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## THE RUSTY BOLTS OF COMPLEXITY

### IDEOGRAMS FOR EVOLVING COMPLEX SYSTEMS

#### ABSTRACT

This essay continues a series of discussions (<http://spirospero.net/complexity.htm>) in which a chemist joins the debates about the **large** and **complex** world outside the narrow professional setting. It aims at **understanding** evolving complex systems (ECS- or X-systems: life, mind, society, culture, economy, language, ideology, etc.). Understanding requires transfer of information in a **language** shared with the receptor. The language must include terms for most **abstract patterns** of action and change regardless of particularities of the system. An attempt to create highly abstract **ideograms** for such patterns was made by René Thom. The problem is discussed here from the point of view of transition state in generalized chemistry. The focus of interest is the origin of the stubborn growth of complexity typical for X-systems. An aggregation through multiple weak bonds is a possible general pattern of complexification. The alternative to algorithmic complexity **pattern complexity** applies not to configurations but to their harboring configuration space. Pattern complexity grows when the space expands. Examples and toy models (ditalini pasta, “brushmobile,” rusty bolt, zipper, “wealth pump,” bow tie, and others) are used as illustrations. Pattern understanding of history is discussed.

**KEYWORDS:** Pattern Theory, Ulf Grenander, René Thom, Hannah Arendt, Gregory Chaitin, Stephen Wolfram, Leonard Talmy, complexity, transition state, evolving complex systems, theory of history, cliology, understanding, X-systems, stability, lability, generalized chemistry, multiple weak bonds, origin of life, origin of society, origin of life, aggregation, cognitive semantics, ideogram, iconic graph, metaphor, bow-tie structure.



“There are flows taking place within society and culture.” ...

“What seem to flow from the wider culture to the scientific activity of an individual, and back, are more easily described as *ideas, representations, or metaphors.*”

David Aubin [9A, p.6 and 7]

## Introduction

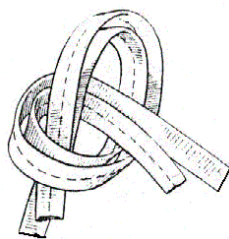
In this essay, as free-wheeling as all the [others](#) [1], I would like to offer a taste of a possible conceptual base for understanding **evolving complex systems** (X-systems: X is short for ECS) **from the point of view of a chemist**. I stop short of SECS, Spontaneously Evolving Complex Systems not out of prudishness, but because I distrust spontaneity. Examples are biosphere, life, mind, society, economy, technology, science, culture, art, media, politics, language, ideology, i.e., everything from molecules to ideas, or, in terms of outer limits, from biosphere to noosphere. Some concepts mentioned here are discussed in [1] in more detail.

Watching the development of the entire area of complexity and complex systems for at least half a century, I see no sign of consensus and not even a hint that anything like formal theory is possible. Taking to account the number of brilliant minds highly successful in their professional areas and looking at a larger world outside the laboratory, I attribute the lack of a unified **theory** of X-systems to the fact that by **theory** everybody understands what it means in a particular professional domain. The best illustration is the rift between sciences and humanities. How can we count on any consensus, regarding, for example, human history, if physicists and historians—who know about history

incomparably more than physicists—do not have a common language not only between each other but also with biologists, psychologists, artists, philosophers, etc? Instead of computer games at one end of the scale, Grand Theories of Everything at the other, and quantum intelligence somewhere in the middle, we could do better by developing a common language for the modest purpose of **understanding** what Everything is, as well as what **is** is.

This preliminary sketch, with an intent to expand on major topics in the future, ties in a loose knot the following strands. Although I am a **chemist**, my major influence for twenty-five years has been **Pattern Theory** of Ulf Grenander, which in my eyes is a **generalized chemistry**. I have been familiar with the ideas of **René Thom**, **Stephen Wolfram**, and **Gregory Chaitin** for as long. Most recently I have been impressed by some other discoveries, among which **Hannah Arendt** had the strongest impact. Having no **formal theory** of its own,

Like **computation**, chemistry between theorizing and *faber*, man the maker, the chemical **catalysis**, the Those are the strands tied in a



**metaphor** and metaphor is one of the strands of the essay, too. The knot in the center of this paragraph is an **ideogram**, which escapes a single definitive explanation. It can be interpreted as: (1) marital knot, (2) movie plot in which two characters become inseparable, (3) coincidence of two policies on some points and divergence on others, (4) military quagmire, etc. The list of interpretations is always open and the prospects of the knot of being untied, cut, or fused into a permanent connection are uncertain.

chemistry borrows it from **physics**. takes an intermediate position **making**. Hannah Arendt's *homo* modern hero, clearly resonates with chemical maker of life on earth. knot in this essay. The knot is a

## PART ONE: CHATTING

I am a chemist and the secrets of life are least of all mysterious to me. I am very much intrigued by mind and language, but most of all by understanding society and its future.

My upfront goal is to illustrate how we can discuss cabbage and kings within the same vocabulary, so that they would look like twins. My secret goal is to infect the reader with the suspicion that **chemistry is about human existence** (human condition, as Hannah Arendt [2] would say) in the widest possible sense—oops! no more a secret. The world looks very peculiar through the eyes of a chemist, whose vision is as different from that of a physicist as the vision of a bee or a dog from ours: it is adapted to see through complexity.

I am driven by a sheer intellectual curiosity because at my age I have little practical concern about the future. Yet I have also some personal reasons to be curious about the larger world.

My interest in large complex systems comes from the time when I lived in the Soviet Union, trying to understand a social system that seemed completely unnatural and doomed. Although hardly anybody saw a quick end to it, the end came soon after I had left Russia. I went to America, swearing to purge my native land out of my mind—the vows of eternal hate are as futile as the vows of eternal love.

About twenty years later, Russia, the country crucial for the fate of Europe and the West, seems to be taking a new historical turn, which I am no more interested in. Judging by daily news, the turn would qualify as a regression to Russia's tsarist past.

I am much more concerned about my new American homeland, which offered me freedom, shelter, and comfort.

I can see in the current presidency in America (2000-2008?) some shocking, however distant, similarities with what I saw in Russia. I suddenly begin to sense the historic fragility of the **present**, in spite of a however glorious **past**, facing the invisible and incomprehensible **future**, which today is as global and unmanageable as never before.

Regarding history, I am a fatalist, which means that I believe that the events have a preferred direction. The ripe apple always falls down. This may seem like a physicist's credo. But our understanding of the world is a component of the events. If I believed in equations, I would say that our understanding and expectations count in the equation of the future. But I do not believe in equations for X-systems.

In his intelligent book *In the Country of the Blind* Michael Flynn [3] imagined a practice of **cliology**, i.e. the applied science of history—with equations—which developed into a true technology, mostly of cloak-and-dagger type, of designing and shaping the future. As every landmark idea, it is valuable for questions it poses rather than for answers.

The technology of making history has been in fact evolving throughout history from the cloak and dagger to the suicide bombers and from the quill to the character assassination through TV ads. I do not share any illusions about possibility of a **theory** of history. The reason for my negativism was perfectly formulated by Hannah Arendt [2]: the historically meaningful events are those that violate statistics. I would also add: and equations. They always come as unexpected irregularities. Instead I have the following five point program to consider.

1. Since we cannot experiment with history—we can and we do, but the experiment cannot be reproduced—cliology is extremely unlikely. **Impossible** is a forbidden word anywhere except mathematics. **Infinity** is forbidden everywhere else. What we can do is to **understand** history.

2. We never know if somebody understands something unless we have some feedback. By **understanding** I mean the ability to convey a doctrine (an open system of

principles, explanations, and examples) to other people, for whom the ideas are **new**, in the **old** terms, so that they will prove their own understanding, not necessarily perfect, by passing it back to the source for the check, as well as further down the line, until it diverges or evolves into another doctrine. Understanding, therefore, requires a **common language** and involves a kind of a teacher-student relationship which **converges to a consensus**. Like a relationship between two gossipers frequently exchanging “if you know what I mean.” If understanding, according to Gregory Chaitin, means compression [4A], the proof of understanding means ability to compress and decompress in more than one way, like folding and unfolding a napkin in various ways.

For comparison, here is Ulf Grenander’s note on understanding:

We claim that we understand the pattern only if we can analyze it in terms of a given knowledge representation or, alternatively, if we can pinpoint in what respect it differs from what the representation prescribes. [5A, p. 100].

3. If we understand history up to its current moment, so that a nearest future brings a delayed test, we will be able to pass the understanding to posterity facing a more remote future than ourselves. It will be irrelevant by that time, however. In other words, our understanding of the world in the short run can be very different from that in the long run, but we never have the long enough run ahead. This contradiction is dramatically different from the post-Galilean belief in the timeless laws of nature on which all our activity in the role of *homo faber* is based.

4. Suppose we can elaborate a set of principles that govern the **preferable direction** of historical events in the short as well as in the long run. By regarding “historical” as “natural,” we will come to a version of thermodynamics, which is a very small set of universal principles about natural and man-made events. Unfortunately, thermodynamics, timeless as any good **science** should be, is silent about the short run, while history is all about the time span of at least one or two generations. We would at

best know **what** could possibly happen, but not **when**. We would know a set of alternatives but not whether it was complete.

All we can do with thermodynamics is to conclude that an earthquake in San Francisco or even the end of the world is imminent. What we need is **kinetics**, i.e., the knowledge of the **relative speed of alternative events** and how to manipulate it. Thus, in the presidential elections of 2004, in which the Republicans were much faster and nimbler than the Democrats—for which there were pervasive thermodynamic reasons—the outcome could be, theoretically, different if the campaign lasted just a couple months longer.

For more about kinetics regarding abstract systems, see [1].

The outcome of the Battle for Britain during the WWII was decided by the faster adaptability of Britain. The outcome of the competition for energy resources between the giant nations and unions (USA, EU, India, China) will depend on who adapts to the exhaustion of mineral fuel faster. The **rate** of the population growth, which seems turning toward negative [3B], is of the paramount importance for the political shape of the globe and a sustainable, however unexciting, economy. The chemical industry is possible because of the differences in the speed (the chemists call it **rate**) of the desired and the unwanted reactions, while the respectable wine industry is based on equilibrium thermodynamics and is in no big hurry: the longer the better.

The world is not flat because **kinetic barriers** warp, wrinkle, and crumple it.

5. If history **always** brings something **new** and unexpected, could our understanding of history be lasting? The property of **novelty** is intrinsically alien to any closed **theory**, but our language is quite agile at expressing **new things in old terms**, after which new terms are assigned to new things and immediately cease to be new. What we can theoretically predict is not new. By definition, the new cannot be predicted, only the different.

End of the program.

Regarding the problem of realistic understanding X-systems, I have two related hypotheses.

My first hypothesis is that **if** we can foresee the physical fate of the earth for centuries ahead—alas, there is a problem, too—we can try to project reasonably far ahead our open-minded understanding of history and its distinctive technology. More generally, **understanding lasts until the larger system that houses the system under consideration changes dramatically.** I hope that there are some limits to meaningful abstraction.

