 10 fair- coin flips for many such sets of flips, the mean and variance that characterize the number of heads we expect don't change in time even thought the number of heads in each 10-flip set will vary a considerable amount. This time series is stationary. Now suppose that the coin is wearing unevenly, so that on average the number of heads is gradually going down, but that the tendency to runs of both heads and tails is increasing. Now, the mean and variance of the coinflip process are changing with time, and we will generate a simple non-stationary data set. Technically then, a stationary process is one in which at least the statistics of fluctuation, like the mean and variance, don't change with time. If the mean, variance, or other statistics change with time, we've got a non-stationary process.

and convergence are evidence of processes that cannot be subsumed in the standard conceptions of science, or at least be explained by adaptive processes. The argument we are about to advance is that things are not at all that simple. There is every reason to expect that perfectly ordinary scientific processes, ordinary in the sense that they result from natural causes and are easily understood by conventional methods, regularly generate history in the sense defined by these two criteria

III. How Do Microevolutionary Processes Give Rise to History?

A. History is Often Caused by External Environmental Factors

It is likely that historical change is at least sometimes generated by abiotic environmental change with historical properties (Valentine and Moores 1972). Long term trends in evolution could result from the accurate tracking of a slowly changing environment. For example, during the last hundred million years there has been a long, slow increase in the degree of armoring of many marine invertebrates living on rocky substrates and a parallel increase in the size and strength of feeding organs among their predators (Vermeij 1987; Jackson 1988). It is possible that these biotic trends have been caused by long-run environmental changes over the same period -- for example, an increase in the carbonate content of the ocean (Holland 1984), which might make it easier to construct bulky skeletons of calcium carbonate.

Similarly, human history is highly historical. Figure 23-1c might almost describe the last 30,000 years of human dependence upon meat in Europe. We began a shift from migratory big game hunting to sedentary, broad spectrum, more labor-intensive foraging beginning about 17,000 year ago, finally developing agriculture about 7,000 years ago (Henry 1989). Some farm systems still support high meat consumption, but others very little. Many authors (e.g., Reed 1977) have argued that the transition from glacial to interglacial climate that occurred during the same period is somehow responsible for the big shift toward increasing dependence on plant foods and eventually to agriculture (see Chapter 25).

Differences among populations in similar environments may result from the environments really being different in some subtle but important way. For example, Westoby (1989) argues that some of the unusual features of the Australian biota result from the continent-wide predominance of highly weathered, impoverished soils on this relatively undisturbed continental platform. Perhaps the failure of horticulture to develop in or diffuse to Aboriginal Australia merely reflects poor soils. It is interesting that New Guinea, the steep, uplifting, good soils edge of the Australian continental platform had horticulturalists rather early.

Historically, the "externalist" or "equilibrist" move in discussions of history is an important one. For the "scientific" evolutionary biologists and social scientists, it gets history out of their court and into the court of the geologists and ecologists. Charles Lyell, Darwin's friend and famous geologist, espoused a non-historical, cyclical stationary theory of geological history. He was very jumpy about Darwin's theory because he could see history in the paleontological record of extinctions and speciation as read by Darwin. He knew "scientific" geologists would get stuck with "unscientific" history if they weren't careful! By imagining that natural selection produced populations in near equilibrium with external environmental conditions, Darwin could have a nice, "scientific" theory of evolution, and pin the awkward problem of "history" on Lyell!

Historical causes from the physical environment are empirically very plausible.The use of "environmental determinism" and climate change arguments by people interested in human history has always been controversial. Modern geology and paleoclimatology have developed irrefutable evidence of a dynamic Earth that changes in all sorts of ways on every imaginable time scale. Continents drift, the heat output of the sun rises, day-length declines, atmospheric gasses fluctuate, etc. Externalist, equilibrist environmental hypotheses to explain historical change in general have to be taken quite seriously. In Appendix 24-A we have provided a discussion of the geological record of climate change over Earth history as but one example of this dynamism. The hominid lineage's tenure on the planet coincides with dramatic climate changes attending the onset of the Ice Ages, and climate history will figure large in externalist hypotheses we'll discuss in the next chapters.

B. History Is Caused by Processes Internal to Evolutionary Mechanisms

It is possible that evolutionary processes themselves can generate non-stationary, diverging historical patterns of change on their own even in a stationary environment. Traditionally, many social and biological scientists have assumed that much of the evolutionary record can be read as a slow improvement and gradual perfection of species and societies by evolutionary processes like natural selection. This idea is often called "*progressivism.*" Gradually, over the whole history of the earth, evolution has been replacing "primitive" organisms with more "advanced" species.

