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Regularities in Human Affairs

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When we review the course of human history or the results of anthropological research we see a delicate interplay of regularity and randomness. This article discusses several regularities in human affairs, including approximate mathematical laws, such as the logistic equation, and semi-empirical regularities, such as a power law or a Guttman scale. The search for regularities in human history is becoming a trifle more respectable than it was formerly. That could well portend some significant improvement in our ability to discuss the human future.

Research at the Santa Fe Institute is inherently transdisciplinary. We have found that the among the best scientists and scholars there are many who long for collaboration with other brilliant researchers trained in fields distant from their own. At universities, such collaborations are difficult to arrange, and in fact they encounter barriers nearly everywhere, not only in the form of university departments, curricula, and degree requirements, but also through institutions such as professional societies and journals. However, the enthusiasm of the researchers who are eager to collaborate helps to overcome those barriers as well as others, perhaps even more important, stemming from differences in terminologies, methods, and ways of thinking.

When we founded SFI, I did a good deal of the telephoning to invite some distinguished scientists to our early meetings, scientists we had heard might be interested in transdisciplinary work. Many of them were trained in fields very different from the one in which I was known, and they had barely heard of me or perhaps didn't know my name at all. I was certain that the reply would be something like the following: "What you are doing sounds interesting, but I'm quite busy with my research and teaching, the books that I'm writing, and my consulting work. Please don't call me. I'll call you." Instead, the answers tended to be more like this: "I've been waiting for this opportunity all my life. May I come sooner?"

The work at SFI is nearly all theoretical and much of it is based on computer modeling. The relevant observational research is carried on elsewhere, but of course careful attention is paid to the facts revealed by observation.

There are significant mathematical parallels between phenomena in very different sciences. It is natural, if barriers are removed, for theoreticians of

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varied backgrounds to form transdisciplinary teams, quite spontaneously or sometimes in response to some request for proposals, to exploit those similarities.

A great deal of our research is connected, in one way or another, with issues of simplicity and complexity, regularities and randomness, and complex adaptive systems, including biological evolution and various aspects of social evolution. Nearly everything one encounters exhibits regularities along with random or incidental features. All around us we find the interplay of law and chance. Closely related to regularities and randomness is the distinction between the simple and the complex.

What is complexity? It would take many different concepts, many different quantities to capture all of our notions of what is meant by complexity or its opposite, simplicity. But there is one quantity that corresponds best to what we mean in every day conversation and in most scientific discourse by complexity, and that is what I call *effective complexity*. In non-technical language, we can say that the effective complexity of an entity is the length of a very concise description of its *regularities*, as distinct from features treated as random or incidental. Complexity does not mean randomness.

A complex novel has many characters, scenes, subplots, and so forth. The US tax code is complex; every provision is a regularity. This chart in an ad for Cognac Hennessy is somewhat sexist but illustrates quite well the concept of effective complexity (Figure 1).

Neckties can be used to illustrate simplicity and complexity, but we would be likely to concentrate on the patterns rather than on the soup stains, wine stains, and so on. However, a dry cleaner would perhaps pay more attention to the stains. What matters is the coarse graining, the distinction between features that are treated as important and those treated as unimportant.

The distinction between the regular and the random is often context-dependent. Music and static on the radio would seem to exemplify that distinction perfectly, but then we may reflect that the science of radio astronomy arose out of the study of static on the radio. In science, we search for regularities. As Isaac Newton wrote, “It is the business of natural philosophy to find them out.”

What gives rise to complexity? The fundamental laws of physics are simple, as far as we can tell, but they are probabilistic, not fully deterministic. The history of the universe is co-determined by those laws and by an unimaginably long sequence of chance events (or “accidents”) governed by probabilities.

The alternative possible histories of the universe form a branching tree with probabilities at the branchings. (Remember *The Garden of Forking Paths*, by Borges.) Some of the accidents produce, in conjunction with the fundamental laws, a great deal of regularity over regions of space and time. Those are the “frozen accidents.” For example, the little fluctuation that produced our galaxy

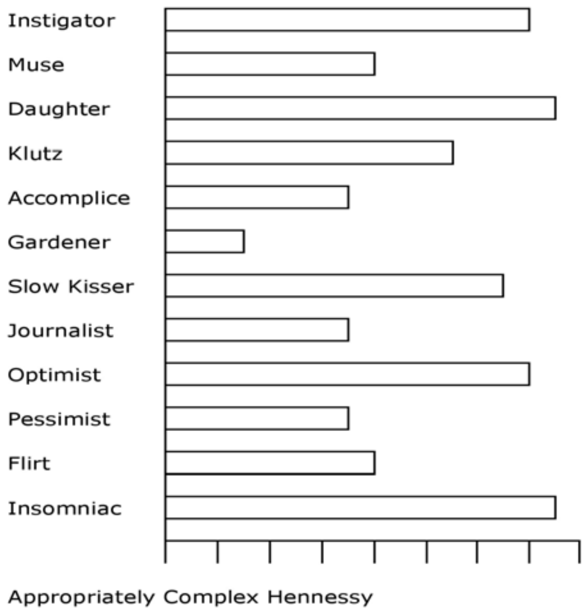

Figure 1

may be a minor event on a cosmic scale, but it is quite important for anything in our galaxy, such as the inhabitants of this planet. Likewise the chance events that produced the earth and gave rise to geology are frozen accidents.

