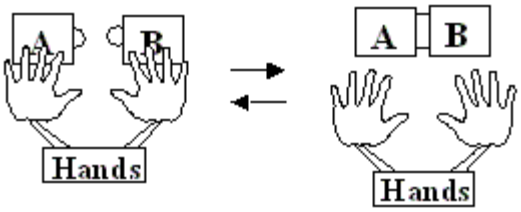


Yuri Tarnopolsky

The Visible Hands

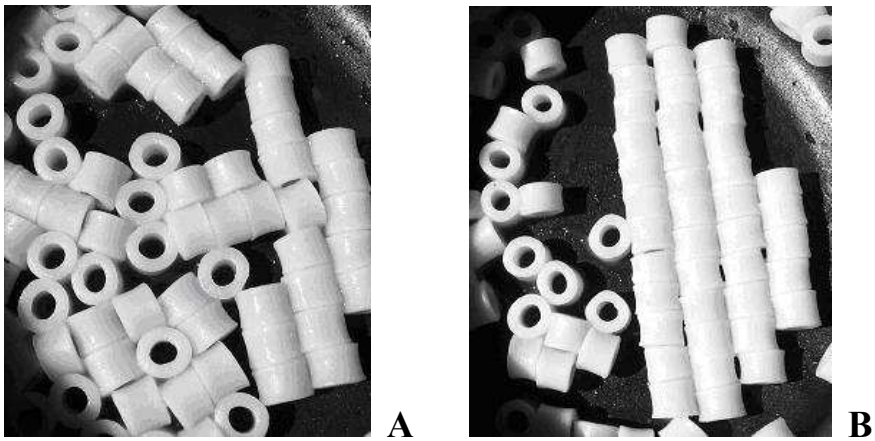
Homo Faber and the Chemistry of History

ABSTRACT

Studies of evolving complex systems (X-systems)—organic life, society, language, mind, culture, technology, ideology, science, art, politics, economics—do not have a common language either between themselves or with any particular natural science. This essay continues the search (at http://spiropero.net/complexity.htm) for a common interdisciplinary language for understanding X-system, using the paradigm of Pattern Theory (Ulf Grenander) as generalized chemistry and emphasizing the kinetic aspects. The semantic units for this language are labeled as **ideograms**. From this angle, Hannah Arendt's *homo faber* is seen side by side with chemical catalysis and Werner Heisenberg's casual remarks on technology as large scale biological system are extrapolated on the double function of *homo faber* as source of both kinetic chaos and catalytic order in the X-system of technological civilization.

1 BACKGROUND

This essay continues the search for a common interdisciplinary language to understand evolving complex systems (X-systems: organic life, society, language, mind, culture, technology, ideology, science, art, politics, economics) at ***complexity*** [1A] and tightly hooks up to *The Rusty Bolts of Complexity: Ideograms for Evolving Complex Systems* [1B]. **Figure 1** in *The Rusty Bolts* is the starting reference point, from which photos **1D** and **1E** are reproduced here as **Figure 1A** and **B.**



A **B**

Figure 1. Configurations of cooked ditalini pasta generated by shaking (A) and work of *homo faber* (B).

Earlier I suggested the term **ideogram** for common patterns of structure and behavior of X-systems. The concept of the ideogram, not yet finalized, stems from two sources: topological "archetypal morphologies" of René Thom and patterns of Ulf Grenander. The original meaning of ideogram is graphical symbol that represents an idea, but its validity in linguistics has been practically lost (linguistics is a real pandemonium of arguments), which brings the term, so to speak, in the public domain. The meaning I attribute to the term is closer to: **idea that can be represented by a symbol**. Examples were considered in [1B]. Here chemical catalysis and *homo faber* of Hannah Arendt are discussed as an ideogram symbolized by "hands."

2 SELF-ASSEMBLY

In **Figure 1** the left photo (**A**) registers organized tubular clusters of cooked and drained ditalini pasta cylinders resulted from shaking the pan, which is supposed to imitate "natural" kinetic chaos. The right photo (**B**) shows a much more organized "raft" cluster produced by deliberate hand movements. In either case my **hands** were the source of both chaotic and organized movements. My **mind** had **analyzed** the **configuration** on the left and **used** the **pattern** to **create configuration** on the right.

The **self-assembly** of parts into large regular conglomerates, seen in **Figure 1A**, is well known in various fields of science and under different names [2]. It is widely discussed, used, and is responsible for intimate mechanisms of organic life, as well as for some areas of technology. Formations of crystals from molecules, viruses from components, and self-assembly experiments in the kitchen [2B] are some landmark examples. They are, however, outside the X-system of main interest for me, i.e., social evolution and, especially, assembly and separation by human intent, which was called **craft** (τέχνη, tekhnē) by Ancient Greeks, **work** by Hannah Arendt, and, I believe, is **technology** for majority of modern writers. Plato regarded legislative politics as a kind of craft, too. Did he anticipate the political business in America today, based on refined technology and managed by professionals?

The self-assembly takes hold when the local interactions make the whole more stable than scattered parts and the intensity of spontaneous chaos (i.e., temperature) stays within a certain rather narrow interval.

In Pattern Theory (PT, [3]), **configuration** can be regarded by a chemist as a self-assembly from **generators**. Of course, PT is an abstract mathematical discipline, but for a chemist it is strikingly realistic. Ulf Grenander listed realism among the four main principles of PT, along with atomism combinatorial principle, and observability, [3D, Volume 3, pp. 63-83]. It is the metric properties of PT, however, which turn an abstract theory into an actual real dynamic system open to novelty and growth of complexity. In metric PT, probabilities or **energies** are attributed to interactions between generators, introducing thermodynamics, and, potentially, kinetics. In this sense PT is a theory of Everything, including histories. René Thom, on the contrary, seemed to ignore structure.

If the left photo shows self-assembly and the right one shows assembly, what is the difference? The right photo is also self-assembly in the system including the cooking pan and myself. I could say that the second system has a long history, but the history of the first system is as long because I designed the experiment. I could say that the assembly in a complete absence of human participation is true self-assembly, but this is a tautology. My firmer answer is that in the second photo I played the role of a catalyst and thus accelerated an event that could happen anyway, maybe after a year or two of shaking. At the same time I suspect (together with Werner Heisenberg and Hannah Arendt) that there are questions that make little sense.

3 COMPLEXITY OR REGULARITY?

The photos illustrate the case of structural regularity emerging from chaotic or ordered motion guided by local interactions. The natural growth of regularity in **Figure 1A** is amplified and accelerated in **1B** by my **human work** controlled by the stored and

mutable information about the **natural** structural pattern. If we attribute this summarized description to a universal launching mechanism of evolving complex systems (X-systems), the two photos are, in a sense, an ideogram of the border strip between an organism and the mind. In a more formulaic language, borrowed from Pattern Theory, **local interactions** of **generators lead** to reproducible **patterns**. The terms in bold font do not contain anything specifically human. The ability to **analyze** the pattern, **memorize** its **template,** and **catalyze** its **expression** leads to **amplification** and **acceleration** of evolving **complexity**. In the previous sentence, only **analyze** sounds as a human prerogative, but animals and machines can do it as well.

Complexity is understood in [1A,B] and here as the size of the configuration space. While we cannot measure the absolute complexity of an X-system with unknown history, we can evaluate its increase or decrease for a particular step of evolution. Complexity, however, does not tell us all about the system. Regularity matters as much. Since the building blocs do not change, complexity remains the same in both photos, but regularity increases.