Naive progressivism is unsupportable. As we have seen, microevolutionary studies have shown that natural selection and the decision-making forces of cultural evolution can produce rapid, usually adaptive, change to local conditions. *There are no known foresighted processes in evolution that seek long term goals*. On this account, there is an embarrassingly large amount of time available for internal processes to account for historical trends. Natural selection and similar processes seem to be able to get to equilibrium rather quickly, and hence seem unable to account for much history. Darwin was always worried that the Earth was old enough to account for all the evolution he saw, but then he faced Lord Kelvin's calculation indicating that the planet is only about 50 million years old. Now that we know that life has existed on Earth for a few billion years, the shoe is on the other foot. It is easy to imagine that an immense amount of evolution can occur due to internal processes on the millions of years time scale. A progressive, internal process that took billions of years to get from bacteria to Queen Victoria is not completely plausible, and, at least on these long time scales, some version of external equilibrist hypothesis seems required. (All progressivist schemes, following the 19th Century evolutionists like Spencer, also had a suspiciously ethnocentric and anthropocentric tendency to put their own society at the pinnacle of evolutionary progress, and are also suspicious on the grounds of ethnocentrism.)

On the other hand, certainly, the overall trajectory of human evolution has at least the appearance of long term historical "progress" of some sort. We began as narrowly distributed East African upright apes 4 million years ago. We have gradually enlarged our brains, expanded our range, increased the diversity and sophistication of our cultural adaptations, increased the size of our social units, and burgeoned in numbers to become the most dominant single vertebrate species the Earth has ever experienced. Whether "progress" has to go inside or outside quotes, this historical trajectory itself is something we have to account for. Progress or not, such long term, non-stationary trends demand some sort of explanation.

What is required to escape the externalist objection to naive progressivism are historical mechanisms internal to the evolutionary processes of genes and culture that could produce a modified, more plausible, less ethnocentric form progressivism. The historical patterns generated by these processes might well have time scales somewhat to much shorter than billions of years, and so have to share the long-term explanatory stage with external, equilibrist, environmental hypotheses. Still, on the 100 year to million year time scales of human history, internal, reformed progressivist accounts of various kinds may be quite correct. Let us count the ways that a reformed progressivism might be constructed from plausible internal contraints on the rate of evolutionary change!

1. Random Processes

Mutation and drift and their cultural analogs can create history by random walks. We begin with the simplest internal process that could generate history (though not much that you'd care to call progress). It could be that most evolutionary change is random. Much change in organic evolution may be the result of drift and mutation, and much change in cultural evolution may result from analogous processes. Evolution by mutation and drift is slow compared to simple adaptive change. Raup (1977) and others argue that random-walk models produce phylogenies that are remarkably similar to real ones. To the extent that cultural and genetic evolutionary change is random, populations in similar environments will diverge from each other.

It seems likely that some variation in genes and culture evolves mainly under the influence of nonadaptive forces -- for example, much of the eukaryotic genome does not code for genes and might well evolve entirely under the influence of drift and mutation (Futuyma 1986:447). Similarly, the arbitrary character of symbolic variation suggests that nonadaptive processes are likely to be important in linguistic change and similar aspects of culture. In both cases, isolated populations diverge at an approximately constant rate on the average. However, to understand why a particular species is characterized by a particular DNA sequence, or why a particular people use a particular word for mother, one must investigate the sequence of historical events that led to the current state.

Indirect bias can create historical patterns. Some evolutionary processes give rise to dynamic processes that are sensitive to initial conditions, and have no stable equilibria. In Chapter 14 we discussed the evolution of symbolic characters under the influence of indirect bias. Recall that in this case (like mate choice sexual selection in biology) runaway dynamics, strongly dependent on initial conditions, can lead to unique, exaggerated display traits in a population. These symbolic traits may come to serve functions like ethnic boundary marking, but non- adaptive, random effects may determine how a particular trait is developed into a symbolic system. Also recall that in the case of expressive symbolic systems like art that neophilia (boredom with old stimuli, the little thrill of seeing something a bit new) can drive an endless wandering in "style space." Language apparently evolves under the influence indirect bias, and language evolution is a classic example of continuous long term *change and divergence of ancestral societies.*

Most defenders of "scientific" approaches are quite willing to accept that random processes like drift and indirect bias operating on symbolic systems like language generate history, but they often want to be able to divide problems into those that are purely, random- historical and others that are purely, causal-scientific. The most pointed controversy comes over whether the history that can't be attributed to geology can be attributed to afunctional style, leaving all the important (e.g. adaptation producing) internal processes purely universal general laws free of historical residues, as many "scientists" and "historians" both seem to want. (Both sides seem to want this distinction to hold up to make their subjects easier, and to disputes with their colleagues fewer by dividing the intellectual labor so neatly. If the main argument of this chapter is correct, these very human desires to make life easy have to be foregone.)

