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The Social Tendentiousness of Science

One of the most disturbing statements about science is Francis Bacon's "*Scientia est Potentia*" [science is power, or knowledge is power]. This phrase is interesting not only for what it says, but also for the ways the Latin has come down to us. Originally, Bacon wrote in his *Sacred Meditations*, "*Nam et ipsa scienta potestas est*," [for knowledge itself is power]. The curious thing is that *potestas* appears to have been retranslated into Latin as *potentia*. The word *potestas*, is a legal term suggestive of right and authority; whereas *potentia* was often used in medieval philosophy as a potentiality (of a person or thing). Thus it suggests a kind of schism of thought developing already in the 16th century: on the one hand it is evocative of alchemy, and on the other it presages the connection of science with technology and war. (Interestingly, although alchemy was originally considered a neutral science in medieval society, it acquired a nefarious reputation, perhaps due to excesses and a connection with magic among some practitioners. The artistic branch was connected more to the observational, and thus less threatening.) And indeed, this interconnection perhaps may not have been avoided. Personal power is quickly subsumed by political power, and observation can quickly lead to manipulation—not always for beneficial reasons.

Although modern perception of science suggests a disinterested, objective discipline, it should be recalled that its modern origins developed at a time when religious thought still prescribed the proper view of reality. Indeed, Newton probably spent more time studying the Bible as opposed to the more "traditional" subjects such as physics. Certainly some scholars feel he strongly influenced the perception of God as a disinterested creator of a rational mechanistic world. Although here too, it is not clear exactly how Newton felt about much of what he studied. He described the phenomenon of gravity, but when one examines the concept carefully, "gravity" could also be considered a magic, alchemic idea. Indeed there was nothing "physical" about gravity as he described it, rather, what Newton did was to describe it as a property mathematically existing between bodies. Certainly, an alchemist of the time would have no problem accepting the idea. To this day there are still disputations regarding the concept of 'action at distance' at the basis of Newton's universal gravitation. Indeed, contemporaneously, some related ideas or findings are spoken about as "spooky" since no easy way of explaining the phenomena are easily obtainable. Thus, one can see why science, religion and the occult still engender so many disputations. It may be argued that many political initiatives based on "rational" science (the question, of course, being the source of the rationality) have engendered ideas such as eugenics, which so horribly affected societies in the 20th century. The latent memory of such ideas may in fact influence contemporary debates about the ethics of science. Historically, concepts such as social Darwinism similarly may be seen as a natural, rational justification for national primacies and the attendant bellicose attitudes. (Is it science or political justification?).

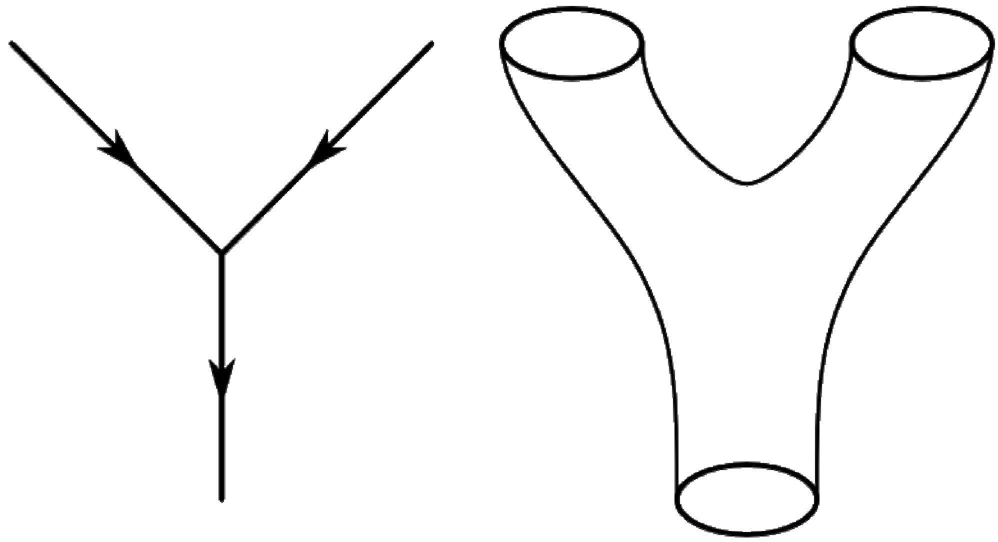
This link between knowledge and warfare was probably present since the beginning of human culture but had a sharp transition with the development of fire arms. For the first time in history a very weak, malevolent person could prevail over a very strong, righteous one. Modern times start with this transition—after this achievement a time honoured system of values abruptly changed. Many philosophers and artists of the 15th and 16th centuries (the age in which fire arms came into widespread use) clearly understood the relevance of this transition. In the ninth canto of his masterpiece, "*Orlando Furioso*," the great Renaissance Italian poet Ludovico Ariosto describes a rifle as "terrestrial lightening":

