CAN HISTORY BECOME AN ANALYTICAL, PREDICTIVE SCIENCE?

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Can history become a Science in the same sense that physics and biology are Sciences? By asking this question I do not mean to denigrate the academic field of history and its practitioners. Analyzing a text written in medieval Latin is a task requiring no less technical expertise than analysing a database on the effect of global warming on bird populations. But Science (with a capital S) goes beyond description: it looks for general regularites and then seeks explanations of them. Ultimately, the task of the natural scientist is to identify laws of nature (understood broadly). Yet the great majority of historians vehemently deny that there is any such thing as a law of history.

The track record of previous attempts to discover laws of history is, indeed, quite poor (the Historical Materialism of Karl Marx and Friedrich Engels is perhaps the most famous example). Many philosophers, including Karl Popper, came to the conclusion that there is a qualitative difference between history and natural sciences. Historical processes are too complex and different in nature from physical or biological processes. For one thing, people have free will, while atoms do not.

Vitalism

As a biologist-turned-social scientist, when I hear such arguments, I cannot help but think back to the state of biology in the nineteenth century, before the scientific triumphs of Charles Darwin and Louis Pasteur. The reigning theory in biology at that time was vitalism, a doctrine that the processes of life were not explicable by the laws of physics and chemistry alone. It was believed that biological entities contained a "vital spark" or "*élan vital*," which could not be studied with the methods of physics and chemistry. Vitalism is now thoroughly rejected, but this does not mean that it was a silly theory for its times. Early scientists noted that substances seemingly fell in two general classes. An inorganic substance, such as a lump of gold, could be heated to the point where it changed its state (melted), but on cooling it returned to its orginal form. Organic substances, when heated, changed irrevocably. The process of heating seemingly expelled the vital force from such substances. The destructive effect of heat on the vital force was the reason why Pasteur had to design the famous "col de cygne" (swan neck) bottle to disprove the theory of spontaneous generation—his first experiments were criticized on the grounds that by boiling broth in closed bottles he destroyed the vital force needed for spontaneous generation of life.

Ultimately vitalism was discredited not because of critical experiments, such as that of Pasteur, but as a result of hard, and often mundane, work by myriads of biologists who consistently applied the scientific method to biological questions and eventually found that there was no need of a vital force to explain general regularities in their data. In the process biology transformed itself from the descriptive discipline that it was in the nineteenth century (just like history is today) to an analytical, explanatory, and predictive science of the twentieth century. Are there lessons for those of us who would like to achieve a similar transformation of history?

Mathematical history?

One of the most important lessons is recognizing the key role of mathematics in the transition of biology from the descriptive to explanatory science. It was mathematical reasoning that almost discredited Darwin’s theory of evolution in the late nineteenth century. The dominant theory of inheritance in Darwin’s time assumed that the offspring’s traits were a blend of its parents’ traits. Such blending inheritance destroyed genetic variation that was absolutely necessary for natural selection to work on. No genetic variation meant no evolution. When biologists discovered that the theory of blending inheritance was wrong, it was again mathematical modelers who established the firm logical foundation for the Neodarwinist Modern Synthesis during the 1930s.

One of the most striking examples of the value of mathematical models comes from the field of population dynamics. In 1924 Charles Elton published a paper entitled *Periodic fluctuations in the number of animals: their causes and effects*. After reviewing the population data on lemmings, hares, and mice, and considering various hypotheses that might account for periodic changes in their numbers, Elton concluded that these fluctuations must be due to climatic variations. What is remarkable is that Elton never considered the cause that we now know is one of the most common drivers of population cycles—the population interaction between predators and prey. The reason is that it never occurred to him. In *Modeling Nature* the historian of science Sharon Kingsland relates how two years later Julian Huxley walked into Elton’s office and showed him an article by the Italian mathematician Vito Volterra that was just published in *Nature*. The article presented a simple mathematical model of predator-prey interaction, and showed that the outcome is population cycles of both species. Huxley, one of the founders of modern evolutionary biology, and Elton, often considered as the father of animal ecology, were very intelligent people. But it took a paper written by a mathematician, who knew nothing about real animals, to open their eyes to the possibility of predator-prey cycles.