2. Adaptive Processes Can Give Rise to History.

It is more difficult to understand how adaptive processes like natural selection can give rise to historical trajectories. There are two hurdles: *First*, there is the problem of too much time referred to above. Theory, observation, and experiment suggest that natural selection can lead to change that is much more rapid than any observed in the fossil record (Levinton 1988:342-347). For example, the African Great Lakes have been the locus of spectacular adaptive radiations of fishes amounting to hundreds of highly divergent forms from a few ancestors in the larger lakes (Lowe-McConnell 1975). The maximum time scales for these radiations, set by the ages of the lakes and not counting that they may have dried up during the Pleistocene, are only a few million years. The radiation in Lake Victoria (200+ endemic species) seems to have required only a few hundred thousand years.

Adaptive cultural change driven by decision-making forces can be very fast indeed as is evidenced by the spread of innovations (Rogers 1983) and by the rapid evolution of new adaptations, such as the case of the Plains Indians' development of horse nomadism in a century and a half or so. It is not immediately clear how very short time-scale processes such as these can give rise to longer term change of the kind observed in both fossil and archaeological record unless the pace of change is regulated by environmental change. In the absence of continuing, long-term, nonstationary environmental change, adaptive processes seem quite capable of reaching equilibria in relatively short order. In other words, both cultural and organic evolution seem, at first glance, to be classic scientific processes that produce functional adjustments too rapidly to account for the slow historical trajectories we actually observe.

Second, it is not obvious why adaptive processes should be sensitive to initial conditions. Within anthropology the view that adaptive processes are ahistorical in this sense underpins many anthropological critiques of adaptive explanations. Many anthropologists claim that it is self-evident that cultural evolution is historical, and that therefore adaptive explanations (being intrinsically equilibrist and ahistorical) must be wrong (Hallpike, 1986). Again, it seems to suit the arguments of both "historians" as well as "scientists" if adaptive processes are ahistorical.

Sahlins' (1963) contrast of Melanesia and Polynesia is a classic example of the "historians" argument. Sahlins notes that Melanesians and Polynesians each live on a a very diverse set of Tropical Pacific Islands, using the same basic technology. There are many ecological differences within these two large cultural groups, but each covers the whole range from very large Islands (New Zealand, New Guinea) to tiny atolls. If adaptation and convergence were all, the main cultural variation should be governed by environment and be replicated within each group. What struck Sahlins is some striking similarities shared within each group and not replicated between them. His main example was in the realm of social organization. Polynesians have an ideology of ranked lineages and sacred chiefs, which on large islands leads to the formation of large chiefdoms and even small-scale states. Hawaii is a good example; societies there were just either very advanced chiefdoms or small states, depending on your definitional preferences. The Melanesians lack the idea of ranked lineages, and typically have the bigman style of political organization. They lack big chiefdoms and states even on large islands with dense populations. History seems to make a big difference in a telling case where a natural experiment helps us control for environment, and provide plenty of replication to boot.

Is there any way that path dependence and long-term change can be consequences of any adaptive process analogous to natural selection? Sahlins himself (1976) argued that such facts require abandoning adaptive accounts in favor of a vague historical process he called "cultural reason." Let's use for discussion the adaptive topography model of genetical or cultural evolution under the influence of a basic adaptation producing force like natural selection or direct bias with and adaptive decision rule. As noted in the chapters on evolutionary processes, we often model evolution as acting on quantitative character like height or political conservatism. Under many assumptions, the evolutionary response of such systems is for the population to "climb" the fitness "topography" until the mean phenotype of the population is optimally adapted at a peak on the topography, whereupon stabilizing selection keeps it there.

I*n this simple model the evolutionary trajectory of the population will be completely governed by the shape of average fitness as a function of mean phenotype*. If the adaptive topography has a unique maximum then every population will evolve to the same equilibrium mean phenotype, independent of its starting position, and once there be maintained by stabilizing selection. On the other hand if there is more than one local maximum, different equilibrium outcomes are possible depending on initial condition. The larger the number of local maxima, the more path dependent the resulting trajectories will be (see fig. 23-2).

You can imagine that natural selection and adaptive decision making forces make populations act like blind mountain climbers. They can sense which way is up in their immediate vicinity, but they cannot see what the overall topography is like. They have to search for the overall fitness maximum by climbing upwards wherever they are. Put three independent Darwinian climbers anywhere on 23-2a and they will all soon arrive at the fitness maximum. Start the same three off even close together on 23-2b and they will drift apart and end up stuck on different local maxima. If search capabilities are limited, it will be exceedingly difficult for our climbers on 23-2b to get off these local peaks and begin climbing toward the highest point in the topography.

Indeed, we might imagine that it would take geological processes or some similar rare big change to create a new ridge or slope to get a stuck population started again, something that would happen very rarely. Theoretical studies of genetic drift confirm an old intuition of pioneering evolutionist Sewall Wright that drift can jump populations from one adaptive peak to another, but the process is very slow relative to the rate selection can drive a population up a simple slope. In short, even a very efficient local hill climber will be able to climb a rough topography slowly and inefficiently, creating the conditions for a long, slow, divergent, progressive, historical pattern of adaptive improvement.