Only elementary particle physics and cosmology are truly fundamental and universal in scope. All the other sciences depend to a greater or a lesser extent on historical accident as well as on the fundamental laws. Even chemistry, which we tend to regard as derivable in principle from physics, is dependent to some extent on historical accident. After all, the validity of chemistry requires temperatures and pressures that permit atoms and molecules to exist. In the center of the sun, there is little or no chemistry, because it is too hot for the particles in atoms and molecules to stay together. There is nuclear physics in the center of the sun, but in the very early universe it was too hot even for nuclear physics.

Just as geology depends on historical accidents, including the ones that produced the planet Earth and others that occurred in the course of its early development, so biology on Earth depends on numerous accidents having to do with the ancestral life form and with biological evolution over four billion years or so.

Also, there are fairly regular "laws" associated with social and behavioral sciences and there must be some for human history. We should not be put off by discovering that they are approximate and exhibit occasional exceptions.

Since the fundamental laws of physics are simple, almost all complexity originates in the regularities that are consequences of frozen accidents. When the accumulation of such consequences outstrips the processes that erase them, then we observe the familiar phenomenon that more and more complex entities come into being as time goes on. That by no means requires that individual things increase in complexity. For example, organisms die and civilizations die as well, with a decrease in complexity.

Think of all the accidents that have gone to make up the people assembled here. Many of those are just individual local events with important consequences mainly for us, while others are associated with the whole of the solar system, our galaxy, and so forth.

When we review the course of human history or we look at the results of anthropological research, including data from linguistics and archaeology, we see a delicate interplay of regularity and randomness. Whether we are considering the alternative possible histories of the universe from the fundamental physical and cosmological point of view or contemplating alternative possible courses of human history on the planet Earth from the much coarser-grained perspective appropriate to that case, we are faced with a branching tree with probabilities at the branches. At both scales we can think in terms of frozen accidents contributing to a whole range of regularities that are not inherent in the fundamental laws alone.

There are historians of human affairs who are tolerant of speculation about contingent or "What If?" history and they are growing in number. Some articles about particular counterfactual speculations are to be found in the collections *What If? I* and *What If? II* and in a collection edited by Niall Ferguson. The authors have picked out a number of apparently random events that may, as frozen accidents, have divided the branching history after them into well-defined domains. But historians have long disputed to what extent these wounds in the fabric of history remain indefinitely as scars and to what extent they are eventually healed by grand historical forces.

This is related to the argument between the great person, great idea view of history and the great historical force view. We can look at the European Union today and ask to what extent its development was essentially inevitable and to what extent it resulted from the genius and foresight of Jean Monnet and his founding of the Action Committee for the United States of Europe.

The following quotations are from Mark Sullivan's book *Our Times, the United States 1900 – 1925, I: The Turn of the Century*.

> Carlyle: "All things that we see standing accomplished in the world are properly the outer material result, the practical

> realization and embodiment, of Thoughts that dwelt in the Great Men sent into the world."
>
> Walt Whitman: "Produce great persons; the rest follows."

But on the other side we have

> George Bernard Shaw: [the world is] "finally governed by forces expressing themselves in religions and laws which make epochs, rather than by vulgarly ambitious individuals who make rows."
>
> Louis Napoléon, 1841: "Marchez a la tête des idées de votre siècle, ces idées vous suivent et vous soutiennent. Marchez a leur suite, elles vous entraînent. Marchez contre elles, elles vous renversent."
>
> William Jennings Bryan, letter to Mark Sullivan, 1925: "You are entirely correct in describing public men as the creatures of their age. I have often used the same explanation in regard to myself. I lived in the very centre of the country out of which the reforms grew, and was quite naturally drawn to the people's side."

If we look at those published collections of counterfactual speculations, we soon encounter the story of Buffalo Bill's Wild West Show touring Europe in 1889. The star was, of course, the noted female marksman Annie Oakley. She would challenge the men in the audience, asking for a male volunteer to smoke a cigar and let her shoot the ash off the end. Normally there were no male volunteers and her husband, himself a noted marksman, would step forward, start to smoke a cigar, and have the ash shot off by his wife. When the show reached Berlin, however, there was a male volunteer, the Kaiser, Wilhelm der Zweite. He had come to the throne just the previous year, after the premature death of his father Friedrich, the son-in-law of Queen Victoria. The Kaiser came forward, pulled out an expensive Havana cigar, clipped off the end, removed the band, and lit it. As the ash grew at the end of the cigar, he waited for Annie to shoot. She was worried. She had been drinking quite a lot the night before. Her husband was one thing, the Kaiser another. After a while, she took aim and fired, and we know what happened. The Kaiser was unharmed.

But he went on to fire Bismarck, to cancel the Reinsurance Treaty with Russia, to engage in a naval arms competition with Great Britain, and to contribute in other ways to the tragedy of the First World War. What if Annie had killed him? Would the World War have taken a different course? Would it have occurred at all? A number of the scholars and researchers assembled here have pondered this kind of question at length.

