THE LONG NOW OF INFORMATION

Dr Bengt-Arne Vedin

Via teldok. 40

ISSN 0281-8574 • Price SEK 150

TELDOK was initiated in 1979 by the Board of Telia, Sweden's largest telecommunications operator, to facilitate early and easy-to-read documentation on the use of new IT applications.

TELDOK aims at documenting, as early as possible, actual use of new information systems and arranging study trips and seminars directly related to this task.

TELDOK activities are coordinated by an Editorial Board with wide representation from the IT corporate user community, academia, trade unions, government authorities, and suppliers. TELDOK and the Editorial Board can best be reached by email to teldok@ett.se or to its Secretary PG Holmlov, pg@stones.com.

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Reports are still stored in Ture's cowshed.

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ISSN 0281-8574

Graphic design: Ateljé Faktor, post@atelje-faktor.se, Stockholm 2000

Cover: PG Holmlöv, pg@stones.com

Printed by: Elanders GOTAB, Stockholm 2000

http://www.teldok.org/

Preface

This is not the usual Ten o'clock News, nor your everyday TELDOK Report. – TELDOK, of course, was initiated in 1979 to enable the documentation and dissemination of early experiences stemming from actual use of novel IT applications – although in 1979 one talked about office automation rather than information technology.

Since its inception, TELDOK has issued close to 200 reports in Swedish and a dozen in English; mostly case studies and/or reportage stories, looking closely at how selected leading-edge technology installations are being put to productive use.

Not so here. Instead, Dr Bengt-Arne Vedin deals with something much more basic, in one of the senses of that word: our human resources and faculties. Boldly he sets out to discuss fundamental patterns in human information handling, and how these may be changing alongside current developments in information technology. As we live in a "Long Now" – la Longue Durée – we may not notice small changes, or even differences that make a difference.

Enjoy your read! And should you find this treatise interesting, you will find a few similar reports (to order or to download) at www.teldok.org/reports/first.htm – although most TELDOK reports are more comfortable with a more basic and down-to-earth perspective on modern IT use and its consequences.

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Introduction

The improvement in machined surface finish displays steady and regular progress over the last 100 years – with two distinct knees, marking accelerated rates in refinement. These abrupt discontinuities in the change rate itself are not associated with advances in machining tools but rather with better measuring methods, improvements in obtaining information.

What would be the tools to look for when attempting to generate future trajectories of information technology and, indeed, the employment of human knowledge? Here those measuring methods in engineering correspond to, i a, new concepts, new symbols and notations, as well as to the discovery or development of intellectual tools. Such new concepts may also cause the abandonment of what turns out to have been preconceived conceptions, even prejudice and mental blocks.

But isn't it true that man is programmed biologically, and nothing much could possibly affect our thus given set of faculties? This proposition, however, forgoes social and cultural influences of the most profound kind. While our hearing may be constrained to a certain frequency range – as is our seeing – we may learn to remember tunes and appreciate music; we may learn at an early age to be aware of or oblivious to certain sounds or phonemes, different for different languages. Some languages contain many more words for different colors than others, which seems related to the ability of discerning colors too. If we acknowledge that there are important constants in human ways of treating, understanding, coping with information, we must also ask what might cause such constants to change.

This book is a search for such constants, a search necessitating a broad scope. This is the Long Now, that which seems never to change, that which we do not even recognize because we take it for granted – after all, it's constant, isn't it? If it really is constant, then it also establishes the base for what is at all possible, and for what is not, when it comes to new types of information and knowledge tools, to the soft and the hard and also the social aspects of information technology.

Here, we have touched upon human cognitive skills. In the realm of physics, we know the uncertainty principle to set firm limits to what we may know or, rather, what information combinations may be attained. Information technologists would associate with quantum computers but some advocate an even more profound idea: that information may constitute a fundamental element of nature.

Contemplating instead the social context of information, of knowledge, the real constants may be phenomena such as lock-in, critical mass, positive marginal returns, tacit not just declarative knowledge, and balancing the rewards for creating something new with mechanisms for its wider diffusion. If that is the case, the Long Now is constituted by stable but not necessarily fundamental or unshakeable interpretations or implementations of such constants. In science, may IT cause the invisible college to change in a fundamental way, or may perhaps that college be substituted? Tacit knowledge we associate with men but what about an adaptive computer program's acquisition of tacit knowledge, offering us the very best solution often enough (always?), but with no explanatory power but for the circular answer: this is the way it is because of my experience? In employing formula in scientific and social dynamics, may there be discoveries of fallacies of those constants termed rules of thumb, like when chaos mathematics revealed linearity to be exception instead of basic rule?

Such fallacies, as we shall learn, are present in human "common sense" as well as in much teaching and learning. Sometimes they can be overcome only with new social critical mass, sometimes through new business, institutional, or procedural ideas. There is always one word covering the outcome: surprise.

1. Thinking about information, knowledge of thinking

There is certainly a huge step between a large part of humanity slowly going from animism or polytheism to monotheism to something as relatively mundane as the introduction of photography in newspapers and the concomitant loss of relative anonymity. The question is whether there are any connections at all on a conceptual level between such seemingly disparate pieces of change, despite the fact that they share the feature of being associated with how we perceive the world.

For us to know how ancient man looked upon and understood that world is squarely impossible. We may ponder cave paintings and what seem to be ancient musical instruments but there is no direct way to substantiate whatever our contemporary hypotheses. Yet rely as we may upon interpreting sources such as surviving artefacts, legends and myths – that's what we have to do. The big question is whether, even if we were able to trace the past trajectories of mankind's more profound belief and cognition and knowledge systems, if we could then also extrapolate them into the future. Perhaps not: "the only thing we learn from history is that we do not learn from history"; but might we not at least gain some clues as to what to look for? After all, seeing from a new vantage point might prove profitable; if the vantage point stems from our own history, why not? Which all begs the question as to how such cognitive, information, knowledge, and value systems might be described.

The Gods were present

Reading ancient literature, including the Bible, we are struck by the fact that the Gods – there are in a number of cultures, including the Greek, several of them – are present and actively engaged in human activity, something which people accept as a fact of life. The explanation supplied is that people listened to inner voices that they took to be the voices of the Gods. There were no reasons for doubt; everyone shared those same perceptions[1].

To borrow a phrase from one of these thinkers, intuitive and emotional thinking of this type is our most profound in the sense that it constitutes a human individual's most basic thinking faculty, the primary process or paleologic thinking[2]. Logic and rational thinking would then just be man's own constructions – social constructions indeed – slowly, consciously developed. And, by the way, early on, they were allowing freely for a quite natural blend between this secondary process and the basic primary one – the combination manifest in Pythagoras' belief in the magic in numbers or, much later, in Newton's eager pursuit of alchemy.

It may seem hard to get to grips with the then perceived reality of what we would now call hallucinations – shared emotions, incorporating the certainty of divine intervention – but of course we know of mass psychosises of a violent political hue as well as of that displaying a religious deliverance type. Propaganda, perpetuated also by modern media such as television or movies, singing and other music, may be instrumental in preparing for an exhilarating experience very far from logic – in fact, defying, challenging, discarding logic. The magic just described would lend itself to cult, to cults, and here monotheism, embodied in, e g, Christianity was a novelty since it contained also a belief system. Mind you, this is a view leaving out Buddhism and Hinduism; the point is that a belief system comprises much more of comprehensive knowledge treatment.

There is another line of development that might conceivably be linked to the one sketched out above. Would you regard Confucianism as a religion, or rather as a moral and behavioral code? The organization of legal thinking and a profusion of legal structures – religious law, inheritance practices, Magna Charta – into one body of knowledge, albeit initially full of loopholes and contradictions, made for, next, discussion and annihilation of these contradictions, thus for some of the elements of what we call rational thinking to be established. Moslem culture served as a bridge

1 Arieti, Silvano: Creativity the magic synthesis. Basic Books NY NY 1976; Gelernter, David: The Muse in the Machine. Fourth Estate, London 1994; Nørretranders, Tor: Märk världen. Bonnier Alba, Stockholm 1993; even Minsky, Marvin: The Society of Mind. Simon and Schuster, NY NY1986

2 Arieti, Silvano: Creativity the magic synthesis. Basic Books NY NY 1976

to bring its own and Greek learning into the West; then, when Aristotle dogma in 1277 was found to be in some instances pagan, the Church started preaching criticism to Aristotle and old Greek knowledge. Thus were sown the seeds for dogma busting, Galilei's Dialog emerging as one of the results.

Somewhat later, Descartes laid down as the foundation for believing anything at all in his own existence "cogito, ergo sum", I'm thinking, thus I exist. He understood to exist himself because he was conscious about himself thinking. We might demote this self-evident suggestion to formal philosophy, but that's just because we cannot imagine not being conscious.

Now I am present –

"Not being conscious?" Yes, the suggestion forwarded by research – and, as I have stressed already, it's tenuous, speculative, working with indirect clues – is that consciousness has not always existed but is rather a recent development. Reflecting on it, we don't believe animals to be conscious (or? –[3]), so the question narrows down to the claim "recent" – how recent? And then, with the same cautioning as to the interpretations of a rather indirect set of indicators, there is even the argument that consciousness developed and existed for a while, a couple of thousand years ago, then disappeared, to reappear only a bit more than a thousand years ago. And now, partially because of information technology perhaps, our perception of consciousness may be said to be turned upside down.

Logic, consciousness – are there any other such profound and possibly overlooked changes in the nature of human cognition, perception, and thinking? With the same caution as previously, there are strong arguments to suggest that the perception of color is also fairly new. Think of it; Homer's descriptions of colors are distinctly odd. So color perception, the way we have it and with the same rainbow, may be another recent development.

How could this be? I have, as my brother, as had our father, the faculty of waving my ears. It is impossible to describe how I do it; I just do it – impossible to teach. I have a friend who can whistle with his ears. Developing a faculty for distinguishing colors might serve some purpose and thus benefit evolution, in the case of colors, the evolution of human culture. Waving one's ears, I suspect, may not carry the same intrinsic value.

The main point is that we are blind for those things that seem,

[3] Dennett, Daniel C: Kinds of Minds. Basic Books, NY NY 1996

are, must be – so self-evident that we just would not understand how they could be otherwise at all. But, on the other hand, if they were to change, that would be the most important and pervasive change of all.

Progression at three different paces

So – this is my starting point: if that which is self-evident were to change, that would be the most important change of all. The great French historian Fernand Braudel suggested that history could only be properly understood by distinguishing between three different patterns of development, three different cycles in time. Ordinarily, history has been understood as a series of events, battles, inventions, business cycles. The time horizon, the event horizon, is short. Underlying these events, however, are changes that are important in understanding the whole series of events – changes in trade routes, in markets. Finally, there is something even less moving or changing, *la longue durée* or the long permanence. The life and tools of a Swedish farmhouse did not change very much between, say, the 14th and the 17th century.

Consequently, changes in that long permanence are really earth-shaking if and when they happen, even though they may happen too slowly for people to observe. The last two centuries have certainly seen a number of permanent structures, previously belonging to the *longue durée*, turning into fast-changing features of the market restructuring or even event horizons. Most futurologists concentrate on tracing trends, which is to trace a series of events or the sum of such an event sequence.

My proposition is that future studies should also be more concerned with *la longue durée*, simply because it is the backdrop for profound structural change and events happening "on top" of them. Furthermore, if they set the stage for the future, a change in that stage that we perceive as permanent and unchangeable would be the most important of all.

You should now have recognized my concern for the development of consciousness and our perception of colors (which we will come back to later). If we were to develop some other faculty of the same type, that might be of overwhelming importance. The question is whether we would be equipped to see it. To give another example than ear waving: recently it was discovered that there are some olfactory sensors in or under the nose allowing us to smell without "smelling"; yet another example is the recent discovery of a fifth fundamental taste. How should we interpret such discovery? Answer regarding the new smelling system: we are not conscious of smelling anything, but brain signal measurements reveal a sensory arousal directly linked to smell-less odours (which is then no oxymoron).

To some, this would not be a very large surprise. We may tie this to the fact that our consciousness is capable of handling, of being conscious of, at the most, 50 bits per second, but more likely something like 15 bits per second. We also know that through our senses we receive something like 11 million bits per second, so there must exist some very powerful sorting mechanism somewhere. We take in a large number of sensory inputs, and they constitute an unconscious base for creativity, intuition, and, most importantly, emotions. When ancient people felt the Gods present in a direct way, this might have been due to their direct contact with their body sensations.