The questions are: (1) Are adaptive topographies mostly like the simple hill portrayed in figure 23-2a or more like the real mountain used in 23-2b? (2) If they are rough, exactly what makes them so? If simple topographies are common, we'd better look for the causes of history mostly in external equilibrist environmental changes or random processes, except perhaps at very short, out-of-equilibrium time scales. On the other hand, any tendency for complex topographies to be realistic will make internal "progressivist" patterns easy to imagine, even on long time scales.

There are a number of internal processes that are good candidates for producing rough adaptive topographies for cultural or genetic evolution:

(1.) Complex design problems have multiple solutions. The character of most biological or cultural evolutionary "design" problems has not been worked out, but multiple solutions is a notorious complexity of human engineering design. A computer design problem discussed by Kirkpatrick et al. (1983) provides an excellent example. Computers are constructed from large numbers of interconnected circuits each with some logical function. Because the size of chips is limited, circuits must be divided among different chips. Because signals between chips travel more slowly and require more power than signals within chips, designers want to apportion circuits among chips so as to minimize the number of connections between them. For even moderate numbers of circuits, there is an astronomical number of solutions to this problem. Kirkpatrick et al. present an example in which the 5000 circuits which make up the IBM 370 microprocessor were to be divided between two chips. Here there are about 10^{1503} possible solutions!

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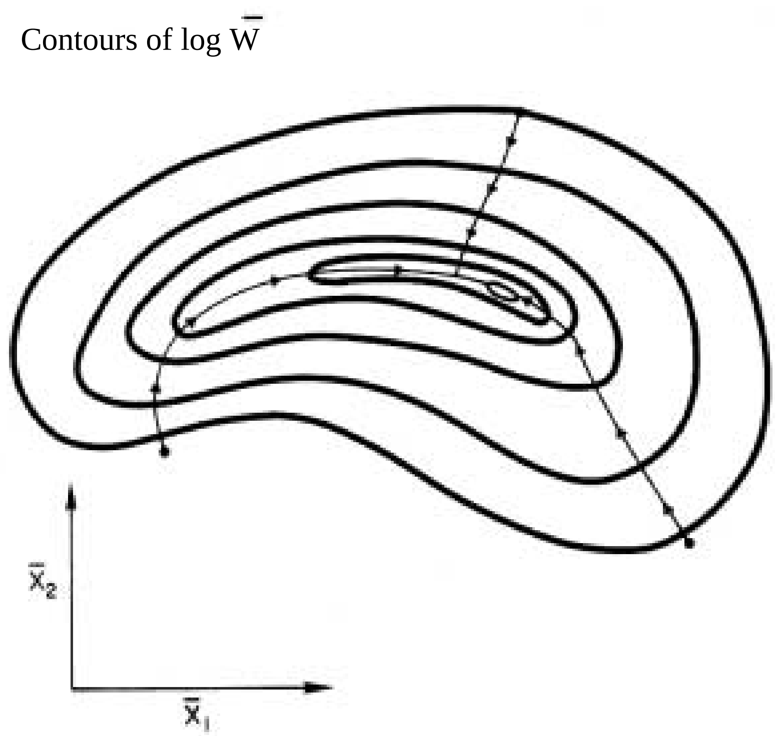
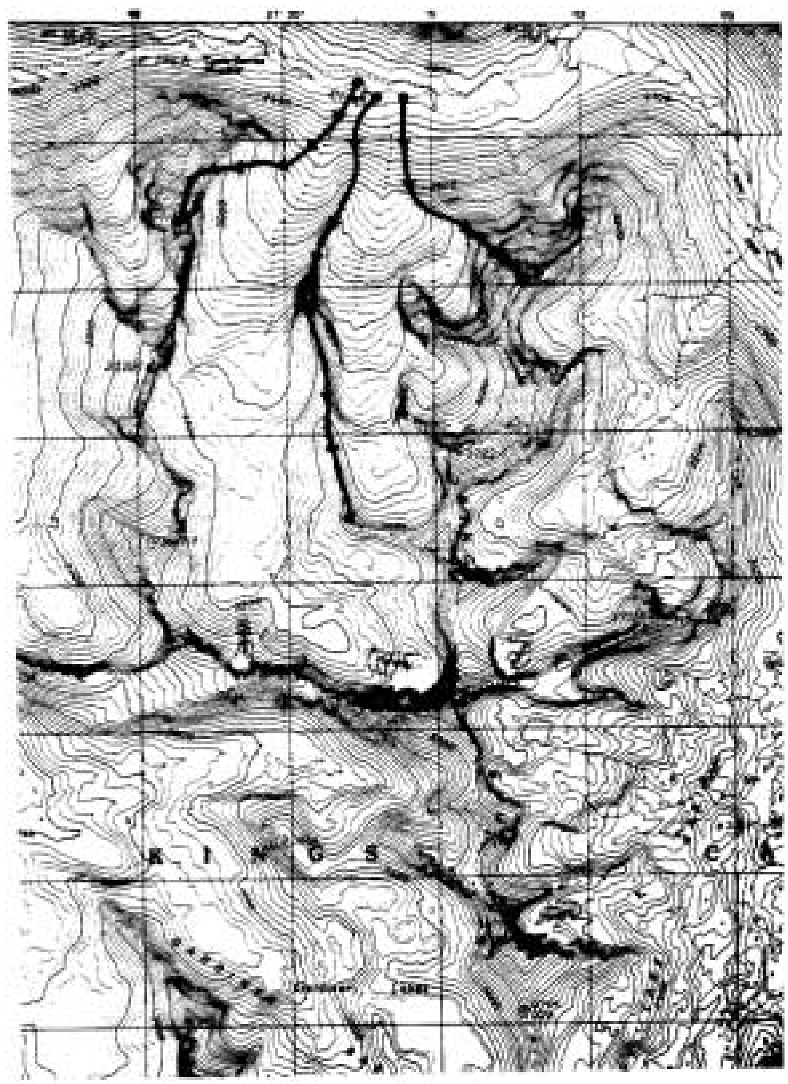
Figure 23-2. This figure shows two adaptive topographies. The axes are the mean genetic value in a population for two characters. The contour lines give contours of equal mean fitness. Populations beginning at different initial states all achieve the same equilibrium state. Part a shows a simple unimodal adaptive topography. Part b (next page) shows a complex, multimodal topography. Initially similar populations diverge owing only to the influence of selection (Boyd & Richerson 1992:190-191).





