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Information evolution -
in past and future history

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Abstract

Language is certainly an information structure; money and markets are also; as is music and computer programs and various associated data. Human perceptual and cognitive skills belong to the same realm of information handling systems, evolved as they have by some process, most often described in Darwinian terms.

Competition, selection, mutation; is that all there is to it? Over a long period of time, with replication and reproduction taking terms? How did it all start — in clay structures, in different chemicals symbiotically merging? And without the particular properties of water and of carbon and carbon based chemistry life and the information that it depends upon would have been impossible.[1] *We should not here be engaged in a full blown discussion of intricate arguments as to how evolution may have come about, we are only — and that is not a small order either, though more restricted — concerned with the processes whereby information, and especially information handling systems, may emerge.*

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1. The power of spontaneous positive feedback

The first proposition is autocatalysis. A catalyst is an agent that promotes, facilitates, or produces a certain chemical reaction without being part of the end result, without being consumed. Thus it can be used for the same purpose over and over again. Let's assume we have just two molecules in some vessel or environment, A and B. If they are allowed to combine into sets of two also, we may have these two single molecules, plus AA, BB, AB, and BA, assuming the two latter are structurally different. That's six different combinations.[2] Allowing for combinations also of three molecules adds another eight, making the total sum of fourteen. Four molecules admits another power of two to the club, another sixteen, bringing the sum up to thirty.

Molecules combine and the combinations are dissolved again. But if the combination BAAB were to catalyze the combining of AA and B to make AAB, then AAB would be privileged. Assuming that this agent in its turn catalyzes the formation of ABA which makes for a catalyzed reaction forming BABA, creating a catalytic reaction resulting in AAAAA. Which we assume would be the catalyst facilitating new production of BAAB. Now we have a closed loop. Against the background of all random combinations and reactions, this series of catalytic events is self-reinforcing — it is autocatalytic. It will grow and grow in strength. There has beedn created a privileged route to the formation of certain combinations of more intricate molecule aggregates.

This is a process of scaffolding, of self-reinforcing processes that is rather general. In a language, there may be letters or hieroglyphs. These may be combined to make for words, if the hieroglyphs aren't already words or concepts. The words allow for the production of sentences, these being combined into novels or theatre pieces or studies in the nature of information. The scaffolding may take different vistas: we may feel that the Western letters constitute an economic way to learning but should not forget that a Japanese can decipher a Chinese script despite the fact that the two languages are entirely different (and it has been suggested by linguists that the Chinese kanji system is almost the least suited for representing the structure of the Japanese language) just because of the inherent meaning of the kanji signs.

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2. The information power of specialization

In a society of farmers, no one is specializing very much, though small villages are formed to facilitate joint defense against intruders, and possibly a feudal structure is emerging, with the reciprocate provision of protection and some payment in kind. Then, slowly, some farmers get more specialized in various handicrafts: someone is a good carpenter, someone can undertake to butcher, having more utensils. The blacksmith is dependent upon resources such as hydropower and fire.

Specialization turns out to be a self-reinforcing process. Specialists produce products, not just services: the butcher may make sausages and dry hams, the blacksmith makes axes, ploughbills, and knives. Learning is taking place, knowledge has to be transmitted from master to apprentice, tools are being developed in conjunction with the new craft. But the butcher and the blacksmith have to get their food from other producers — specialists in farming that may now develop into niches such as dairy production, sheep, oats, wine, or whatever. Markets and towns are emerging,[3] a new structure of society, and one that has been caused by self-reinforcing processes, by scaffolding — and by the economy inherent in the information processing allowed for by the growing specialization.

Specialization equals more information mastered; not by any single individual, but rather by the system, the market network itself. The basic point is that "information wants to be free" — that the system can accumulate more information the less controlled it is in the sense that there is a central planning or controlling authority. That is not to say that there must not be any rules regulating the free information exchange, the specialization process, and the communication involved.

To facilitate the process, there was, historically, the continuation of a feudal structure but now with subtly different means and functions. There is the evolution of something akin to money or monetary instruments, something facilitating economic exchange, be that salt, pepper, cocoa, or gold. That money is growing more and more abstract, thus more and more recursive;[4] money has value because it has value because it is money that has... The growing specialization makes for more varied opinions, judgements, morals, not less, and this growth would seem to preclude the "ends" forecast to be imminent — the end of history, the end of science.