The clock is a simple regular system. The solar system and computer are complex and regular. I am not quite certain, but an atom of a radioactive element is simple and irregular. Complexity is extensive and regularity is intensive. X-systems are complex and partially regular. More importantly, their complexity and regularity change with time and depend on the flow of energy. There is no consensus in treating this issue, however.

My references to chemistry here should not be given too much trust. Some important and indispensable for a chemist details of catalysis are omitted throughout this essay, but they could be found on the Web.

"*Homo faber,"* man the maker, refers to the discussion of the creative instrumental function of man in Hannah Arendt's *The Human Condition* [4A,B]. Werner Heisenberg, to whom Arendt refers in her book on various occasions, regarded technology, i.e. the activity of *homo faber*, as a "large-scale biological process," increasingly escaping human control [5A]. I prefer to use the term **X-system** for anything that looks like a "large-scale biological process."

4 LOW MAN ON THE TOTEM POLE?

Half century after Heisenberg, anything large-scale is called global. For the first time, the globe, long adapted to earthquake, flood, pestilence, and bloodshed, awakens between Scylla and Charybdis genetically engineered by the Industrial Revolution: shortage of fuel to burn and shortage of the capacity of the globe to assimilate the products of burning. While people, most probably, will adapt to the new reality (Green Revolution next?), the true meaning of the reality is that life is, in fact, an X-system that includes earth's crust, atmosphere, and everything contained between them: biosphere, noosphere, and technosphere. Gaia is not a hypothesis anymore. We can debate, however, the place of *homo sapience* in this global labyrinth of nested dolls.

Explaining today the divergence of chimps and humans from the common ancestor, a journalist on Public Radio turns to the analogy with the origin of Ford Mustang and Thunderbird from Model T, biochemists use the analogy with money to explain the role of ATP (Adenosine Triphosphate), and Richard Dawkins' *meme* brings culture in the realm of generalized life. In our time the idea that evolution of technology runs along the same pattern as evolution of life seems natural. Technology is as much a form of life as animals and plants. But are we at the steering wheal or technology is going to run us over?

The destiny of man in technological civilization is a topic of a whole sedimentary rock plateau [6C, 11] of mostly pessimistic papers, books, and sci-fi movies, among which works of Langdon Winner [6] rise above the surface. The original warnings of Norbert Wiener (1894-1964) are already buried deep, with the doubts of H. G. Wells (1866-1946) and optimism of Jules Verne (1828-1905) lying, consecutively, even deeper. Of course, the Colorado River of not metaphorical but real money cheerfully cuts through all the gloom and doom, as unstoppable as time.

Concerning rivers, we have already left Hannah Arendt (1906-1975) and Werner Heisenberg (1901-1976) upstream, behind the bend of the river of time. Indigenous to a different era, immediately preceding ours, they had witnessed the very beginning of the

transition to a new evolutionary turn and made some concise but weighty remarks on what was coming.

> NOTE. What makes the Arendt-Heisenberg era so different from the era of the post-WWII generation? I am convinced that TV was the watershed. The post-computer generation will be even more different. After TV imposed itself as a surrogate of perception, the computer barged in as a surrogate of action. This is, however, a separate topic.

My own generation, gradually settling along the same river, may have a spectrum of opinions about what is coming, but history is a natural process and as such is no more bad or good than a chemical reaction, weather, or digestion. Distinction between good and bad, joy and anguish, fear and confidence is what makes us individuals rebelling under the yoke of the laws of nature. If we want to understand the world, however, we should take the Archimedean point, far from the Earth, and look at our own passions as at the light of a long dead star. Naturally, it is a wishful thinking.

I am not a social critic, but I have my own instinctive preferences. In order to reconcile fatalism with activism, I try to think not in absolute values but in measurable differences and trends, as it habitual for chemists. I believe that we should know whether a trend is accelerating or slowing down, an attribute is increasing or weakening, but whether it is good or bad is the right of an individual to decide at his or her leisure.

Hannah Arendt, in her essay *The Conquest of Space and the Stature of Man* came to the conclusion, that Heisenberg's large-scale biological system would substitute "formalism of mathematical signs" for speech and everyday language [4B, p 279]. She ended her essay as follows:

> The conquest of space and the science that made it possible have come perilously close to this point. If they ever should reach it in earnest, the stature of man would not simply be lowered by all standards we know of, but have been destroyed.

Instead of using emotional and nostalgic language, I would prefer to find the exact position of man in the picture of the world, not as linear as the totem pole, but consisting, nevertheless, of distinctive images, which I call ideograms: raven, whale, beaver, and other actors of the evolutionary play.

5 WHAT IS SIMPLICITY?

Reading Hannah Arendt, I found an excuse for my incorrigible habit of starting from afar: I instinctively try to take an Archimedean point (Arendt's term), so that I could see my subject from afar, against an ample backdrop of environment and history, from which my own presence would be cut out. What I see in **Figure 1** is just a faceless—and **with invisible hands**—*homo faber* in two roles: source of chaotic motion and source of ordered motion. In both photos, remarkably, order seems to be created, although of different degree: the cylinders of pasta stick together on a hard flat surface, forming tubular structures, instead of being arranged at random in the plane.

Approaching the subject as a chemist, I see life larger than lifestyles of organisms and chemistry larger than the intimate habits of molecules. Chemistry is about thermodynamics and kinetics of structure, which is donated by physics. Unlike physics, however, chemistry deals with enormous combinatorial space of individual structures. The following comparison seems to me appropriate: the space of all molecules and their transformations is comparable with the combinatorial space of all phrases of a language and all conversations in this language. Two things are specifically chemical: first, there are correct, less correct, incorrect, and senseless conversations. Second, there are overheard and recorded, highly probable, easily imaginable, fictional, and impossible conversations. (Test: place *Waiting for Godot* on both scales).

Ultimately, chemistry off the lab bench is about two things:

(1) Compiling a small set of most probable alternative outcomes in the form of configurations and

(2) Narrowing it down to the even smaller set of the fastest outcomes at particular conditions.

Coming to the bench, the chemist triggers a chain of planned events and compares results with expectations, in which the chemist is no different from any experimental scientist or, for that matter, politician.

If in such description chemistry sounds like a political strategy or mission to Mars, this is exactly the sound that I am trying to amplify. Any planning—even in private life—is always an exercise in experimental futurology, often disastrous in spite of very rational analysis.

Both the chemist and the politician have various mean to control the course of events, while the director of the Mars mission has only limited ability to do so. Control, however, loses meaning in an X-system, which could even be a definition of the latter. One reason for that is that the source of control is always part of the system. We can control only simple systems, which, again, could be a definition of simplicity, if one is interested in definitions. Anything that allows for a clear definition is simple, if not trivial. It would make a far away digression to discuss this here, however. Here is an interesting remark of Ulf Grenander [3D,Volume 3, p. 454]:

> Wittgenstein is often as obscure as he is thought provoking, perhaps intentionally so. When he speaks of "things" for example. it is not clear if these are material objects or, say, sensory data.

Complexity, which, as I believe was Wittgenstein's ambition, cannot be understood within an axiomatic and logically closed system. But what about the simple systems that can be controlled? Any local subsystem is small and can be approximated as simple. Thus, catalyst and *homo faber* can control what is in their immediate topological neighborhood of the systemic configuration. Next I would try to portray them with **visible hands**.

6 THE LORD OF FLIES

For many years I have been captivated by the **similarity** between the roles of man in the modern industrial system, machine in technology, enzyme in the living cell, and personality in history. I have addressed catalysis many times in [1]. Next I am going to look at *homo faber* through a chemical lens, as another take at the often misunderstood subject of universal relevance.