Che si puo' dir che tuona e che balena
Ne' men che soglia il fulmine ove passa
Cio' che tocca arde, abbatte, apre e fracassa.
(IX, 29, 6-8)

[It can be said that thunder and lights
Not differently as the lightening uses to do where it goes
What it touches fires, defeats, opens and destroys.]

He equates firearms to the work of the devil simply because a weak, dishonest man can win over a pure-at-heart paladin, thus placing upside down the sacred order of things. Japan's ruling class of those times had so clear a perception of this, that they purposefully banned the use of firearms on national territory so that war could remain an affair of a restricted oligarchy of brave warriors (Samurai). In order to maintain this situation they completely closed their relations with Western countries. This state of affairs came to an end in the second half of 19^{th} century, when the Meij emperor, afraid of Western colonialism and of the consequences for national independence, decided to abruptly introduce Japan to the modern technology of war. Wars, after the introduction of firearms, stopped being a restricted affair of a social elite and became a much more bloody affair with all citizens involved.

Embedded in the use of fire arms there is the notion of reductionism: you no longer have to care about a lot about "boundary conditions" like physical conditioning, the art of duelling, your psychological mood and motivation – the only important thing is that you centre the target, that's all. A situation with many facets collapses to its centre, all the accessory (but nevertheless crucial) things simply fade away and become "vanishingly small" and thus irrelevant. But this is exactly the alchemic dream of "essence"! And it is analogous to the modern science desire for the "basic principles" or "laws of nature" from which all the other (accessory) things can be derived by pure rational means (Fig. 5). Basically it is only our ignorance that does not allow us to do so but, at least in principle, a theory of everything can be drawn and put in action—the world can be reduced to an equation and then human man-made science is no longer important to be pursued: all can be put in the "hands" of a computer, as has been depicted in some Isaac Asimov science fiction novels.



Obviously, many thinkers of all the ages [from Pascal to De Finetti] recognized the intrinsic fallacies of this way of thinking, and a significant paper by Laughlin and Pines, [R. B. Laughlin and David Pines (2000). The Theory of Everything, *PNAS* 97: 28-31] clearly and definitively (at least we hope) destroys this naïve paradigm, but this paradigm has so intrinsically embedded itself into modern science that scientific language (and consequently scientific concepts) is filled with "war-like" metaphors. Thus we are very good in identifying the "target" causing an illness and hitting it, like an enemy. We talk about drugs like "magic bullets," and we want to know the "exact trajectory" of something like for a bomb. This kind of "warfare" mentality has had some evident successes: for example this was good for developing drugs against acute illnesses or to individuate some very major etiological causes of disease such as bacteria and viruses, but it has been less successful in the face of chronic illnesses where there does not exist a single enemy to find and defeat, but instead many small events and co-factors each one absolutely not relevant by itself, but altogether causing the problem.