This design problem has two important qualitative properties:

A. *It has a very large number of local optima*. That is, there is a large number of arrangements of circuits with the property that any simple rearrangement increases the number of connections between chips. This means that any search process that simply goes up hill (like our model of adaptive evolution) can end up at any one of a very large number of configurations. An unsophisticated optimizing scheme will improve the design only until it reaches one of the many local optima, which one depending upon starting conditions. For example, for the 370 design problem several runs of a simple hill climbing algorithm produced between 677 and 730 interconnections. The best design found (using a more sophisticated algorithm) required only 183 connections.

B. *There is a smaller, though still substantial, number of arrangements with close to the globally optimal number of interconnections*. That is, there are many qualitatively different designs that have close to the best payoff. In the numerical example discussed above there are on the order of 70 such arrangements.

These results are quite typical. To quote from the introduction of a classic textbook on optimization "...many common design problems, from reservoirs to refrigerators, have multiple local optima, as well as false optima, that make conventional [meaning simple, blind, hill-climbing] optimization schemes risky" (Wilde 1978). Thus, if the analogy is correct, small differences in initial conditions will commonly launch different populations on different evolutionary trajectories which end with qualitatively different equilibrium phenotypes. Populations will commonly get stuck on local peaks for varying lengths of time. Many evolutionary changes will be progressive jumps to improved technology, not simple tracking of environmental change Just as in figure 23-2b, evolutionary change due to attempts to make better tools should be demonstrate our two criteria for being historical.

(2.) "Developmental" constraints may impose history. Developmental constraints could play a major role in confining lineages to historically determined "bauplane," as many biologists have argued (e.g. Seilacher 1970). "Bauplan" is German and means something like "building plan." Development proceeds in a hierarchical fashion, so that events early in development have a large influence on events later in development. Thus, the basic number of limbs that vertebrates have is manifest very early in development, and many subsequent developmental episodes appear to depend on there being four limbs. Developmental anomalies, such as calves with six legs, sometimes occur, but the resulting individuals are almost always inviable. So many developmental pathways in later development are keyed to events early in development that it is almost impossible to alter early events without merely messing everything up. Adaptive changes are usually possible only by tinkering with events late in development.Thus, there might be many circumstances where selection might try to favor an insect with four or eight legs or a vertebrate with six, or a bird with wings converted back to legs, etc. However, such things very rarely happen. Once a lineage establishes a basic bauplan, it seems to be essentially fixed for geologic time.

Perhaps culture has become part of the human bauplan. In the case of humans, it would seem that culture has come to play an essential role in our development; children without proper socialization are pathological basket cases. Our species and any descendent species we have for the indefinite future will probably be culture bearing, so matter how modified we are in other ways. We probably depend upon cultural transmission for basic essentials that other animals inherit genetically.

In terms of our adaptive topography picture, we might view developmental constraints as like impenetrable thickets on the adaptive landscape. The terrain may sometimes be smoothly uphill in the direction of acultural hominids or four-legged plus two arms centaur hominids, but there may be no useful genetic variation that can penetrate the adaptive constraint thicket in these directions.