This scaffolding, these recursive processes take place within a system. It is not just the blind mutations, competition, and selection that characterizes Darwinian evolution; but it is that too. There are computer languages that have been designed so that they can evolve by themselves, like Lisp, designed for work in Artificial Intelligence. These may be used for modelling the kind of self-organizing processes and structures that we are trying to describe in a general way.

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3. Information versus our environment

Self-organization seems, as we just said, to be the only way to go for handling vast amounts of information. This would seem also to apply on our concerns for the environment, for the impact of mankind on the global ecology. This too may be described in information notions. Think, for example, of a copper pan, used for the preparation of food. If copper is growing more scarce, prices — that carrier of information in an economy — go up, and there may be substitutes for copper launched, aluminium or whatever.

Copper is thus not necessary, but neither is, at close scrutiny, the pan. We like to have our food cooked, to make it healthy, perhaps, and to get it tasty enough. The taste, however, may — in some future — be generated through information fed into our nerves directly, so we could make good cooks operate in a world of virtual reality.[5] The basic need, besides the pleasure evolving out of that information package, is for energy to make or work, and that energy might be provided through other means entirely, healthy certainly, and without any effects on the nature whatever, just relying upon the most energy efficient production methods and those least impacting on the ecology.

Biology, language, society, ecology — all those examples hint at a series of hierarchical levels. Sentences become paragraphs, paragraphs chapters, chapters become — The early craft specializations were neither the first nor the last steps on an evolutionary ladder. Complexity science has been developed in the last fifteen years or so to attempt to come to grips with the general structures and laws behind self-reorganizing processes — providing there are any such generalities. The basic idea is that at the most primitive level there are only a few different types of components — perhaps some more than our As and Bs — and that these are linked to each other by simple rules. But it is the shear numbers that cause complexity to evolve from such simplicity.

There would seem to be certain patterns that are recurrent; among the vast space of diverging possibilities, only a few gain currency — with a word from chaos mathematics, there seem to be attractors, making for a remarkable stability of development. We can only speculate as to the development of information structures and one such obvious principle is the one of economy.

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4. Economy in information handling, too

What, for example, could be the origin of music? For an individual to be able to defend himself or herself, to wield a spear, to throw a stone with precision, against a foe, human or animal, precision is of paramount importance, i e, some kind of rhythm in the movement. To trigger the right sequence of motions, it might be done by invoking a particular rhythm. And so, music is born. Perhaps throwing the stone or the spear turned on pacing one's steps — and dance was born.

The better music is the one that serves some such purpose for survival. That also stays in the ear, that bears repeating, that is melodious and catching enough. Thus a number of melodies are created, evolved, refined, weeded out, improved — developed and, some, established.

The same for the telling of stories, stories that evolved to become legends about heroes but which also served to impart some important lessons, some useful knowledge. Studies of bards in the former Yugoslavia showed that since they could not conceivably remember the enormously long stories, with intricate rhyming and alliteration, there were a number of standard tricks of the trade, ranging from standard epithets (like Homer used them) to rhythm, rhyme, alliteration,, and, of course, a certain set of characters and a basic story line.

This is an example of economy as directly applied in a process of imparting information. Even more economic would be a system that could do without information handling. It is just too plain easy to see information as a central resource or base for action or decisions and control everywhere. A simple example serves so as to caution this view a bit.

Make a puppet with the proportions of a human being. Most essentially, equip the legs with joints such as those that we have, wrist, knee, hip. Then place the little doll on a reclining surface. And it will start walking down, somewhat awkwardly perhaps, but steadily and without any real problems. By the same token, it has been demonstrated that it is sufficient with just a few neurones to make a robot act like an insect — there may be "less to animal behavior than meets the eye".[6]

Thus nature offers us a number of ingenious designs — that we knew already — which are also extremely economic in the handling of information. We certainly know that our nervous system displays parts which are autonomous, offering a responsibility sharing between centralized and decentralized functions, but the walking piece of mechanics shows that a good design may be for little need to resort on information in the actual execution of a particular task.