Catalyst is a major ideogram of X-systems, for which the label "hands" seems to me appropriate. The hands selectively and repeatedly connect previously separate things or separate previously connected ones, thus forming a triangular arrangement. So does—in a sense—the catalyst. Hannah Arendt's analysis of instrumental work for the sake of the product as distinct from life-sustaining labor is complicated and circular, which she seems to feel herself. In what sense catalyst and *homo faber* are configurations under the same pattern is a much simpler task. Ideogram "hands" applies to a triangular pattern in **Figure 2K**, in which the initial and the final states differ in a single bond.

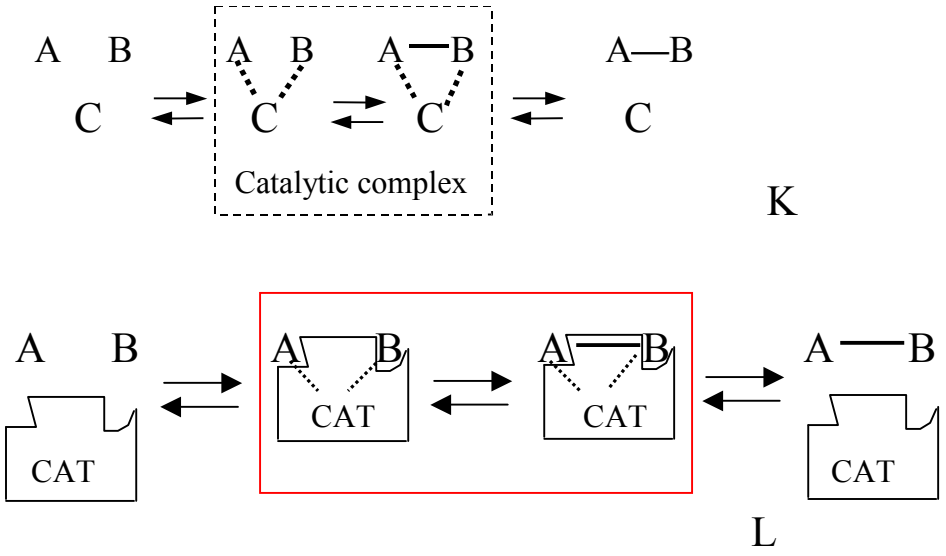


Figure 2. **Catalysis in less (K) and more (L) detailed versions.**

Suppose, a chemical system consists of a very **large number of A and B**. The chemical catalyst participates in converting (A , B) into A—B and back in reversible stages. Whether we start with (A , B) or A—B , the catalyst will speed up the movement to the state of equilibrium which depends on the relative stabilities of formation of (A , B) and A—B. If we have only **one of each A and B**, the average times in each state will correspond to stabilities in the same fashion. This happens because the catalyst increases stability of the transition state, which remains low enough, so that it cannot be isolated. The catalyst, in other words, selectively expands the **bottleneck** (which is another ideogram) between the two stable states.

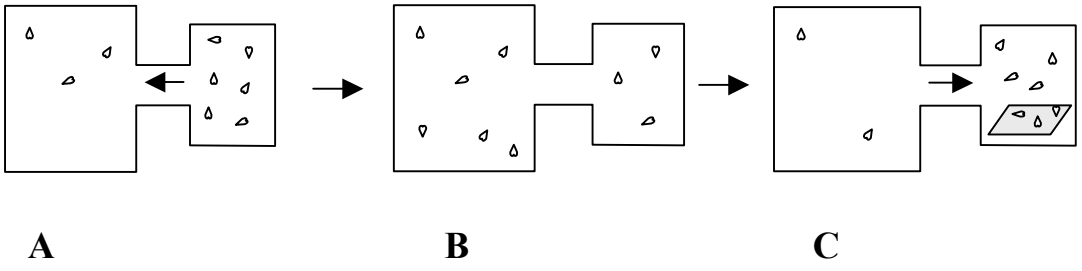


Figure 3. Movement to equilibrium (A), equilibrium (B), and shift of equilibrium (C) in the system with flies in two compartments.

The concept of equilibrium is illustrated in **Figure 3**, depicting two chambers, connected with a passage, with a number of flies inside. If we start with the state A , the flies gradually, by moving back and forth between the chambers, arrive at an equilibrium distribution at B, according to their biology and individual interactions. If we insert food in a chamber, as in **C**, the equilibrium will shift. The food, however, is not a catalyst, but an equilibrium shift, the change of the system itself that redistributes stability between the states in equilibrium. To illustrate the case of catalysis, for example, we would need to have two species of flies in the system and invent some device to increase the passage for only one species of flies. I hope this gives an idea of the unique mysterious power of catalysis in the role of the Lord of Flies. Catalysis is an instrument of discrimination whether in the form of prejudice (negative catalysis, inhibition) or affirmative action (a euphemism for discrimination but possibly a positive social catalyst).

7 TO BRIBE OR NOT TO BRIBE?

Here we come to the two major means of control in chemistry and organic life: **thermodynamic** control (shift of equilibrium) and **kinetic** control (selective change of speed). People might not be aware that the same mechanisms are employed in social and political control, as well as in large historical events out of control, for example, the great global migration of people and jobs in our time or just the one-way flow of people across the US-Mexican border. Thus, with an awful degree of simplification, the intensification of a hunt for illegal immigrants looks like thermodynamic control by a honey trap, while the punishment for illegal employers is typical negative catalysis, although both may lead to a less stable and more stressed state. In both cases, new equilibrium will be established, but note that those will be different equilibriums because of different conditions.

Whatever I say, however, do not believe me if I treat people as molecules, unless you are from the Andromeda Galaxy. X-systems never come to global equilibrium, although local equilibrium can exist for some time. They can be in the state of homeostasis, which, again, is not the same as steady state in physics and chemistry. For more about homeostasis, see [1] and the Web. Homeostasis is the global complement of the classical local Darwinism of mutation and selection. I will come back to it later.

Taking other examples, the immigration discrimination in favor of educated or wealthy professionals is also a catalysis of affirmative action type. It speeds up the drive to equilibrium. Attractive salary for rare specialists is an equilibrium shift (honey trap) because it does not discriminate between competitors. Ideally, neither does exploitation of foreign labor. Bureaucracy is a global thermodynamic freeze that can be selectively overcome by 100% catalytic connections and bribes. Severe punishment for bribe is thermodynamic control. The use of undercover agents looks like a local catalyst: you can wait for the crook to make a mistake or you can speed it up. Tax incentive or burden is a shift of equilibrium. Preferred (or discouraging) treatment of competitors is catalysis (or inhibition).

There is no catalysis without selectivity and no selectivity without competition. Equilibrium, however, is not selective: it applies globally to the fluid enough system.

Organic life, society, and economy operate by both equilibrium shift and catalysis. I omit here the factor of temperature, which is the third, although inconvenient, means of chemical control.

More examples: by manipulating the interest rate, Federal Reserve employs thermodynamic control; by tax cuts for efficient use of energy, the government employs kinetic control, until saturation comes.

My interpretation of the above examples cannot claim any validity. All of my statements should be turned into questions. A search for my mistakes can be a useful exercise. But the questions, I believe, will make sense.

Thermodynamic and kinetic factors are necessary for understanding X-systems, although only professionals can talk about them reasonably, but they are not sufficient. History is not chemistry because organic life and human society develop by design patterns, so to speak, or archetypal abstract devices, which do not follow from any physical laws. Some examples of such abstract design patterns, which I call ideograms, were given in [1B]: zipper, ratchet, pasta (multiple weak bonds), pump, brushmobile. They all, together with René Thom morphologies [1B], have roots not in thermodynamics but in topology. I am not qualified to follow the roots to that depth, but I believe that they go even deeper to Plato. One day somebody will extract them to his or her deep satisfaction which only the depth can give.