A similar argument has been made for cultural variation itself. Social scientists at least since Freud have tended to believe that events early in childhood strongly and permanently influence personality, and that societies with different child rearing practices come to have different average personality types. The kind of psychological anthropology associated with Margaret Mead and like minded mid-century types advocated this hypothesis. To the extent that such structure exists, path dependence is likely to be important. Basic personality types will have a big influence on basic values that people hold, and basic value orientations in turn will affect what sorts of economic organizations people can manage, and what sorts of occupations that they will find rewarding. Changing fundamental attributes of a culture underpinned by a set of personality types will tend to undermine values and economic activity in complex, hard to predict and control fashion. Therefore, once a society is committed to a certain personality profile (cold Germanic, warm Latin, disciplined Asian), it is very hard to change it with catastrophic disruption of the shallower parts of psychology and social institutions that depend on such psychology.

There is much skepticism in both biology and social science over the importance of developmental constraints as a cause of complex evolutionary topography, notwithstanding the arguments and examples above. Constraints on major morphological evolution seem to break down in cases like the adaptive radiations of tropical fishes when the environment is essentially empty, and many new designs come into being in short order. Bandura (1977), a pioneering student of the processes of social learning, argues that there is relatively little complexly embedded structuring of socially learned behavior. He stoutly defends a "bean bag" theory of culture. People may have a lot of cultural traits, but they are not tightly structured or linked. The tendency of cultures to readily adopt revolutionary innovations from quite foreign sources (such as the Japanese adoption of European industrial technology in the mid 19th Century) might make us wonder that personality type constraints are very constraining. Religious conversion to new sets of apparently quite basic values is also fairly common, often quite apart from other changes, for example in economy.

(3.) Games of coordination and similar phenomena can cause history. "Games" of coordination are those kinds of social interactions in which at least part of the payoff de-

pends upon doing what everyone else does. Recently, game theorists (Sugden, 1986) have come to suspect that an element of coordination is very common in the kinds of complex cooperative societies in which humans live. Which side of the road to drive on is a simple example. You are barreling down a dirt road and round a curve to find an oncoming car. Do you veer left or right? Either right or left is equally good in the abstract, but it is quite important that you and the oncoming driver "agree" to conform to one convention or the other. Now the shape of our adaptive topography is no longer fixed, it also depends upon where the population is. In America you should swerve right, but in Australia left. In this simple case, the adaptive topography is flat until some consensus begins to form, and then a hill and valley emerge. In general, games of coordination have many solutions, many more than two for more complex ones. Moreover, games of coordination can be mixed with other games, like games of cooperation, and the total payoff of some coordination equilibria may be higher than others, generating once more the complex, lumpy evolutionary topography that can generate history.

Arthur (1990) shows how locational decisions of industrial enterprises could give rise to historical patterns due to coordination effects. It is often advantageous for firms to locate near other firms in the same industry because specialized labor and suppliers have been attracted by preexisting firms. The chance decisions of the first few firms in an emerging industry can establish one as opposed to another area as the Silicon Valley of that industry. More generally, historical patterns can arise in the many situations where there are increasing returns to scale in the production of a given product or technology. Merely because the QWERTY keyboard is common, it is sensible to adopt it despite its inefficiencies.

If you have ever spent any time in a foreign culture, you know that there are a host of petty, annoying differences between the ways you are used to and those of your hosts. If your hosts have ever lived here, you can trade stories all night about whose customs are more odd than whose. These are mostly issues of games of coordination, and point up their pervasive and important role in regulating behavior in complex societies.

Once a culture has reached a particular solution to a coordination game, changing to another solution, even if the other solution is better, can be a very difficult task. Everyone has to change at the same time, and it is a big production. Take the US conversion to the metric system. It is obviously a benefit for the US to coordinate with the world standard system, but so far we cling to the English system because of the immense costs of the transition.

We might hypothesize that one problem that the former Soviet Block societies now face is that they must abandon many old norms of coordination, and negotiate new ones. If we suppose that a functioning society is made to work by a vast array of interlocking "games" of coordination, this extensive renegotiation will make adopting the metric system seem like child's play. Even if the capitalist system is absolutely better than the Communist in all ways, it is liable to be extremely costly to make the transition. If Yeltsin's fast transition strategy fails but the Chinese slow strategy succeeds we might have a test of the importance the stickiness of games of coordination to creating history in cultural evolution. If both fail, it would seem likely that they are even more important.