A common objection to employing mathematical models in the study of historical dynamics is that social systems are so complex that any mathematical model would be a hopeless oversimplification without any chance of telling us interesting things about these systems. This argument gets it exactly wrong—it is because social systems are so complex that we need mathematical models. “Naked” human brain is not a bad tool for extrapolating linear trends, but it fails abysmally when confronted with systems of multiple parts interconnected with nonlinear feedback loops. This is probaby why it took a mathematical model to point out that cycles are inherent in the interaction between predators and prey (and this is a very simple system, with just two interacting components). We need mathematical formalism to express our ideas unambiguously, and both analytical methods and fast computers to determine the implications of the assumptions we made.

“Mathematical history” sounds strange, almost quaint. But I am convinced that history cannot become Science without a healthy dose of mathematical modeling, coupled with rigorous statistical methods for testing theoretical predictions with data. Certainly, that is how the transition was made in physics and biology. In social sciences such disciplines as economics have largely made the transition, while sociology and political science are in the process of doing so.

Social complexity

It is undeniable that social systems are very complex, and have little resemblance to such paradigmatic success stories in physics as Newton’s planetary motions. A biologist, however, is unimpressed with social complexity. Next time you are in a forest, stop and look around. You will find yourself in a very complex ecosystem. There is likely to be at least a dozen species of trees and shrubs and a hundred or more of herbs, forbs, and other smaller plants. There will be innumerable species of insects, mites, lower invertebrates, fungi, protozoa, and bacteria. All this life will be busy doing its thing around you; mice will scurry underfoot and birds will be singing in the branches. It is a horrible mess (or glorious complexity, depending on your point of view). How could it possibly give rise to any laws of nature? Yet it does.

Over the last century ecologists identified many kinds of empirical regularities in forest ecosystems. To continue with population cycles, almost every forest, especially those in boreal and temperate climatic zones, has a particularly voracious species of insect that periodically runs amok denuding trees of their foliage, or even killing them outright. These population cycles can be quite predictable. For example, the populations of the larch budmoth reach a peak in the larch forests of the Swiss Alps every 8.5 years. The amplitude of these oscillations is remarkable—the population density in the trough is five orders of magnitude (100,000 times) lower than at the peak.

Somehow large-amplitude regular oscillations arise from the mess of nature in ecosystems. Why should the social systems be different? After all a social system consists of only one species. Of course people are not all the same—there are different social classes and professions, different religions and ethnic identities, and so on. Still, when we add together the different kinds of humans in an average historical social system (an agrarian state, for example), I doubt that the total would come anywhere near the number of species in an average ecosystem.

Free will

Atoms do not have free will, but people do. In practical terms (for example, if we want to model the behavior of a group of people) this means that the behavior of a human individual is to a certain (perhaps a very great) degree unpredictable. Is this an unsurmountable obstacle for developing a predictive social science?

When I was a graduate student I spent innumerable hours observing a species of beetle who ate bean plants. I was struck by how random-looking, and at times seemingly irrational their behavior was (later I learned that other entomologists had also noted this pattern). Plots of beans are a tiny fraction of the landscape, and finding them, even for bean beetles, is quite hard. Yet many a female beetle with lots of eggs, which she could only lay on a bean plant, would suddenly take off and disappear into the blue sky. The chances were that she would never find another place as nice for reproduction that she has just left.

In fact, this behavior only looks irrational. Mathematical models demonstrate that this strategy (called "spreading the risk") could be quite a good one in evolutionary terms. Most dispersing insects die (and we find their bodies on the tops of the highest mountains and other unlikely places), but a few hit the jackpot, finding their "insectopia", and those rare successes more than compensate for all the unlucky ones. So behaving in a random, unpredictable way pays. It is as though there is a random number installed within an insect brain (such as it is). I do not know whether insects have free will, but certainly their behavior is much less predictable than that of most people.

The reason I was watching bean beatles for my Ph.D. research was because I wanted to figure out how their populations redistribute themselves in space. It turned out that although each beetle was behaving in an extremely unpredictable way, at the population level their dispersal was quite predictable—the process was well described by the diffusion equation that physicists developed to understand how particles spread in a solution. While there was chaos and complete unpredictability at the microlevel of individuals, there was a lot of order and predictability at the macrolevel of populations.

Empirical regularities

In the Second Afterword to *War and Peace*, Leo Tolstoy argued that in order to find laws of history, we should focus on large masses of people and not on individuals, no matter how important they seem (his example was Napoleon Bonaparte). If from the microchaos of molecular motions arise the laws of thermodynamics, and from individual bean beetles hopping among plants arise the regular patterns of population diffusion, why should not there be general regularities characterizing the dynamics of human societies, even though the behavior of each person is unpredictable? In fact, we have already found many regularities in social systems. Here are just three examples.