I am aware of only one work on "topological evolution" [10], but not competent to comment on it. Anything that cannot be presented in terms of points, lines, and **interactions between the points** (which I don't see how topology can judge) is far from chemistry. Topology is blind to metrics, but if PT were not metrical, it would be just a version of graph theory.

8 HANDS ON

Figure 4 presents some examples of abstract catalysis, sharing the same ideogram.

The first line from the top, **Figure 4K**, presents a case of chemical catalysis. Chemical bonds are often formed or broken indirectly via a four-point exchange:

$$A—x + B—y \leftrightarrows A—B + x—y$$

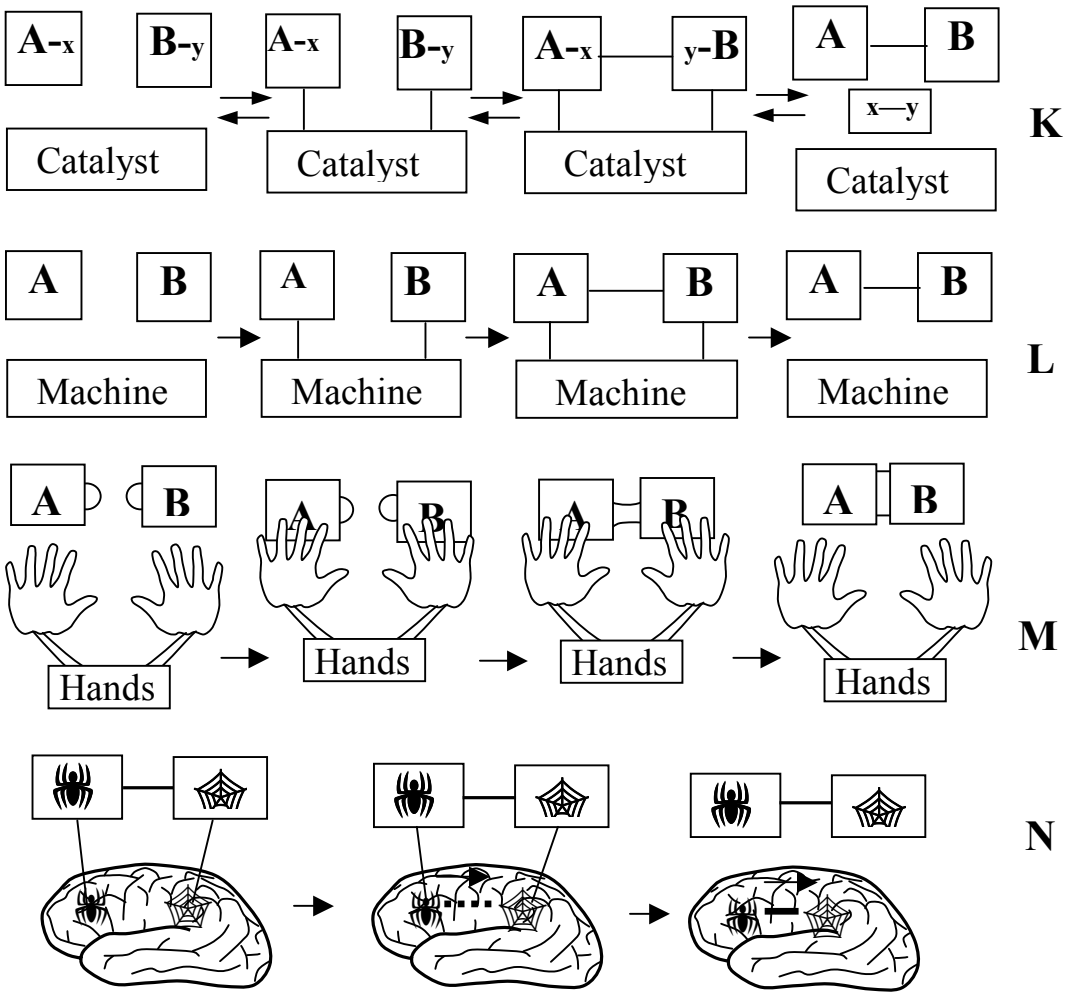


Figure 4. Examples of abstract catalysis: chemistry (K), machine (L), hands of *homo faber* (M) , brain (N).

The chemical catalyst forms catalytic complex through direct bonding with its substrate A—x and B—y. The substrate rearranges into A—B and x—y. The catalyst separates from the transformed substrate. All stages of this mechanism are reversible.

Figure 4L substitutes machine for catalyst. This could be, for example, a machine for irreversibly capping bottles, with A for caps and B for bottles.

The **hands** participate in gluing two pieces **A** and **B** together (**Figure 4M**). This is the closest symbolism to Hannah Arendt's *homo faber*: man the maker.

The simultaneously observed spider and its web catalyze a connection between their images in the **brain (Figure 4N).**

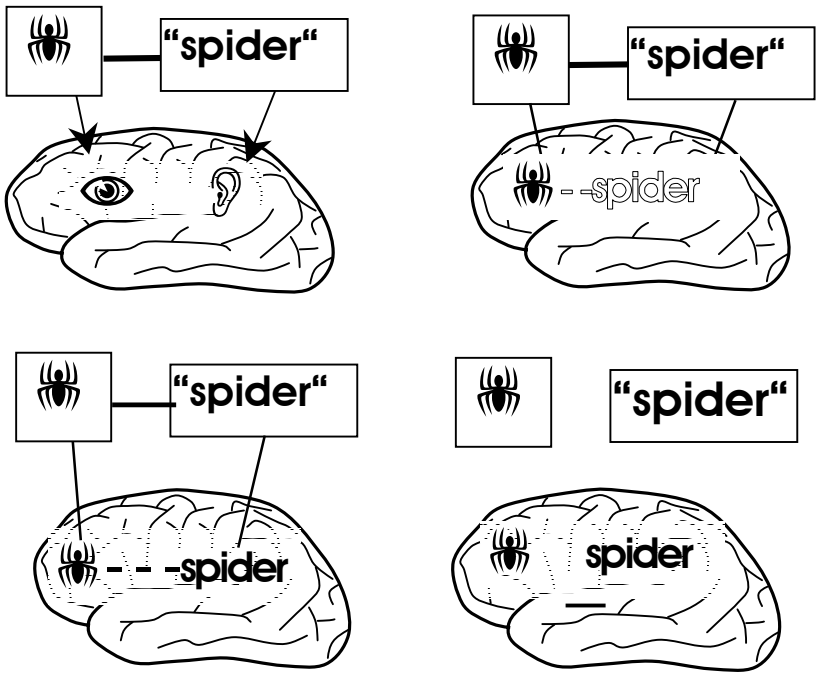


Figure 5. An episode of word acquisition

Of all examples only the chemical catalysis is reversible. The **hands** and properly designed **machines** can also perform reversible operations, as with **A** and **B** for the nut and bolt. The connection cannot be reversed, however, without separate commands for connecting and disconnecting. A bond in the brain cannot be undone by command, but it can be manipulated. The frequency of message shifts the equilibrium. The content can be a catalyst.

To the above examples I would add the Plato's view of building a political system as craftsmanship.

Powerful and sophisticated political machines are involved in modern American elections. Since patents for political design are not yet issued, the theory is no secret and the contest is largely reduced to the amount of money pumped into the machine. It is extremely important, however, that the commands are issued by humans, whose liquid brains are prone to fluctuations, so that the political contest includes the contest of money as much as the contest of mistakes. The function of the American political machine is to catalyze the binding of the voter to one of two candidate, as in the mating rituals of large animals but with more bluff and fluff.