(4.) The existence of socially approved sanctions and punishment creates a special kind of coordination problem. Take basic social norms and customs that are enforced by public opinion (or stronger sanctions). Scandinavians are rather law abiding, and even economic crimes like tax evasion are viewed as serious offenses. People who cheat on their taxes are liable to be turned in by anyone who knows about the evasion, and even knowing about such a crime and not reporting it would be viewed askance. On the other hand Scandinavians are very liberal on matters of sexual conduct. Few parents seriously object to or interfere with their teenagers active sexuality beyond basic emotional support, safe sex advice, and the like. Parents who do more are viewed as narrow-minded prudes even by other parents. In Italy, by contrast, tax evasion is very widespread and no friend is likely to turn you in for cheating on your taxes. But the Italian concept of family honor that requires males to closely control the sexuality of "their" women. In many Mediterranean cultures men are quite prepared to murder men who seduce their wives, sisters and daughters, and to deal very harshly with any signs that the women concerned were willing participants in illicit affairs. What is adaptive to do in each place differs substantially merely because what the community is prepared to tolerate and punish differs.

Theoretical models suggest that any behavior that a community is generally prepared to sanction can be stabilized by punishment if the punishment is harsh enough but not too costly to impose, even if the behavior sanctioned is not particularly adaptive (Boyd and Richerson, 1992). Punishment is something that can stabilize a virtually infinite variety of quite amazingly non-adaptive behaviors. Wearing ties to work in business and English spelling (why not "speling"???) are a couple of mild homegrown examples. Many other conventions enforced by punishment are undoubtedly functional, along the lines of the drive on the right rule. The point is that punishment exaggerates the already large tendency for games of coordination to generate protected local optima. Many protected optima mean diversification. It is likely that some local optima are better than others (there has got to be something better than wearing ties and krazee spelling), so we have another mechanism to produce topographies like fig. 23-2b.

(5.) Interactions between populations and societies (or interacting internal elements like classes) can result in multiple equilibria. Models of the coevolution of multiple populations have many of the same properties as games of coordination within populations, although the theory is less well developed (Slatkin and Maynard Smith 1979). The evolution of one population or society depends upon the properties of others that interact with it, and many different systems of adjusting the relationships between the populations may be possible. For example, Cody (1974:201) noted that competing birds replace each other along an altitudinal gradient in California, but latitudinally in Chile. Given the rather similar environments of these two places, it is plausible that both systems of competitive replacement are stable and which one occurs is due to accidents of history.

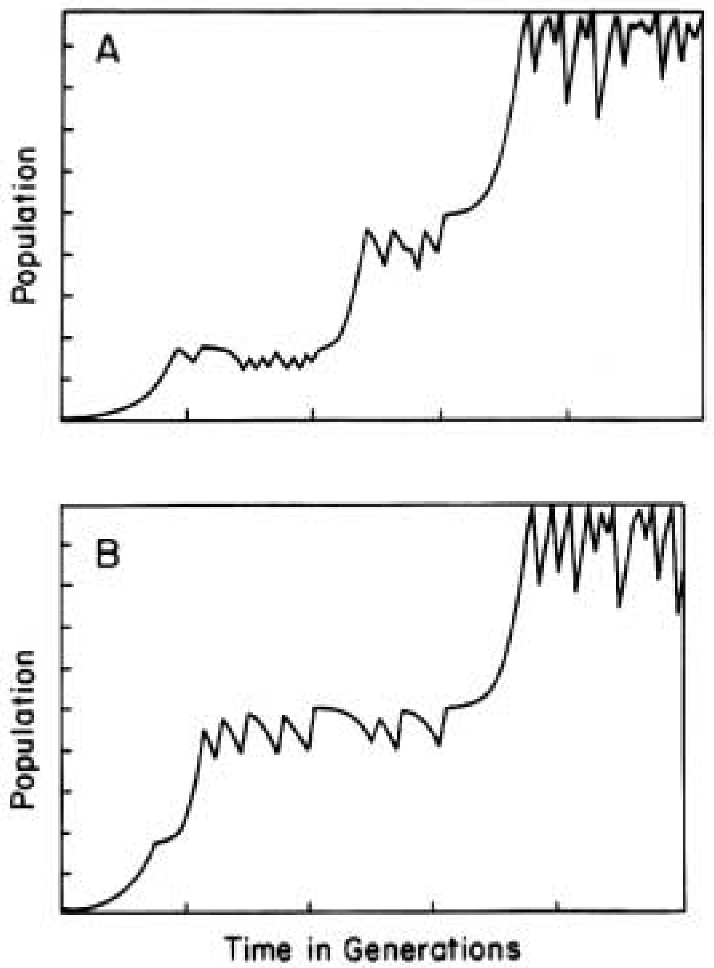
The stratification of human societies into privileged elites and disadvantaged commoners derives from the ability of elites to control high- quality resources and/or to exploit commoners using strategies that are similar to competitive and predatory strategies in nature. We will examine some experiments by Insko et al (1983) in Chapter 26 that seem to show that both an exploitative or a more legitimate form of stratification could arise and stabilize in the same environment. It seems plausible that the diversity of political forms of complex societies could result from many arrangements of relations between constituent interest groups being locally stable. The distinctive differences between the Japanese, American, and Scandinavian strategies for operating technologically advanced societies could well derive from historic differences in social organization that have led to different, stable arrangements between interest groups, in spite of similar revolutionary changes in production techniques of the last century or two.