My second hypothesis is that **from a high enough level of abstraction, our understanding of an X-system will be simple.** In practical terms, the number of alternatives for the future will be very limited. At least we would not care about the next president. Alas, this makes computation, the God's manna for tenure seekers, useless, but this is not my problem.

The two hypotheses can be combined in a statement that may seem paradoxical. **In order to make predictions more accurate we need as less detail as possible.** In other words, we should step back and look at the Earth as a whole from a distance: from what Hannah Arendt [2] called **Archimedean point.** We will not see much, but we will see what is large and lasting. In practical terms, we need to develop an abstract language to talk about Everything over the Grand Canyon dividing sciences and humanities. Neither formal mathematical systems nor physics can bridge it, to which a century of debate with no consensus testifies, because **formal systems are not open to novelty.** They are designed to be timeless and this is why they are disposable and can be out of favor if a **new** formal system (paradigm shift) looks more realistic.

Chemistry, on the contrary, is an open system because it is not formal. Chemistry, like art, is a collection of old novelties, but it expands by the minute. Novelty is a recognized, however ephemeral, property of chemical compounds, see [1A, Chapter 1].

Of course, chemistry, as everything else, looks simple only from the Archimedean point.

Paradoxically, biology has a theory based on chemistry, but chemistry does not have a theory in the **common** sense, except for physical theory. It possesses a very compact, but extremely successful, set of principles involving thermodynamics and kinetics, as well as efficient methods of handling the ferocious structural complexity. Of course, reducing it to simplicity, what else? Chemistry, however, has been silent on the subject of Everything and for a good reason: the proof of the chemical pudding is always in the making, not talking. Fortunately, Pattern Theory [5] (Ulf Grenander) is available as a mathematical generalization of chemistry applicable for Everything, from molecules to thoughts.

We can now glue generators together and the bonds will tell us what combinations will hold together. This is a bit like chemistry: atoms (generators) are connected together into molecules (configurations) and the nature of the chemical bonds, ionic, covalent, and so on, decides what combinations of atoms will be stable enough to form molecules. [5A, p.83]

This is why Pattern Theory gives to a renegade chemist like myself a podium for an oration, but words are often too heavy for a chemist to convey **understanding**. A chemist usually expresses his or her ideas in the graphic form—as ideograms—and this is what I am looking for as a medium for communication. Like music and visual arts, images appeal to universal human nature. This is why the advent of TV was a real revolution in propaganda: the visual perception outruns thinking. The velvet coercion of TV is more powerful than prisons and concentration camps.

My intent, driven by my belief in the unity of the world, is to contribute to the development of a distinct **language** to talk about X-systems in the most general, but informal way, equally accessible to physicists, poets, chemists, and historians, as long as they are interested in tall problems that cast no long monetary shadows. Another metaphor.

Concerning shadows, I believe that Ulf Grenander, as well as, on a smaller scale, René Thom, Stephen Wolfram, and Gregory Chaitin (himself brilliantly referring to Leibniz) cast the longest **intellectual** shadows onto the slowly developing understanding of X-systems as **open systems**.

I use the term *open* not in the classical physical sense of exchange of matter, energy, and information with the environment—they are open in that sense, too—but in the sense of inherent **incompleteness** due to the phenomenon of **novelty**. X-systems are open to all of the above but also to a **future** that cannot be derived from the present—as Stephen Wolfram’s deep conviction and models testify [8]. If so, can we speak about **theory**? Not in the **contemporary** sense (here comes **future**, which is always before the date) and this is why it is a different kind of science. But we can still **understand** such systems. I see the “theory” of organic chemistry as a typical **understanding** tool, as open to future as a Lego set.

Whatever the new understanding might be, the grandiloquence of some pioneers should be forgiven until the course of history vindicates them and the steamroller of habit levels the highway asphalt over the former trail.

I hope to expand elsewhere on how computers reminded the timeless mathematics about the ticking clocks. Until then, here is a quotation (secondhand) from René Thom [7B] :

We cannot consider catastrophe theory as a scientific theory in the usual sense of the term. . . . [W]e must consider it as a *language*, a method, which allows to classify, to systematize empirical data, and which provides these phenomena with the beginning of an explanation that makes them intelligible.

Earlier I suggested [1A] the terms Aristotelian (A) and Heraclitean (H) for the two kinds of systems and, perhaps, sciences. **A-systems** are the subject of science as we know it and **H-systems** are waiting if not for a new science then for some liberalization of the existing science.

To understand means to tell somebody who can tell it to somebody else. Obviously, what we must have for this is common language. An example of such common language in the larger world is the universal language of nucleotides by which the **future** generations of organisms **understand** their predecessors and send a message to the posterity.

The previous paragraph is itself an example of the language of metaphors, analogies, and similarities, shun by most so-called serious scientists as metaphysics but

legitimate in the pursuit of understanding. Hannah Arendt's *The Human Condition* was written in this language on the other side of the great divide between sciences and humanities, but the divide is also **open to the future**—a strangely sounding phrase meaning that it could be closed. How? By an earthquake? Hannah Arendt was listening to the voices across the divide, among which the voice of Werner Heisenberg [6] was the clearest, operationally schooled in the widest acoustic range of Goethean traditions.

The new ideas are not going to undermine “real” science in any way. But they are still met with mostly indifference and rarely hostility (as in case of Stephen Wolfram; but many negative reviews still sound more like praise) because they are different. René Thom acknowledged a formal failure of his work. He came to a conclusion that the theory, met initially with enormous enthusiasm, had failed because nothing could be **calculated** from it.

For as soon as it became clear that the theory did not permit quantitative prediction, all good minds ... decided it was of no value. [7C]

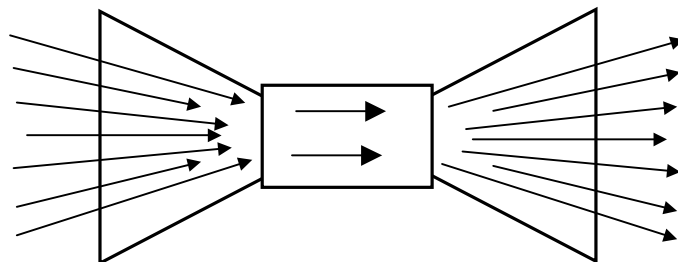
In other words, it did not pay in terms of grants and tenure. It turns out that Thom regarded his theory as a “new kind of science:”

This would not be the old science, but a new one, which would endeavor to provide explanations rather than mere description or predictions. [7D]

The problem of hostility toward “a new kind of science,” echoes, in a fascinating manner, another modern phenomenon: religious zeal against Darwinism. This is an example of a social pattern, which we should keep in mind. Whether this is an X-system pattern, is an intriguing question. Let us keep it in mind until we discuss the “rusty bolt” ideogram.

Speaking of money, there is another beautiful—and exact—analogy, promoted by biochemists, between **money** in society and **ATP** in living cells as universal currency of energy—the analogy (search the Web for “money ATP adenosine”). This is definitely an X-system ideogram.

Another example of what I call ideogram is the **bow-tie structure** [11]. It is not actually a structure in the common sense but a very abstract pattern of organization consisting of a large number of inputs being converted into a small number of intermediates further converted into a large number of outputs. In other words, “complexity  $\rightarrow$  simplicity  $\rightarrow$  complexity.” Two examples follow.



**Nutrients**

**Metabolism**

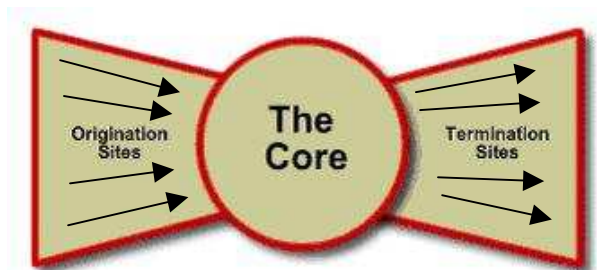
**Biomolecules**

**Genes**

**Expression**

**Proteins**

Sources [11A, B]



Organization of the Web.

The sites in the core are all interconnected with links. Sources [11C, D]

From the pattern and chemical viewpoint, the bow-tie ideogram means a decomposition of configurations into generators and a recoding and/or recombination of them into a new array of configurations. The combinatorial configuration space is always larger than the generator space. Further examples are, behavior, government and management, language and information processing, etc. There is something hidden in the bow tie ideogram, however: a complex system of rules or algorithms governing the processing. It is an open question, however, whether **the set of rules is also simple**. I

believe it is and [I tried to illustrate it](#) on the example of language. Genetic code is certainly simple. Another intriguing question is the **optimal complexity of government**. Excesses toward both simplicity and complexity of government can be dangerous, as American political history keeps illustrating with fresh examples.

ATP, rust, and even money are in the legitimate sphere of interest of chemists, who, however, are conspicuously absent from most discussions on X-systems beyond chemistry. There is very little on chemical complexity (for example: [9C]) and no consensus on measures of structural complexity, although algorithmic complexity seems to have passed the time test. The words **chemistry** and **catalyst**, however, belong to the common vocabulary from the street corner to political debate because they embody powerful analogies. On catalysis, see [1A-E, K, L].

Chemistry has a unique attitude toward **time**. It is concerned with the **intimate and delicate mechanism of change** and is not satisfied with the question: “what is going to happen?” because there are typically multiple outcomes. Anything we can imagine in the combinatorial chemical space can happen. The main question of chemistry is: “what is going to happen faster?”

Chemistry shares its approach to time with other sciences about X-systems, for example, with history (the French *Annales* School): it emphasizes the distinction between the long run (*long durée*) and the short run. There is an intriguing anti-symmetry relation between chemistry and history, however. Chemistry states that what we know about the long run—and we know a lot—does not tell us about what is going to happen in the short run, which is a matter of educated guess, best of all substituted by a simple experiment. History states that what we know about the short run—the period of the Clinton prosperity and the technology bubble, for example—could not tell us a bit about the next (current) radical turn in American history, which cannot be analyzed until long afterwards. The only safe prediction was that both would come to an end.

The next—third—turn could bring even more division, shame, and death, as well as profits, or it could heal some wounds and repair the battered roofing and flooded with

mud foundation of American system. Can we see it ahead of time? It may seem that the politics, unlike the vagaries of the market, is a game within a limited circle of players and statistics does not apply to it. But if the masses of voters are involved, shouldn't be there some thermodynamics in it? On the other hand, with the growing power of hedge funds and big mutual funds, the market might cease to be anything but a televised poker party. Since the masses follow the leaders, what politics can be the fastest? Such dilemmas constitute a typical problem of understanding history in the making. If we understand history, we probably will be able to look a little behind the time horizon. Note that this is a typical example of the need to express the new in terms of the old, as understanding should be.

Our views of society are highly diverging and polarized. Experiments with society are mostly unintended, sloppy, or rigged. While technology in experimental science brings us in a close contact with factual reality, technology in politics and business puts a TV screen between us and the factual truth. The modern presidential debate is a classical case of a rigged experiment. Can we have any degree of consensus in understanding “what we are doing,” the central question of Hannah Arendt's *“The Human Condition?”*

If the primary question about an X-system is how stable it is, history is scientific enough to tell us that no X-system is stable forever. If the question is about the next stage, history is not scientific enough to tell us that, either. If the question is how soon the current state is going to become unstable and collapse we are able to evaluate that, but our evaluation immediately rises the next question: how soon the current state is going to become unstable and collapse after we have evaluated its stability and found it low.