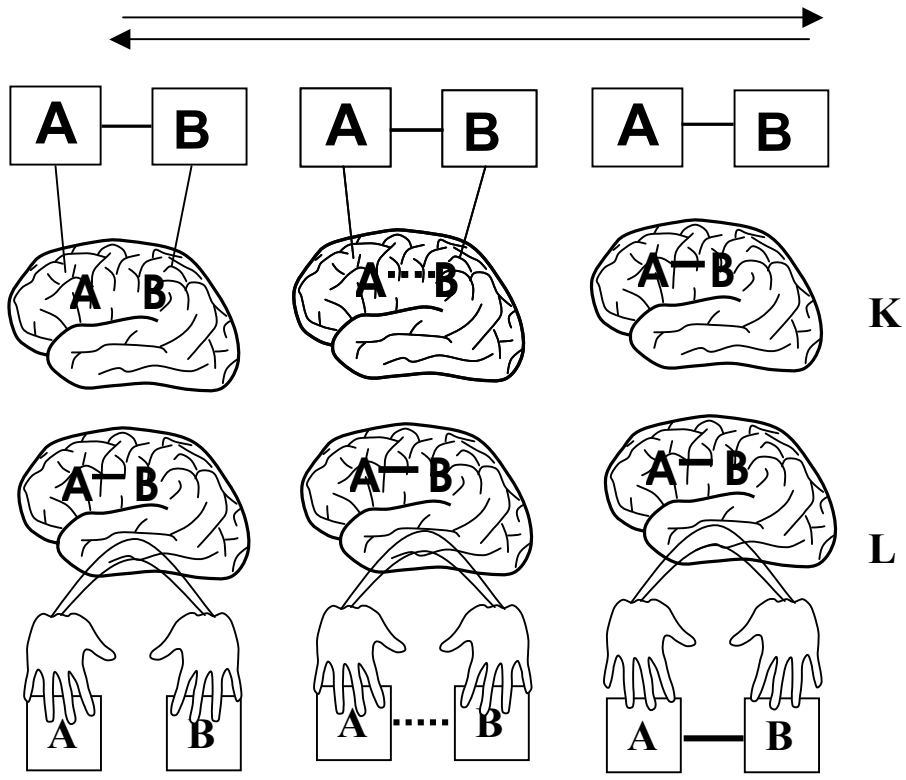


Figure 6. Learning (K) and making (L) in the mind of *homo faber*

Next example in **Figure 5** illustrates the formation of the bond between image and sound, as in language acquisition. Here the brain is not a catalyst but a substrate, while the closeness of image and sound ("time bond") performs the catalytic function.

Figure 6K presents the mind first in the role of a substrate, as in Figure 5, and then (**L**) as a catalyst for work on an external substrate. Note the reversibility of learning: you can be taught to either love the Big Brother or hate him in any order. While our brain can forget only spontaneously, the mind can unlearn under instruction. The brain can be controlled only as much as any other organ in the body, while the mind is a double-edge learning/control machine. The brain physiology is based on molecular chemistry, while mind functions as a generalized X-system.

9 CHEMISTRY AND INDIVIDUALISM

Hannah Arendt (see also Heisenberg, [5B]) explained the reason for the limits of physical models in her enviably X-systemic language:

> The laws of statistics are valid only where large numbers or long periods are involved, and acts or events can statistically appear only as deviations or fluctuations. The justification of statistics is that deeds and events are rare occurrences in everyday life and in history. Yet the meaningfulness of everyday relationships is disclosed not in everyday life but in rare deeds, just as the significance of a historical period shows itself only in the few events that illuminate it. The application of the law of large numbers and long periods to politics or history signifies nothing less than the willful obliteration of their very subject matter, and it is a hopeless enterprise to search for meaning in politics or significance in history when everything that is not everyday behavior or automatic trends has been ruled out as immaterial. [4A, pp. 42-43].

Compare with Werner Heisenberg [5B]:

> The closed-off theory contains no perfectly certain statement about the world of experiences. For how far one may be able to grasp phenomena by means of the concepts of this theory remains in the strict sense uncertain, and can be seen only by success.

Next, Arendt notes:

> The Greeks, whose city-state was the most individualistic and least conformable body politic known to us, were quite aware of the fact that the polls, with its emphasis on action and speech, could survive only if the number of citizens remained restricted.[4A, p. 33]

Hannah Arendt, probably, over-idealizes the Greek polis, see [7], but she continues:

> In reality, deeds will have less and less chance to stem the tide of behavior, and events will more and more lose their significance, that is, their capacity to illuminate historical time. Statistical uniformity is by no means a harmless scientific ideal; it is the no longer secret political ideal of a society which, entirely submerged in the routine of everyday living, is at peace with the scientific outlook inherent in its very existence. [4A, p. 43]

Hannah Arendt hints here to totalitarian Communism. I believe that a restaurant menu, this surrogate of freedom of choice, was the major ideogrammatic invention that became today's political, social, economic, and computer design ideal.

A chemist, looking at molecules against the background of social life, finds collective behavior of large numbers of molecules completely deterministic, but the chemical structure completely individual. Writing a chemical formula on the blackboard, the chemist treats it as the only single such molecule in the world. Like mathematical formulas and political situations, molecules in this sense are all unique individuals. Moreover, a chemist may find, as I do [1C], an idea and a molecule similar to the Greek polis as a small circle of individuals all directly interacting with each other, see **Figure 7**.

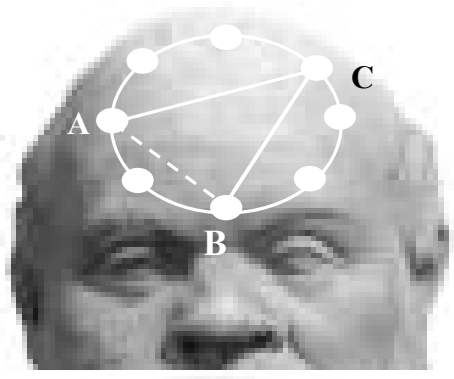


Figure 7. The thinking mind

The generators of a configuration of the idea form the **content and connector** (Ulf Grenander [3C]) or **content and structure** (Leonard Talmy [8]) of thought. Generator C catalyzes the bond between A and B. All generators in the content are topologically close.

Figure 8 compares the stability of configurations during the act of catalysis. There are two stable configurations, **(A, B)** and **A—B** . An unstable configuration A---B lies between them.

If the final state is less stable, as in P, work (free energy, more exactly) is needed to maintain the system in a less stable state. This is characteristic of all X-systems, from organic life to the modern technological state. The function of the catalyst is to stabilize the transition state, not the system itself.