A question of seeing

Brunelleschi, who was responsible for completing the cathedral of Florence, was more of an engineer and architect than an artist, and he succeeded in inducing the local authorities to allow for an early type of patent system for him to gather a better return on his inventions (or at least one particular among them). But he seems also to be the one responsible for a turning point in art history, introducing perspective – yes, that convergence of lines at a distance that we learn of in drawing class. Before, all paintings were flat: there existed no foreground nor distance in the sense we are now used to.

"Are used to". How could we possibly ever unlearn such a discovery? And how could we ever miss making it? Well, that's the definition of discovery – and here is another one that might seem self-evident once it has been made; still ingenious and rightly famous artists before the 15th century never did it.

It is a question of seeing. Our ways of seeing are primed by what we – "are used to". There is a book collecting paintings produced by Europeans who had just arrived in Australia in the 19th century. The landscapes look distinctly odd. That is because they are European landscapes in an Australian setting. It was plain impossible for the newly arrived artists to really see and register what their eyes transmitted; there was an element of interpretation, an intermediary information process in between, and that was pre-programmed by their upbringing, by what the were used to. Likewise, when European ships first arrived to the straits of Magalhães, the Patagonians could not just comprehend them as ships. No such ships could exist, according to their frames of reference; the Indians of America first perceived the mounted conquistadors as a new kind of monster, horse and man combined and fused together. (All of this has to do with perception and cognition rather than brave scientific or technical pronouncements that it is impossible to make flying aeroplanes.)

Seeing is linked to, as well as constrained by, the existence of notations. Thus the development of such vehicles for thought, for memory, for knowledge accumulation has to be dealt with. The prime example is of course mathematics.

There are a number of changes in interpretations characterizing various schools of thought that can only be understood, that make sense just within the framework of the epoch when they were forwarded. Two relatively minor first. We mentioned Newton's engagement in alchemy. The superficial view is that alchemists tried to make gold – transmutation. The stone they sought was in reality wisdom, insight, the expression of an esoteric longing for that which could not be translated into words or by logic but that touched, even contained the most profound meanings of the world. This longing came from the same sources as Gnosticism, gnosis standing for knowledge and wisdom. Another slow change dwells in the root to our word technology, the Greek *techne*, which stood both for the functional – technology, problem solving – as well as the beautiful. Initially, there existed no distinction between the beautiful and the functional, they were equivalent. (A historian of technology might add that the machinery and the factory of the early industrial age were designed with aesthetics in mind, machinery and even products equipped with adornments lacking in function but adding to beauty – just look at an old sewing machine.)

– of establishing that seeing is worthwhile

Early on in medical history there existed enormously detailed instruction books for medical doctors, with an abundance of beautiful illustrations. The odd thing is that they had nothing whatsoever to do with reality, with the actual anatomy of the human body. Again, the innocent expectation would have been that what was there for the eyes to see would prevail. But that overlooks the fact that the real practitioners were the surgeons, often operating on the battlefields of war, and they did not really belong to the medical profession, they much lower ranked, regarded as they were more as plumbers, as workmen.

The same attitude, no, the same philosophy, paradigm, *longue durée*, doctrine, prevailed, as we well know, in physics. The Greek pagan Aristotle (sometimes supported by others, such as Ptolemee) had told how nature should work, and, as in a planned economy, that plan held forth despite any incidents to the contrary in plain nature. So much worse for nature, or at least for the heretic that believed in what his eyes told him. Until, as we have seen, the Church opened the doors for criticism of Aristotelian dogma in 1277.

The tower of Pisa makes for a colorful part of that unfolding history. Certainly the earth moves but it is really Galilei's experiment, showing that two bodies of the same weight fall with the same speed (or, rather, acceleration – needing the same time to make the same distance falling) regardless of material. Lead, clay, or eggs – it didn't matter. While Descartes produced an aphorism, Galilei became the symbol for a new type of thinking: instead of being straight jacketed by a doctrine you should believe in what you are seeing, something that later was transformed into the creed that everything should be able to be tested and tried, and that experiments were the way to learn to understand nature. Empiricism: only that is true is that has been tried, not something pronounced by some authority. The effects of the Church parting ways with Aristotle were indeed slow to emerge: observations such as Galilei's were still, in Galilei's time regarded as an attack on Church dogmas. *Eppur si muove*.

There were some important institutional inventions that helped these philosophical changes permeate society, in a way institutions taking on the all-comprising institution the Church, such as the scientific society and the learned journal, and we will return to mechanisms for accumulating practical knowledge, including that which is embedded in machines. Through journals, within learned academies, throughout an invisible college, observations might be shared, theories might be discussed and criticized! In other parts of society other institutional inventions turned out to be of pivotal importance for the development of economy and technology: the patent system and the limited company. As argued in another chapter, a very important precondition was Gutenberg's printing press, and not only patents, scientific articles or corporate data but also criticism of the powers that be found its way into pamphlets and journals, eventually newspapers, thus forming one of the foundations for democracy.

Spectacles, clocks, the compass –

The printing press was most probably instrumental in bringing about reformation and the eventual pluralism of Christian creeds. Books no longer were as rare as before so ideas could be spread more freely, making the acquisition of literacy much easier. And preceding the printing press by less than two centuries was another important reading aid, especially for the elderly: eyeglasses.

This optical device came about just as the mechanical clock was invented. It took some time for the clock to become standardized – turning clock-wise or counter clock-wise; the terms had no meaning until after a couple of decades – but then it changed work organization and church-going forever. A real change in *la longue durée*, even though clocks could be found only on church towers.

Again, there are so many things that we just take for granted. Who would think of the compass, the clock, or the eyeglass as information technology? And better maps, with better ideas about how to interpret different projections. In the era of discovery, they were even state secrets. Information technology, yes, that is what they constitute, and if we transform the eyeglass into a binocular, which took a couple of centuries, we also have a number of important tools for navigation – navigation which changed trade routes and thus markets and economies, that changed the view of the world and brought new peoples, animals, and plants into the minds of the Europeans. Certainly the world was a globe now. How important to the navigator isn't a means to define the longitude. A sketchy image of development certainly. But, then, what shaped, allowed for, provided the basis for any development (as we define the word) at all occur? Again, a theme to return to.

To keep track of money, of economic performance

Book-keeping and accounting procedures are no mean feats of human development, nor is the banking system, allowing someone to draw a check at one place and cash it somewhere else – developed as they were by something else than modern franchise chains: Lombard families and Knight Templar crusaders. It would take some time for a tangled web of local, regional, and national restrictions, taxes, customs, monopolies, expropriations to develop first into mercantilist state interventionism, then into an approximate market economy where a Newcomen steam engine might be calculated to operate at a loss instead of allowing for sub-optimization.

Aristotle had had a hard time trying to understand whether women and slaves could actually think. Again and again, perceptions change over millennia. The new idea of enlightenment, progress, begot what was a rallying cry first of the American revolution, then of the French: there are inherent, inalienable human rights. Liberty – "we, the people" –, equality, fraternity. And yet another organizational invention was introduced, the draft. It is superfluous to return to the importance of the printed medium to spread these ideas and the seeds of the ideas of nationalism that the French revolution were to plant. This revolution also carried the idea of general education, however. But it took another century for the human rights laid down in, e g, the American declaration of independence and the constitution to be applied to slaves, and even longer for most countries to recognize equal rights for women.

We will abstain from yet another retelling of the history of information technology, with Vaucanson's duck, Jacquard's punch cards, and Babbage's incomplete machine (which was actually built in Stockholm, and did function, but there was no substantial market for it). It took another century and a half for computer technology to have an impact on man and society. Let us instead get back to our ways of seeing.

An artist got his pay from his sponsors, who, as is evident from, e g, the Dutch Golden Age, often enough wanted their portraits. In the early 19th century, art had developed into an ever better reproduction of the object – with the license always to improve on the object's beauty. This is ironic, because the invention of photography of course meant that now reproduction would be exact. As a consequence, art changed, first attempting to trap magic lights and, with Seurat the pointillist as an example, to allow for different impressions from different perspectives, then into non-figurative art.

More directly important, however, was the possibility of diffusing the likeness, the portrait of a person. It has been remarked that before the advent of photography, Queen Victoria and Benjamin Disraeli might have performed the sensational act of walking hand in hand through Hyde Park, and no one would have recognized them. They lived in the age of photography, however (and the Queen was extremely enthusiastic about the novelty of three-dimensional pictures, taken by cameras featuring two lenses), so now their faces were family to most people.

Their faces were so familiar since it was now also possible to reproduce photographs through the agency of the printing press, something that had required yet another invention. And again, the first casualty of war turned out to be truth. Prince Albert, Queen Victoria's husband, was active in harnessing the popular newspapers in turning an unpopular war, the Crimean War, into a more popular one, using photographs as a major vista in distorting the reporting so as to sway general opinion.

The world as digitally reconstructed

With all this, let us now return to the present and see what we may divine about possible future impacts of information technology. If we pursue the rather basic line about photographs as apparent witnesses of the Truth being used for manipulative purposes because of this quality – what about data bases and global information and representations that purport to make the intangible tangible?

First, there is the acknowledged existence of McLuhan's global village. As Daniel Dennett has pointed out, this raises disturbing ethical questions. When, in the old days, our mental horizon was limited to the immediate village, or the immediate battlefield or hospital for that matter, we might express our compassion in a direct way. But with atrocities and suffering in Rwanda, Somalia, Bosnia, and Brazil present in the electronic fireplace that constitutes our TV set – what should humanly be our response? One reaction might be dumbness and cynicism, an alienation from something that is too disturbing to be allowed to affect us. The other extreme is taking that suffering so to the heart as to commit suicide in a literal sense, or more indirectly, in going mad.

A completely different line of development which has nothing to do with our deep moral concerns is the one suggested by such effects as morphing or such movies as Forest Gump or Toy Story. Josef Vissarianovitj Dzugasjvili alias Stalin used to eliminate fallen competitors by not just executing them but also through changing the Soviet Encyclopaedia and editing existing photographs. Such manipulation is now child's play for about everybody mastering a personal computer. It is conceivable that this first hand experience of manipulation may have profound effects on our perception of reality – and they must not necessarily be all to the bad, though one scenario is that they too would foster cynicism.

We may link this to post-modernist thought and deconstructionism, which claims that reality is just a social construct. Certainly, this line of thought has been thoroughly criticized. The salient features seem to be, however[4]:

- all explanations as to how reality "is" are themselves constructs, and we may leave them, whichever they are, exchanging one for another
- a different sense for personal identity and its delimitations: those delimitations vanish – there are no clear cut classes, races, etc but many multiple identities, like Hispano-Americans
- learning is of paramount importance – or, rather, discovery, to open the way for role changes. Science is a good model for this
- ethics is a living phenomenon. Even if creeds become bankrupt, morality does not, but it is a living and changing creation
- we realize that we have to belong to, have to inhabit one or several social constructions of reality and accommodate to the fact that they are constructs and constitute a conscious choice – and responsibility.

Do we do what we can rather than what we ought to?

Empiricism, the heritage from Galilei, begot positivism, which is certainly not wanting for critics. The heritage of Descartes included the idea of a clockwork universe that had to be amended with that quantum mechanics theory that so concerned Einstein. The clockwork model was further rocked by the discovery of chaos effects.

Again and again, we are in trouble with cause and effect relationships. Quantum mechanics were developed long before a notion such as information technology was launched, and though chaos mathematics got its name only in the 60s or the 70s, it goes back to the great mathematician Poincaré almost a century before. Computers, however, make it feasible to exploit the nature of chaos much easier, and to discover and play with phenomena such as fractals at personal computers.

Thus chaos mathematics – we might almost say chaos mechanics, meteorology, physics, etc – has profoundly shaken our picture

[4] For these five features, I am basically following Walter Truett Anderson in "Reality isn´t what it used to be"

of the clockwork universe. For a century, students of mathematics were told that a small change in a parameter or a value of variable meant just a small change also in the outcome. Now, for non-linear equations, an arbitrarily small disturbance may lead to a whole world of a difference – and non-linear equations (with friction, viscosity in liquids, air resistance against a bicyclist, an auto, or a train) actually govern the world. This is the butterfly effect: the flapping of the wings of a butterfly in Beijing may cause a hurricane in the West Indies three weeks later.