In a talk I gave some years ago to the IIASA in Laxenburg, near Vienna, Austria, I mentioned the role of chance in the branching alternative histories. I alluded to such incidents and how they appear to affect history profoundly, as do assassinations, the results of famous battles, the lives of great persons, and so on. Fortunately, I mentioned too the countervailing arguments about the grand forces. I say fortunately because a gentleman named Cesare Marchetti, trained, like me, as a physicist, got up to argue strongly against the tyranny of the individual chance events. If I had not mentioned the alternative point of view favorably, I'm sure he would have launched a verbal attack. As it was, we got on famously.

He was, however, not thinking so much about the kind of historical forces that I had in mind. Marchetti was thinking, rather, of certain mathematical regularities, approximate mathematical laws that seem to go on holding without reference to specific events or individual people. He provided me with many examples that he had collected, some of which I plan to share with you. But let me start with another one, provided by the distinguished Russian journalist, Sergei Petrovich Kapitsa, also a physicist by training and the son of the famous physicist Pyotr Kapitsa.

He took a very crude look at the time variation in human world population, using the differential equation

(1) $$\frac{dN}{dt} = \frac{N^2}{b}$$

not a totally implausible formula when we remember that it takes two people to make one new person. The solution is $(T - t) = b/N$ or

(2) $$N = \frac{b}{T - t}$$

where T is an arbitrary constant, a critical time.

In this approximation, N becomes infinite when the time t equals the critical value T. Obviously, the equation loses its validity as t approaches that value, but for a long time before that, the equation agrees fairly well with people's estimates of world population. Say we look at the fifteen hundred years leading up to 1925, when the population was around two billion. The critical value T turns out to be around 2025, and the populations then come out one billion in 1825, 1/2 billion in 1625, 1/4 billion in 1225, and 1/8 billion in 425. These numbers are not so far from educated guesses that have been made about the actual values of N at those times.

Since the population will evidently not be infinite in 2025, the equation must be modified by adding a term that becomes important at large N and avoids the singularity. However, that modification should begin to change the solution appreciably only during the last quarter of the twentieth century, when the observed departure from the simple singular solution provides the first *direct* indication of the leveling-off of the world population that is now taking place. In fact, the point of inflection, the time when the rate of increase reached its maximum and started to decline, was in the late twentieth century.

For the sake of completeness, we should remark that the simple equation requires another modification – at small N – in order to agree with plausible estimates of N for times many thousands of years ago. Eq. (2) gives populations that are thought to be a bit too large for those early times. But that modification does not have appreciable effects during the last couple of millennia and, like the modification at late times, we can ignore it in this discussion.

Between 425 and 1975, say, the simple equation (2) is thus not that bad, provided we smooth out fluctuations like those associated with the Black Death. The result is that a hypothetical student of world population working, say, seven hundred years ago, having access to world population figures since 400 or so, and fitting the trivial formula above to those figures, could have identified correctly the approximate time (around 2000) when N versus t would start to level off, without having any information about future technology or future contraceptive devices or future trends in the education of women. Of course we know of no such student around 1300 and no way for such a person to obtain at that time the requisite population data, but it is still true that the estimate we are discussing was there to be found, without going into the root causes of demographic change.

A familiar example of a mathematical regularity in today's world is Moore's Law, the observation by Gordon Moore, a co-founder of Intel, that the information capacity per unit area of computer chips is increasing exponentially, in fact doubling every eighteen months. That has been going on since the 1980s. Of course it cannot continue forever, and it is usually supposed that the curve will start to level off in a decade or two, perhaps when the size involved has decreased to atomic dimensions.

Neither of the simple laws we have discussed is fully explained, in my opinion. Nor is another one, emphasized by Cesare Marchetti. Consider France, a typical Western European country, and look, over the last two hundred years, at the average distance covered in a day of travel using a vehicle, taking into account the mix of transport modes. (Not traveling in a vehicle scores zero for that day.) That distance has been increasing in roughly exponential fashion over the last two centuries, if we smooth out the fluctuations. The rate of increase is around 3.8 per cent per year. But here we are dealing first with travel on horseback or by horse-drawn coach; then railway travel is added to the mix, followed by automobiles, propeller-driven airplanes, and jet planes. (We should probably omit the supersonic jet, which was never an important part of the mix and has now been discontinued.) Somehow all these developments have accommodated themselves approximately to a rising exponential. Using nineteenth century data and the idea of an exponential, one could have estimated crudely the average daily distance of vehicular travel at present without knowing the nature of the vehicles involved.

What do we make of such regularities that seem to proceed without regard to mechanism? If people in the past could have used them for making crude predictions about today's world, can't we find similar ones today that facilitate some approximate insights into the future? We shall return to that question.

A noted economist is quoted as saying, " When something can't go on forever, it doesn't." When exponentials level off, as they must eventually do, they usually turn into logistic curves, obeying the equation

(3) $$\frac{dy}{dt} = ay\left(1 - \frac{y}{Y}\right)$$

instead of

(4) $$\frac{dy}{dt} = ay$$

which yields the pure exponential.