Chemistry always asks: “how soon?” What happens faster is the most likely future. This is similar to the process of thinking, when out of a combinatorial immensity of all possible thoughts only one enters the consciousness, see [5C]. The abstractness of this similarity is exactly what makes it relevant for understanding X-systems. It illustrates the main problem with the rusty bolts (we will come to them later) of understanding “new kinds of science.” In order to accept a new view of X-systems we have to abandon the old paradigm that provides us with daily sustenance.

At a closer look, the problem is imaginary. The ambiguity of the term “new” is responsible for some rusty resistance to a “new science.” A new refrigerator means that the old one is discarded. But it also could be a second refrigerator for food storage in the basement. I am inclined to leave only three necessary attributes to the notion of science: observation, understanding, and consensus. Thus, I do not expect the idea that the universe is a computer to come close neither to consensus nor to observation.

I believe that that the science of X-systems, when it takes its shape, will be not the new and only science but a second—**complementary**—science. It will be based not on closed axiomatic timeless mathematical or logical systems, but on open combinatorial systems of simple local interactions with laws and rules of limited rigor and validity and with yet unknown but definitely limited predictive power.

Not surprisingly, the enormous factual material about X-systems has been accumulated mostly in humanities. Science I (physics) and “Science” II (understanding) are the overlapping components of the human picture of the world, to which humanities contribute their intuition and flare.

Today complex systems are studied by Science I in terms of dynamical systems—an area as logically closed as any physical theory. The current interest in the less hermetic **data-driven dynamical systems** testifies to the drive toward realism, but such systems do not break out of the enclosure of formalism. Nevertheless, modern science of complexity is more conscious of the long and short run, as well as of the large and small cognitive grain size.

In the later three above-mentioned application fields [meteorology, chemistry, and physics] the data is typically sampled from a complex biological, chemical or physical *dynamical* system, in which there is an inherent notion of time. Many of these systems involve multiple time and length scales, and in many interesting cases, there is a separation of time scales, that is, there are only a few "slow" time scales at which the system performs conformational changes from one meta-stable state to another, with many additional fast time scales at which the system performs local fluctuations around these meta-stable states.

From: Boaz Nadler, Stephane Lafon, Ronald R. Coifman, Ioannis G. Kevrekidis, *Diffusion Maps, Spectral Clustering and the Reaction Coordinates of Dynamical Systems* (2004). [Meta-stable state needs a light push to descend to a stable state].  
[http://www.math.yale.edu/~sl349/publications/reaction\\_coordinate.pdf](http://www.math.yale.edu/~sl349/publications/reaction_coordinate.pdf)

It seems to me that Science I is moving toward **complex** theoretical solutions of **complex** problem (complexity square), instead of understanding “what we are doing” while creating the problems. Complex problems may have simple reasons, but not simple solutions. On simple reasons, see *Essay 28. Simple reasons* in [1M].

It is worth noticing that computation—the greatest most recent novelty of science—runs in intrinsic and measurable time and size (equivalent of space), unlike the classical mathematics, but very much like a chemical reaction. A unit of time is an elementary act of computation: a single beat of the processor clock.

Computer is a great embodiment of Leibniz’ idea that time is the sequence of events. When the computer is paused, its time stops dead. The unnatural property of computer is that it can be revived from its clinical death by the magic wand of a slight touch.

The passion of Gregory Chaitin for computation and the simple local rules of Stephen Wolfram, regardless of mathematics and philosophy, resonate sympathetically in my chemical heart. I was brought up in the openness of chemistry that weaves complexity out of 100 kinds of blocks of atomic Lego in the same manner art is weaving its complexity out of couple dozens of the letters of alphabet and maybe couple hundred color spots.

The recent *Meta Math!* by Gregory Chaitin [4A], in my chemical interpretation, carries a clear and universal message of mistrust in all closed logical systems, on which, as I see it, physics, but not chemistry, is grounded. As a chemist I see what looks to me as an underlying deep reason why perfection is imperfect: the world is in change, while abstract **Aristotelian reasoning**, like equilibrium thermodynamics, is heavenly beautiful

but never lasting. Physics keeps pace by breaking old paradigms—as a glass at a Jewish wedding—and espousing new ones. We all do that at new turns of history and personal experience. Regarding history, however, we do not even have a consensus-sanctified paradigm to smash.

Alas, what mathematics still lacks is the measure of energy (or stability, probably, related to mathematical elegance) of a mathematical expression, but human languages clearly rank by energy required to use them. English and spoken Chinese are easy to handle, German is heavier, Russian is very heavy, and Navajo is the hardest of all languages I am aware of.

In [1J] I casually suggested that Navajo verbs were in essence ideograms, like in Chinese writing, only not graphic, but acoustic ones. The acoustic analog of a pictogram would be a *sonogram* (not in the usual sense; *phonogram* is also taken): an imitation of a natural sound, which is regarded as a source for language origin, according to some hypotheses. I suggest a further (tentative) generalization of ideogram: **a symbol for representing an abstract idea as an entity of a very coarse grain, leading to simplicity.**

I have not escaped a metaphor in the previous sentence. Metaphor is the closest notion to ideogram. The difference is that metaphor names an object with a name of a different object, while ideogram names an abstract property of many objects with a single name and does it with a non-verbal symbol of its own. This, however, smells of a definition. I prefer to rely on demonstration, as, probably, Neanderthals did.

Concerning names, I see in Gregory Chaitin's description of understanding as compressing [4A] an echo of Henri Poincaré's casual remark that mathematics calls many things with one name. Ideogram is, therefore, akin to a mathematical symbol.

Complexity is a very tricky subject. The problem I have with complexity of finite sequences of zeros and ones, as well as with the finite output of a cellular automaton is that each of them is a closed object—if we leave infinity to mathematicians and theologians to wrestle with. I am uncomfortable with ascribing randomness (and even **regularity**, which is a much better term) to single objects and using it for a complexity

measure. My discomfort only deepens when I read in Chaitin's lecture [AIT = Algorithmic Information Theory]:

In these lectures I discuss philosophical applications of AIT, not practical applications.

Indeed, I believe AIT has no practical applications.

The most interesting thing about AIT is that you can almost never determine the complexity of anything. This makes the theory useless for practical applications, but fascinating from a philosophical point of view, because it shows that there are limits to knowledge. [4B]

This is as much overboard as anybody can go.

An alternative approach to complexity is possible. I believe that the property of complexity applies to open combinatorial **spaces**, such as configuration space of Pattern Theory, or molecular structures in general, or an individual language as a whole, and not to individual configurations in those spaces. My thesis, in terms of Pattern Theory, is that all individual configurations (structures) are equally simple or complex within the same configuration space defined by the generator space and regularity. To be concrete, all chemical structures, from water to DNA and proteins, have equal pattern complexity defined by the size of the Periodic Table and properties of atoms.

For the first awkward take on this difficult to accept—and formulate—issue, see *The New and the Different* [1K]. From this standpoint, all sequences of 1 and 0 have equal pattern complexity, I would say, about 2. It jumps to  $\sim 3$ , however, if we add number 2. As a consequence, while all chemical structures are equally complex (or simple), the history of chemistry is a record of growing pattern complexity, from the four elements of ancient Greeks to the first periodic systems and to its subsequent expansion. This applies also to larger structural blocks, such as carbohydrates, proteins, steroids, and aromatic cycles.

In addition to the above idea, I suggest setting aside any absolute measure of complexity. What we can evaluate is a **difference** of complexities within a larger space. Moreover, the difference matters mostly in terms of **more** or **less**. More exactly, I am talking about a partially ordered set (scale) of complexity values. (See *Essay 13, On*

*Numbers*, [1M] for more about partially ordered scales, for example, in Confucian ethics; in short, we cannot measure somebody's virtue, but can compare two virtuous persons).

The wide use of differences instead of absolute values is typical for traditional pre-computer chemistry. Differences, unlike absolute values, are always accessible and practical. Will you be **more** or **less** happy if you divorce XYZ and marry ZYX or buy UVW shoes?

To prefer relative values to absolute ones means admitting that algorithmic complexity must somehow include the knowledge about how the author of the algorithm understands the system and what is the size of the grain in that understanding. Thus, we can compare various computer outputs, but we cannot compare a computer output and a protein unless in a larger abstract system which would somehow include some knowledge of computers, as well as of chemistry, and, more dramatically, the knowledge of human nature. Nevertheless, this is exactly what I advocate in this essay: we need not the largest, but just a larger system.

I understand incompleteness as the inherent lack of a larger—in time, as well as in space—system to describe the system under consideration. To put it simply, in order to create a scientific model of eight years of American history (2000-2008), we need to collect the historical record for at least a century (1950-2050; we never know in advance for how long). We can monitor the expansion of the conceptual space by comparing the expansion of the vocabulary in use. This is why I am pessimistic about any “dynamical model” theory regarding X-systems. There is an additional reason for that: “dynamical model” requires (if I am not mistaken) a large enough statistical ensemble. Individual human mind, however, is incapable of operating with large number of cognitive entities. Nor, for that matter, are we capable of directly handling a large number of things and people.

We always maintain a certain density of information by well known hierarchical aggregation. Thus, contrary to popular opinion, the **chemists** who deal with **really complex** molecular structures **do not necessarily think always in terms of atoms**—they do not even write all of them in their ideographic formulas—but operate with larger blocks of stable fragments of structure. As everybody, they decrease the complexity of configuration space until it is manageable by human mind. The politicians, spitting out frozen clichés, slogans, and sound bites, use the same trick for managing the minds of the

public who has enough complexity to deal with in private business and family life. Not that there is anything wrong with that, except that the democratic elections become irrational. Love can be irrational, but an irrational vote could be literally suicidal or even murderous, if it is the vote of a court jury.

There is a curious document, *The Use of Complexity Science. A Survey of Federal Departments and Agencies, Private Foundations, Universities, and Independent Education and Research Centers*. October 2003. A Report to the U.S. Department of Education ( <http://www.complexsys.org/pdf/ComplexityScienceSurvey.pdf> ). The title speaks for itself. I see it as money well earned by riding a wave. Complexity must be practical.