This may sound rather technical though the weather is of some concern to everybody. My speculation is that this is such a profound discovery – which we will return to later – when it comes to our understanding and hence description of nature that it will have to impact on our thinking in the long run, though it will take some time for curricula and teachers to learn and to adapt. The application of chaos in everyday life may seem moot now, but since there is nothing as practical as a good theory, there will be a number of practical applications of chaos mathematics that will impact on various activities in society and which then have to be explained to those affected.

Information and quantum uncertainty

As Einstein was never satisfied with quantum mechanics, he developed a number of counter-arguments. Many of these have been laid to rest, with Einstein the loser. But there is one experiment that he and some of his collaborators suggested that has become quite a stumbling block – not just to quantum physics but to physics itself.

The argument is rather technical and it has taken time to develop ideas and facilities as to how to test the conjecture. Basically, in quantum mechanics, a particle's characteristics are unknown until you measure them. But they are not just unknown to the one making the measurement but also to the particle itself – it is undecided! Under certain circumstances, a particle may be split into two other particles, "smaller" and with characteristics that in some sense are opposite, so that if they are "summed up" the sum of that characteristic is zero because that is the value it had for the original particle, before it split up.

Now since the characteristics add up to what was the original particle, the two new particles speed away in exactly opposite directions from where the original particle was. They have opposite characteristics, say opposite spins if the original particle had no spin. But as long as they are not subject to any measurement there is no spin expressed. Only when we measure on one of the particles does it suddenly "obtain" a definite spin – and its twin, which may be extremely far away by now, acquires the opposite characteristic, here the opposite spin.

The mystery here is that the "signal" telling the second particle what spin to acquire is momentary, so it surpasses the speed of light, which, according to Einstein's theory of relativity, is insurmountable. It goes without saying that much ingenuity has been vested into performing these experiments in a sound and foolproof way, and inasmuch as modern physics and information technology are closely linked, IT has been indispensable here.

Again we might be justified in saying that this is no everyday experience and that it touches upon only the outer limits of those difficult laws of nature, relativity at velocities that we cannot really comprehend, and quantum effects at such a minuscule scale as to render it meaningless. But there are a number of suggestions as to how to explain the apparent contradictions, involving, for example, the idea of universe as necessarily regarded as one single entity, possibly one that in a sense is "aware" and "thinking", alternatively as a new type of force field, transcending just everything. These and other theories are early attempts to come to grips with something thoroughly disturbing to current theories. As is indicated by the word within quotation marks – aware, thinking – a firm explanation might very well involve descriptions that might affect our comprehension of the universe in a profound sense. We will dwell more on these and related quantum effects in two later chapters.

Mediated experience?

And now for something completely different again. It is said that a young generation, steeped in television, computer games, net surfing, and virtual reality will have an entirely different worldview. The killings performed by under-age kids would seem to underpin in a most chilling way a distortion of the sense of reality and human suffering that television programs may induce. It is discussed whether computer nerds loose social abilities or whether it is just a passing stage for most and rather a way out for those that would always be socially handicapped. When a five-year-old in

Washington, D C has a keyboard pal in Australia, it makes for a difference in perception both of time and geographical differences that might be akin to the upheaval caused by Columbus' discoveries.

There are also discoveries such as those which demonstrate that when a space or air pilot is going off to a mission that will require superhuman concentration and rapid decision making beyond what is normally feasible, he or she could enhance his or her capability through simulating a similar mission in virtual reality. This could be another clue as to how our brain works, or it might be just a good way of training in an environment that is safe and non-threatening. There are particular games, developed out of multi-user dungeons, where the play is dedicated to literally thousands of people creating and forming virtual societies. Sometimes people's behavior goes astray, and the participants defect so the society just dies. Possibly, there will develop certain ground rules for sustainable societies wholly dependent on their acceptance by the participants – the citizens – in an organic way, complementing focused tests of ways out of the "prisoner's dilemma" and alike. That again might affect social thinking, discussion, and social action.

To underline that not everything is information technology, we may take of note some other developments of importance for future thinking. The Gaia hypothesis, that all global life, and conceivably all the universe, should be regarded as one living organism, is such a hypothesis which has already had quite some impact. Rupert Sheldrake is still rather alone in supporting his idea of morphogenetic fields; new developments are formed by what happened earlier (my description does not do justice to Sheldrake's intricate arguments). The spirit of the earth existing for mankind to exploit, supported by some verses in the Bible, may be substituted by strong beliefs that all activities must allow for sustainability (and if this would become the governing paradigm, it would certainly affect knowledge and information technology development).

If we take the clue from Braudel, we should look for those hidden permanencies. While culture and social structures have seemed to be rather malleable, we would see man's biological nature as a given constant. There are limitations to what we may carry out physically, as we see when the sportsmen move the limits. There would seem to be a larger latitude for mental capabilities if we catalogue what has been mastered, possibly because the expression of what is genetically endowed is culture and environment dependent. Information technology may offer ways to establish links between the human genome and various human faculties. If so, this may constitute another major change in man's view of himself – and a trigger to discuss another dimension of ethics.

Learning more about learning – and about learning less

There is yet another permanence in our lives, and that is education. Whyteboards and overhead transparencies aside – the Greeks used sand for geometry and mathematics lessons, and the teaching techniques have changed in no significant way since. No, that's not true! Gutenberg had a profound influence; the modern school, a century and a half old, would not have existed without printed materials. But apart from print, television, slide series, radio, computers and video – educational technology has so far made less impact than does the dedicated and gifted teacher. Such a teacher may, of course, employ modern technology, but the issues should not be confused.

It is conceivable that information technology may help us gain new insights into our mechanisms for learning, obscure as they still are. It is even conceivable that the various ambitious attempts to harness video games and computer software and virtual reality to improve teaching or the learner's own discovery of knowledge will gain real breakthroughs. If so, such a break from *la longue durée* would be of utmost importance. Perhaps we would learn to learn rather than just learn mathematics or the Catalan language or biology.

Not all learning shortcuts are necessarily all that beneficial, however. With the advent of the cheap electronic calculator the faculty of making sums and other calculations by hand or in the head was less necessary. Thus one can see the man in the shop take out his calculator to sum up 75 and 14 or read a technical newspaper make a "small correction" when there was a number that was precisely 1000 times too large; the power of ten had been mistaken. Let's not forget NASA's enormously costly mistake in the normally straightforward conversion between metric and inch units. With computer simulations, physical experiments can become more exotic and colorful and also much more efficient for learning; they might be made more complex and involve situations that would have been just too cumbersome or costly in real life. For all the positive effects, the apprehension lingers whether there might also be the distance from 75+14 in the sense that the direct contact with the real physical reality is lost, and with it an intuitive feeling for what is reasonable.

Let us now return, at last, to human consciousness. If this is a recent phenomenon in human history, it may also be an illusion. As a matter of fact, how can we comprehend some kind of a Master Governor reflecting over and controlling our behavior? Who would then control that Governor, and who would then, in turn, … ad infinitum? There are a number of phenomena from perceptual psychology and measurements from physiology that make sense only if we recognize that there is no single, central locus of control.

To abstain from information

What is consciousness then? It is, if we follow Dennett and others, the result of a collaborative effort between a great number of specialized agents, communicating their various information. As we saw before, there is a powerful selection mechanism involved in our perceptual apparatus – those 11 million bits of sensory inputs per second are concentrated into something closer to 15 than 50 bits per second. And it is no haphazard sifting process either, we make do with this compact representation to take us through life and obviously our fellow human beings share much the same selection preferences, else we could not communicate, collaborate, and function as social beings.

Apart from the enormous concentration or sifting involved in consolidating all those 11 million bits there is also another conundrum. It turns out, by means of elaborate and ingenious experiments, that if I decide, say, to raise my hand to write down the next letter of this chapter, then the signal to my arm, hand, and finger has already been on its way for something between one half and one second before I consciously feel making the decision. So who made it for me?

Dennett calls his hypothesis the multiple drafts theory. While our perceptions are gathered through the enormous sensory input, all those specialized agents of our brain, working in parallel in a large neural net, together form a number of hypotheses about what is happening, about how sensory inputs should be interpreted. When reality arrives, the false hypotheses are rapidly weeded out, and what is underpinned by reality stands out as the one single experience. This is why dreams may end with a signal just as the telephone rings; this is why there is a necessary slightly more than half a second of latitude for consciousness to receive this after-the-fact construction. We may also regard the sifting and sorting as an evolutionary process much like the Darwinian one. Different "drafts" represent different mutations, and they compete – may the one best suited for survival win out!

This description resolves a number of psychological paradoxes but it is certainly not lacking of critics. It might be improved, amended, or substituted in future; the point is that there are a number phenomena that point to the fact that our intuitive feeling for how we think and act is patently false and misleading. Again the proposition is that a more truthful understanding will also affect human life and future society. Here, for once, there is a direct link between the profound changes in the picture of man on the one hand and information technology on the other. The new ideas about consciousness stem from the quest for artificial intelligence, created through programming computers. The early intuition was that people's brains worked like computers, but with ordinary serial or von Neumann computers this did not fit. So learning from how the eye could input all that information at the same time, the idea of parallel computing was spawned.

We know that we can take in and handle at the most "seven plus or minus two" chunks of information at the same time, as psychologist George A Miller stated in 1956. This is one of the most influential articles in all psychology literature[5]. It remains to define those chunks.

Still, there a large number of questions and mysteries remains to be tackled. What happens to all those millions and millions of bits that we input but of which we are never conscious? It has been suggested that they are instrumental in creating affect, mood, emotions. They are available in another sense than that of logic and consciousness.

We are also back to the nagging question: who is in control, if not me, if not my conscious self? Luther solved the dilemma of telling whether it was good intentions or good works that counted by claiming that good intentions should, if they were really any good, result in good deeds. But here my deeds are already decided upon by some unconscious part of me, asking me to take charge only after the fact, just allowing me the efficient illusion of having

[5] Miller, George A: The Magical Number Seven, Plus or Minus Two. Psychological Review No 63, 1956, pp. 81-97

decided. Should I opt for always displaying (to myself at least) good intentions, and leave the responsibility for any doubtful deeds to my unknown and uncontrollable unconscious?

My unconscious self, however, is affected by all sorts of inputs, presumably also my own good intentions. The resulting, winning draft of all those tried and tested is the one most resembling reality. This is ascertained by a procedure that was one of the most important features of Watt's steam engine: negative feedback. Our consciousness, our creed for logic and rationality, is fostered during a number of years when we have difficulties understanding grown-ups, mysterious plants, animals, and inanimate objects, and ourselves. Logic and rationality are part of our social conditions, as is the perception of color.

Some readers may be reminded of a phenomenon that was for a while much disputed: subliminal perception. According to the prevailing myth, a hidden message was inserted in a movie in the 50s: buy ice cream! the screen said, but only so infrequent as to not register consciously. And people bought ice cream. Later the myth was amended to claim, rather, that the subconscious featured more of subtlety than the ad agency had perceived – some people felt cold and got out to hire blankets.

With the spectrum of eleven million bits per second on offer, and given the fact that they are blended in some yet unknown way with previous inputs of the same kind, that "Buy ice-cream" approach would seem all too crude. The only we could say is that there is something to it in the sense that the message reaches our unconscious – but what that unconscious makes of it, in you, in me, and in all the other various visitors to the movie theatre, with their vastly different backgrounds of past perceptions, that is quite another story.

The discrepancies that call for change

In very broad lines, the story I have reported is surprising to me. Early on, learning was an exclusive privilege, mostly for clerics, thus related to religious dogma. Even philosophers and doctors of higher learning were steeped in dogma, however. Rather than much production of new discovery, some old leaked into Europe by way of the magnificent culture of the Arabs of Spain's Caliphate.

When the contrast between Church dogma and actual practices became too glaring, Luther affixed his 95 theses to the door of the cathedral of Worms. His was an empiricism of religious practice, but a scientific awakening slowly substituted reality for a petrified doctrine. Still, science was a privilege for the few, and scientists and philosophers competed with artists and magicians for royal sponsorship.

The French revolution did not feel to "need any chemists" but education should be made to be available to everybody. This was the beginning of a quest for creating basic education for everybody in the Western world; in Japan something akin already existed, though more based upon Buddhist creed and initiative. Later on, close to our days, more than basic education became a right.

Speculating about the future, it is possible to suggest that we now find ourselves at a new juncture in that scientific experimentation may be at the reach of just everybody. We have seen new theories relating to consciousness, quantum mechanics, chaos mathematics. We might add complexity theory and artificial life and systems analysis with its features of counterintuitive behavior. And we have met virtual societies developing in an organic and egalitarian, non-authoritarian way, raising the question as to whether there might be emergent properties governing sustainable societies.