The same is true for ecological modeling, neurological problems and practically all the real problems we must face nowadays. The persistence of bellicose paradigms for scientific discovery need to be rethought in order to regain an effective ability to operate in the real world. When describing multi-factorial "problems" one must talk of probabilities. This is the reverse of the history of "physics." In this history we started out with major laws which are really very constrained probability distributions, whereas the probabilities on the atomic level are very more "diffuse." Thus (the De Finetti works of the thirties in this respect are enlightening) we must reverse the relative role of probabilities and laws: laws are only special cases of probabilities (very constrained distributions). The root of scientific thought, from which it derives its unity is the concept of probability which cannot anymore be considered as a surrogate of the "real laws to come." But if this is the case, the boundary conditions (as in face to face duels with swords) become the most important thing of all! Science comes back to its artistic branch: probability strictly depends on boundary conditions and the subjective judgement of the scientist who critically evaluates (in these two words are hidden the ethical bases of science which cannot be anymore considered as a necessary consequence from some premises) the evidence the scientist has in his hands is used to go forward with an experiment and judge the meaning of the results. This activity is performed by a peculiar, personal (and thus artistic, not repeatable, necessarily human and individual) use of a set of both material and conceptual tools like statistical methodology, plan of experimentation, properly assessed measures in a way not basically different from a carpenter. In the natural world, the primacy of boundary conditions with respect to basic principles can be easily recognized at the same level at which so called "complexity" starts.

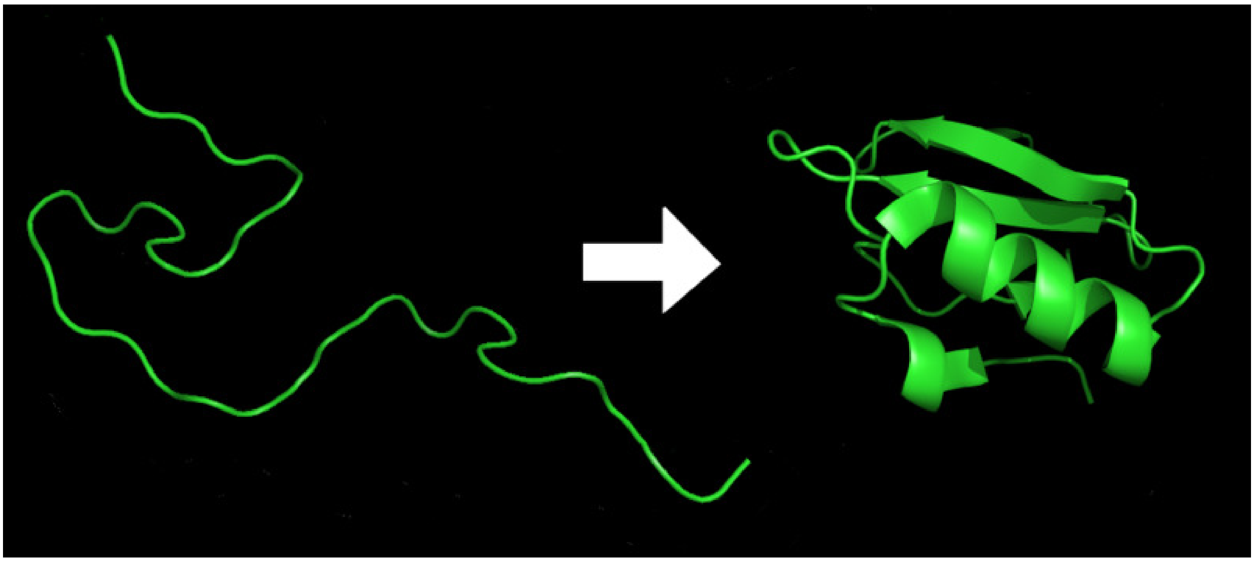


Figure 2: Protein Folding

Consider the contemporary problem of protein folding (Fig. 2). Although genes have captured the popular mind, in fact, one thing that is ignored is that genes have a purpose; namely, to help create and direct proteins which do the major work in biological processes. One of the interesting aspects of their creation is their folding: proteins are made of unique amino acid strings (derived from genes). Because these strings are created in an aqueous environment, the strings tend to fold up directed to some degree upon their propensity for exposure to water; i.e., do they like or avoid water. In principle we know the main physical forces governing this process, but in fact, this does not allow us to specifically predict the final "folding." Indeed, it is increasingly becoming acknowledged that the process can be better described as a stochastic process, i.e., a probabilistic one. The statistics of the processes involved suggest that at several important points, folding becomes a multi-valued choice. Depending upon the "boundary conditions" a protein may fold in one of several different ways. Furthermore, the processes are time-dependent. Depending upon what point in time you look at it, you may see a different kind of folding.

Moreover the "form" of the final folding brings to it varying attributes in terms of whether it is "functional" or not.