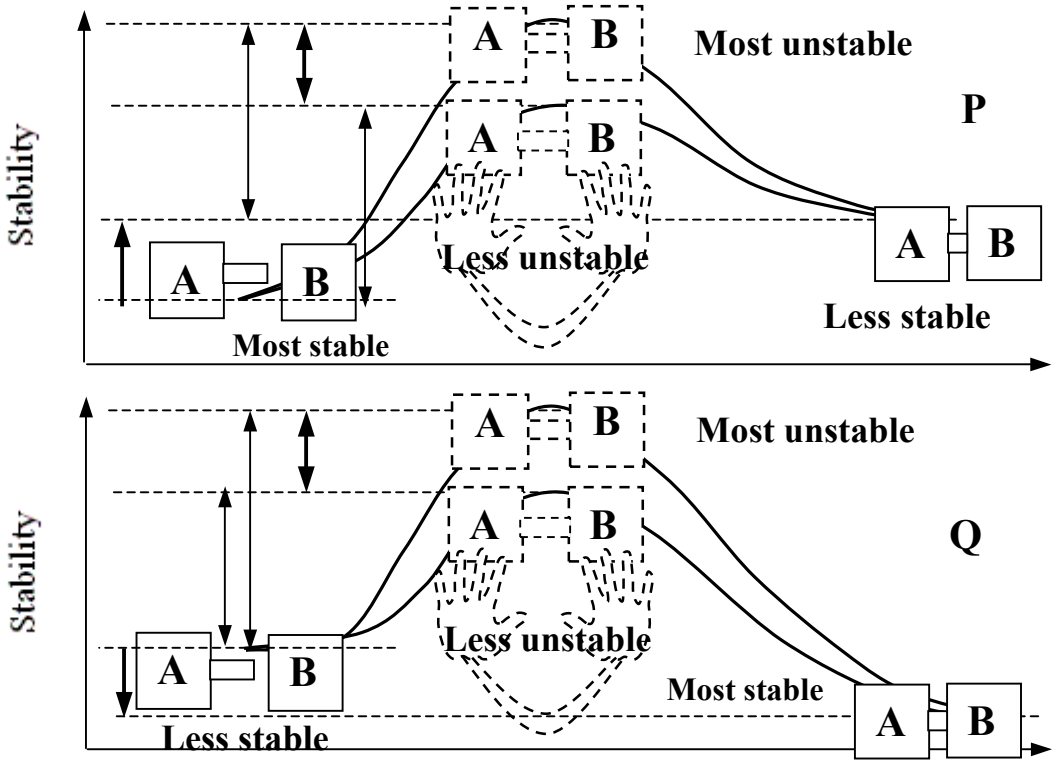


Figure 8. Stability in catalysis

10 THE PLANT USES THE GARDENER

Hannah Arendt's emphasis on Locke's distinction between work and labor ("The work of our hands, as distinguished from the labor of our bodies…" [4A , p.136]), i.e., making a product and staying alive, reflects in different sources of energy for both. Staying alive for an animal requires a source of energy in the form of chemical bonds.

Manual work diverts part of this energy, ultimately, for speeding up the search for food. As result, more time is freed for other activities, among them, thinking, chatting, and experimenting. As soon as wind, water, and fuel, which cannot be consumed by the body directly, become a source of energy, work and labor diverge. The modern technological civilization becomes a form of non-organic life in which humans perform a role of generalized enzymes. "**Hands**" becomes an ideogram of this role, even though making consists of connecting and disconnecting words and sounds (**Figure 6L**). The things are produced not for the purpose of staying alive but, if we may say so, for their own sake. Returning to Werner Heisenberg,

> While this subordination to a single purpose [extending man's power] can probably be proved to exist m every single technical process, the connection is often so indirect that it can hardly be considered a part of a conscious plan to reach an aim. Here technology no longer appears as the result of a conscious human effort to extend man's material powers, but rather as a large-scale biological process in which man's organic functions are increasingly transferred to his environment. In other words, we have here a biological process which, as such, is removed from man's control; for *while wan can do what he wishes, he cannot will what he wishes.*[5A, p.19,20]

Of course, we should remember that the "human use of human beings" (the title of a Norbert Wiener's book) in the form of domination, coercion, and slavery preceded any technology and remains a staple ideogram of society. The notion of use, (purpose, benefit, sake, etc.) however, becomes very murky outside human relations. As Michael Pollan noted [12], it is hard to decide whether the gardener uses the plants or the plants

use the gardener. I prefer a version of Darwinism in which selection through local mutations and global homeostasis of the entire system ("punctuated equilibrium") are complementary and inseparable.

As a momentous example, local decisions lead to the global decline of the birth rate as result of competition between children and things:

> Cars and children share at least one thing in common: they are expensive, particularly so in urban surroundings (Ben Wattenberg, [13, p.31]).

11 WHAT IS IDEOGRAM?

Figure 4 gives me another opportunity (compare to [1B]) to explain what ideogram is and what is different about metaphor.

Topologically, all examples, if reduced to points and lines, are identical. From the Pattern Theory perspective, all four **configurations** belong to the same **pattern**, although **generators** are different. Ideogram, as I understand it, is a configuration within a pattern, chosen as a **template**. Thus, **hands** can be converted into other configurations if we change one **set** of generators for another (**similarity transformation** in PT). Any of the four could be chosen as an ideogram.

In Pattern Theory, practical application of which focus on image processing, template is simply what looks like the most typical image, for example, of potato, human hand, tumor, or cellular organelle. An object is recognized as a potato if the similarity transformation, usually expressed mathematically, transforms the template into the observed image. The reason why I prefer *ideogram* to *template* is exactly because template already has an established meaning in Pattern Theory. Ulf Grenander reserved the term "non-numerical" Pattern Theory for the situations—most relevant for human affairs—where the similarity transformation could not be expressed within the framework

of group theory, but even a superficial look at his works confirms the complete universality of his approach. I think that **ideogram** is good enough but it is not the best.

Metaphor establishes a topological relation between two objects, usually, in an intuitive way. Metaphorically speaking, metaphor is as different from ideogram (or template), as a straight line between two points from the entire coordinate plane with a marked zero point.

Having chosen the **hands** of ***homo faber*** as an ideogram, what can we do with the hands?

The first thing we could see that the hands cannot do anything without a source of the movement, which is either natural chaos, or algorithm, or a combination of both, plus a source of non-thermal energy for work in all cases but a chemical reaction.

The second observation is that *homo faber* works as a catalyst that speeds up the movement toward equilibrium.

Third, equilibrium is incompatible with evolution and life in particular. X-systems need chaos as much as the information that they accumulate along the way.

As an example, the overpopulation, energy crisis, and global warming threaten to destroy a lot of organic and industrial X-systems, together with already ongoing cultural impoverishment. In this situation, the only option for *homo faber* seems to be turning into an inhibitor (negative catalyst). We already see that trend in the negative population growth, movements for cultural independence, environmental movements, anti-WalMart actions and, probably, even in the militant Islam. What may lie ahead is a wide cultural and quasi-religious movement toward slowing down and stopping the explosive phases of Industrial Revolution. Even more so, we might one day oppose the post-Industrial Revolution, which tags humans as parts of a business machines (or cells of a Leviathan), controls their every step by designing menus and monitoring the behavior, modifies their behavior and even biological instincts, tames their natural chaos, standardizes them in all aspects. Where the Russian Communists failed, the unbridled market capitalism might well be able to succeed.

Regarding menus and choices, one cannot monitor something that has not been recorded before. The fixed menu of choices, therefore, performs the function of chaos suppression. Psychologically, it creates an illusion of freedom and equilibrium.

Again, I do not paste any ideological or moral (good/evil) labels with my comments. I do not aspire to stop the future. I urge to understand it and incorporate into history. How people saw the future, how they reacted to their vision, and what came out of it is popular among writers but not yet an established area for historians. *The Pity of War* by Niall Ferguson [9A], however, contains such material.

I do not believe in any completed theory of history. I regard applied knowledge of history as something like monitoring a working nuclear reactor, performance of a company, or a person's health. Historian, like a family physician, is born, grows, learns, ages, and matures every day together with his patient. Instead of prescriptions, however, the historian tosses over the desk a slip with alternatives, their stabilities, and relative proximities in time. In other words, the historian is the one to turn to for a second opinion.

12 THE LORD OF THINGS

Approaching the subject of history as a chemist, I can now apply to history what I wrote about chemistry.