(6.) Chaotic dynamics can create history. An understanding of “chaos” is one of the most important scientific achievements of the last 20 years. Some of you have undoubtedly been exposed to at least popular treatments of the subject (e.g. Gleick, 1987). Chaotic dynamics are completely deterministic; there is no random element. Yet, in many cases, even fairly simple dynamic systems wander about in a very random-like way. If we start of two systems exactly alike, they will move exactly in parallel forever. However, if we start them off just a little bit differently, the differences will grow.

Chaotic dynamics were first discovered meteorologist Edward Lorenz, who was doing simple numerical simulations on a primitive computer. He discovered that nearly identical runs of his equations diverged in the most surprising manner in just a few “days” of simulated weather. Today numerical meteorologists believe that chaos causes the frustrating unpredictability of the weather due to the “butterfly's wing” effect of chaotic dynamics. If a butterfly beats its wing just so in Japan, the tiny eddy created will tip atmospheric processes slightly and launch the North Pacific on a trajectory that will grow into a storm that hits California a week later. A flick in a different direction, and it will be dry. Thus, weather forecasts of even four or five days in the future are very difficult. Given that it is impractical to know exactly where the system is starting from at this moment down to the last butterfly's wingbeat, we could be on any one of many chaotic paths to five days from now, and these paths diverge pretty fast in the case of weather. The 24 hour forecast is pretty fair, but the 96 hour is already only a little better than a guess based on long term averages.

It is not surprising that chaotic dynamics appear models of social systems. For example Day and Walter (1989) have analyzed an extremely interesting model of social evolution in which population growth leads to reduced productivity, social stratification, and eventually to a shift from one subsistence technology to a more productive one. Examples of the resulting trajectories of population size are shown in figure 23-3. Population grows, is limited by resource constraints, and eventually technical substitution occurs, allowing population to grow once more. The only difference between figures 23-3a and 23-3b is a very small difference in initial population size. Nonetheless, this seemingly insignificant difference leads to qualitatively different trajectories -- one society shows three separate evolutionary stages, and the second only two.

Figure 23-3. Both parts show the trajectories of population growth generated by the same model of social evolution for two slightly different initial population sizes. In part a, the society goes through three distinct phase of growth, while in part b, there are only two (Boyd & Richerson 1992:199).



Thus, it seems that there are many candidates for creating rough topography for adaptive evolutionary processes. History is easily accounted for by a number of well-specified Darwinian mechanisms. At the same time, we know little about the relative importance of each process in the actual generation of human evolutionary history.

IV. Conclusion

Scientific and historical explanations are not alternatives. Contingent, diverging pathways of evolution and long-term secular trends can result from processes that differ only slightly from those that produce rapid, ahistorical convergence to universal equilibria. Late 19th and early 20th Century scientists gave up restricting the term "scientific" for deterministic, mechanistic explanation and began to admit "merely" statistical laws into fundamental corpus of even physics (very reluctantly in some cases, recall Einstein's famous complaint about God not playing dice with the universe to express his distaste for the essential probabilistic indeterminacy of quantum mechanics).

Similarly, historical explanations cannot be distinguished from other kinds of scientific explanations except that some models (and, presumably, the phenomena they represent) generate trajectories that meet our definition of being historical. These history-generating processes do not depend on exotic forces or immaterial causes that ought to excite a scientist's skepticism; perfectly mundane things will do.

There are challenging complexities in historical processes. For example, even well understood processes will not allow precise predictions of future behavior when change is historical. However, all the tools of conventional scientific methods can be brought to bear on them. For example, it should be possible to use measurement or experiment to determine if a process is in a region of parameter values where chaotic behavior is expected or not. At the same time, the historian's traditional concern for critically dissecting the contingencies that contribute to each unique historical path is well taken. Process oriented "scientific" analyses help us understand how history works, and "historical" data are essential to test scientific hypotheses about how populations and societies change.

If the arguments in this chapter are correct, the ***conceptual*** *problem of linking macro and microevolution in a way that should satisfy both "scientists" and "historians" is solved.* In fact we have a rather large number of hypotheses that will do the work. The problem of the complexity of historical processes and gaps in the historical record means that the far harder *empirical* problem still gives future generations of scientific historians, perhaps you, plenty of most excellent work to do!

In the final chapters in this course, we'll examine some of the major historical transformations of human societies in order to see if we can make this synthesis between history and science seem reasonable in these concrete cases.

V. Bibliographic Notes

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