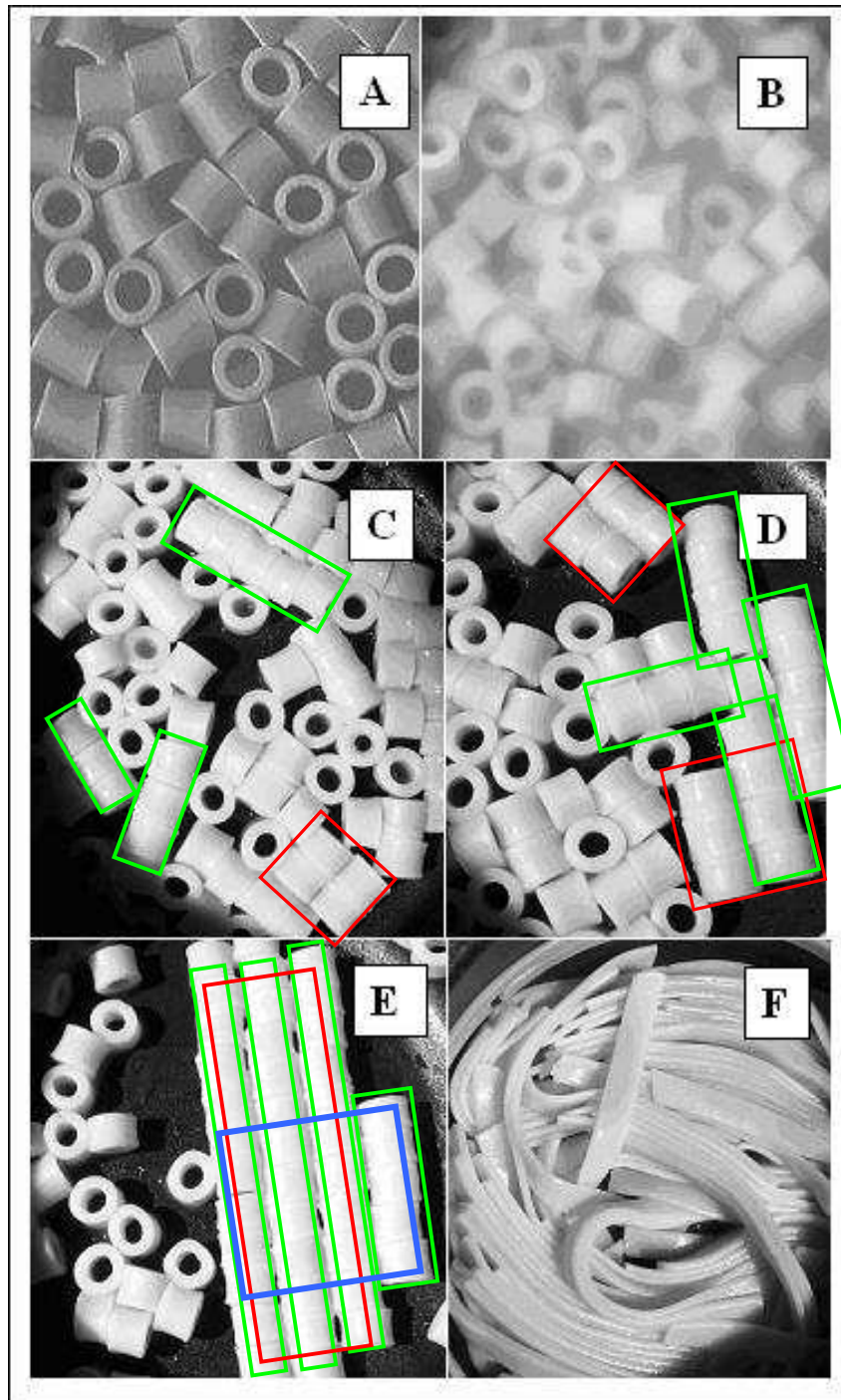
Complexity is practical. As an example of the **kinetic consequences of complexity**, I regard evolution of language as simplification of grammar in order to increase the speed of communication and keep it up with the speed of events [1C], as well as with their complexity. By the same token, I anticipate the political leadership of the USA to be more and more superficial in the future, religion and obscurantism more and more attractive as a refuge from complexity, and the voter's behavior more and more capricious and self-damaging—until a new phase transition in the mechanisms of civilization.

I conclude **PART ONE** with another personal note. While reading Chaitin's exuberant book, I recalled my own excitement when discovering—long ago—Leibniz' ideas about time and space, the concept of meta-mathematics, the first publications of Stephen Wolfram on cellular automata, the idea of algorithmic complexity ("Kolmogorov-Chaitin" complexity, although Kolmogorov's contribution seems only casual), Ulf Grenander's books, and having recently discovered Hannah Arendt. Witnessing the birth of the modern chemical paradigm of transition state was also an unforgettable experience.

Blessed be ignorance that gives us the sharp joys of discovery.

I count on some tolerance of my going overboard with Chemistry of Everything. Well, this is just "Words, words, mere words..."

We are moving from chatting to making: cooking pasta, which is a real thing, and assembling a brushmobile, which is even more real than one would think.

**PART TWO: MAKING**

**Figure 1.** Pasta: **A**, Dry ditalini; **B**, Cooked ditalini in water; **C** and **D**, Drained and slightly shaken pasta; **E**, *Homo Faber* was here; **F**, Cooked linguini.

To take photos for **Figures 1A to E** and **2A**, I cooked some ditalini pasta. The diameter of ditalini is approximately equal to the length, which makes the circumference more than three times longer than the length. The cylinders have substantial flat ring areas at the ends.

The dry cylinders have only two axial orientations on a firm flat surface: vertical and horizontal. The cooked pasta, still in the water(**Figure 1B**), has more **degrees of freedom** at low effective weight than on a hard surface. But how many? To answer this question, we should collect statistics of the orientation and plot the distribution. Intuitively, I do not expect it to be random, unless in zero gravity, but I am not going to check it. The data will be true for as long as ditalini is on sale, cooking is done in the present manner and utensils, and the cooks still exist. I am interested not in what the cooked pasta tells me about cooking pasta, but about the world outside: the X-system in which pasta emerged, ditalini was invented, and which will probably exist after ditalini is extinct. I am interested in what the short run tells me about the long run, because all I can see is all of the short run and the past part of the long run, sometimes fragmentary.

The still photos do not convey any idea of time. Nevertheless, I am going to interpret the difference between the photos in **Figure 1** in terms of **stability** and **lability** which imply the notion of time.

**Stability**, points to the preferred direction of events in the long run: toward higher stability. Like energy (which it essentially is), it depends on the intensity of chaos, i.e., abstract temperature, in the system. A frozen abstract system at zero chaos does not change. I should be more precise: an abstractly frozen abstract system at abstract zero of abstract chaos does not change, which means that the Leibniz' abstract time stops. Nothing is stable in a very hot system even in the short run. Of course, long and short time are also relative notions, but all we need is some distinction between them. For example, an average human lifespan is long as compared with an hour, although both are short on a cosmic scale.

Physics abstracts from human presence and ignores the chance that a human hand will catch the falling Newtonian apple in mid-flight. History does not argue with physics but stretches human presence over particles and waves. Chemistry and biology take intermediate positions.

With my aversion to definitions and absolute values, all I can do is to distinguish between **more stable** and **less stable** configurations or states. While **configurations** are abstractions, **states** relate to a particular system in which not all configurations and their sequences in time are possible. Ulf Grenander reflects this subtle distinction by using the term **image** for an actually observed “realistic configuration,” not yet processed into the more idealized **configuration**.

In other words, a configuration is a mathematical abstraction, which typically cannot be observed directly, but the image can. [5A, p.91]

Photos in **Figure 1** are exemplary images in this sense. Images cannot be interpreted as configurations without some arbitrary participation of the mind or a man-made program. It is needed for choosing generators and rules of identification. Pattern Theory acknowledges the human presence in mathematics: “we introduce the equivalence relation,”[5A, p.91] we have to decide whether two images are **similar**.

A third principle deals with observability: given two combinations, when do they appear identical to an ideal observer (with perfect instrumentation)? [5B, p.3].

With some relative measure of time we can detect the differences in stability between two systems and the difference in the temperature for the same system. We do not need any absolute numbers for that, but we need a **human observer of the images**. Recalling Heisenberg’s prophecy [6],

When we speak of the picture of nature in the exact science of our age, we do not mean a picture of nature so much as a *picture of our relationships with nature*. [6, p. 29].

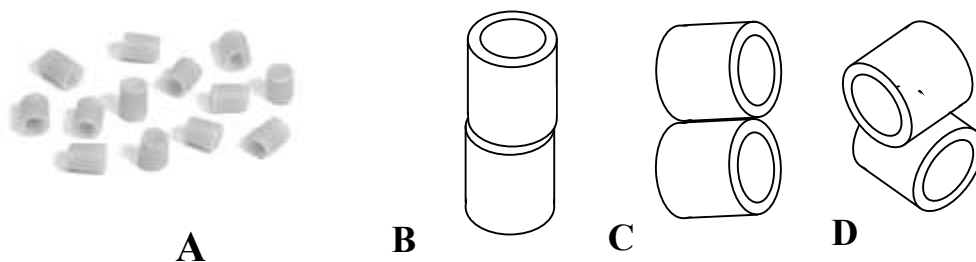
We can see the inherent difficulty with all formal systems as soon as we ask the question “Are we, humans, nature?” Or: “Are we the undercounted part of algorithmic complexity?” **We are present in any description of nature because we choose the size of the grain in the hierarchical generator space**. We have little choice only in the case of computation, where the universal grain is 0 and 1. I am not sure this is so, however,

because we have to code the non-numerical notions, like symbols  $+$ ,  $=$ , and  $f$  (function), but my expertise in mathematics is closer to 0 than to 1. Besides, infinity—incompatible with anything human—creeps in, if not in computation, than in our chatting about it.

The difference between configurations and **images** comes to the foreground when we deal with human fantasy, creativity, invention, and planning, i.e. **imagination**, of course. I wish to draw attention to the ability of Pattern Theory to speak about both nature and mind in a unified language, or, in Heisenberg's words, about **our relationship with nature**.

When by nature we mean X-systems, we should get used to do without anything perfect, exact, definite, and precise, as we already do in calculating the behavior of complex inanimate systems like bridges, airplanes, and weather. They all can let us down.

Back to pasta. The cooked cylinders form relatively stable coaxial assemblies several pieces long (oligomers, as a chemist would say) because their bases can stick together along their flat cross-cut rings. (**Figure 2B**). The significant, almost biological regularity comes as no surprise because pasta is man-made. Similar tendency to form organized structures is seen in linguini forming strands of parallel filaments, **Figure 1F**. It is also used in liquid crystal electronic displays.



**Figure 2. Pasta bonding: A, no bonding; B, at the base surface; C, along the generatrix line; D, at a point.**

Other types of connection, such as **Figure 2C** and **2D**, may occur as dimers but hardly as polymers. The area of contact along the generatrix of the cylinder is much smaller than that of the basal ring and, therefore, the bond of **2C** type is weaker than that of **2B**. The **2D** type connection is even weaker.

For elongated particles the parallel bonding is more stable than the consecutive one, compare with **Figure 1F**.

The green rectangles encase single linear strings and the red ones emphasize a weaker parallel bonding. The blue frame in **Figure 2E** displays an **unusually high degree of regularity** in two dimensions, which reminds a raft structure. This image, depending on the angle of view, looks either **artificial** or, just the opposite, as **natural** as a biological formation. No wonder, because, philosophically speaking, it is both: it is artificial because here I became *homo faber* and arranged pasta bit by bit by hand and not by shaking; it is naturally biological because I am alive and I have a mind of my own. This painful relativity of life and mind has been causing endless discussions about both, but on the platform of Pattern Theory I have as little problem with mind as chemists have with life. Which means: little but not nil, maybe even a lot.