Here Y is the asymptotic value of y, which y approaches as t goes to infinity. We can define F to be the fraction of Y that y has attained at a given value of the time t. Then the differential equation for F is

(5) $$\frac{dF}{dt} = aF\left(1 - F\right)$$

and the solution is

(6) $$a(t - m) = \ln[F / \left(1 - F\right)]$$

The fraction F increases steadily with time, going from 0 at minus infinity to 1 at plus infinity, while $\ln [F/(1-F)]$ increases linearly with time.

Here m is the value of the time at which F is 1/2, so that $F/(1 - F)$ is 1 and $\ln[F/(1 - F)]$ is zero.

We see that the solution of the logistic equation is characterized by only three parameters, the relative rate of increase a, the midpoint m in time of the process, and the absolute scale Y, which we have eliminated above, leaving only a and m. The diagnostic feature is the linearity in time of the quantity $\ln[F/(1 - F)]$. The original quantity y follows an S-shaped curve with the absolute height determined by Y (the asymptotic value), the midpoint in time given by m, and the relative rate of increase at early times (when we are close to a pure exponential) given by a.

Logistic enthusiasts like Marchetti go wild applying Eq. (4) above to all manner of processes for which historical data are available. We can start with the cumulative deaths in almost any plague, such as the Great Plague of London in 1665. The equation fits very well indeed. One can use it also for the cumulative casualties in nearly any war, as long as fluctuations are smoothed out. The important point is that the logistic curve marches steadily on, without much regard for famous battles and skillful generals. Again certain features of the broad outlines of history are not very sensitive to the detailed accidents along the way.

Peter Turchin has shown me logistic curves that fit very well the phenomenon of mass religious conversion, say to some brand of Islam or Christianity.

Marchetti is particularly pleased with the results of applying Eq. (6) to the work of individual artists or scientists. He looks at the cumulative production of various famous people (using, on the whole, just quantitative measures without judging quality) and finds linearity of *ln[F/(1 – F)].* He can estimate the midpoint time m (when the logarithm is zero) and see where in the process death (or some other cause of a halt in production) takes place. He finds the surprising result that Mozart's death at the age of 35 actually took place when F had already come close to saturation. But most of the results are quite straightforward and simply support the idea that careers of great artists and scientists follow logistic trajectories that don't depend much on historical accident.

Sometimes a great person has two distinct careers, one getting under way as the other is saturating. Marchetti then finds two logistic curves.

He likes to speak of "clockwork geniuses." But we must always keep in mind that it is only certain very general features of history that exhibit these particular remarkable regularities. It is not the actual musical achievement of Mozart that is captured by Cesare, but only its distribution over time, and even then only in its quantitative aspects. Of course more such regularities may turn up, but they will still not address the whole picture, only a few characteristics of it. There may well be additional regularities, however, that are connected with the deep aspects of human history, say with the rise and fall of civilizations, which Arnold Toynbee and others have tried to describe.

At the Santa Fe Institute, we are often concerned with attempts to construct simple models or simulations for complex real phenomena, say in the life sciences or in the social and behavioral sciences. We hope to treat some phenomena of human history in the same fashion. Now how do we judge whether a model is successful? Normally a scientist would test a theory by comparing its predictions with the results of observation. But here we are dealing with theoretical models – whether computer-based or analytical – that are so simplified that it would be astonishing, even disconcerting, to find detailed agreement with reality. What can we do then? Most of us are convinced that the best course of action is to look at "middle level theory" – to find semi-empirical regularities in the real world that might be reproduced in the model and try to find reasons why they might exhibit a kind of continuity all the way from the real world down to the highly simplified model. If so, then one can seek an explanation for the regularities in the model – perhaps not such a difficult task – and have some hope of extending that explanation to the complex reality.

That notion fits in very well with what we are doing here when we call attention to regularities in human history and the social sciences, particularly ones that could have been used in the past to predict certain gross features of history fairly well without going into detailed mechanisms. But we must make every effort to understand why these regularities persist the way they do.

In the social and behavioral sciences as well as the life sciences one often finds power laws holding over wide ranges of certain variables. Sometimes one quantity varies like a power of another. For example, the average metabolic rate of a mammalian species varies like the three-quarters power of the average body weight. Often we have power laws of distribution, where the frequency with which a certain quantity attains a particular value varies like a power of that value. A famous example is Vilfredo Pareto's observation that incomes obey a power law of distribution over a considerable range.

His law illustrates how regularities can affect proposals for public policy. Suppose someone wants to reduce the gap between rich and poor. If Pareto's power law is really a robust regularity, then it may not be so wise to try to fight the power law itself by means of public policy. Rather one might try to reduce the exponent, thus flattening the curve.

We also see how important it is to make a judgment about whether a supposed regularity really is one and is robust. For example, it was claimed for a long time that the fraction of GDP assignable to wages (or "the share of the national income accruing to labor") was always in the range 60 – 70%. In a well-known paper the noted economist Bob Solow tried to debunk this regularity by questioning whether there is anything surprisingly small about that amount of variation. According to another economist, Sam Bowles, a more serious objection is that after the collapse of communism in Eastern and Central Europe the wage share in a number of ex-Communist countries was actually notably different, showing that the regularity was at least not universal.