The virtual society is a game. Complexity and chaos and artificial life are all available in various programs to be investigated on an ordinary personal computer. They will only be exploited if sufficiently playful and intriguing games or quests are developed. The Gaia Hypothesis, mentioned above, has been embodied in a game, SIMEarth, one in a series of computer games. For the first time, what is happening at the forefront of science – not all science, but some of physics and mathematics and also chemistry and sociology – might be translated into truly fascinating and discovery-making games. In some, natural laws may be changed and amended. The speculation, then, is an number of ifs: if this happens, if it catches on a broad scale, then there might be a new public perception of both science as such and a genuine and profound adoption of these new views of the world, of human thinking, of conditions for social communication.

2. Bits more basic for physics than fundamental particles?

There are several links between information theory – between "information as such" whatever that might mean – and the foundations of nature, i e, basic physics. Well, since physics is a science still evolving (despite propositions that "the end of science" should now be in sight), some of the links between information and physics are hypothetical. One linkage is fairly obvious – thermodynamics depends upon entropy or some measure of order or disorder, and that clearly has something to do with information. The other possible relationship might be between the uncertainty that is a key characteristic of quantum mechanics. We can never know everything on the quantum scale; the Heisenberg uncertainty principle tells that the more information we gain in one direction the less we know in another. If we, on that scale, obtain certainty as to one factor, then another will stay entirely undecided – try to affix a position to a quantum particle, and momentum will be out of bounds entirely. (This is the established dogma currently, though there are some deviating ideas[6].) Then the question arises: who does the actual measuring, with what – what particles, at what level, are involved in this act of, as it is captioned, forcing the wave function to collapse? This wave function "is" the indeterminate particle: the various statistics describing the probabilities that the particle (which simultaneously takes on aspects of a wave) may be in one state or another. We will now attempt to discuss these different –

[6] Stewart, Ian & Cohen, Jack: Figments of Reality. Cambridge University Press, Cambridge 1997

or are they really different? – interdependencies, starting with black holes.

On the border of a black hole

A black hole is an odd creature, so odd that it sometimes seems to defy the laws of nature, of ordinary physics. One prime example is the so called information paradox, posited by Stephen Hawking and a potentially serious conflict between quantum mechanics and the general theory of relativity. In principle, it is easily described. Everything sucked into a black hole will vanish, and it can never come out of that hole again, never be retrieved in this universe. Possibly it might exit in some other, parallel universe on the other side of the black hole, but that is a possibility entirely inaccessible to us, and we can only be concerned with our own universe, and the rules and laws governing it.

Suppose that we send something with a high information content into that black hole: a book, or a computer with software and memory perhaps. Suppose this is the only copy, that is, some original, unique information. If this information is truly lost, then quantum mechanics breaks down. Yes, such a breakdown must take place because quantum mechanics like all of physics is based upon reversibility – in principle, any and all processes should be able to run in the reverse direction. Not so with black holes, however. Once something is lost into such a hole, nothing is retrievable any more. The consequences would be far reaching: energy also might be created or destroyed, even a perpetuum mobile designed.

This is very much at the forefront of physics – a hotly disputed topic at that (the forefront may be defined as where disputes are). Thus there are suggestions as to how the conundrum may be resoved. How do we, from the outside, at a safe distance, perceive of a black hole? There is an outer limit to it in the sense that when something has passed this absolute borderline, this something is inevitably sucked in, which holds even for light, which is why the hole really is "black" – nothing, not a single photon that has passed that outer limit can escape.

But relativity still holds. This means that if you where to pass that borderline, you would not perceive it at all, not realize that you are going to get lost into that blackness. You would just move on, and move on until the eventual crash or annihilation or passage into another universe. It also means that from the vantage point of an outside observer, the vehicle – you, the computer memory, or book – would slow down all the more the closer you, the memory, or the book came to the limit, the kind of outer boundary[7] that is created at the point where "sucking in" starts.

The slowing down would be of the most radical type, which means that also the movements of atoms or smaller particles making up the atoms would grind to a near halt. They themselves would not discover that, of course – in their frames of reference, nothing of the sort would happen. We would, from a distance, be able to see in minute detail, as if they were glued to a wall, the innermost parts of nature, innermost parts of that book or that computer memory, or of your brain. Eventually those smallest parts, which – according to one of the fresh theories of the inner makings of reality – may take the forms of strings (if that is what they really are, see below), will also be visible.

And it then turns out that such strings constitute the exact counterparts to bits. We can, from the outside, see in slow motion – still motion? – the most detailed informational structure of that which in its own frame of reference, another than ours, is falling to its death in the black hole.

A computer with zero energy consumption?

The entropy of a system is, as hinted at previously, a measure of the disorder of system. It is also proportional to the capacity of a system to hold information.

We know – or we believe, according to the standard theory of physics, so with good reason – that the universe is grinding to the heat death, to an absolutely even even distribution of all matter which then will have been translated into heat, distributed all over that universe, a universe then just a fraction of a degree warmer than absolute zero. Heat does not mean hot, on a human scale.

If a computer can be made to work at slow speed, it will consume very little energy. It would seem as if this could be made to just exactly balance with the slow tailing off of order in the universe. The clock speed of the computer might be adjusted so that it would never discover the slowing off. Just like when we never see the information vanish in the black hole but instead see it in ever greater detail, may we possibly design a thinking machine that features eternal life in its own time frame? Zero energy consumption would hold only for information within the machine, though, but

7 Susskind, Leonard: Black Holes and the Information Paradox. Scientific American, April 1997 pp. 40-45

getting it in and out cannot be made for free. Furthermore, zero energy consumption would possibly mean operating at 0 K but the balance for the universe weighs in at 3 K[8]. By the way, there is an upper limit to computation speed, set at 10^{21} bits/Ws so we have some way to go since today's fastest computers are at the order of 10^{10} bits/Ws. The one concern, paradoxically as it may seem, is that information processing should not reach such a high energy consumption that the whole universe is incinerated.

In the meantime, we know also that there are dissipative processes, far from equilibrium and the overall trailing off, processes creating local chaos and thus lots of new order, local order – at a price: "dissipation". Thus for a long long time we have to look for these local chaotic processes rather than the overall pattern and what in comparison would seem to be rather uninteresting panorama.

So, talking of the long history of information, we cannot discard the links between that which seems so transcendental, information, knowledge, and its physical underpinnings.

A measure of order

May we see information, bits, as physically founded regardless of links to those embattled strings? Embattled they are in the sense that they constitute but one theory – recently evolving into a theory of small thin surfaces, membranes or super membranes, as previously there were superstrings in many dimensions, most often ten, sometimes up to perhaps 26 (we will return to the subject of dimensions presently). What interconnections, if any, may exist between energy, entropy, and information? Because we know that there seems to be a connection between the latter, and the first connection exists by pure definition, drawing energy into the picture.

The creation, our world, is said to consist of mass, energy, space, time. To regard information as a fifth fundamental, and not just a derivative of the others, may seem like a bold conjecture, but there are some strong arguments for it.

A long time ago, Claude Shannon generated the formula as to how much information there existed in a message but he was reluctant to link his equation with entropy even though the formula turned out to be formulated exactly the same. The link to entropy stems from the fact that a closed system, left on its own, sees its

[8] Barrow, John D & Tipler, Frank J: The Anthropic Cosmological Principle. Oxford University Press, Oxford 1996

order decrease, which means that entropy increases – this being a somewhat sloppy rendering of the laws of what is called thermodynamics. Energy is conserved but degraded into heat, more and more evenly distributed. Heat can never be fully recovered into, e g, mechanical energy. The pattern that existed previously is vanishing, thus information. There is more information in order than in disorder.

The mind has a habit of creating patterns, of establishing order, of gathering information. Then there is the problem of subjectivity: who might be able to discern order in a sea of disorder? What are the tools for doing so, tools like mathematics? Then, also, we have the mystery of quantum mechanics, a mystery for the human brain at least, the mystery that Einstein so detested – 'God seems to play dice'. Yes, if we look at the innermost parts of the atom, we have already been told that we cannot know simultaneously both position and momentum, i e, speed. So far so bad – but how does it happen, then, that this basic uncertainty coalesces into our own orderly world? There must be some information transformation in between, giving credence to the idea that information is a basic property of nature[9].

There is of course an obvious link between information and physics. To actually register anything to memory, we would have to use some medium, be it the brain or some electronic, mechanical, or other contraption. We certainly know that electronics is becoming ever more miniaturized, but somewhere there must be some tiny bit of difference in electrons, atomic states, photons, or whatever, to tell of what the memory contains ('information is the difference that makes a difference' - Bateson).

Now suppose that we have one atom, just a single one, that may oscillate between two chambers of a vessel, the chambers linked through a narrow channel. The atom will be equally often in the two chambers if the two are alike. If we only were to measure the position of the atom and then closed the channel at the right moment, we would of course know that it was to be found in that particular chamber, not the other one. That observation, affecting the closure, equates with information. But this information is not gained for free. It may be calculated that the loss of entropy that our ordering of the system implies equates exactly with the energy consumed in measuring, in the intelligence gathered from pinpointing the position of the atom, where thus entropy is increasing in-

[9] Johnson, Geroge: Fire in the Mind. Vintage Books, New York 1996

stead. Entropy is flowing from our contraption for the atom to the measuring system itself.

Once and again, there have been attempts – we are still referring to the contraption – to close the channels (very often thought experiments, Gedanken experiments) without measurements and the concomitant intelligence. Those attempts were always in vain – information is an absolute necessity.

Eventually, though, it actually turned out to be possible to do the recording of the information for free. But there was a particular twist, an important caveat: it was not possible to erase the information without some cost. Indeed, in principle it is not the collection of information that is costly, but rather the creation of a clean slate, an empty medium to do the recording on. If we start with an empty memory, then the investment has already been made.

Heat death (which, as has been mentioned in passing, is now somewhat doubted also) springs out of something called the Carnot cycle. Heat can, as we have noted already, never completely be recovered as, say, electrical or mechanical energy. Might there, for all other parallels, not be an equivalent to the Carnot cycle for information?

Well, if we make an addition, a subtraction, a multiplication, or a division, we impute a couple of numbers, and we arrive at the answer, which is just one single figure. We may do the simple subtraction 4 – 1 = 3 but if we are just told the answer, 3, we may suggest an infinite number of ways to arrive at it: 5 – 2, for example, or 6 –3, or 1 + 2. Our original formula 4 – 1 thus contains more information than the answer, so something must have been lost in the computation. (When we measure on a quantum particle, its wave function collapses, and just one of many previously potential, indeterminate states prevails. And just not as to render "measurement" too magical – this holds for all interaction with the "environment" of the quantum particle.)

Here is the link to the energy cost for erasing information. In a calculator, be it our brains or a computer or an abacus, the original numbers are stored discretely, in some cells. When the answer is arrived at, these stored numbers are erased, and irretrievably so; it would cost energy to restore the original state, energy that is dissipated in the process.

The energy used for clearing memory is negligible in any of today's computers. The more sophisticated memory and calculating devices we design, the lesser will this loss also be. Still there is a natural limit to how cheaply we can erase bits.

There is, however, at least one more trick. Let us never erase anything! We may then run the tape, the computer, backward to get back to the raw, the full information. But then those results are necessarily erased instead? Yes, they are, but before running the thing backwards, we may have made a copy. And copying does not need any minimum energy. The suggestion is that the whole computer might be powered by just Brownian motion, those minuscule thermal vibrations of molecules. The information would manage a trick that is impossible in ordinary thermodynamics – possibly indicating that information is even more fundamental than matter and energy. Well, after all, that tape must have been blank in the first place, and to produce it, energy was required.

There is at least another trick too, and that is to distinguish between different types of information. Remember that information in the sense of discerning patterns must be said to be subjective, and how might subjectivity – relations with the environment, that particular environment – tie in with the world of physics, of quantum states of the electron or the blank tape or the small electronic computer devices?

As a matter of fact, a highly patterned system is something that is highly unlikely, very far from high entropy, and it can be said to contain a lot of information. On the other hand, to describe such a highly ordered pattern takes very little information, while describing a very disorderly system requires a description of its every crook and nanny. The orderly state may follow a mathematical formula, or a certain rhythm of figures in a frame of reference. There is even a term for this, algorithmic information. Here the orderly system needs little such information, the disorderly huge amounts. Various mathematical entities may be described as more or less orderly in this sense, 1, 2, π, $\sqrt{2}$, e (the base of natural logarithms), and many others.