An interesting side dish of a problem comes here into view. How can we detect an artifice, for example, on another planet? The evidence of artificiality of **2E** can be seen in the **absence of the intermediate** forms between chaos and extreme order. Artificiality, so to speak, is anti-Gaussian and in this sense abnormal. The absence of intermediate forms in paleontology comes to mind as a sign of both natural and artificial origin of species. Artificiality here means that the species, probably, develop not (or not only) by a random genomic walk but in response to a new source of non-equilibrium order.

The problem of elephant's trunk—antagonizing biologists over Darwin and even Lamarck and Cuvier—remains a mystery. In biology it has the status of Fermat's Last Theorem with a big difference: it is a problem about possibility and not about impossibility, as in mathematics.

Now we are coming to the main treat. Once arranged, the regularity of **2E** type has a significant stability because the **multiple weak bonds** along the generatrix keep the entire pasta “raft” together **as if they were one strong bond**. Only **as if**, because there is no such single bond and the aggregation can be explained in terms of overall stability. In other words, stability is additive: it is a sum (approximate) of increments.

This is the heart of chemistry: the global property of a structure can be derived from local components. It seems that in social chemistry the global property can be imposed from a local point (King Hammurabi or Joseph Stalin), but the star topology is reducible to individual bonds. To follow the law or not is our personal decision. We obey because otherwise our stability will be decreased. I believe there are physical theories based on strictly local interactions, but I am not an expert. Look for works of physicist Gerhard Mack on universal dynamics.

Once formed, the raft disintegrates only at a higher chaos than that of its creation. In order to bring the raft to existence and make it stable, I had to perform work, i.e., a series of gentle movements against some weak forces in a particular order. Moreover, an **idea** of the final configuration in my mind preceded the actual work. The idea was neither an image in PT sense, nor a single configuration, but rather a pattern of a 2D arrangement similar to 2D natural images. The idea itself had developed in two stages. Initially I only wanted to make long strands of cylinders, but having made a couple of them I decided that to put them side by side would make more effect. The artificial raft is an **ideogram** of my idea of artificiality (imposed regularity). There could be a variety of graphic symbols for this idea and even a superficial browsing through literature on semantics and semiotics (see some examples at [10]) shows that everybody can invent his or her own symbols. Nevertheless, the symbolic systems could be arranged in order of their complexity. There are some standard Platonic components in them, like point, line, arrow, and circle.

The bits of pasta are held together only at low generalized temperature. If shaken above a certain level, they can separate and reassemble. The intensity of shaking or stirring, therefore, is a **metaphoric image** of the temperature, which illustrates the **idea** of what chaos, temperature, and bond means in physics, chemistry, and beyond, including history. This image is generated by my mind—reverse-engineered—from a configuration of an idea and presented to the reader as a language construct.

Temperature is an ideogram, but I cannot imagine a static visual symbol for it. It can be well rendered in dance, however.

Thus, high social temperature, often called “political pressure,” (indeed, high temperature increases the pressure of the gas in closed vessel), or “turmoil” can split a coalition or weaken the bond between the leader and his party.

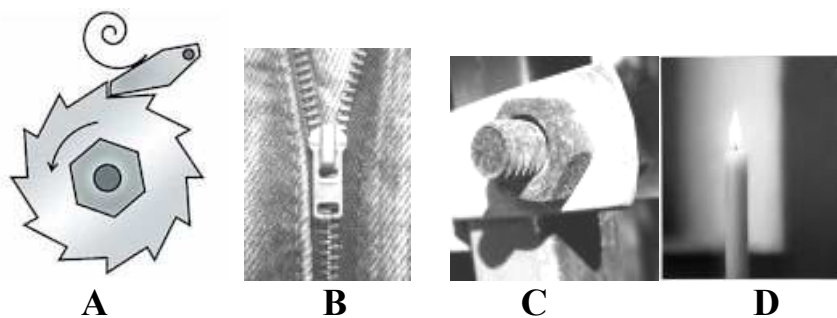
Note that I know nothing about the actual physical mechanism of interaction between the pasta cylinders. Nevertheless, I venture to propose a kind of understanding by choosing the **language** of stability: the bits of ditalini stay together because it is more stable than to stay apart.

**IMPORTANT:** bonds can be **positive**, so that the bonded state is more stable than unbonded, and **negative**, when unbonded state is more stable than divided. In the second case, a force or work is needed to keep atomic units together, as it commonly happens in modern societies, especially, created, like Iraq, by external initiative or, like Communist China, by a revolution. In such cases the internal binding force can be quite brutal.

**Figure 1** leaves us in the dark about the origin of life, but it tells us something about the origin of complexity. First, it can grow gradually and irreversibly because of a variety of bonds that generators can form; second, the concepts of life and mind do not have sharp borders in the language of generalized chemistry, i.e., Pattern Theory. It might be possible to erase borders completely in a language of Pattern Theory enriched by adding the **kinetic** concepts to the **thermodynamic** ones.

On the above foundation of pastology one can devote his entire life to elaborate study of the world of pasta. Far from that, I further intend to build just a little more on that foundation by emphasizing the kinetic aspect of generalized chemistry, although in vague, tongue-tied, non-mathematical terms, which, as I heretically believe, are most appropriate for X-systems. In chemistry, business, and politics, as in cowboy movies, the quickest shooter wins ... in the short run.

Lability and stability are two characteristics of molecules regarding their propensity for change.



**Figure 3. Lability (A, B) and inertness (C, D):  
A, Ratchet and pawl; B, Zipper; C, Rusty bolt; D, Candle.**

**Lability** or **reactivity** (in chemistry), unlike stability, means that the change from one stable configuration to another, even less stable one, occurs pretty easily. The word comes from the Latin *labilis*, tending to slip. The politician that easily changes positions can be called labile. Bureaucracy is **inert**, difficult to move, which is the opposite of labile. When the resistance of bureaucracy is overcome in one particular case, the next will be as tough. The furniture is hard to slide on a carpet, much easier on wooden floor, and even more labile if low-friction pads are under the legs.

The concepts of stability/instability and inertness/lability are confusing because they overlap in common use and even students of chemistry often make mistakes.

Intuitively, both instability and inertness should have stability as the opposite, and they indeed have. Stability, however, as many widely used terms, has at least two meanings: immediate (short run, in a particular act) and a prolonged (long run, at unspecified circumstances).

Their distinction can be clarified with pictures in **Figure 4**.

**1. Ratchet and pawl.** The ratchet wheel, **Figure 3A**, easily turns only in one direction because the transition from one position to the next runs into obstacles of different strength, depending on the direction. This **asymmetric** system is labile counterclockwise and inert in the opposite direction. It is **labile**, however, because it takes only a little work to change its state. Otherwise it is sturdy enough and if not exactly reversible, then movable into any initial position.

The ratchet is, in my eyes, an ideogram for irreversibility by design, not by thermodynamics—a very important distinction. This kind of irreversibility has human or biological origin. It is life-made, if not man-made.

There is significant recent literature on ratchet as a general principle [11], or **ideogram**, as I would say.

**2. Zipper, Figure 3B.** Multiple weak bonds formed by the teeth of the zipper form a strong bond between the two connected pieces of fabric. The connection is labile and symmetrical (reversible) because the bonds can be locked and broken one by one. This type of connection is typical for the biochemical structures of life: the coiled enzymes, structural proteins, and nucleic acids can be unfolded relatively easily by an excess of small molecules capable of forming labile bonds with them.

The typical chemical bonds that form the skeleton of a molecule are strong (covalent) bonds, difficult to break up. They are inert, but not necessarily stable.

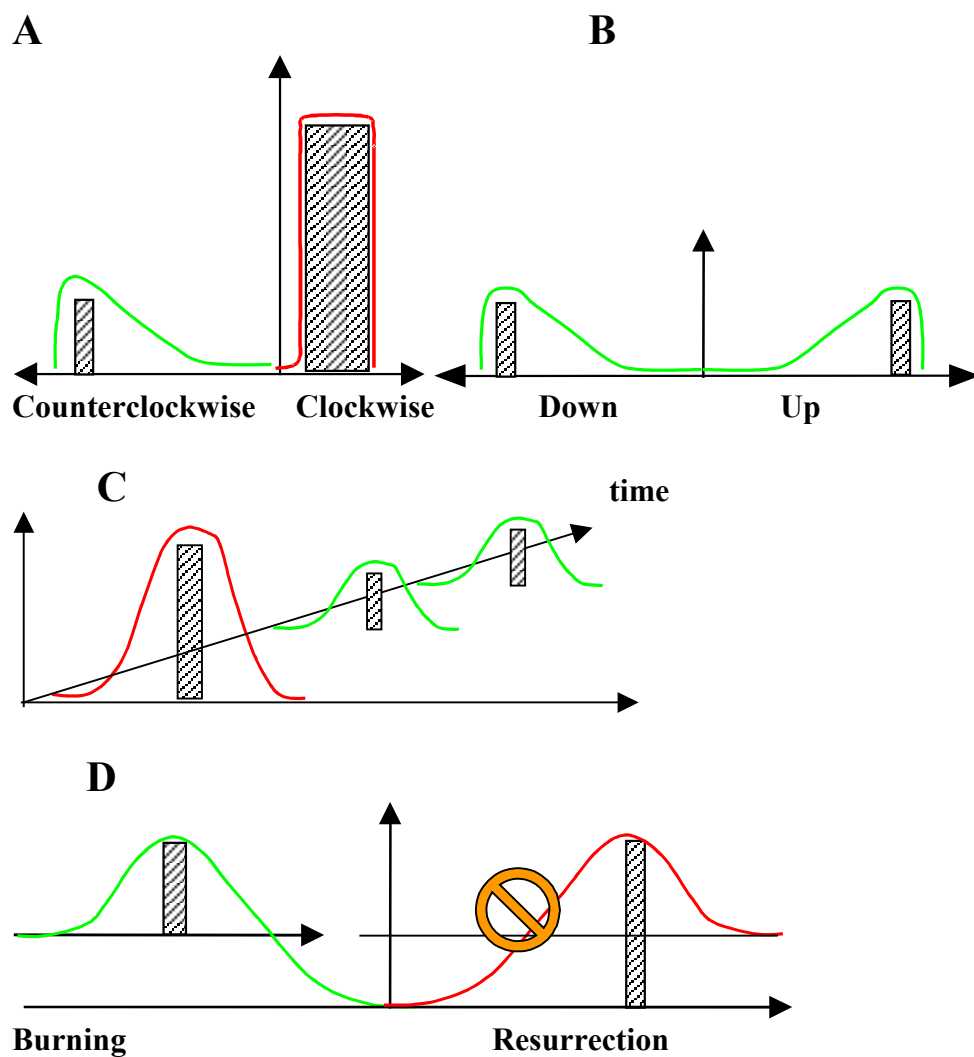
Now we can step aside and watch the zipper from the Archimedean point. We immediately note the master of the zipper, whoever he or she is.

**Why** does the zipper open? Because the final state in the largest possible system, including a human, with bonds to and from the zipper is more stable than the initial state. The human master of the zipper feels relief or satisfaction after having opened it. The tension drops, but it might jump up next moments, if two humans are involved. **The zipper stands as an ideogram** for much larger and more complex X-systems, such as a conflict between two powers over a border incident (easily reversible in principle).