History is about thermodynamics and kinetics of structure. Ultimately, history is about two things:

(1) Compiling a small set of most probable alternative situations in the form of configurations and

(2) Narrowing it down to the even smaller set of the fastest events leading to them.

History of the past uses the above paradigm for explanation. History of the future uses it for planning and selection of catalysts and equilibrium shifts.

If in such description history sounds like a political strategy, the latter is always an exercise in futurology, anyway. So is any planning. This is exactly the sound that I am trying to amplify.

The more global the future, the more catastrophic the consequences of a misstep. Yet there is no firm, common, and rational ground for looking behind the jagged horizon of immediate future. I believe, we have to start with a common language, not for the sake of saving humanity—such missions have always been big and destructive calamities for humanity—but with the purpose of understanding "what we are doing," which was Hannah Arendt's starting—startling today—question.

The current stage in human evolution can be characterized as the shift of the relevance from past to future. The future comes at us so fast that the previous experience fades away. We do not feel compelled to remember the lessons of history because history seems to be re-written anew every day.

My main thesis is that the destiny of man in the currently developing global X-system is neither a domination by machines nor a triumph over them. It is twofold:

(1) to be the source of chaos by virtue of the **liquid** and therefore naturally chaotic brain,
(2) to be the source of order by virtue of **catalytic** ability as *homo faber*.

If *homo faber* and chemical catalyst are two meanings of the same ideogram, in the large scale biological system that is larger than organic life they play the same role, shared also by our information technology.

A more distant future depends on whether these two functions can be taken over by—or surrendered to—machines, and I see no principal obstacle to that. I have already noted earlier, that the constraints on energy might shift evolution toward using the advantage of non-organic life, as some sci-fi writers (Stanislaw Lem) long ago imagined.

Today, when the energy crisis has two equally hostile to human and organic life aspects: the lack of sources and the lack of the environment to absorb the heat and matter produced by dissipation of energy, computers look lusciously green: they consume little energy and emit nothing but heat.

In cold New England winters, my desktop (actually, under desk) Dell gives me enough warmth. Its whimsical uncontrollable behavior and its Poisson distribution of erratic messages coming from the Microsoft's hormones, however, deepens my historical fatalism.

The role of technology since the Industrial Revolution has been a constant acceleration of energy consumption and dissipation in the course of its conversion into work. Technology, therefore, works on Earth as a universal catalyst, and the function of the catalyst is to accelerate the movement toward an equilibrium. In the case of humans the equilibrium refers to the relation between the Earth and the solar system.

The evolution of technology has created a new form of life: inorganic life of things that ends up in the dumps that are similar to the sedimentary limestone deposits. We are taught to think that technology serves people, but most of our technology is not necessary for supporting human life. The Lord of Things rewards humans for their zeal with their beloved toys, while the Lord of Heavens dispenses rewards and punishments with closed eyes.

13 HISTORY AS EXPERIMENTAL SCIENCE

Our future depends on what we think about it. If we imagine the future as over-standardized and over-burdened by the rituals, repression, and rivalry as a tribal society, the function of man as preordained as that of an enzyme in a living cell, and creativity as thoughtless as shuffling a deck of cards, our self-image may suffer and our emotions may kick in. Contrary to wide spread opinion, our irrational emotions are exactly what is needed for adaptation because the state of excitation is never stable and it slides into another stable state. Homeostasis is a search for a more stable state through a series of unstable states.

What follows is a passage from Hannah Arendt's *The Concept of History* [5B, p. 59-60].

> Fabrication is distinguished from action in that it has a definite beginning and a predictable end: it comes to an end with its end product, which not only outlasts the activity of fabrication but from then on has a kind of "life" of its own. Action, on the contrary, as the Greeks were first to discover, is in and by itself utterly futile; it never leaves an end product behind itself. If it has any consequences at all, they consist in principle in an endless new chain of happenings whose eventual outcome the actor is utterly incapable of knowing or controlling beforehand. The most he may be able to do is to force things into a certain direction, and even of this he can never be sure.

Arendt's description is a remarkable insight of a humanitarian who independently discovers a scientific subject, first introduced by W. Ross Ashby [14] from the other side of the divide between sciences and humanities, and captures its very essence. The difference, on which she insists, rises, however, an important question. Obviously, *homo faber*, **unlike catalyst**, takes part in a typically **irreversible** process of fabrication. *Vita activa* (Arendt) and *bios politicos* (Aristotle) are as irreversible. Can we then put man and catalyst side by side?

The best answer is *organic life* (i.e., life based on molecular mechanisms): it is a completely irreversible process completely controlled by reversible catalysts. It is driven by the ratchet ideogram of a kind: consumption of energy and matter and dissipation them into waste. The major—and I would say tragic—difference between organic life and technological civilization is that the former is a metabolic cycle and the latter is not.

> I am tempted to formulate an optimistic view of the future civilization as the cyclical metabolitic system in which the humans are guaranteed stability as species at the price of becoming reasonable, sensible, balanced, and utterly green hybrids of plants and animals of a kind, driven by solar energy, as the rest of life on earth. Machines, however, in a different scenario, are much better equipped to be reasonable sensible, balanced, and even charged by the sun , especially if they get rid of the tinted Microsoft's Windows. This is my view of the major evolutionary dilemma for humans.

The homeostatic wandering property of society is the reason why cool-headed scientific professionalism is not equipped to deal with history, which takes each sharp turn only once, for the very first and the last time.

Following Hannah Arendt, I am interested only in what we are doing, but not in what we should do. Everybody casts the critical vote alone—or with the tribe. But, unlike Socrates, the sages of modern science do not speak to people in understandable language. Hannah Arendt saw it as one of the most important signs of denaturalization of life, as I would call it.

> The trouble concerns the fact that the "truths" of the modern scientific world view, though they can be demonstrated in mathematical formulas and proved technologically, will no longer lend themselves to normal expression in speech and thought [4A, p.3].

I cherish and idea that understanding, neither formulated, nor in any way proved, could reverse the denaturalization to some extent. Moreover, it could ease the crisis of the education broken by the sheer number of scientifically proved knowledge.

I wonder if somebody has ever noticed that history is an ideal experimental science. Watching in amazement the current stretch of global and American history, I believe it is. The current experiment is about human control of human condition. Can it be controlled by the power of destruction?

No historical experiment ever fails to generate new knowledge. Sooner or later, humans always have an opportunity to attend at no cost a public test of her (Clio is a daughter of Zeus) predictions and generalizations. History always answers all questions addressed to it, although too late. But do we know what are the right questions to ask?

> **NOTE ON HOMEOSTASIS**. W. Ross Ashby was not the first to offer this term. He was the first to give it not only a new meaning but also a technical realization. The interpretation of homeostasis varies greatly in the literature. Recently a concept of **allostasis** was proposed by McEwen and Wingfield [15]. It is remarkably close to the understanding of homeostasis by W.Ross Ashby—and human action by Hannah Arendt—as an open-ended search for stability of a complex system, requiring constant consumption of energy (“allostatic load”).

14 CONCLUDING REMARKS

David Aubin's dissertation and later publications [16] contain uniquely rich material on the dramatic history of the attempts to apply traditional and non-traditional mathematics to complexity. The results could not satisfy either mathematicians or the professionals in areas related to life and society partly because science itself, as I believe, was becoming a complex social phenomenon rather than noble and selfless search for the truth. The history of the problem is the best introduction to the continuing attempts to approach complexity from new directions inspired by chemistry instead of physics.