Here is how Wojciech Zurek suggests reconciling the various aspects of information: the ignorance of the observer is measured by Shannon's statistical entropy, while the randomness of the object is given by its algorithmic entropy – the smallest number of bits required to record it. When measuring, the observer's ignorance decreases as its memory recording grows so that the sum, the physical entropy, stays constant. We thus have the observer and the observed being parts of the same system, the flow of entropy internalised, and another onlooker, regarding the whole system, will see it as constant and indeed consistent. There is thus a law of information conservation.

If, however, information might be compressed, when we are relying upon clever coding, discovering hidden pockets of order, a pattern where none seemed to be? Then such intelligence would beat the law we have just seen formulated. Actually, it turns out that information theory and computation laws in combination put a limit on how much a message might be compressed. The most compact description still has to contain at least as much information as was present in the original. As with thermodynamics, the best we can ever expect is to break even.

The upshot of all this is that a tape of memory could be used as a store of energy. As Charles Bennett has suggested in George Johnson's book[10], why not for powering a car?

The absolute randomness or entropy of a number, like π, e, etc., is, as we have just seen, defined by the shortest algorithm that is sufficient for its calculation. With this rule, π is not that random, since there is a finite formula for the calculation of its infinite string of figures.

Recently, there has also been developed a heuristic, a way of calculating the approximate figure of randomness, something that might prove of great value in, e g, medicine, such as when trying to detect irregularities in the heartbeat of children, preventing sudden child death[11]. Information to save lives! Information arrived at by what seems like the most circuitous route. This heuristic does not coincide precisely with the algorithmic result. Thus π, e g, would be very random if attempts were made to calculate its entropy. It also turns out that here the base for the counting system, 2, 10, 12 etc. is all-important to the actual result, seemingly indicating a particular type of subjectivity.

Information deeper than reality?

As far out as though it may seem, some physicists believe information even to be a certain kind of physical substance, in a sense more real, more fundamental than those fundamental particles that themselves are being reduced to complicated mathematical formula. Information constitutes the foundation of all that, the claim suggests.

Information would not change no matter how we choose to transmit it. Well, that certainly holds for the ordinary world. But

[10] Op cit

[11] Casti, John: Truly, madly, randomly. New Scientist 23 August 1997 pp. 32-35

quantum effects impinge upon information too. Information linked to a quantum particle will be everywhere and nowhere, just about to collapse – still indeterminate. The idea here is that it is not information that is affected in this way but rather the other way around – information is the fundamental agent behind. Then quantum theory would be a theory of information[12].

A particle can exist in several states. An electron in a magnetic field has two options, spinning clockwise or anti-clockwise versus the field, being "up" or "down" in the physicists' language. Affixing the numbers 0 and 1 to these two states might seem fitting enough – one bit, that is, would be stored.

Not quite so. A basic tenet of quantum physics is that the electron carries no determinate spin until you attempt to measure it, until you measure the spin. Before measurement, it is schizophrenic enough to exist in a superposition of states offering both up and down simultaneously. Instead of talking about one ordinary bit, we have the information unit of one qubit, with the two ordinary options plus the two mixed in any intermediate proportions.

One might think that two electrons together would offer two qubits. Not so, either, as long as they really belong together. The two electrons would be entangled, even at a large distance, and in an entangled state, if one spin is up, then the other must be down. This again is radically different from classical physics, and because of entanglement, these electrons cannot store the full two qubits.

What is trivial in classical physics no longer is in the quantum world. Superpositions collapse irreversibly when measured upon so there is no way of knowing an electron's state – superpositions and all – before you carry out that measurement.

In the early 90's, Charles Bennett of IBM showed that teletransportation would be possible – in principle – in the sense that you might define the exact state of all the particles of an object at one end of a transmission line, transmit this information, and then reconstruct an exact replica at the other end. This must be done by using entanglement since quantum information can neither be copied nor read. Replica, that is: we would have an original at the one end and a true copy at the other.

Suppose we want to teletransport a particle X, e g, a photon, from one place to another. We would then use an entangled pair of particles Y and Z, the first at the sending end, the other at the receiving. As mentioned, we cannot just measure the properties of

12 Buchanan, Mark: Beyond reality. New Scientist 14 March 1998 pp26-30

X because then it collapses and loses some of these properties, all those superpositions. But we may measure a combined property of Y and X, yielding some information about X mixed with some about Y also. There is some collapsing taking place, to be sure, but the missing quantum information about X instead slips down to Z because of its entanglement with Y. The incomplete information about X combined with particle Z allows us to reconstruct a particle identical to the original X – something demonstrated for the first time for photons in 1997.

The caveat is that any small disturbance will destroy the effect completely so going from photons that might be kept isolated could prove just an impossible task in reality. There are, however, ideas about how to correct the errors introduced by the nearly inevitable noise and other imperfections. Error correcting codes and built in fault tolerance are two options proved to be feasible.

The quantum world is so weird that Einstein said it could not be so; there must be some certainty (here we go again); 'God does not play dice', but to this Niels Bohr replied: 'don't you tell God what to do'. The new idea is that the quantum world is the way it is because of some deeper phenomena – in a world of information. Among the smallest pieces of quantum information we have mentioned the qubit. The maximum amount of entanglement in a pair of particles would be an ebit, a single unit of entanglement.

To regard qubits and ebits as particles of information is not just using lofty metaphors. We think of space as being empty, and yet, within the realm of quantum physics, we also regard it as boiling with life as virtual pairs of particles are created and vanish again during a short period of time governed by the Heisenberg uncertainty principle. This even creates a certain force, recently measured. Should such a virtual particle happen to interact with a real particle during its brief existence, then, and only then, it would also have signalled its existence.

The theory goes like this. An ebit, which is the entanglement, represents a kind of virtual information – observe how we here have introduced something new to information theory, because ordinarily, information would always be real. The entanglement of two particles corresponds to creating a virtual pair of information particles, a qubit and an anti-qubit out of an information vacuum – again a correspondence; what, then, about a Heisenberg uncertainty principle for information?

The analogy goes on. Virtual information particles would not let know of their existence if they were not to interact with real information. When a qubit, which constitutes real but somewhat peculiar information, meets an ebit, the result of entanglement, two classical bits are created – remember the collapse of information – but if then an anti-ebit is created out of this, a cubit is recreated and the anti-ebit may combine with the ebit to define the entangled pair of particles.

Heresy or discovery? This is the way that the proposition we mentioned above comes about: that information is the foundation of all existence and that the basic properties of physics, from quantum matter and up, could all be derived from the basic laws of information, yet to be discovered.

The mechanisms described here are also some of the foundations for the quantum computer that will be much discussed and experimented on in years to come.

There is, however, yet another route for arriving at the conclusion that information is the basic "matter" of reality, or behind all physical matter. If we think of perfect knowledge about whatever natural phenomenon as being one particular entity, and then succeed in making the most exact measurement that fundamental laws will allow, then there will remain a difference between the two. That difference can be deduced formally, and it turns out that it takes the form of a differential equation. For different phenomena, different fields, forces, etc, there are different differential equations, and these turn out to generate our usual laws of nature which are, indeed, differential equations also.

It is thus established – the argument goes – that those laws of nature are the very closest approximates to "the real world", *das Ding an sich* if we like, that we may ever arrive at. What is especially impressive to physicists is that in this way even the central law of relativistic quantum theory is derived – most often, other laws of nature, like Maxwell's equations, have never before been successfully and conclusively linked to this cumbersome part of physics.

The arrow of time – information is the key

Perhaps it might seem even more surprising to find that the very existence of time is linked to information, as well as its characteristics as a physical entity. The fact that time exists can be viewed as associated with a process of information loss.

To most of us, this would seem awkward since we all have a very personal relationship with, yes, an experience of, time. Of course it exists. Of course it may be measured, even though it may experienced, subjectively, as flowing at different speeds. And from Einstein we learnt that it constitutes the fourth dimension of universe, adding to the three spatial ones.

It differs from those spatial dimensions, however, in the sense that time has a direction. In space, we may move about up and down, forward and backward, while time does not seem ever to move backward. How may this asymmetry be explained? Because explained it needs to be, even though our experiences feel self-evident to us.

In the equations of relativity theory, time is one of those several dimensions, and as they, it is relative, which is something else than subjective. Signals linking different places in space follow the curvature of time-space, and it makes little sense to speak of "simultaneity" over distances in space. Relative velocities and especially accelerations play important roles. Nonetheless, time features a direction, an arrow.

In physics, reversibility is, as we have claimed, the rule but there is one important field where irreversibility reigns supreme: thermodynamics. Again: all energy is slowly converted to heat and it is impossible to change the direction; entropy increases inexorably. Entropy is a concept for less order, more disorder.

The big bang that most physicists believe was the starting point for our universe is seen a having been characterized by an immense degree of disorder (it is at that starting point that the supplementary dimensions of string theory may not yet have curled up to be so minuscule as not to be observable). How, then, might we conceivably explain a development from maximum disorder to – what? – even larger disorder? The explanation is given by the fact that we have an important force called gravitation. The second law of thermodynamics, which is the one we have just implied when speaking of the heat death of the universe, applies only in isolated, self-contained systems. In the universe, gravitation and heat are certainly not isolated from each other.

A new, unbroken deck of cards is well ordered, with each color separate and in hierarchical order. After a number of shufflings, it is immensely less ordered. The shuffling as such does not imply any direction, and it is not irreversible in any fundamental sense.

But shuffling has destroyed a given order or symmetry, and the unique, the very abnormality was constituted by this pre-existing order.

Let us now introduce our subject, information, into the discussion. A system in total disorder needs only a few bits to be described. A bottle containing a gas randomly distributed and in equilibrium needs little information to be defined. A container with several hot spots, chemical reactions and unevenly distributed molecules features numerous forces and fields, and therefore it requires, by contrast, a very detailed and information rich description. When the system approaches equilibrium, when the deck of cards is shuffled, information gets lost – irretrievably, irreversibly.

When a body collapses into a black hole, it loses information. The increasing field of gravity prevents light from exiting and since light cannot travel faster than light, it is also trapped by the hole. To the spectator, the information seems irretrievably lost. The black hole would function as an information sink. As we have seen, it all depends on the frame of reference.

Where, then, did this process start? How can we explain that development may have a direction at all? Especially if it turns out to be true that the universe is pulsating, finally getting itself back to the starting point for the big bang?

The answer may be found in, if we like to express it that way, a version of the anthropic principle, that the universe can only be in a very particular shape for it to allow for the existence of human beings (well, not necessarily us, human beings, but information processing systems, evolving with eons of time and the workings of auto catalytic systems and variation, reproduction, selection pressure and coevolution and competition – a story we turn to in another chapter). So the fact that we – mankind – are here to observe the universe, to experience it having a dimension of time, requires that the very same universe features certain characteristics, including the arrow of time. If this seems somewhat circular, remember that we now have brought the observer into the picture.

This is where we have to return to the number of dimensions constituting our physical world. As was told previously, to explain the fundamental forces of nature, it has been suggested that there exists something between ten and perhaps up to twenty-six different dimensions, not just four, those dimensions, however, now – but not necessarily early in the history of the universe – folded up in very small, imperceptible measures; and there have been suggestions that there exists several time dimensions also, not just one. For the macroscopic laws of nature existing, however, there must be just three space dimensions, and one for time – else, among many other things, information transmission would be hopelessly distorted, so impossible. This may be a minor inadequacy compared to the fact that intelligent life would be entirely impossible. This is the weak anthropic principle: we wouldn't be here to discuss the world of three plus one dimensions unless there were precisely those dimensions[13].

As we have seen, entanglement between quantum particles means that when one of two particles collapses from a state of indeterminacy into a specific state, then the state of the second particle collapses also, and it does so instantaneously, even if the particles have travelled far apart. The conundrum is how this might happen while the rule that nothing can travel faster than light still applies.

The conundrum is actually much more profound. All particles of the universe, or at least quite a few, have a history of relationships like this, so all of it would seem to be linked through an invisible web. Explanations from invisible force fields to mystic powers of our senses have been evoked and suggested. This problem will certainly continue to be in the focus of physics research for quite some time. It may well be that here is a key to the mysteries of physics. Or it may be that precisely what we perceive as reality, aggregated actions of particles whose wave functions have collapsed, constitutes an impenetrable shield from the entirely different "reality" that physicists are striving to come to grips with, developing ever more sophisticated mathematical models, containing ever stranger concepts like chromodynamics and quarks and charm.