**3. Rusty bolt, Figure 3C** is trickier than it seems. It is **inert** the first time you try to unscrew it, but right after that it can behave like the zipper, unless again abandoned to the elements. I choose it as ideogram for a rejection of new ideas by a majority. Note that the rusty bolt sits tight because of multiple weak (non-covalent) bonds.

Some people display the rusty bolt pattern of behavior: reserved and cautious the first time but friendly and warm afterward. The same pattern can be seen in resistance to new ideas. “Screwed up” is another ideogram, effective in politics and business.

4. **Candle, Figure 3D**, is my favorite example. It is made of paraffin, a mixture of hydrocarbons capable of burning in contact with the oxygen in the air, which means that the **stability** of the candle-air system is low. Its **lability**, however, is also low, so that it can be stored indefinitely, unless ignited, while an iron nail reacts with the same oxygen and turns into rust in a moist atmosphere.



**Figure 4. Transition barriers of: A, ratchet and pawl; B, zipper ; C, rusty bolt; D, burning candle (vulgarized!).**

White phosphorus, as an extreme example, spontaneously ignites in the air and burns brighter than the candle. The red phosphorus is **inert** and does not change if

exposed to air. Both consist of exactly the same atoms, like Dr. Jekyll and Mr. Hyde, only arranged differently.

High stability, therefore, means that the system is inclined to remain in this state no matter what and not to move to less stable states. High lability means that “no matter what” does not matter and the system will move if slightly prodded.

The reason why, unlike the Phoenix bird, the candle cannot be resurrected is that the products of the burning are much more **stable** than the starting candle and oxygen.

The physical-chemical picture behind **stability** and **lability** is rather complex and technical. As far as **lability** is concerned, most chemical transformations are reversible and a dynamic equilibrium establishes between all participants and products of transformation. Natural lability has no ratchet properties. The position of the equilibrium depends on the temperature.

The principal reason for the irreversibility of burning is that the heat of the burning, as well as the gases, are dissipated and dispersed over a large volume. I don't know about the Phoenix birds, but if a hundred sparrows are released from the cage, there is no chance they will come back without a team of skillful catchers.

The candle as ideogram stands for an **unstable inert system in a precarious environment**. It is just a little bit stable that a gasoline can with a matchbox nearby. Today I would associate the intact candle with all nuclear weapons on earth and the burning candle with the process of burning mineral fuel, ignited by the Industrial Revolution. The intact candle is in the initial state of the process and the burning candle is in a long transformation that we can observe in all detail. In the short run, the mineral fuel will be exhausted, but in the long run—we do not know how long—there is a chance that plants and algae will do the job of catching the carbon sparrows, using the sunlight as the source of energy. This is exactly what they have been doing since life emerged on earth. The problem is that the long run of Industrial Revolution is a very short run in the history of biosphere.

The fact of crucial importance is that we are unable of predicting what will happen next. What we call a true historical prediction is a winner in a race between many runners. Of course, somebody with a good record has decent chances. From the human standpoint, pessimism is as justified as optimism. This is a typical example of the openness of X-system. The largest X-system on earth is always pregnant with novelty. All we can say is that some human societies will adapt better to the burning process than others. *Collapse* by Jared Diamond [3C] is, by the way, another example of the Archimedean point taken by an author in a non-technical language.

Answering the call of Hannah Arendt to think about what we are doing, what comes to my mind first is burning the candle at both ends.

I believe that with the above examples of some very general patterns of systems behavior I follow in the steps of René Thom's, *Structural Stability and Morphogenesis*, [7A] see **Figure 5**. What he called archetypal morphologies, I would call ideograms in the sense some Chinese and Egyptian characters are. See [1J]. I regard ideograms as highly compressed, large-grain alternatives to dynamical systems.

I have already used the term **ideogram** several times, but my description (no definitions!) “any symbol for representing abstract ideas” needs some illustrations for symbols other than acoustic, pictorial, or gestural, i.e. verbal. There is a problem, however.

If you decide to venture into the jungles of X-systems, you must be prepared to get immediately lost in the thicket of literature that grows right before your eyes. As soon as you cut through a couple of publications, twenty new ones spring right from the ground or dangle from the branches. Moreover, you have to be prepared to venture into quite disconnected and distant areas of knowledge—as if you were required to speak all languages of the globe and have degrees in all sciences. One cannot do all that without a good deal of ignorance, hubris, and naiveté. Even some respected authors, who use similar terminology and ideas and live in the same period, seem not to notice each other's presence. As a striking example, semantic topologist Leonard Talmy in his vast bibliography misses semantic topologist René Thom and scores of authors writing about

patterns do not even mention Pattern Theory. The excitement, however, is exactly in mapping them all in a compact single image. What helps is gradual triangulation: somebody can see two distant mountain peaks and put them side by side in a single frame. This is how the science of Everything is being built. Formal systems are picket fences around private lots.

The literature on graphic representation (topology, more accurately) of meaning is large, growing, and with little consensus in sight. I include select references at [10]. I am planning to return to this subject and compare the ideas of cognitive semantics (Leonard Talmy) with Pattern Theory (Project **Golem** of Ulf Grenander [5C]).

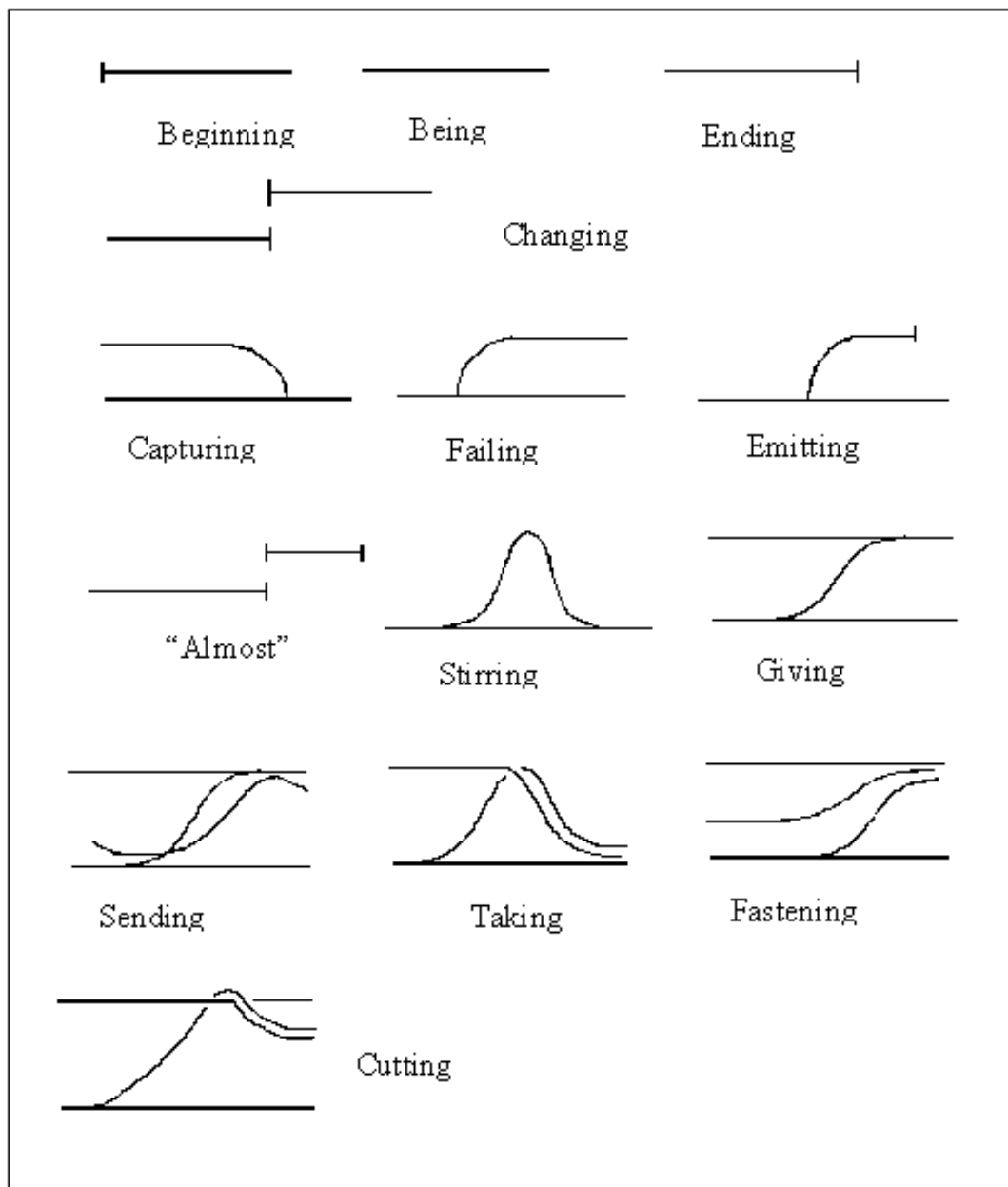
Ulf Grenander designates **content** and **connector** (i.e., structure ) as the two aspects of a **thought configuration**; Leonard Talmy calls **content** and **structure** (i.e., connector) the components of cognitive representation.

Here I limit myself to René Thom as one of the founding fathers—and a martyr—of the subject.

Thom's idea, as I interpret it, was that a graph could represent an essential type of change in the state of a system, which he called a catastrophe. His graphs, however, are pictures and not graphs in mathematical sense. It comes as no surprise because a graph, i.e., simply speaking, a combination of points and connecting lines, is static by its very nature.

Thom's ideas and illustrations are often vague and his text is sometimes a banal chat. I think it is unfortunate that his work of cardinal importance remains unsettled and unfinished, although his ideas were used or emerged independently in linguistics. For more about ideograms and metaphors, see [1C, Chapter 6].

My primary exasperation with Thom is that I see nothing that a chemist would qualify as structure. Ironically, while writing about structural stability and morphogenesis, Thom never actually cared about structure and was indifferent to “material evidence” of making.

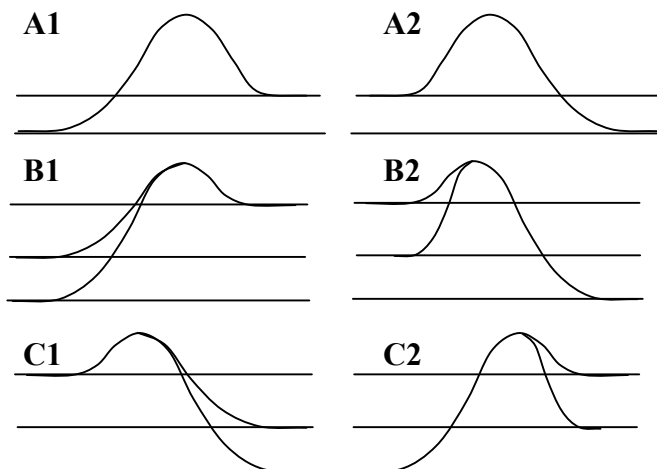


**Figure 5. Abstract patterns of change (archetypal morphologies), along René Thom.**

For real structure as the chemist understands it one should turn to Ulf Grenander.