This points to the fact that the processes are "complex," but the complexity comes not from a deductive deterministic scenario, but from a combinatorial one (Fig. 3). At each of the important junctures of the folding, the probabilities possible (and the actual "route" chosen) govern the final form. Thus one can quickly see that "complexity" in this context is relatively simple: choices are often easily identified, but their concatenation quickly becomes a "complex" problem difficult for the human mind to appreciate without the help of computers. In other words, it would seem the complexity is a question of size—specifically a size which would appear to be manageable for a human brain to grasp. Is there a specific size? Probably not. It would appear to depend upon age, maturation and prior education/experience.

If we think about, for example, of the ability of an average adult to understand how electricity is directed to a home, in most cases, it would probably seem to be complex, which is why, if there is an electrical problem in a home, the typical homeowner calls for an expert, the electrician. To the electrician, the system is relatively simple. Which points to the observation of anthropologists that as cultures enlarge with divisions of labor, they become more "complex," to the point that specialized knowledge of experts becomes an important aspect of survival. Or consider the experience of the fall of the Roman Empire: cultural artefacts as simple as sewer systems were lost to Europe for many hundreds of years.

Even more striking is the evidence derived from the most basic of atomic processes. Consider the fact that the combination of two hydrogen atoms with one oxygen atom results in a substance (water) which has properties not resembling the original two gases. This point needs to be underscored given that a frequent remark is that complex systems are responsible for "emergent" properties. In fact, water is not a "complex" system if you look at it from a constitutive view. (One may argue that in fact its dynamics is complex, but here we are speaking about the constitutive elements only.) Certainly, water is not the only example, as any basic student of chemistry knows. Or consider the periodic table of elements. Elements are distinguished by the addition of protons, yet the resulting properties cannot be *a priori* deduced from knowledge of their number of protons.

These are emergent properties not obvious from a description of their basic constitutive factors. Indeed, physicists posit these facts as a given, and have sought to find additional constitutive factors in atoms, resulting in a myriad of sub-atomic particles (and the search for a "Theory of Everything").

From what we said above it is clear that there is significant work left to methodology for deriving "holistic ways of thinking" for approaching complex systems without dissecting it into pieces. We need methods that allow us to maintain a systematic, holistic view of the phenomenon even when necessarily going down to its constituent elements. (Indeed as we see with the periodic table, the constitutive elements do not in themselves provide any magical insight.). There are some methodological approaches, mainly (but not exclusively) derived by multidimensional statistics that allow for a tentative holistic approach to problems.

All these methods need "first-hand" experience of the system studied. This need to change route and cope with complexity is nowadays widely recognized through the flourishing of "systems biology studies," and "network paradigms." Moreover, it is a proof of this attitude. The trend seems to be the creation of "multidisciplinary teams" collectively able to look at the same problems from different perspectives. Our sense of the situation is that these teams cannot per se provide the right answer to start a new "tendentious free" science able to deal with complex problems. Multidisciplinary teams implicitly maintain the fact that any unit in the team keeps its unique disciplinary persona, and the integration is expected to come up by the simple addition of different competencies. This addition cannot spontaneously "coalesce" if the participants do not make the conscious effort to forget a great part of their special skills while retaining only those portions of operative knowledge that can be effectively shared with the other members. In our experience this can be obtained only if the team is kept together by very strong and effective friendship links.

It should be recalled that many of the great scientists of the past were polymaths—they were conversant with what we now categorize as different disciplines, many were even schooled in the