This is what we should probably do in order to understand X-systems outside closed mathematical approaches:

1. Compound an open list of elementary evolutionary mechanisms common for all X-systems and represent them as ideograms.

2. Use ideograms as generators to construct evolutionary configurations in particular X-systems.

3. Synthesize, if possible, the general pattern of X-system not in terms of functions and equations, but in terms, so to speak, little dirty tricks all X-systems use to bootstrap and extricate themselves from inanimate matter or the preceding X-system from which the next X-system emerges.

At this point I have no idea how to do that, except the search for the tricks, but other ambitious minds could try to shoebox the pieces and assemble this jigsaw puzzle.

15 DISCLAIMER

Neither this essay, nor anything at spirospero.net/complexity.htm should be viewed as an attempt to:

1. Develop a theory.
2. Reveal the truth.
3. Refute existing views.
4. Create a new kind of science.
5. Offer a new vision of the world.
6. Provide guidance for better politics.
7. Improve this world.
8. Warn the world.
9. Discuss doomsday scenarios.
10. Start a revolution.
11. Condemn technology.
12. Condemn wealth.
13. Condemn anything.
14. Encourage anything but understanding and intellectual independence.

SELECTED REFERENCES

Literature on the subject is enormous and I am not familiar with most of it.
See [1B] for the principles of selection.

1. Yuri Tarnopolsky

A. http://spirospero.net/complexity.htm

Also: Exercise in particular cases http://spirospero.net/simplicity.htm

Exercise in metaphoric expression http://spirospero.net/poetry.htm

B. *The Rusty Bolts of Complexity: Ideograms for Evolving Complex Systems*
http://spirospero.net/ideograms.pdf

C. 2003. *Molecules and Thoughts: Pattern Complexity and Evolution in chemical Systems and the Mind* (2003)
http://www.dam.brown.edu/ptg/REPORTS/MINDSCALE.pdf

Alternative site: http://spirospero.net/MINDSCALE.pdf

2. Self-assembly

A. "Self-assembly is the ubiquitous process by which objects autonomously assemble into complexes. Nature provides many examples: Atoms react to form molecules. Molecules react to form crystals and supramolecules. Cells sometimes coalesce to form organisms. Even heavenly bodies self-assemble into astronomical systems."
http://www.usc.edu/dept/molecular-science/fm-self-assembly.htm

B. "What is self assembly? Simply put, we're talking about collections of objects *that put themselves together*. Imagine holding a box containing a jigsaw puzzle, giving the box a shake, and peeking inside to find that the puzzle had assembled itself!"
http://www.math.udel.edu/MECLAB/Projects/SelfAssembly/selfassembly1.htm

3. Ulf Grenander: **Pattern Theory**.

A. 1995. *Elements of Pattern Theory*. Baltimore: Johns Hopkins University Press. [It is written for students of mathematics, but large sections and main ideas are accessible to non-mathematicians].

B. 1993. *General Pattern Theory. A Mathematical Study of Regular*

Structures, Oxford, New York: Oxford University Press. [Advanced].

C. *Patterns of Thought*. www.dam.brown.edu/ptg/REPORTS/mind.pdf

See also: www.dam.brown.edu/ptg/**publications**.shtml

D. 1976. *Pattern Synthesis. Lectures in Pattern theory*, Volume 1. New York: Springer-Verlag. Also: 1978, *Pattern An*alysis. Vol. II, and: 1981. *Regular Structures.* Vol. III. [Advanced, but very rich of general ideas].

4. Hannah Arendt.

A. 1958. *The Human Condition*. Chicago: University of Chicago Press.

B. 1993 (1961). *Between Past and Future*. New York: Penguin Books.

5. Werner Heisenberg

A. 1958. *The Physicist's Conception of Nature.* New York: Harcourt, Brace & Co. Also published: 1970. Westport, CT: Greenwood, 1970.

Technology: Intereffect of Technology and Science, p. 16.

B. 1974. *Across the Frontiers*. New York: Harper & Row, Publishers, Inc.

The Notion of a "closed theory" in modern science. p. 39

6. Langdon Winner

A. Web page and links: http://www.alteich.com/links/winner.htm

http://www.rpi.edu/~winner/

"Technopolis, a weblog by Langdon Winner, offers occasional reflections on historical, philosophical, and contemporary questions that involve the perplexing intersection of human ends and means:" http://technopolis.blogspot.com/

B. 1986. *The whale and the reactor: a search for limits in an age of high technology*. Chicago, University of Chicago Press. Chapter *Do Artifacts Have Politics?* is at:

http://www-personal.si.umich.edu/~rfrost/courses/Women+Tech/readings/Winner.html

Chapter *Techne and Politeia: The Technical Constitution of Society* can be found at: http://www.umsl.edu/~rkeel/280/class/winner.html

C. 2003. *The Technological Condition: An Anthology*. Ed. Robert Scharff and Val Dusek. Oxford: Blackwell's.

Contents: http://www.blackwellpublishing.com/book.asp?ref=0631222189&site=1

7. Donald Kagan.

2003. *The Peloponnesian War*. New York: Penguin Books.

8. Leonard Talmy

2000. *Toward a Cognitive Semantics*. Cambridge, MA: MIT Press. Homepage: http://linguistics.buffalo.edu/people/faculty/talmy/talmyweb/index.html

9. Niall Ferguson

A. 1999. *The Pity of War: Explaining World War I*, New York: Basic Books.

B. *Virtual History: Alternatives and Counterfactuals*, (1997). Editor: Ferguson. N. New York: Basic Books.

10. Robert M. Kiehn

A. *Continuous Topological Evolution*

http://www22.pair.com/csdc/pdf/gordan2.pdf

B. *Non Equilibrium Thermodynamic Systems and Irreversible Processes. From the perspective of Continuous Topological Evolution*

http://www22.pair.com/csdc/pdf/ams_abq.pdf

C. *Applications of Continuous Topological Evolution*

http://www22.pair.com/csdc/pdf/arw.pdf

11. Robert Keel

*Robert Keel Online***:** http://www.umsl.edu/~rkeel/ [a lot of material]

12. Michael Pollan

2001. *The Botany of Desire: A Plant's-Eye View of the World*. New York: Random House.

13. Ben J. Wattenberg

2004. *Fewer : how the new demography of depopulation will shape our future*. Chicago: Ivan R. Dee, Publisher

14. **W. Ross Ashby: homeostasis**

1960. *Design for a Brain: The Origin of Adaptive Behavior*, 2nd Ed., New York: Wiley, 1960 (originally, 1952).

1956/1964. *An Introduction to Cybernetics*, London: Chapman & Hall,

15. Allostasis

A. 2003. B.S. McEwen BS and J.C. Wingfield JC. The concept of allostasis in biology and biomedicine. *Hormones and Behavior* **43**:2-15.

B. 2004. Allostasis, Homeostasis, and the Costs of Adaptation. J. Schulkin, Editor. Cambridge: Cambridge University Press. Introduction by Peter Sterling.
Contents: http://assets.cambridge.org/052181/1414/sample/0521811414ws.pdf

C. Peter Sterling. *Principles of allostasis: optimal design, predictive regulation, pathophysiology and rational therapeutics.* In [15B].
http://retina.anatomy.upenn.edu/pdfiles/6277.pdf

D. Interview with Bruce McEwen.
http://www.esi-topics.com/fbp/comments/october02-BruceMcEwen.html

16. David Aubin

1998. *A Cultural History of Catastrophes and Chaos: Around the Institut des Hautes Études Scientifiques, France 1958-1980*, Ph. D. thesis (Princeton University), UMI #9817022 [a truly remarkable, keen, and inimitable work].

Table of contents: http://www.math.jussieu.fr/~daubin/These/toc.pdf

Web site: http://www.math.jussieu.fr/~daubin/

Publications: http://www.math.jussieu.fr/~daubin/publis.html