Of course the best way to avoid being fooled by spurious regularities is to understand the reasons behind the empirical relationships in question. Then the applications both to forecasting and to the realm of public policy will be much more secure.

Let us review the place of the regularities we have been discussing in thinking about the human future. It is fascinating, and important for forecasting and for application to public policy, that such regularities go marching on without much regard to changes in the underlying mechanisms, and clearly we need to understand how these things can happen and to identify which regularities are really robust. But they do not usually capture the most important features of the human condition or of the policy landscape, and they fail to solve the problem of neglect of human passions (or human volition in general) in so many otherwise very scholarly treatises on the future.

An additional concern is that so many studies divide up the world situation into economic, social, political, ideological, informational, environmental, demographic, military, and diplomatic issues and hope, through essays on all these separate aspects by suitable experts, to be able to put together a picture of the world. But this is a case where the whole is different from the sum of its parts. We have neglected the crucial supplementary discipline of taking a crude look at the whole. The situation is highly nonlinear and very complex, and the interactions among these domains are very strong. In an analogous situation in physics, we might say that perhaps there are collective variables in terms of which the description might be simplified, but those would have to be variables that cut across the conventional boundaries of the subjects and they would have to be discovered, not arbitrarily imposed at the beginning.

We mentioned power laws as a type of middle level theory. Let me go on to discuss another one, called “Guttman scaling” or “implicational scaling.” The sociologist Louis Guttman introduced it during the early years of the Second World War, when it was important to measure American attitudes toward Great Britain. Were Americans friendly enough, on the whole, to support massive aid to the beleaguered British? Did they have faith in the British armed forces? Guttman devised a questionnaire composed of many questions. Say each one required a “yes” or “no” answer, with “yes” indicating a friendlier attitude than “no.” What he discovered was that it was possible to arrange the questions in a particular order so that the answers came out, roughly speaking, all “yes” up to some point and then all “no.” Say there were 50 questions. Out of the 2^{50} (more than a quadrillion) possible response patterns, most of the actual ones clustered around just 51 different patterns, ranging from all “yes” to all “no” and characterized by one parameter: the place where the “yes” responses ended and the “no” responses began. That was a most remarkable and completely non-trivial result. If the questions were of the following kind, the result would not be surprising: Can you jump over a two-foot hurdle? Can you jump over a two-and-a -half foot hurdle? Can you jump over a three-foot hurdle? Of course you can arrange those questions so that the answers are "yes" up to a point and then "no." But the questions were not like that at all.

In 1961 the linguist David DeCamp found a linguistic example of Guttman scaling in connection with Jamaican Creole. Most of the vocabulary of Jamaican Creole is drawn from English, which is also the official language of Jamaica, even though most people there speak Jamaican Creole among themselves at home. (In some other Caribbean countries, the official language is different from the "lexifying" language that supplies most of the vocabulary of the local Creole; for example, on St. Lucia the Creole is French-based although the official language is English.) In Jamaica, we encounter the phenomenon of progressive decreolization. As people become more urbanized and more highly educated, their Creole is affected more and more by standard English. The resulting distribution of linguistic behavior is sometimes called the decreolization continuum. DeCamp took six linguistic traits, two of pronunciation and four of vocabulary, and looked at how they were affected by decreolization. Out of $2^6 = 64$ possible responses, most were concentrated on only 7, forming a Guttman scale (Figure 2).

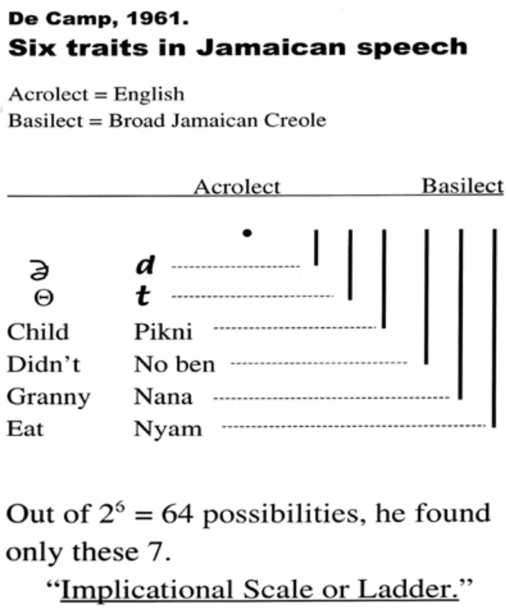

Figure 2

Now we can go on to discuss Guttman scaling and related matters in anthropology, particularly as they turn up in cross-cultural surveys. The late George Peter ("Pete") Murdock of the Yale Department of Anthropology left behind, as one valuable part of his remarkable scientific legacy, the Human Relations Area Files, carefully coded summaries of anthropological data about hundreds of cultures around the world, indexed so as to facilitate cross-cultural comparisons. His professional heirs, those now running the Files and others who collaborated with Murdock but have since moved elsewhere, have fallen out over a number of things, particularly an issue of data analysis, the so-called problem of Galton.