There is thus a tradeoff between design and demand for information handling. We must steel ourselves against believing that there is the necessity of introducing information as a basic resource emerging just about everywhere. We must learn to see and to understand the very tradeoffs involved.

In the case just related there is no information handling involved. In most cases tradeoffs may be concealed or convoluted. Thus the development of animals with a constant temperature like the humans' 37°C meant a drastic reduction in the genetic codes: the DNA program was much reduced. Likewise, mammals have reduced genetic encoding for cultural endowments — the young ones are fed, protected, and taught in a highly protected environment, first the womb, then the nest.

The genetic code was reduced; human brains seem to have shrunk, possibly because of this development towards more economy. Our brains, by the way, carry a huge handicap: first, they require a long period to develop before birth, then they depend for nurture and shelter many more years — all of this expenses and vulnerabilities in a hostile environment.

Since we have followed the route of the selfish gene, of genes carrying all what we inherit, we should add a caution, discovered, tentatively only recently. "But there are tantalising hints that you inherit something else as well."[7] Some evidence suggests that changes in the "instruction manual" for the actual operations of the genes can sometimes be passed from parent to offspring (epigenetics).

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5. How may music be of service to genes?

Evolution in the biological sense is an inherently slow process so we should only expect cognition and perception to mirror priorities, perhaps stark necessities, in eras bygone. Let us get back again to music, art, and literature. We must assume that music, painting, literature would not have developed had they not served some purposes for the proliferation of our species. Why else would we find art, and fine and technically sophisticated art at that, in caverns used singularly for this purpose some 30 000 years ago, or, with the latest finds, even before that? Those paintings were made under the most excruciating circumstances; still with an acumen that is just stunning.

Music and literature are more difficult to trace but for some remnants of what might have been musical instruments. A 60 000 year old bone fragment, found in Slovenia, looks like a flute. Long time before writing was invented, speech developed. Music and poetry and some other speech habits share the prevalence for rhythm. It would seem as if much the same faculties were needed for the production of music as were required for speech, and so we can only try to analyse whether ancient skulls of early humans and their hominid forebears had the physical abilities to produce sounds, especially vowels. This presupposes a vocal tract resembling ours, and since this is of soft tissue, there are no fossils but those leaving sufficient room for such tissue.

Another way of going about the problem is to collect music from different parts of the world. Music exists everywhere but while there are many similarities, there is no single feature that all music shares. Most music follows a regular beat — but not all. There is a set of distinct notes everywhere but if the rules that those constitute are broken, the result may still be regarded as music. So rules are to be broken, but only so much musical anarchy is tolerated. If a scale is played to a (Canadian) baby twice, changing one note on the second occasion, then the baby discerns the change more often if the scale is diatonic, i e, when the notes are unequally spaced in pitch, such as in Western music than if it is a whole-tone scale.[8] The Slovenian flute (?) fragment displays holes corresponding to a diatonic scale.

It is disputed whether the Neanderthals could manage to speak. Thus current estimates as to when speech first became possible range from 40 000 to two million years ago; there is little consensus. An indirect way to reach a conclusion is to assume that speech would allow for sophisticated collaboration, information sharing and transmission, and the consequent development and utilisation of new tools, traced by latter day archaeologists. Such tools indicate the appearance of speech no earlier than 100 000 years ago.

When musicians listen to music or when they make it, they activate the same parts of the brain (among other areas) as those which are used in conversation. Thus it would seem that the brain regards music as a form of language. But an untrained musician, whistling a wordless tune, will activate the right hemisphere equivalent of the left hemisphere area used for the same persons speech. This specialization on the right and the left hand side of the brain is poorly understood but it is different between man and woman: women display it less markedly.

Evolution would normally not create different development paths for men and women, since the ecology is the same. There is one exception, however, and that is of course related to the production of offspring. Women can produce only a limited number of offspring regardless of how many mates they have, and would thus want to mate with the best available male. A male shares this predilection but may, in addition, increase the proliferation of his genes by mating with many females, regardless of their "quality" (remember, this is the selfish gene talking). The end result is male rivalry, often leading to violence, allowing the females to choose which male to mate with. Therefore males tend to develop characteristics serving to convince females that they are "the best".