There is an entirely different way to come to grips with this problem, and that is by adopting a multiverse point of view. Every collapse of the wave function is associated with the particle "opting" for one of several more or less likely outcomes. The multiverse view suggests that this is what happens in one universe; but there are an infinite number of parallel universes where the other options are realized. As a matter of fact, there are physical phenomena that can be explained by this version of physics but which confound all other currently available theories – while there have been no loopholes discovered in the multiverse view so far[14].

[13] Barrow, John D & Tipler, Frank J: The Anthropic Cosmological Principle. Oxford University Press, Oxford 1996

[14] Deutsch, David: The Fabric of Reality. Penguin Books, London 1997

This is obviously very far away from our intuition. Even further away is the concept that in such a multiverse, time does not exist. We have to remind ourselves, time and again, that we here discuss on the applications level of quantum physics, thus far away from classic physics. In the world of our senses, which observe phenomena according to classic physics, time and thermodynamics and just one universe do exist – but when we come down to more profound problems, classic physics won't do.

Such problems, such phenomena are fundamental enough to be mentioned here though they would crop up in many other treatises as well, in physics to be sure, in philosophy, and in discussions of the human conditions – not to mention science fiction. It will not be possible to use, for example, the effect of instant disentanglement to transport material bodies of distances with an immediacy beating the speed of light. But what might happen – and we should here only take this as an example, and warn about the fact that such speculation, discussion, and development are already taking place – is that information might be transported over large distances instantaneously, if systems profiting from this effect may eventually be developed.

3. Information evolution – in past and future history

Language is certainly an information structure; money and markets are also; as are 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.

Reproduction, mutation, competition, selection; is that all there is to it? All – this is quite a handful. Over a long period of time, with replication and reproduction taking terms? How did it all start – in clay structures, in different chemicals merging symbiotically? And so, without the precious properties of water and of carbon and carbon based chemistry, life and the information systems that it depends upon would have been impossible[15]. Here is of course not the place for 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.

15 Barrow, John D & Tipler, Frank J: The Anthropic Cosmological Principle. Oxford University Press, Oxford 1996

The power of spontaneous positive feedback

The first proposition may be 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 that, intitially, 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 that the two latter are structurally different. That's six different combinations[16]. 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, i e, another sixteen, bringing the sum up to thirty.

Molecules combine and the combinations are dissolved again. But if, e g, the combination BAAB were to catalyze the combining of AA and B to make AAB, then AAB would become privileged. Assuming that this agent in its turn would catalyze the formation of ABA, which then in its turn makes for a further catalyzed reaction forming BABA, the net result would be a final catalytic reaction, producing, say, AAAA. Which we in its turn assume would be a catalyst facilitating new production of BAAB. Now we have a closed loop: BAAB (by chance)–>AAB–>ABA–>ABA–>BABA–>AAAA–BAAB (by catalysis). Against a 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, until the supply of one or several basic ingredients is exhausted. There has now been 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 turn out to be rather general. For purely mathematical reasons, they are even hard to avoid. 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 on 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). This deciphering feat is possible just because of the inherent meaning of the kanji signs.

16 Johnson, George: Fire in the Mind. Vintage Books, New York NY 1996

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 the job of the butcher, each having and mastering more specialized tools. 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, plowbills, 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[17], 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 growth in 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 of central planning or a 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 with ever more subtle and differentiated 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[18]; money has value because it has value because it is money that has valure because... The growing specialization makes for more varied opinions, judgements, morals – not less, and this growth would seem to preclude the "endings" recently forecast to be imminent – the end of history, the end of science.

17 Stewart, Ian & Cohen, Jack: Figments of Reality. Cambridge University, Cambridge 1997

18 Dyson, George: Darwin Among the Machines. Perseus Books, NY NY 1997

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 modeling the kind of self-organizing processes and structures that we are trying to describe in a general way.

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 to our concerns for the environment, for the impact of mankind on the global ecology. This too may be described in information terms. Think, for example, of a copper pan, used for the preparation of food. If copper is growing more scarce, its price – that carrier of information in an economy – goes up, and there may be substitutes for copper offered, aluminum 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 the food tasty enough. The taste, however, may – in some future – be generated through information fed into our nerves directly, so we could have good cooks operating in a world of virtual reality[19]. The basic need, besides the pleasure evolving out of that information package, is for energy to sustain the human who is eating, and that energy might be provided through other means entirely, healthy certainly, and without any effects on the nature whatsoever, just relying upon the most energy efficient production methods 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 –. Early specialization in crafts 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-organizing processes – provided that there are some 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 sheer numbers that cause complexity to evolve from such simplicity.

[19] Barrow, John D & Tipler, Frank J: The Anthropic Cosmological Principle. Oxford University Press, Oxford 1996

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 just speculate as to the development of information structures; one seemingly obvious organizing principle might be the one of economy, of efficiency. As one proposition has it: when intelligence has evolved, it may act independently, affecting future evolution.

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, that precision is of paramount importance, i e, some kind of rhythm in the movement. Triggering the right sequence of motions might be done through the invocation of 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 of them, permanently 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 roles and a basic story line.

This might be seen as an example of economy as directly applied to 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. As a matter of fact, it has been demonstrated that it is sufficient with just a few neurons to make a robot act like an insect – there may be "less to animal behavior than meets the eye"[20].

[20] Graham-Rowe, Duncan: March the Biobots. New Scientist 5 December 1998 pp. 26-30

Music actually follows some peculiar regularites – or peculiar for those not steeped in mathematics. The power spectrum of Bach's Brandenburg Concertos, for example, follow a regular power law. The details of the mathematical analysis should not concern us here but to sum it all up, if plotted in an appropriate diagram, after some mathematically straightforward transformations, the data desribing the compositions follow a straight line with a slope of 45 degrees. The amplitude of the music (instantaneous "loudness") and the spectrum of the frequency intervals follow both a homogeneous power law with the same exponential[21]. At a particular degree of redundancy in a artistic design, there is a significant increase in brain response, as signalled by brain wave patterns. Redundancy means repetition, and the repeated patterns are those of ornamental geometry – or perhaps doodling; geomtries found as early as in rock carvings and cave paintings.

Thus nature (and our own 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, and a good design may have a minimal need for information in the execution of a 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, tradeoffs that may be concealed or convoluted. 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; human brains seem to have shrunk over time, possibly because of a 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. Human brains are also abnormally huge and heavy (compared to those of other species).

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 tantalizing hints that you

[21] Schroeder, Manfred: Fractal, Chaos, Power Laws. W. H. Freeman and Company, NY NY 1991

inherit something else as well."[22] 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).

How may music be of service to the 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. At the same time, the actual representation of our inherent endowments may be affected by culture, by the environment. 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, 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 analyze 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, just one note changed on the second occasion, then the baby discerns the change more

[22] Vines, Gail: Hidden inheritance. New Scientist, 28 November 1998 pp. 26-30

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[23]. The Slovenian flute (?) fragment find displays holes corresponding to a diatonic scale.

When nerve cells fire, they do so in characteristic rhythms and patterns. Play a computer simulation of such processes through a loudspeaker instead of studying a wave pattern on a screen, and the result is astonishing. It sounds as music; not great music, but distinct styles, like baroque or Eastern music. It is still early days, and the results are disputed, but it would seem that listening to, e g, Mozart improves learning and test scoring abilities. Less controversial and even more pronouced are the positive effects on Alzheimer's patients and epileptics[24]. Somewhat older is the finding that "non-melodious" music (like Bach's) may improve language acquisition.

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 utilization 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 that 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 person's 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 this 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 man shares this predilection but may, in addition, increase the proliferation of his genes

[23] "A sonic boon". The Economist, June 7th, 1997 pp. 94-97

[24] Kliewer, Gary: The Mozart Effect. New Scientist 6 November 1999 pp. 34-37

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, murders are mostly committed by men and murderers 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 men show a 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 that 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.

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. This is 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, some important details also obscured by ideology. What important details do we miss because we are unaware of the ideologies shaping our perceptions?

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 randomly. This means that there is less risk that the ecology at large will be upset as it would be if fishing, hunting, or deforestation was concentrated to pinpointed and preferred areas, causing such profound changes so as to 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 physics. Still we know Newton's physics to be the "correct" one (as long as Einstein's relativistic effects can be safely left out), and that the

Aristotelian variation is some kind of antique superstition, refuted from Galilei and onwards. The reason our senses react in this way is that if second order effects like friction, air resistance, etc are included in the calculations – as they may be also in a Newtonian physics calculation of course – then the end result is more akin to Aristotle's version than to an ideal, i e, simplified Newtonian model.

Strands to turn evolution into development

So far, we have seen evolution as proceeding in a Darwinian way. There is reproduction, variation, competition, weeding out, but there is no progress, just opportunism. Mustn't that blind watchmaker be supported by cunning, though? There might be three ways of looking upon evolution, i e, as the development of information, intelligence, and knowledge. Some parts of the process are truly blind but some might act consicously, the intelligence that once it has evolved affects further evolution. David Deutsch 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 another chapter) time may be a meaningless dimension in a quantum world[25].

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. Quite a few of the results of quantum mechanics seem paradoxical, certainly when looked upon with our macroscopic eyes. If we apply the multi-verse model, introduced in the previous chapter (recalling that it is not at all universally accepted), quantum physics for all its uncertainty is completely deterministic. It can be so because the constant generation of new parallel universes, which together constitute the multi-verse, realizes in parallel all those different potential options embedded 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 specter 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

[25] Deutsch, David: The Fabric of Reality. Penguin Books, London 1997

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. Simulating the world, completely, 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 a on 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 multi-verse view, and accounting for the fact that entanglement of quantum particles encompasses the whole of the universe, quantum effects combined with the generalized quantum Turing computer makes for a seemingly bold forecast. It goes as floows: the whole world will, before the heat death of the multiverse, become one giant computer or omniscient knowledge system. This development 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[26] (we are currently at midlife). At current rates of energy requirements for computing and for a reasonable increase in information processing, through the evolution of science, the Solar system has been calculated to sustain 10^{70} 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.

[26] Barrow, John D & Tipler, Frank J: The Anthropic Cosmological Principle. Oxford University Press, Oxford 1996

4. Some not so obvious effects of the obvious

There are a number of rather well known facts that allow us to put together a number of less obvious but certainly intriguing equations and connections related to information and communication, and to the effects of knowledge. Nature holds a number of data just in its regularities and irregularities. If you take a set of random numbers, the number 1 will always be over-represented as the first digit, and 9 will show up with the lowest frequency. This has been relied upon for finding faked bookkeeping records: the ignorant embezzler would tend to allot the same frequency to all numbers.

Or, to take nature – if you plot in a log-log diagram the number of avalanches on a snowy mountain or the number of earthquakes of different sizes versus how often they have been recorded to appear, you will get a straight or almost straight line. This means that there is a power law at work[27]:

$$N(s) = s^{-T}$$

Here N is the frequency and T is the slope. Such laws seem to appear very widely in nature, including human culture. So, for example, it also turns out to describe the frequency of different words in, e g, the English language[28], or many other natural languages (Zipf's Law). This law can be used to calculate the entropy of, e g, an English text, and its turns out to be bounded by roughly two bits per character (since word length is appr. 4.5 letters on average). For a witty author with an active vocabulary of 100 000 words, the ten most frequent will occupy 24 per cent of the text while for an

27 Schroeder, Manfred, Fractals, Chaos, Power Laws. Freeman, NY NY 1991

28 Bak, Per: How Nature Works. Oxford University Press, Oxford 1997

easy to read newspaper limiting its vocabulary to 10 000 words this percentage is 30. We should note, however, that the famous monkey hitting the keyboard entirely at random will also generate "words" with frequencies obeying Zipf's Law!

Furthermore, there is a simple multiplicative effect in the way ideas may get established, described by professor T Gold. This is how it works. Let us for a field of knowledge or activity denote the degree of non-acceptance by a distance x from zero, zero representing the dominant idea, though without any dominant idea, chance and randomness making for a dominance by very very little. Here there is then a Gauss curve, bell-shaped, i e, $\exp(-x^2)$. If now people act upon this, which means writing articles, holding meetings, performing experiments, there will be a multiplying of $\exp(-x^2)$ by $\exp(-x^2)$ which yields a curve of exactly the same general shape $\exp(-2x^2)$ but with a slightly more pronounced "bump" at zero. And so the initial tendency, possibly just haphazard, is multiplied, again and again. Sometimes the slight inclination was the result of some action and some feedback. Or so it may have been the effect of a deeply felt conviction that then went on to become self-fulfilling.