Notably, only Thom's *fastening* includes three parallel timelines. It would be logical to assign three timelines to all cases with donor, acceptor, and the migrant: giving, taking, and sending.

*Stirring* is the only "one-line" pattern in his René Thom's classification. This is where the closed system fails to open to the novelty of X-systems which never come to the same state. As a chemist, I would interpret Thom's *fastening* as bonding, for example,



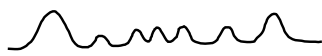
**Figure 6. "Thomist" patterns of abstract change (A), binding (B) and splitting (C).**

which would require a reverse *breakup*. Adding the stability dimension, I would use a *stirring* transition hump in "Thomist" ideograms, see **Figure 6**, for destabilization **A1**, stabilization **A2**, and their combinations in binding **B**, and splitting **C**.

Ulf Grenander's operations of pattern dynamics, ADD, REMOVE, MODIFY, etc., applied

to generators and bond couples, conform to those of chemistry. They include formation and breakup (more generally, modification) of the bond and removal, insertion, and substitution (more generally, modification) of a generator. They all amount to a breakup and formation of a bond, but, unlike anything I am aware of, they accommodate the property of **novelty** which distinguishes the X-systems from the traditional closed ones.

If Thom's patterns are reduced to horizontal timelines of stability alternating with ascending, descending, or hump-like transitions, they will conform to the familiar chemical minimalism. In [1L, Fig. 21.8, p. 284] an irregular stability graph



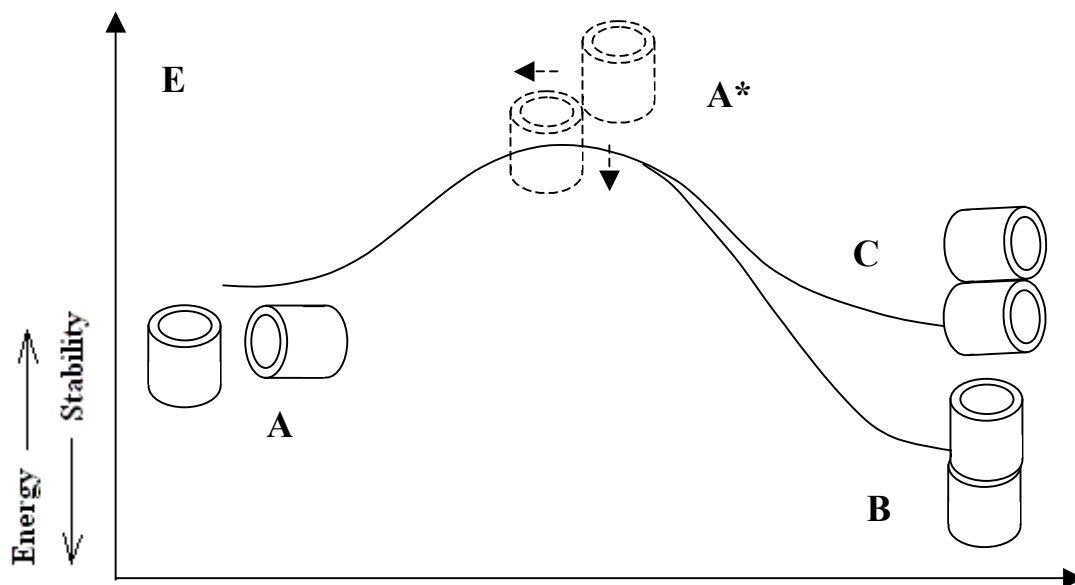
is used to portray the period of French history starting with the French Revolution, the latter itself looking like the back of a stegosaurus



[1L, Fig. 23.1, p. 323].

Coming back to pasta, its “chemical physics” is illustrated in **Figure 7** . The vertical axis corresponds to increasing generalized energy and decreasing stability.

Two pasta cylinders can be disconnected (**A**) and connected (**C**) and (**D**). If the system is “heated” by shaking, a certain equilibrium establishes between all possible mutually convertible more or less **stable** forms. This conversion occurs through a set of very unstable and ephemeral states of mutual reorientation and rearrangement, as, for example, **A\*** . The asterisk emphasizes its transient and both highly unstable and labile character. It can slip (remember? **labile** comes from the Latin for **slip**) toward **C** and **B** or dissociate into **A** .



**Figure 7. Interaction of pasta cylinders.**

We can evaluate stability experimentally by observing the pasta behavior and comparing the average life time of the stable states, as well as of the transition state, depending on the degree of chaos. The transition states are very short living.

The main premise of the theory of transition state in chemistry is that the speed of the transformation from one stable state to another decreases with the height of the transition barrier. For example, the transition barrier from **A** to **C** is a function of the energy difference between **A** and **A\*** .

The exact numbers for X-systems can hardly be available and even if they were, they would be of no importance. What matters is the comparison of a few alternative pathways of transformation. Of course, as Michael Flynn noted in his book, the standardization of the society would drastically simplify predictions.

A uniform, docile society is more predictable, and Theirs [clyologists'] forecasts would be simpler and more precise" [3A, p. 108].

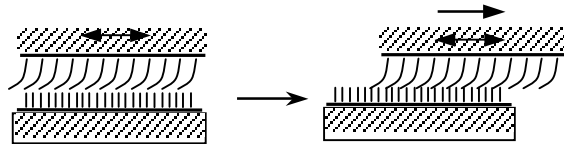
The problem with predicting the future is that you cannot ask whether an event X will happen unless it has already happened. Otherwise you do not have even a name for it. In your imagination you have to invent new chimeras and give them flashy names. This is still an open question whether there are patterns of historical events that cover all foreseeable and relevant future, and I believe that we should find the answer. Imagination, fantasy, and thought experiments are instruments in a laboratory for experimenting with the future. To think takes much less energy than to wage a war or build a sandcastle of a paradise on earth. Imagination is equally necessary for a chemist and for a detective. See [1A].

In order to compare a few scenarios (called mechanisms or pathways in chemistry) we need some criterion to distinguish between more probable and less probable ones. In other words, we need some knowledge about the **preferred direction of events**, and the first step toward this knowledge is the admission that the preference exists. Physics is the science of possible and impossible. The Newtonian apple can fall down but cannot jump up from the ground on its own. Within an X-system, however, it can move against gravity from the ground into the basket. The Newtonian horse can neither stop nor turn on its own. Chemistry is less radical: it is about predicting the outcome of the horse race. History is all about twists and turns.

The following example illustrates a special case of a preferable direction of events.

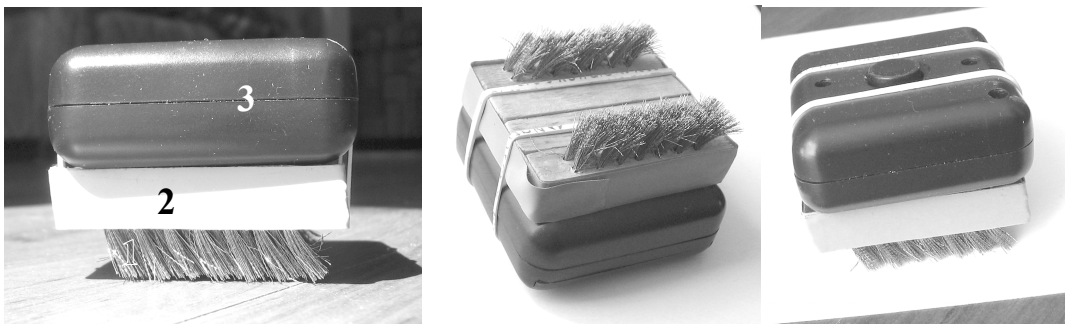
A property of an object is called isotropic if it is the same in any direction and anisotropic if it changes. Animal fur, for example, is smooth in one direction and rough

the wrong way. A wooden board surface is smooth along the grain and rough across. Corduroy fabric is another example of a highly anisotropic surface. If an anisotropic object is placed on a rough surface, chaotic disturbance moves it in the direction of the minimal friction. In **Figure 8**, a brush with orderly bent (anisotropic) bristles is placed on a rough isotropic surface. Chaotic disturbances, symbolized by  $\leftrightarrow$ , result in a sliding of the upper piece in the direction of the least friction.



**Figure 8 Irreversible lability in the case of anisotropic friction**

**Figure 9** presents a photo of a “brushmobile” (not related to Art Dog) capable of moving and even climbing up a slight slope. It has a couple of bent brass wire brushes fixed under a small vibrator.



**Figure 9 Brushmobile. 1, Brush; 2, Platform; 3, Vibrator with a battery inside.**

The working toy model moves because it dissipates the electric energy from the battery, wasting most of it on friction. It also moves without a vibrator if placed on a vibrating surface. On a planet with chaotically vibrating surface the brushmobile could transportation loads against gravity. It embodies an abstract pattern that would be very difficult to symbolize graphically. A simple arrow  $\rightarrow$  does not tell the whole story. This

emergence of regularity from chaos is the long known ratchet effect, widely used in technology, for example, in clockwork mechanism, as well as in cellular mechanics.

NOTE: Readers with background in engineering could compare the brushmobile with the clever **Ultrasonic Motor** (USM), in which the circular movement is generated by an ordered circular wave of mechanical deformation of a surface in contact with another high friction surface. The literature on USM with discussion of anisotropy has been growing and some is on the Web. An USM-like analog of brushmobile could probably work on purely chaotic deformations and jolts, using anisotropic friction.

As it was shown by Richard Feynman, no order can be produced from pure **thermal** chaos, unless the system is far enough from equilibrium. This may seem to contradict the history of technology with human mind as the source of order. We actually produce most of our mechanical work from thermal energy, but only until the system does not come to a halt. On a snapshot, our technology and the global civilization are in a steady state. Over a longer time segment, it is homeostasis, which is different from the steady state because of a series of distinctive transitions. The curves for the French Revolutions on page 34 correspond to homeostasis, not to a steady state. France has been inhaling and exhaling in a perturbed homeostasis ever since the Revolution. America, of course, is not exempt from riding a serpentine bumpy road and turning red, blue, and white in the face.

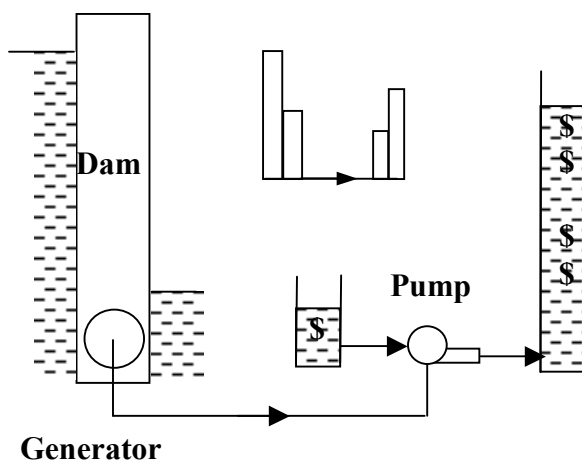
Life on Earth must have come from somewhere. The aggregation of multiple weak labile bonds into strong labile bonds, in my opinion, is the crucial source of order in the genesis of life. We can say the same about the mind, which is essentially a device for perceiving weak but repeating regularities as configurations bunched together into recognizable patterns. This is the same type of process that creates river beds—an analogy noticed by C. H. Waddington, whose term *chreod* was borrowed by Thom. The Grand Canyon, however, would never be possible without gravity which is responsible for the asymmetry of the system.