Through the link "rivalry—violence", researchers have arrived at the statistics for murder as a proxy for this male tendency to demonstrate his desirability. Murder rates vary greatly from place to place but regardless of rate, they are mostly performed by males and they show the same age profile everywhere. The age group most at risk to become murderers is the one between 20 and 25; then it tails off. This coincides with the age when men are sexually most potent. It now turns out that musical production shows an activity curve much resembling this murder curve, with the peak at a somewhat higher age, 30, according to a thorough study of jazz albums released in the US and Europe since 1940. Musicians are predominantly male, possibly because their greater predilection for showing off. Music then serves as a way of demonstrating physical fitness. Singing loudly requires good health, singing in tune good muscle control, singing many different songs good memory. Love songs may indeed transfer some other messages than those of their words.

So we concluded that economy was one factor in human information handling. But then this drive to show off may lead to a blatant dissipation of energy, of a demonstrative urge to forgo economy, just for the male to show the abundance of his power. This is the argument why the peacock carries such a grandiose, but also useless, tail. We learn that while we may construct such stories which contain more or less likely explanations, we must be wary not to dream up stories that make for good fairy tales but which have little or no explanatory power. The point must be that there should be some different ways of cross checking.

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6. Patterns to economize, and to lead astray

One avenue to economy would be to organize, to see, to identify patterns, patterns being a way to reduce information, to compress it into a formula. Thus also why we are sometimes fooled into seeing patterns where none are; psychologists have proven people quite gullible to their own ideas about patterns concealed in, e g, a simple series of numbers. That, by the way, is a popular pastime among practitioners of creativity: where should we place the next letter, on the upper or on the lower line?

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A     EF  H
  BCD   G
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On the other hand, that gullibility may lead astray, as the very word connotes. There is an important law, laid down by Ross Ashby, the law of requisite variety. This law says that to describe a complex system, the same level of complexity is needed.

This does not say that patterns cannot be found or used to reduce information. Furthermore, it does not mean that we cannot structure a system hierarchically, discounting unnecessary detail on levels subsidiary to the level of primary interest to us. It just implies that we get a distorted view if we discard parts of the complexity on the level that we are concerned with. The point has been made that the failure of planned economies was due to disregard for the law of requisite variety. The planning could not take into account all details, not all relevant details, partially also blinded by ideology.

Man as a seeker of patterns thus has to reconcile this instinct with the false allure of chimera. Evolution bred behavioral patterns that sometimes may be at odds with modern theory, science, or social organization. It has been regarded as entirely irrational and primitive, for example, of proceeding like some Canadian Indians when choosing the next area for the big hunt: throwing old bones to let magic decide the best direction. The procedure, however, turns out to be an elaborate guarantee that hunting grounds are chosen entirely at random, which means that there is less risk that the ecology at large will be upset as it is when fishing, hunting, or deforestation creates such profound changes as to not prevent the previous balance to be upheld, eventually threatening the whole venture, possibly a trade, possibly even a culture.

It also turns out that when we handle mechanical tasks like receiving a ball thrown at us, our movements, which seem automatic, more resemble those of Aristotelian physics than Newtonian though we know Newton's to be the "correct" one (as long as Einstein's relativistic effects have not to be taken into account), the Aristotelian some kind of antique superstition, refuted from Galilei and onwards. The reason our senses react this way is that if natural second order effects like friction, air resistance, etc are included in the calculations — as they may be in Newtonian physics of course — then the end result is more akin to Aristotle's version than to an ideal Newtonian model.

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7. Strands to turn evolution into development

So far, we have seen evolution as proceeding in a Darwinian way. There is variation, competition, weeding out, but there is no progress, just opportunism. David Deutsch, however, suggests that there are four strands in the fabric of reality that do indeed point in a direction "forward", even while (as we saw in the previous chapter) time may be a meaningless dimension in a quantum world.[9]

Apart from evolution, which may be seen as a more general process also, applying, e g, with appropriate modifications, on the level of culture, quantum physics is indeed another important strand of reality, in describing reality. Some results here seem paradoxical, certainly when looked upon with our macroscopic eyes. If we apply the multi verse model, introduced in the previous chapter, quantum physics for all its uncertainty is completely deterministic. It can be so because the constant generation of new parallel universes, the multi verse, realizing in parallel all those different options endowed in the uncertainty of an indeterminate quantum state. As we have seen, this is far from classic physics, also in the sense that while there is chaos — the extreme dependence upon initial conditions for many, perhaps most physical processes — in the classic world, there is no such thing in the quantum world. The spectra of chaos is of course linked to our quest for knowledge, for gathering reliable information.