Banal Facts

Let us posit some evident facts that might seem to have no particular effects on the workings of the world of information:

- the world population is growing
- technology options proliferate
- communication speeds are increasing

To this we might add an obvious development in the particular field of information:

- information costs are always falling

We might even claim knowledge costs to be decreasing. With the advent of various methods of writing, it was possible to write down and transfer information and indeed knowledge in new and more efficient ways. Various notational systems, like in mathematics or accounting or book keeping, meant the introduction of shorthand, again implying an increase in efficiency. Later, printing heralded a quantum leap downward in information costs, and also in costs associated with the transfer of knowledge. Some innovations with the same effect have been organizational, like libraries and scientific journals and learned societies.

When man was hunter and gatherer, there were few instruments for the transfer of knowledge but oral tradition and hands-on demonstrations. There were other transfers that were prohibited, too: viral and bacterial infections quickly died out because the critical mass of people allowing them to proliferate was non-existent.

Only with the advent of agriculture, conditions were to become such that they allowed for the concentration of people – men were no longer constantly on the move but tilling the same soil, year after year. Eventually, towns and cities were also to evolve. Apart from the fact that something new to the agricultural society, domesticated animals, served as a source of bacteria, allowed for epidemics to originate from animal origins, some societies now were sufficiently densely populated and also hosted large enough populations for epidemics to be sustained instead of just fizzling out. There turns out to be a critical mass of about half a million people that has to be surpassed for this condition to be met[29].

There is an obvious analogy to information and knowledge, regarded, if we like, as bacteria and epidemics. Here the critical mass, of course, need not be that half a million inhabitants – required for epidemics – it might be interesting, even important, to find a way to establish such a measure. The mechanism would have something to do with specialization – only a sufficiently large population would sustain the existence of different specialized guilds. Certainly their tasks might be performed also in a small, isolated village, but for more sophisticated trades, total dedication would yield great gains, possible furthered by increasing marginal returns that appear in many instances of knowledge development.

A larger population sustaining ever more specialized skills, communicating so as to share the benefits – there is more to commend an open world than just the economists' competitive advantages. As to whether there are countervailing mechanisms, making for an optimum speed of knowledge transfer or limits to the benefits of specialization, we do not know.

We may state it rather succinctly: if an economy is not large enough, it cannot develop[30] – there will not be enough of resources, of abilities to sustain variation. The same holds for knowledge, there must be a sufficiently large population communicating to

[29] Diamond, Jared: Guns, Germs and Steel. Vintage, London 1998

[30] Kauffmann, Stuart: At Home in the Universe. Viking, London 1995

sustain variation – i e, specialization. In a sense, we may propose that knowledge grows when it is used: more experience is gained, know how is exchanged and traded.

Combinatorial explosion

Enter our next element: the proliferation of technology options, of specialized knowledge options, of artisanship and competence options. With some communication and exchange, specialists might, as we have just claimed, build upon each other's achievements, offering improvements and new combinations. Often just the clue, the idea that something should be possible to carry out was sufficient to open the way for it being done. An Indian, Sequoia, saw the workings of writing and set out to design a writing system for his own language – independent of the alphabet but dependent of the very idea that spoken language could, in fact, be written down. Only a decade after some sailors had arrived on the shores of Japan with guns, Japan had most guns of any country on the globe, and the most advanced guns at that. Metal production was already sufficiently advanced; gunpowder manufacturing likewise; what had been lacking was the very idea of the gun, and perhaps the idea of making that little component, the screw.

Apart from some crude ways of signaling, with sounds from drums, trumpets, or human voices, or optical signals from mirrors and fires, more sophisticated communications were for centuries dependent upon physical transportation. This meant that improvements in horse riding, better rigs and better maps for sailing, and also roads and canals might increase the ability for information and knowledge to spread. There is, then, a quantum leap to the optical and electric telegraphs.

Early mathematics was partially equated with geometry with its important functions in agriculture, including water management. Writing had its applications in inventorying and storage and also in keeping track of land titles and experiences of seasonal variations. It was important enough to be kept for the privileged, as a tool for power and a link to religion. Thus information and knowledge were kept constrained, pointing us now to the fact that social organization also has important effects on information and knowledge evolution.

As we just noted, in only a few years, Japan had become the country with the largest number of guns. A number of decades later, the guns were gone. This could only happen because the society had been closed to the outer world, and because there was one ruler supreme, the Tokugawa Shogun. A similar story of absolute power happened when China abruptly stopped all sea travels, which up to that point had been bold and far-reaching and successful, creating what might have been the nucleus for a large overseas empire. The Indian Ocean might have become the Chinese Sea. Here again, there was an absolute power with the Emperor, putting paid to the expansion.

Since isolation is the exact opposite of expanding communications networks, it is fairly obvious that it would not be conducive to the proliferation of knowledge. A dictatorial power that feels the need for controlling certain aspects of social life risks being forced to control more and more of that life since like no man is an island, no field of knowledge is either. For two centuries, one single Japanese port was open to just a few ships from one natione, the Dutch. One item that was allowed to be imported in a controlled way was knowledge, like for medicine and chemistry.

Let us play just a little with numbers. As we have claimed, knowledge develops both through specialization and the concomitant deeper understandings, and the new combinations possible through the linking of different pieces of knowledge, sometimes in serendipitous ways. One might question an attempt to measure human knowledge but reliable proxies exist, like the number of articles published in scientific journals. That knowledge has been growing exponentially for a long time, yes, for as long as the measures have any meaning at all. This means that there is a constant doubling period: after N years, knowledge is twice as large as initially; after 2N, it has increased to fourfold its original volume, etc:

period	1	2	3	4	5
volume	1	2	4	8	16
combinations	1	2	24	40 320	20 000 billion

The third line, the number of combinations, has been arrived at through calculating the mathematical function “faculty”, written 1!, 2!, 3!, 4!, and 5!, respectively. On might object, quite correctly, that not all of those theoretical combinations have any value whatsoever in reality (though no one person would ever be able to just make the judgement). Since this will be true, the numbers come down quite a bit. But even so, the power of exponential or faculty growth, though somewhat reduced, is such that what in the earlier stages is entirely possible to encompass and control is completely out of hand at a later stage.

The Case for Openness and Competition

Another way of expressing this is to say that certainly the Chinese Empire or the Japanese Shogunate could exist and sometimes thrive. But they were condemned to lose ground constantly to an outside world that had perhaps less resources and less centralized power but which as a whole, precisely because of the decentralized power structures there, thrived on its larger community.

A lot of information is created, much of it through all those new combinations and permutations. All new information is not equally valuable, and some is not worth the while at all, certainly never just because it is new. With the enormous proliferation of information described, no single person, and, by extension, no organization either could, in the long run, decide on the value of different new pieces of information. There must be some thoroughly decentralized process, and that process, of course, is competition.

Different knowledge would evolve under different circumstances. Thus an exchange between, say, guilds in parts of the world with different climates and soils should be beneficial to everybody, not just those solving local problems. This would not mean that solutions always were converging but rather that new leaps in creativity and efficiency might take place. Communication must be possible, and it must be allowed, experimentation and the introduction of new practices must also be allowed.

As the tell tale histories of China and Japan demonstrate, we may interpret a lot of the waning and waxing of various powers on the template of knowledge evolution. The underlying principles are simple and straightforward, the conclusions not necessarily so.

Apart from the driving forces listed above, there is a more tangible one – society's concern for or valuation of information and knowledge. In another chapter, we have underscored Confucius' and Aristotle's' beliefs that merit should be the yardstick when allocating men to important positions in society. Communications luck and skills created the huge Spanish colonial Empire. The major concern of that society was not, however, information and communication, e g, expressed as trade, but with gold and silver mines, and to some extent agriculture, and merit was not the top priority. When Europe's center of gravity moved north (again), it was to trading and communications centers with little dictatorial powers from above like Amsterdam and London (where one king was beheaded and another ousted). In another chapter we have described the importance of objective measures rather than arbitrary Royal privilege.

Critical Mass and Speed Thresholds

As the example of a critical mass required for any existence of epidemics demonstrates, there are critical thresholds that prove decisive for development. The question is of course what such thresholds might apply to the field of human information.

One such event might be hinted at as follows. Early on, emperors, kings, and princes protected and used for their wielding of power privileged "knowledge monopolists". Knowledge was proscribed, its distribution severely restricted. Later on, under various religions, churches and alike took upon themselves to apply similar restrictions, at least in certain important fields. The invention of the printing press had, in Europe, something to do with breaking the church's monopoly on religion and knowledge, it had something to do with the creation of newspapers and scientific journals, the Enlightenment and the Encyclopaedists. And it was a prerequisite for the school systems created in the 19th century. With a literate population, another barrier to the proliferation of knowledge had been dismantled.

The passing of yet another threshold has been suggested and we will offer it as a hunch. Literacy did not guarantee everybody equal access to valuable knowledge. The suggestion is that the ever decreasing costs of information, *pace* Moore's Law, means a definite transfer of power from those privileged, from producers, to just about everybody, to consumers. The availability of worldwide contacts and information bases on the Internet would serve to underscore this argument. The more doubtful would warn of information overload and the privilege that might consist of mastering search systems, intelligent agents, knowledge robots, etc, or the fact that information might be valuable only as a lever for those who have some resources to leverage.

Another might be described by telling of a particular instant. The electric telegraph spread, after early problems, rapidly in the mid-1800s. During the Crimean War, it was employed to link the British headquarters at the Black Sea directly to the Government in London. To immense field command irritation – for lack of a stronger word – the desk strategists at home could for the first time involve themselves in micro-managing the fighting in the battlefield. Journalists covering the war also used the new communications link, and it must be assumed that their swift reports in the London dailies had some effects on what those Whitehall strategists demanded of its general who thought he had the privilege of being at the battlefield, not a continent away.

This implies passing a threshold but it also highlights a dilemma. Communication speeds may allow for instant availability of information but at the same time for more of centralized decision making – which flies in the face of the need to abdicate at the center since the proliferation of information and combinations and options make decentralization an absolute necessity. Intelligence agencies have learnt that they cannot cope with the mass of information they themselves gather, so they have to contend with news bureau reports[31].

Information, Repetition, and Trust

The prisoners' dilemma is a well known enough test of human collaboration versus uncertainty about selfishness. As we shall see, it has something to do with information behavior also.

The two prisoners, A and B, who have committed some crime together, are tempted to squeal by being offered just a minor punishment by turning the companion in. If both keep their silence, however, the punishment will be less severe than for the only one punished when the other has squealed. The outcomes are decided by the different punishments, the point often being that the smallest combined punishment is the result of the two prisoners both saying nothing.

If played just once, this would maybe just be seen as a test of an individual's behavior. If there are several rounds of "playing", however, the best outcome is arrived at with a tit-for-tat strategy, i e, do as your companion did in the previous round. Under many assumptions of punishment "value", solidarity between prisoners seems to pay off. There is one important qualifier, however, and that is whether the future, and the past, should carry the same weight. We may, in other words, introduce depreciation or inflation

[31] Adams, James: The Next World War. Arrow, London 1999

in a sense that winning now is somewhat, or a lot, better than winning in the future.

This is a clear-cut, and thus rather artificial, situation of handling exclusive and patently valuable information. The dilemma holds much more generally, however, in the sense that when we share information we hope for – exactly that – sharing it. We expect not just tit-for-tat but quid pro quo.

Thus we may suggest some more complicated relationships where the value linked to the information is important (serving time in a prison may be differently perceived by different people, in different ages, in different cultures); where there is some imbalance between the parties involved (even in the case of the two prisoners, they may face somewhat different punishments, one having a background different from the other); and the frequency that the situation is repeated and the "discount rate" or "depreciation" is yet another factor. There might also be the possibility that experience is built up through "small wins", i e, that the quid for pro is established at levels of less value.

We may at least postulate – speculation wise – that the different speeds with which information is developed and potentially shared, as well as the changes in longevity, might affect the equation, thus human information behavior.

Information as a Virus of the Mind

Memes are, with the description of Dawkins their inventor, the informational equivalent of genes. Thus they are "selfish"; they employ us, humans and our societies and cultures, to propagate themselves. Some memes are long term successful, some more are merely ephemeral. A host of attempts to survive make for a number of temporary but finally dead memes. Sometimes a whole conglomerate of memes is tied together in a comprehensive culture, religion, creed of any time, philosophy. Relying upon the analogy with biology and genes, where a corresponding entity is the genome, we might call it "memome"[32] or "memeplex"[33].