The distinguished statistician Sir Francis Galton was present when the anthropologist E. B. Tylor presented, in 1889, his classic paper on cross-cultural comparisons. Galton pointed out the distortions that result from failure of cultures to be independent of one another. Common descent or cultural diffusion can create such correlations. As a result one mustn't treat all the cultures in a cross-cultural sample as independent cases. Sometimes, two of them may have separated from each other only recently. For instance, the aKamba and aGikuyu in Kenya were one people only a few hundred years ago. Likewise the baLuba and baLunda of the Democratic Republic of Congo became distinct only a few centuries ago. One cannot count them as independent cultures to the same extent as, say, the baLuba and the Blackfeet of North America. Also, two peoples in the same region with very different languages and no evidence of recent common descent may have similar customs as a result of borrowing, just because they are neighbors.

Nowadays there are known mathematical methods for coping with this kind of situation, using a correlation matrix to describe the failure of the cultures to be independent of one another. It is especially Douglas R. White and his collaborators who insist that attention be paid to this matter. Another solution is to select only cultures that are clearly quite far apart, thus sacrificing a large body of data. White et al. have turned out a reduced cross-cultural sample in which the autocorrelation difficulties are largely absent.

Here, in figure 3, is a very clean example of Guttman scaling applied to a cross-cultural study in anthropology. This, along with a good deal of the work presented here later on, is in papers by Robert L. Carneiro. For nine tribes of South American Indians there are eight questions with "yes" or "no" replies. Does the tribe have this trait or not? In the first diagram, the traits are not in any particular order, and neither are the tribes. In the second diagram, the traits and the tribes are ordered so as to exhibit the Guttman scaling phenomenon, which in this case is perfect.

The example goes far beyond perfect scaling: the array is nearly square, no two societies have exactly the same number of plus signs, and each one differs from its neighbor in the diagram by just one trait. A scaling situation could

	Kuikuru	Anserma	Jivaro	Tupinamba	Inca	Sherente	Chibeha	Yahgan	Cumana
Social Stratification	–	X	–	–	X	–	X	–	X
Pottery	X	X	X	X	X	–	X	–	X
Fermented Beveragres	–	X	X	X	X	–	X	–	X
Political State	–	–	–	–	X	–	X	–	–
Agriculture	X	X	X	X	X	X	X	–	X
Stone Architecture	–	–	–	–	X	–	–	–	–
Smelting of Metal Ores	–	X	–	–	X	–	X	–	–
Loom Weaving	–	X	X	–	X	–	X	–	X

	Yahgan	Sherente	Kuikuru	Tupinamba	Jivaro	Cumana	Anserma	Chibeha	Inca
Stone Architecture	–	–	–	–	–	–	–	–	X
Political State	–	–	–	–	–	–	–	X	X
Smelting of Metal Ores	–	–	–	–	–	–	X	X	X
Social Stratification	–	–	–	–	–	X	X	X	X
Loom Weaving	–	–	–	–	X	X	X	X	X
Fermented Beveragres	–	–	–	X	X	X	X	X	X
Pottery	–	–	X	X	X	X	X	X	X
Agriculture	–	X	X	X	X	X	X	X	X

Figure 3

violate any of these conditions and still be perfect. In the artificial example in Figure 4, we see a hypothetical perfect scaling situation without any of those simplifications.

	A	B	C	D	E	F	G	H	I	J	K	L	M
9	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	–	x	x	x	x
7	–	–	–	–	–	–	–	–	–	x	x	x	x
6	–	–	–	–	–	–	–	–	–	x	x	x	x
5	–	–	–	–	–	–	–	x	x	x	x	x	x
4	–	–	–	–	–	–	x	x	x	x	x	x	x
3	–	–	–	–	–	–	x	x	x	x	x	x	x
2					x	x	x	x	x	x	x	x	x
1	–	–	x	x	x	x	x	x	x	x	x	x	x

Figure 4

In figure 5 we have another real example, with many more traits and a large number of cultures. It is not perfect (there is some scatter in the results) but the regularity is evident. How close the scaling comes to perfection is measured by a “coefficient of reproducibility” that has values between zero and one. It is one minus the number of “errors” divided by the product of the number of traits and the number of tribes. An “error” is a place where the position of a + violates Guttman scaling. When the “coefficient” is greater than 0.9, it is thought that we have a pretty good scaling situation.