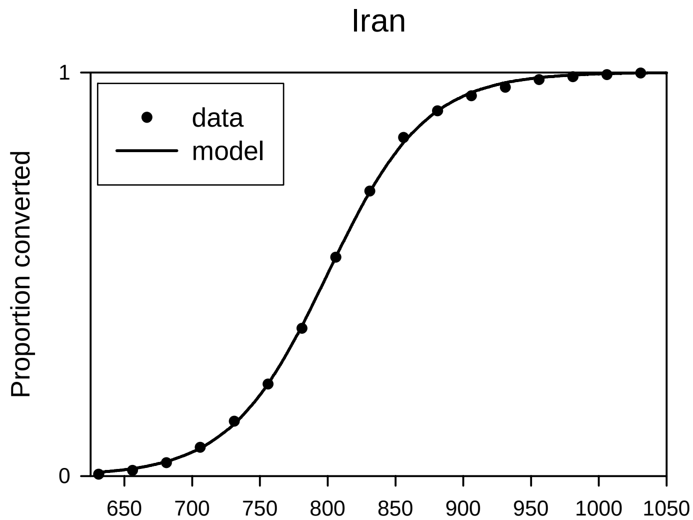
Cities are very complex social "organisms"—they vary in size, layout, environmental surroundings, and the culture, wealth, and technology available to their inhabitants. One might think that each city is a unique and particularistic endpoint of a complex development pathway, which is highly contingent on various historical accidents along the way. But when we plot the populations of all cities in the U.S., starting with the largest (New York), then the next largest, and so on, we get a strikingly regular relationship. On a double-log plot (when both city populations and ranks are log-transformed) the points line up very near a straight line with the slope equal to –1, a relationship known as the Zipf's Law. Furthermore, as Geoffrey West and colleagues at the Santa Fe Institute demonstrated, many urban attributes are related to ("scale with") the city size: the rate at which the city produces wealth and innovations, but also the rate of crime, and even how fast people walk!

The second example deals with religious conversion. At the level of individuals, the decision to convert to a religion must be very complex, involving a lot of soul-searching, but also rational calculations of potential benefits, as well as peer pressure from friends and relatives. At the level of whole societies, however, the dynamics of religious conversion is surprisingly law-like (see the figure). The data points, showing the time course of conversion to Islam in Iran, were estimated by the Yale historian Richard Bulliet from some 8,000 Persian genealogies. The curve is a very simple, two-parameter model fitted to the data, the logistic equation.

The last example concerns long-term cycles that, it turns out, characterize the dynamics of agrarian states and empires. When we consider the long course of history of Western Europe from the days of the Roman empire until the Industrial Revolution, we observe waves of internal instability (widespread rebellions, state collapse, and persistent civil war) that recur every two or three centuries. The internal warfare cycles appear to be dynamically linked with cycles of population increase and decline or stagnation: population peaks are followed, after a time lag, with peaks of instability. This empirical pattern suggests some kind of a Malthusian explnation. However, the American sociologist Jack Goldstone showed that population growth beyond the means of subsistence does not directly bring the onset of civil wars. Instead, its effect is indirect, mediated through the social and political structures (elite overproduction and state fiscal insolvency), which is why there is a time lag between population and instability peaks. This pattern of linked population and internal warfare oscillations is not limited to Europe. Recently two Russian historians, Sergey Nefedov and Andrey Korotayev, showed that the same relationship holds for China during its two thousand year imperial history, for Egypt (from the Hellenistic period to the nineteenth century), and for Russia. It is remarkable that such complex, and very different, societies would all show similar dynamical patterns. On the other hand, if population cycles arise in very complex forest ecosystems, why shouldn't socioeconomic/political cycles arise in such complex social systems as agrarian empires?

The fundamental unity of the world

The Santa Fe Institute researcher David Krakauer argues that all historical sciences—physical disciplines such as geology and cosmology, evolutionary biology, or the history of human societies—employ, at some basic level, the same logic of scientific explanation. This observation agrees with the main premise of my argument, that the world we inhabit in all of its aspects, whether physical, biological, or social, has a certain kind of fundamental unity that can be studied and understood by scientific methods. This does not mean that we should expect to find elegantly simple and highly predictable dynamics, such as planetary motions, in history. Just like any particular forest, each human society is unique, but as in ecology, there are general regularities in history. And empirical regularities suggest that there may be general principles and mechanisms underlying historical dynamics. At this point in time this is only a hypothesis. To demonstrate its validity we will need to do what biologists did, when they transformed biology into Science.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