The precipice between river flow and social evolution seems as deep as the Grand Canyon itself. To bridge it is exactly the point. One of many possible definitions of X-

systems will be “ a system in which the Mississippi Delta (Grand Canyon is too phlegmatic) and social evolution are similar.”

Let us take economy as an example, in which I am an observer, but no expert, however. I privately believe that the machine of economy, starting from ancient times, works as a brushmobile, pumping the distribution of wealth against gravity (entropy) to high inequality in spite of the alleged chaos of individual actions. While the market is chaotic, rent, wages, and profits are as asymmetrical as gravity. The chaos of economy can be compared with a distribution of hail falling from the skies, while the fall is as predetermined as the rise of the kite jerking and wiggling in the wind.

The principle of the machine was described, on a different occasion, in the Bible as “For whosoever hath, to him shall be given, and he shall have more abundance: but whosoever hath not, from him shall be taken away even that he hath.” (Matthew, 13, 12). While the market is chaotic in the sense that deals are not globally coordinated, the sides



are driven by the interplay of the instinct of survival and the instincts of domination and enrichment, both creating **asymmetric friction** to other side's move. Our human nature is openly anisotropic: we **want** to slide in the preferred direction only: up. Even the suicide bomber hopes to ascend to heavens.

**Figure 10. “Wealth pump”**

**Figure 10** (“wealth pump”) metaphorically illustrates the

asymmetry of X-systems from the energy standpoint. Hydroelectric generator is driven by the difference of the water pressure on both sides of the dam. The energy brings into motion the pump which works against the water pressure in two communicating vessels. The entire system consists of two subsystems: the left non-equilibrium subsystem maintains the right one far from equilibrium. If the whole system is insulated, sooner or

later the differences in the levels of liquids will disappear. A more compact symbol for the system is seen in the upper part of **Figure 10**.

To be more specific, the ideogram equally applies to:

1. Production of electric energy from the hydraulic energy of a river or from mineral fuel and its use for work,

2. Production of energy in living systems from sunlight or chemical compounds and using it for maintaining the integrity of the organism which is alive only while it is far from equilibrium.

3. Maintaining the unequal distribution of wealth which characterizes all organized societies, starting at least from the Sumerian civilization. Dollar signs in **Figure 10** symbolize that.

4. The concentration of wealth supports not only the complex system of economics, but also arts and humanities, as well as the form of government, and ideologies, sometimes, conflicting. That was, probably, the underlying idea of Marx.

Ironically, it applies also to moving ratchet devices. As newspapers have recently announced (2006), “the scientists made water flow uphill.” In fact, it was a case of a ratchet effect, [11C], which required a dissipation of heat, falling neatly under the ideogram in **Figure 10**, in the company of the brushmobile and all water pumps in the world.

The difference and interplay between strong (covalent) and weak bonds in chemistry is a separate and very specific subject. More can be found in [1] and, in chemical context, on the Web. It is very meaningful in social context. People in the West are sometimes surprised by the tolerance of the millions of Muslims to the terrorism of Muslims against other Muslims. They were also surprised by the patience of the Soviet people toward the Communist dictatorship. I believe it is a rewarding subject to investigate in terms of the strength and multiplicity of social bonds in different societies.

Freedom is a few (or even none) strong bonds in the sea of fleeting lability. Tribal and repressed societies, under the watchful eyes of rituals, have little lability and a lot of strong bonds.

According to Darwinism, the deep nature of evolution is chaotic. This may be true at a microscopic level, but there is a deep asymmetry on a higher level: the species adapt in order to go on with living, not to collapse. The movie *The March of the Penguins* is a heartbreaking illustration how far the adaptation can go. As the brushmobile moves only forward, the species move only toward procreation and normally not to self-destruction.

Along our contemporary views, which might be possibly disputed, plants do not possess any mind. The source of order for the plants is the sunlight, which is, unlike heat, an ordered form of energy. But how could life originate in the absence of mind or just human—or even animal--nature? I believe that the formation of multiple weak bonds is an example of purely chemical and, of course, mindless irreversibility. Each **new** weak bond in the course of prebiotic contributes to the overall coherence and adhesion of the system. Because it immediately rises the threshold of solidity of the system.

Taking another example, once a religion takes a canonical shape, it is extremely difficult to take it apart and rearrange: it is hold together by a large number of cross-references. Still, it is possible, as reformist religions demonstrate.

The weak labile bonds, like those governing the behavior of the cooked pasta, are the very beginning of the genesis of evolution. But this is not the whole chemical story, for which one should better look into chemistry. In a nutshell, strong chemical bonds are typically inert. They do not dissociate easily into disconnected atoms ( $A-B \rightleftharpoons A + B$ ), which is highly unstable, but rearrange in such a way ( $A-B + C-D \rightleftharpoons A-C + B-D$ ) that the overall change of stability is relatively small. If we were built with weak bonds only, we would dissolve in a bathtub. We can say that a strong bond is labile if the quartet-like rearrangement runs fast, which is usually done by a catalyst, whether in a social or biochemical system, by decreasing the transition barrier. In social X-systems the catalyst is what Hannah Arendt called *homo faber*, man the maker, the term Thom also used.

Similar to the chemistry of life, the social and political chemistry consists of the interplay between the weak labile bonds, which lock and break by the hour, and strong inert bonds of allegiance to family, tribe, institution, or party, which can nevertheless be broken in an act of exchange, exemplified by a love affair, divorce, treason, or just

changing employment. In spite of all declarations of individualism, the modern human is extremely unstable in social isolation, so that the true meaning of individualism is lability, not stability.

Can the immense and ever growing concentration of global capital prepare the soil for the seeds for Michael Flynn's cliology? Can a few world tribes inhabiting the small impoverished planet be a plausible future? Is the American Empire doomed to cede its position of domination to another empire? Words, words, words again. But the question mark is half the answer. Nothing like that has ever happened, but each possibility is an alternative stable state. Anything can happen. We have to understand that what is most probably going to happen is what can happen faster. Whether we can list all possible final states is an open question in an incomplete system of knowledge. I believe that we cannot, but I do not believe we can ever have a proof one way or the other and I do not believe we can have a proof that we can or cannot have a proof, etc. Aristotelian logic is novelty-blind. We can play, however, with a Lego set of building blocks, constructing and testing various alternatives for initial, final, and transition states, checking them against a partially ordered scale of stability for a line-up. This is exactly what Sci-Fi is doing, following in the steps of a chemist who plays various chemical scenarios and compares the configurations—stable and unstable—by energy.

Ulf Grenander has always been a keen observer of the world behind the windows and, as his books testify, a real connoisseur and navigator of Everything. In [1M], he and I (also in [1B]) made an attempt to try on the conceptual goggles of Pattern Theory and look through them into the past. Alas, vision, unlike sound, does not generate an echo. But we have all the time ahead. It is my impression that the skeleton of the past history can be clearly seen in the double-locked cupboard of the future, but the second key is available only to professional historians.

Next, I would like to summarize the main lesson extractable from cooking pasta and driving brushmobile. It seems that there is no connection unless we regard both cases as configurations covered by the pattern of irreversible non-equilibrium process. The two

processes themselves are strikingly different—mechanical movement and growth of complexity—but both require supply of energy to keep them off equilibrium.

In order to descend somewhat from the dizzying heights of abstraction, we need to point to the source of non-equilibrium for the primordial pasta, i.e. , the natural analog of shaking. I believe that this meta-shaking came from periodic change of tide, day and night, weather, and seasons that kept all slow chemical processes at a constant non-equilibrium because the position of equilibrium depends on temperature and concentration. This could be possible only if the rate of primordial chemical reactions was slower than the rate of the change of conditions. The situation can be compared with the contest of a hare and a tortoise moving back and forth between two points: they would never be side by side except for very short moments.

In the end, as an example of a **possible** alternative pattern of further long run course of history, I am submitting my strictly personal view. Please note the blocks of the mental configuration.

From the point of view of a chemist life originates because chemistry is slower than astronomy. Life evolves further because the slow rate of chemical reactions makes catalysis—highly selective acceleration of some of them—a powerful source of order. Life increases complexity because multiple labile bonds hold together large aggregates. Society continues the work of life in the same vein, with *homo faber* in the role of a catalyst and mineral fuel instead of sun. The next step is open to imagination. I personally believe that today man-made things are the dominating component of the new civilization, money shines as the eternal Sun, and the human being is more *faber* than *homo*, more enzyme than DNA. If the resources of mineral fuel are depleted, sun-powered Things have an evolutionary advantage over heavy, errant, and voracious humans who, with their liquid-filled heads, will remain as a source of chaos necessary for further adaptation through mutating social DNA. Biosphere, formerly dominated by life, then by social life, then by exploding ideas, turns into technosphere.

I wish to draw attention that what is stable today may not be stable at changing conditions. The fate of the brushmobile individualism strongly depends on the quality of the batteries and if you are low on energy, the king or a feudal lord may take you as a vassal. Or you are welcome to earn your pasta dinner as a laborer—if the nation's batteries are almost dead. The global change from monarchy and conformism to democracy and individualism was done on mineral fuel. At some stage of resource depletion the trend could be reversed.

Purely intuitively I see the ongoing concentration and consolidation of capital as the first stage of involution.

The guns speak when the national batteries are low, and when they speak the muses are silent, mathematicians work on weapons, and philosophers are hunkering down in the trenches.

## CONCLUSION

A scattered array of talking points and a few making points amount to the following main **hypotheses**.

1. As the century of debates testifies, the traditional formal (axiomatically closed) physical and mathematical theories have little power over Evolving Complex Systems (X-systems) because such theories are devoid of the notion of **novelty**. The X-system changes while we speak and should be analyzed in terms of novelty and difference.

2. Understanding of an X-system in terms of novelty might be possible while a larger X-system remains stable.

3. Understanding of an X-system might be possible in a standard—but expandable—set of **ideograms** (generalized metaphors) that symbolize their most abstract properties.

4. The standardization of language and a consensus regarding the ideograms might be achieved by evaluating them along their complexity.

5. Complexity of the abstract space housing the X-system might be a more appropriate measure for an X-system than the complexity of objects and states. From this point of view, **evolution is expansion (or collapse) of the generator space.**

6. Configuration space of Pattern Theory is an example of an open space housing the structures from molecules to thoughts and with a measure of stability.

7. The main task in understanding X-systems is to shift the emphasis from thermodynamics to **kinetics**. This can be done, following the pattern of chemistry, by comparing alternative transition states.

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The advent of the Web is changing the playgrounds where ideas frolic, mate, and multiply. The Web does not make the landscape flatter, just the opposite: one can fall through the cracks in the constantly shifting and swelling geological maze. In order to get out of the crevice, one would need a tug of a crew of links. The Web, however, has a **kinetic** advantage: it brings you to a distant planet in a few clicks, and then it is up to you whether to dig in or immediately leave.

If the topic is X-systems, one can have nine lives and still be unable to catch up with the literature.

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