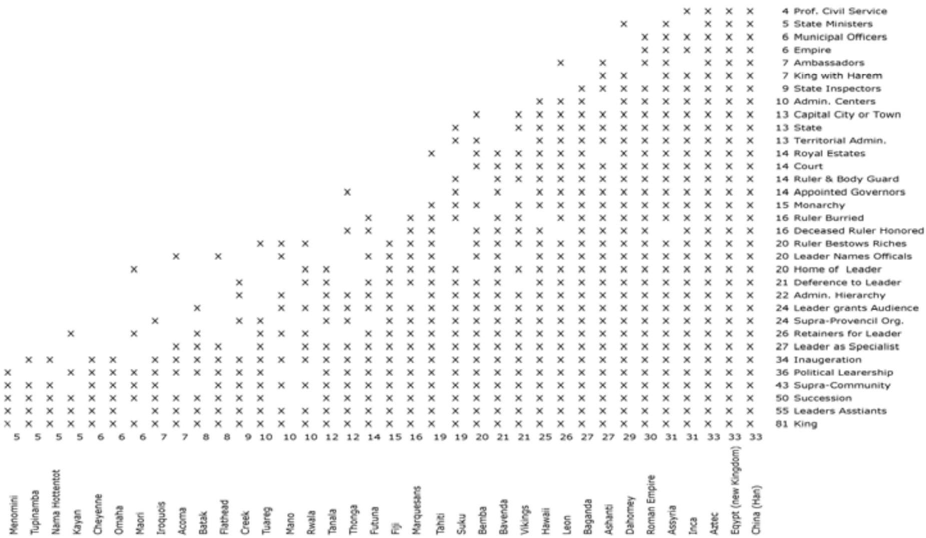

Figure 5

The deviations from perfect agreement are themselves significant and analyzable. On this diagram they occur mainly near the diagonal, indicating that reversals of order are largely restricted to items that are very close to each other on the list. When items are far apart, there are few reversals. Thus the exceptions represent merely a little local sloppiness in the order of traits, not a substantial failure of the whole pattern.

Carneiro also looks at neighboring traits on the scalogram and asks how *often* a given pair gets interchanged. Probably one can say that if they are rarely interchanged then the “distance” between them is greater than if they are often interchanged (very little “distance” between them.) Thus the list of traits on the scalogram can be regarded as a sort of staircase with risers of variable heights, some small and some much greater.

Now what are we to make of these remarkable successes of Guttman scaling in dealing with cultural traits? They could be attributed to a pattern of development in time, an "evolutionary sequence." In the late nineteenth century and the first half of the twentieth century, ideas about such sequences were popular, as in the work of Tylor, Lewis Morgan, and Elman Service. Think of the sequence band, chiefdom, etc.

But there was a great deal of opposition to such notions, too, most of it on an a prioristic basis rather than a scientific one. Franz Boas taught that there were hardly any regularities to be found, each culture being unique, and that evolutionary sequences were certainly not a fruitful area for study. Marxists felt they had a monopoly on evolutionary sequences (slaveholding societies, feudal societies, capitalist societies, then happy socialist societies). Anti-Marxists were sometimes displeased with evolutionary sequences because the Marxists had one. And so on. It is shocking how impressive regularities, well supported by data, were simply discarded by famous anthropologists on ideological grounds.

There is at least one good reason for sympathizing with the scholars who rejected (or still reject) the ideas we have been discussing. Those ideas might be misused by racists to justify their bigotry. We must all fight against such abuses.

One can try to check whether an evolutionary pattern is involved (in other words, a time sequence), by looking at a case studied by Carneiro where at least some of the innovations can be dated. Here, in figure 6, is an attempt to do that using data on 33 traits from Anglo-Saxon England.

The temporal order is compared with the order expected from the "scalogram" showing Guttman scaling for the traits in question in Anglo-Saxon England. Check marks indicate that there is agreement, while crosses indicate disagreement. The S entries mean that some information is lacking. The result has some scatter, but it does definitely point in the direction of confirmation of the evolutionary interpretation of Guttman scaling for this case.

Social complexity as used by archaeologists and other anthropologists can be regarded as an application of effective complexity to things like the diversity of social roles. Here there is a certain trend toward higher social complexity as we go through the sequence of traits. To the extent that the sequence of traits corresponds to a temporal sequence, a trend toward higher social complexity (as time goes on) is indicated. The scalograms can be compared with estimates by various authors of levels of social complexity or other, related scales attributed to societies. We have A. L. Kroeber's personally estimated "levels of cultural intensity" and Raoul Naroll's index of social development. Robert Carneiro takes a list of 354 traits and notes how many of them a given society

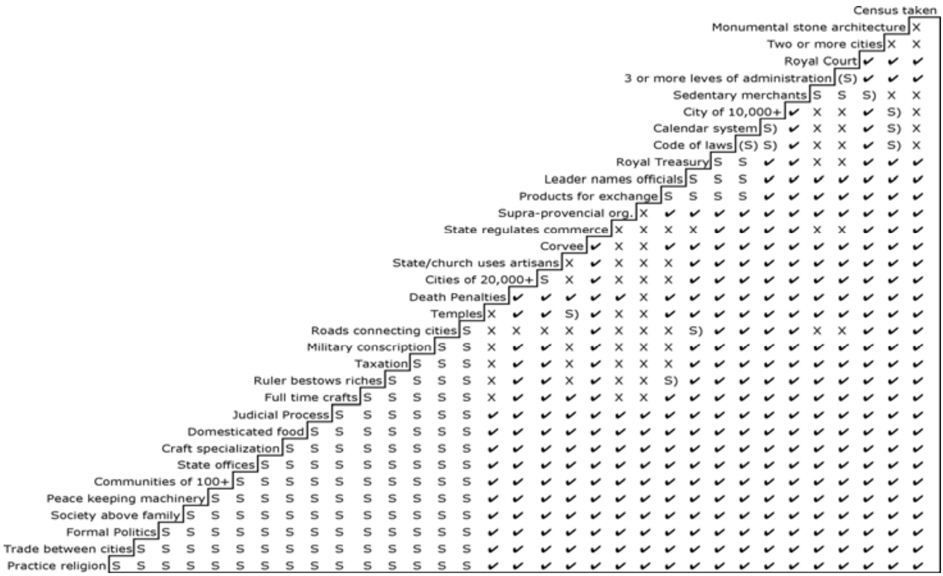

Figure 6. Diagram showing the order of 34 selected traits in Anglo-Saxon England.