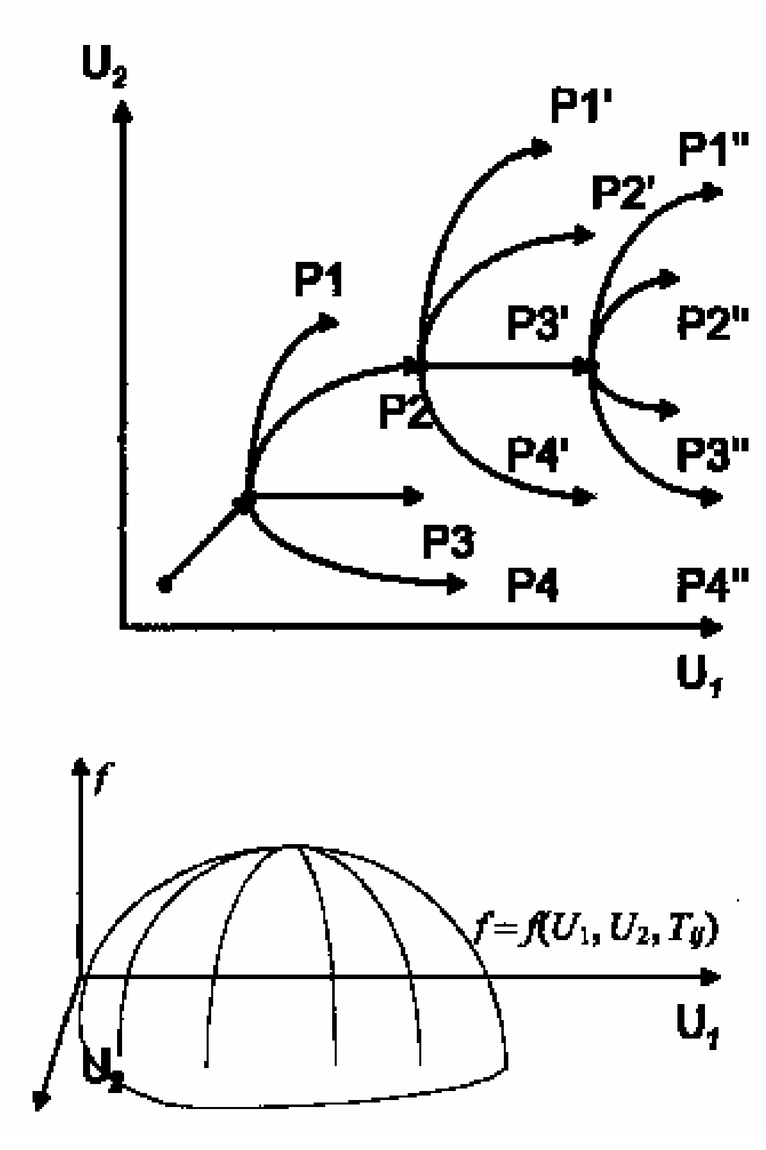


Figure 3: A series of connected probabilities (top) can result in a stochastic attractor (bottom)

arts as well as the sciences. Thus it can be said they were truly systems scientists. Of course, contemporaneously, knowledge has grown to such an extent that many scientists know only a relatively small aspect of the larger scientific endeavour. Even to this day, we marvel at a "Renaissance man," who feels comfortable in many different areas of learning. The poignancy of the current situation is seen in a short story by R. Macauley published in the *Kenyon Review* in 1956, entitled "The Chevigny Man." In the story an academic bases his whole professional career on becoming an expert about the literary output of a famous author—only to find out that his pronouncements were in effect trivial. It has become the norm that scientists must fashion for themselves a niche of expertise which they can exploit—at the expense of becoming truly interested in the interests of colleagues. It is a requisite built on expediency, competition and a pragmatism for survival. Institutions of learning are now aware of the limitations of the narrow perspective and are not only creating "interdisciplinary" institutes, but also developing architectural stimulants to foster contact among diverse disciplines. But is this sufficient? Can casual contact foster a new culture? The drive for the "bottom line" can be overriding, and looking for quick results, whereas relationships need time to build trust.

This is not to indict scientists. The motivations derive from institutional sponsors who increasingly demand notoriety and money. Frequently, the sponsors are academic institutions who have more and more adopted a mercantile and perhaps political model. As history has shown us, this could be risky—not only for scientists, but also for their institutions. Science is now more often than not a costly enterprise, and institutions are always at risk of taking a big gamble by investing large sums of money in a specialty, as well as the people involved in it. The next technique, the next new discovery is always around the corner threatening to make today's cutting edge, tomorrow's obsolete equipment or someone's discredited idea.

This is not to say that the work of the single scientist is over. Too often it is assumed that collaborative science must be communal science. Although history would like to present the idea that many past scientists were solitary geniuses, in fact, they made themselves "available" to the greater scientific milieu. The trick is to understand that science is at once solitary and social, and requires the skills of our species to survive in a collective way, building upon the unique perspectives of the individual.

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Scienza e Democrazia/Science and Democracy
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