The third strand in this fabric is of another type entirely, the advancement of knowledge in a process most often associated with the name of Karl Popper. When we encounter a problem, an unresolved conundrum, we hypothesize — *pace* Popper — as to how it may be explained. From our hypotheses, we try to design experiments to refute or to validate them. So we arrive at a better understanding of the workings of our world, until the next problem arises, and the next, and the next. The striving for ever better explanations can be judged as progress: we leave a number of what previously were enigmas integrated into our growing body of knowledge. Even false starts and hypotheses eventually refuted thus contribute to our ever more detailed, ever deeper description of our world.

The fourth strand, finally, is the one perhaps most closely associated with information handling, the fact that there can exist Turing machines simulating all other computers. Computers themselves can be used for simulating any number of aspects or workings of our physical world — any number? Yes, Deutsch makes the case that as long as we are dependent upon physical processes, including the biochemistry of the neurons in the brain, then it may all be simulated. It may require an enormous computer, but that is another story. It may be very difficult to design, or to make evolve, the program, but that is another story. It may take an infinitely long time, and that is not entirely another story. Perhaps we have to slow down the thinking processes for the participant taken in by the simulation so as to ascertain that everything seems to be acted out in real time, allowing for all intricacies of reality, involving all the participant's senses.

So it is not another story, also because there are problems, and then there are problems; there are phenomena and then there are phenomena. A number of problems turn out to be tractable, that is, they may require an incredibly fast and powerful and memory rich computer, but in the end they will be solved. Then there are problems or phenomena of such a nature that they are intractable, meaning that the time and other requirements — number of computations, requirements for memory capacity — grow exponentially. They are simply growing too demanding for that most general type of computer, the Turing computer, to handle.

There is a remedy, however, and that is the quantum computer, introduced in the previous chapter. As we saw, we may use the fact that quantum indeterminacy allows for a vastly greater amount of information to be handled simultaneously to create computers with virtually unlimited capacity. Most importantly, where problems produce exponentially increasing demands on an ordinary Turing computer, this generalized, "quantum Turing computer" will see no more than a linear increase in demand for time and other capacity factors.

Applying the multiverse view, and accounting for the fact that entanglement of quantum particles encompasses the whole of the universe, quantum effects combined with the generalised quantum Turing computer makes for a seemingly bold forecast: the whole world will, before the heat death of the multiverse, become one giant computer or omniscient knowledge system. It might even be necessary, since life on Earth may be viable only for an amazingly short time span, in cosmic terms that is, of another 41 000 years[10] (we are currently at mid-life). At current rates of energy requirements for computing and for information processing increase, through the evolution of science, the Solar system has been calculated to sustain 1070 bits, lasting no longer than 5 000 years.

There is no provision for some man made Armageddon, such as a nuclear holocaust or an environmental catastrophe, in that scenario. It is based on fundamental physics, however, and it tells something important about what to look for and what to expect in real long term information and knowledge development. Our descendents, by the way, will not be human but some kind of intelligent machines, designed by us, and permeating the values that we hold. In a not too distant future, the claim is, we will discuss "equal rights for machines" (or robots) in much the same way as was done for women, blacks, and others from the last century.

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Bengt-Arne Vedin, Metamatic AB, är ansvarig for Ruben Rausings Fond för forskning om nyföretagande och innovation, ledamot av regeringens Småföretagsdelegation, Teldoks redaktionskommitté mm. Konsult, föreläsare och skribent. Tidigare adjungerad professor i innovationskunskap vid Tekniska högskolan i Stockholm. Arbetar för närvarande bl a med att för Institutet for Framtidsstudier, dit han också ar knuten, kartlägga "fronten" vad gäller forskning och praxis inom kreativitet och innovation. Längsta uppdrag: Teldoks redaktionskommitté, största engagemang: Ruben Rausings Fond.

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