possesses, thus obtaining an "index of cultural accumulation." All of these indices agree to a remarkable extent.

The rates at which various cultures take the steps, while conforming to the pattern, can differ a great deal from culture to culture, thus accounting for the wide variation across the world in the number of steps taken by a given time. There are also numerous details, not captured in the analysis, that give rise to cultural individuality. Appreciating the regularities does not mean that we totally ignore the features that are unconstrained by them. Regularities do not exclude individuality.

Here and there we see flaws in Guttman scaling that are very instructive. Certain traits are "skipped" in particular cultures. One reason can be that environmental factors render that trait less desirable or less necessary or less easily acquired for the particular culture concerned. For instance, pottery and loom weaving are absent for some rather advanced Polynesian societies, but the necessary clays and fibers were hard for them to obtain.

An important point to mention is that in the course of history cultural complexity can occasionally regress as well as advance. We are not always dealing with pure accumulation. For example, a migrating people passing through a difficult environment may lose a number of traits that have little value there. This devolution process may be quite significant for certain cultures. On reaching a richer environment, the social complexity may start to increase again. Now if and when some traits on the list are lost, how are those traits situated on the scalogram? Are they peeled off the end, in reverse order, so to speak? And if so, are they re-acquired in the usual order when the environment permits?? If those questions are answered in the affirmative, then the evidence would continue to support the scalogram. If in the negative, then loss and re-acquisition of traits would disturb the scalogram, at least to some extent.

In any case, the predominance of accumulation over loss is extremely striking. That is what makes the index of cultural accumulation so useful as a measure of cultural complexity.

What is most fascinating in each case is the sequence. Why do the traits occur in the order in which they actually appear? Why do the death penalty and the calendar occur in a particular order, for example?

We should mention an important generalization of Guttman scaling, a weaker condition emphasized by Douglas White, in which certain traits are only partially ordered rather than well ordered, in other words forming a tree instead of a line and leading to an "entailogram" instead of a "scalogram." Again, it is remarkable that certain traits entail others when there is no obvious connection between them.

Evolutionary patterns revealed by the anthropological and historical research to which we have been referring may not be very helpful in speculations about aspects of the human future, since external influences on traditional societies are likely to outweigh in the future the internal influences in forecasting important developments. We may ask, however, "are there other regular aspects to cultural development, ones more relevant to modern conditions?"

For example, we could consider processes connected with acculturation or, more generally, cultural mixing consequent on migration. Those are issues of very great contemporary and future significance. Does the history of culture contact following migration exhibit regularities that have been overlooked or underemphasized? Can material about earlier periods illuminate what is happening or starting to happen in the modern world?

The evidence for implicational scaling of many traits is impressive. The theoretical interpretation in terms of an evolutionary sequence is very attractive, even though the direct evidence so far adduced for that interpretation still leaves something to be desired. Also, a standard time sequence is not the only possible explanation of implicational scaling. For example, the linguistic case we discussed seems to have social class rather than time as the relevant variable. (Still, there is a tendency for people to rise in social class and so time may actually play its accustomed role.) Despite possible criticisms, the case for the evolutionary sequence is a strong one, and the widespread rejection, for many years, mostly on ideological grounds, of this "main sequence" of trait accumulation and of the whole idea of an evolutionary model of social development is unsettling.

Perhaps the most important lesson we can learn from this sad story is that today historians and social scientists may be overlooking corresponding regularities with implications for forecasting and for public policy. If the remarkable evolutionary sequences could be so easily dismissed, why not other insights of equal importance and greater relevance for the long -range future? What ideological prejudice is operating today in history and in the social sciences to suppress work on regularities that combine with random influences to produce history?

One should certainly mention Arnold Toynbee's ambitious attempt to describe and compare the rise and fall of more than twenty civilizations. Of course some aspects of his work lend themselves to caricature, such as his apparent belief that all of history can be viewed as leading up to the foundation of the Anglican Church. And in such a far-ranging piece of work he undoubtedly made a number of mistakes that horrified experts on the various cultures he considered. But as a first attempt was it really so bad that one should not build on it?

On a less grandiose note, we have some recent books on the rise and fall of great powers, such as one by Paul Kennedy. There are also attempts to create a somewhat mathematical theory of historical dynamics, as in the books by Peter Turchin and in this journal.

Perhaps the search for regularities in human history is becoming a trifle more respectable than it was formerly. That could well portend some significant improvement in our ability to discuss the human future.