In an analysis of "thought contagion", Lynch identifies seven different modes of meme diffusion – parenting quantity and efficiency wise; proselytizing; preserving; combating; affecting cognition; and motivating[34]. Thus if, e g, computers by necessity call for more computers, that would imply parenting efficiency while when computers are used to design better and less costly comput-

[32] Stewart, Ian & Cohen, Jack: Figments of Reality. Cambridge University, Cambridge 1997

[33] Blackmore, Susan: The Meme Machine. Oxford University Press, Oxford 1999

[34] Lynch, Aaron: Thought Contagion. BasicBooks, New York N Y 1996

ers, it's about quantity. When computer software systems are ingrained, they serve in the preservation mode, making for the long term survival of, e g, Fortran and Cobol. Apple seems to be losing the battle with PCs, while early on, its adherents displayed zeal to make proselytes. But it would be difficult to affix proselytization or combat to computers, so it's not inherent in those memes. Cognition and motivation might be, though. But many religions on the other hand call forward the missionary zeal. And celibacy, which seems counterproductive from the point of view of the selfish gene, can be explained by religious memes now obtaining full dedication (rather than sex, kids, etc).

Like genes, memes are more successful the more they display all three characteristics of fidelity (it's the same meme that is transferred), fecundity, and longevity. Blackmore provides the example of two persons, one nice and friendly and helpful, the other much the opposite. Who will make friends, who will get the attention, who will get to be the best propagator of memes? This, says Blackmore, is why altruism can be found to proliferate. Here we can see the links to the "Prisoner's Dilemma".

We may also see meme development and meme acquisition in terms of investments. This is another way of arguing that increased specialization may offer the rewards of increasing marginal returns. "The more we know the more we know" – the more we learn about a subject, the easier can we find new consequences and developments building upon prior knowledge.

The point is to find the "universal laws" guiding the development and diffusion, possibly epidemic, by such content carrying entities. From Rogers and innovation theory we learn that there are five different dimensions affecting the transmission of something new:

- importance of advantages delivered
- ease in perceiving this advantage
- compatibility with existing systems
- divisibility: may part of the idea be used first, separately, and easily? may it be introduced just gradually?
- complexity, thus the need for extra skills

We may also note that when information is needed in a hurry, in a crisis, we are constrained to the fairly well-known vistas because time is short. We are used to information being for free, or almost – "information wants to be free" – and are reluctant to pay much for it because it is impossibleto know its value before obtaining and studying it. And then it has already been transmitted, indivisible as it is. It serves as its own content declaration and its value is subjective: it must be related to something, a frame of reference, a problem, a field of knowledge.

Beware of Jumping to Conclusions

It is just plain easy to see information as a central resource or base for action or decisions and control everywhere. We would tend to see – and there is indeed easy to find such descriptions – a true wonder in man's coordinating of a myriad of intricate movements of his limbs. 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.

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 cause only limited little need to resort on information in the actual execution of a particular task. Perhaps our design is even more wondrous, though not in the way we had thought!

There is thus a trade-off 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 trade-offs 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.

Here is another such story about convoluted human information relationships[35]. Hold a hand in water at 14 centigrade for 60 seconds, and it is a decidedly unpleasant experience. Do the same again, and then add 30 more seconds at 15 degrees, and the end result is that what objectively would be seen as greater pain is instead remembered as much less painful because the last 30 seconds were somewhat easier to endure than the first minute.

We may thus conclude that the duration of an experience seems to be severely neglected by our memory. The most intense moments and then the endings are what count. So our information processing has distinct biases which affect what and how we remember.

Common sense would certainly have it that it is better to have an uninterrupted view of traffic when going into a road crossing; you would expect seeing all other cars early on, making for minimal risks for an accident. Not so fast! The less you see the more prepared for the unexpected you become[36]. This is a seemingly unexpected result of research into human cognitive behavior, the study triggered by concern for the design of road intersections preferably less conducive to accidents. So again, common sense is stunted. It turns out that people tend to observe cars that may threaten to collide more easily when the objects approaching are partly obscured. How this might be interpreted in designing information, e g, presentations, information systems, or more efficient teaching lessons is quite another story.

In Lieu of a Summary

As a summary, we may offer some long term indications as to when and where information will develop most rapidly and knowledge be applied most profitably to society:

- information and knowledge will develop and accumulate more eagerly the more efficient competition between different solutions there is
- the less control of information exchange and knowledge development that is exerted the more information and knowledge resources will grow possible
- decentralized power structures and systems in general will be the most conducive to knowledge transfer, information proliferation, and the generation of new combinations

[35] Ayton, Peter: Fonder memories. New Scientist, 25 September 1999 p. 47

[36] Don’t look now, blind corners may be safest New Scientist 2 October 1999 p. 24

- faster means of communication and lower barriers to it will prove beneficial, other factors equal
- less expensive information, access to knowledge and communication allows for the potential knowledge synergies to evolve
- openness to the creation of new combinations, in all possible dimensions, is a powerful positive force; creativity and lack of prejudice thus come to the fore, allowing for a degree of dissent and conflict
- a climate and a value system conducive to knowledge development and utilization might to a certain extent be an endowment of culture and history; it might be self-reinforcing or possibly self-destroying, depending upon how conflicts, inevitably arising and potentially contributing to new combinations in new dimensions, pan out
- power laws related to information and knowledge will continue to be discovered

5. Emotions and choices, thinking tunnels and prejudice

Our brains, our minds have evolved through a process of mutation, selection, and adaptation and are equipped to increase the likelihood of our survival. For us to understand how our brains work and how our minds function fills no basic evolutionary purpose and hence it is no mystery why such understanding is so hard to come by.

Basic genetic conditions change very slowly. Several thousand years back, man was essentially as endowed as today. But if there is an on-going debate as to the importance of inherited versus environmentally conditioned behavioral traits, it must be emphasized that the environment is important in deciding what of a host of genetically programmed traits will come to the fore, and which flavor they may take. Thus the actual social climate, the culture in which the genetic program is acted out plays an important role in how genetic predilections are realized.

Sometimes much is made of the contrast between emotions "designed for the cave man" and the discipline required in an industrial setting – not to speak of a post-industrial one. Clearly, our sensorial and emotional "default settings" have something to do about how we may handle and react to information. We will start out with emotions, moving on to perception and cognition, then scrutinize some obvious difficulties we have in judging problems rationally – are there many more than those discovered so far? –, and then, finally, we will bring up a set of prejudices that may have us seriously misjudge and consequently mismanage our whole process of knowledge acquisition. Again we may pose the question whether there are many more such prejudices to discover.

Windows of learning opportunity

There is a tragic story of a man who was blind for all his life and thus learnt not to adapt to a life in darkness but really knew no other. One day, however, it was discovered that his blindness was of a type that now might be cured through an operation.

Indeed, the operation gave him the faculty of seeing; it did not give it back to him, but he experienced it for the very first time. But he could not make any sense of what he now saw; he was all too adapted to a life in the dark. He grew more and more depressed until he just died.

He died from seeing, you might say.

This is a drastic introduction to something that we know full well without necessarily reflecting too much on it: children learn an enormous amount in a brief period of time. It also seems as if there are windows of opportunity, windows of perceptibility when growing up, windows that make for such fast learning during a certain period in life, and then the window may close or at least be left open only to a small degree. By the age of two or three, children understand the plural. Incidentally, the very fast learning of language by children – learning based upon rather spurious examples and evidence – makes for Chomsky's and others' arguments about an innate human grammar, to some extent hardwired into our brains. If so, what more hardwiring is present there? What different modules are there, making up our minds – some fifteen different have been suggested[37].

To learn more about what serves to condition this behavior might give powerful tools to pedagogy. Might there be a natural sequence to learning? Could we possibly discover shortcuts?

Shortcuts may not be what we think they are. In a developing country, with its high degree of illiteracy, new electronic media were perceived as offering an opportunity for development and learning leapfrogging. Why not teach people relying upon television via satellites, video players, and audiovisual programs instead of the indirect route of teaching reading and writing and then striking out on the actual subjects, using textbooks?

[37] Biology isn't destiny. The Economist February 14th pp. 97-99 1998

Just to learn how much more efficient the audiovisual media route might be, there was the establishment of a control group that took the traditional, indirect way through literacy. This was extremely fortuitous since to general consternation the seemingly indirect route via literacy turned out to be the more efficient one by far. Thus reading seems to create a more structured way of thinking and learning, conducive to faster learning of other subjects as well.

The road to awe

A small child will have a different perception of numbers than you. Put a dozen marbles on a tabletop, well spread out – arrange the same number of marbles in a small, concentrated heap. The child will tell you that there is a larger number of marbles on the tabletop in the first case than in the second. Then, at some point in its development, the child will experience an epiphany and discover that the number of marbles is independent of the degree of concentration or dispersion of what is counted. We have all passed through this epiphany, we were never trained but only discovered the new insight all by ourselves, and we have forgotten it.

There are a number of such discoveries that constitute human development. Child prodigies pass some of them very precociously thus deserving their epithet; the mechanism seems to be one of coincidence, of some important development steps being triggered simultaneously in an unusual way. This seems to tell that we all have the hidden resources allowing us to evolve into prodigies so that the human potential is much greater than currently realized.

Is there a way to produce child prodigies? The question might seem preposterous, yet there are a number of families where precocity seems to be just endowed. Henry David Feldman has studied a number of child prodigies and the result seems to be that there are a number of incident factors that all must be present, and present at the right time and in the right sequence. Furthermore, in some families there seems to exist an implicit awareness and a "family culture" conducive to the development of such coincidences.

Certain autistic children are savants; they perform difficult tasks without any effort and at lightning speed. Several studies are under way that may explain the mechanisms behind this behavior. One theory is that certain parts of the brain are much larger or radically better connected than in the normal person. Another, however, is that these children have the faculty of "letting go", of allowing the subconscious free reign. If so, it may even be possible to develop methods for controlling this process in the sense that "ordinary people" may obtain the same faculties.

The amygdala taking over

Daniel Goleman relates how a friend of his on a stroll along a canal sees a girl "gazing at the water, her face frozen in fear". Before he knows it, he finds that he has jumped into the water, coat, tie, and shoes. Only then he realizes that a toddler who has fallen into the water is causing the girl's shock – and the man proceeds to a successful rescue operation[38]. This, Goleman concludes, is an example of the amygdala's acting, the brain's sentinel, sometimes, as in this case, hijacking the brain, even the body.

We all know of a number of feelings that affect our abilities to take in and to judge information in a powerful way. One is fear, originally evolved to make for fleeing or hiding. A flood of hormones is triggered, making the body alert, edgy, and ready for action. With anger, hormones are also released, such as adrenaline, making us prepared for swift action. Nervousness is a less strong feeling perhaps but those feeling anxiety before an exam, a test, a job interview, or a sports event know that it might be decidedly powerful. The sportsman would like to harness the feeling and the adrenaline to make for a better result. The sumo wrestlers are trained to be very good at reaching the peak performance – for some split seconds only – just when the encounter, after a long ceremony, takes place.

Love is the opposite of fear or anger. As we know, calm and contentment are characteristics of love as well as of happiness. These two feelings allow the body to rest and to acquire enthusiasm. Sadness is opposite to happiness and may well be created by the loss of a loved one. Energy and enthusiasm get lost, and there may be a feeling of nothingness. Disgust, Goleman observes, makes for the same facial expression all over the world – nose wrinkling, upper lip curled to the side – and the origin may be a primitive reaction to bad smell or toxic food.

Our bodily reactions to surprise are geared at assembling more information, and when we feel the pleasure of curiosity, we actively pursue a quest for new knowledge and better understanding. Crea-

[38] Goleman, Daniel: Emotional intelligence. Bloomsbury, London 1996

tivity is another such positive experience – the feeling of being on the pursuit to solving a challenging problem. Sometimes this is accompanied by an elevated feeling of happiness and of total control of the thought process: flow, a concept introduced and developed by Mihaly Czikszentmihalyi[39].

Every reader may like to complement this list with other feelings or emotions; the question of how to group them together may never be answered to everyone's satisfaction. Goleman lists, in an appendix, yet another one – shame, which would include, i a, humiliation. Then we have, e g, awe, and indeed the classical eight sins. I would like to add one more, however, and that is empathy, our ability to understand, as it were from his or her own standpoint, the feelings of another person. This has clearly something to do with our propensity or ability to take in information.

There is one thing to be aware of "primitive man" within all of us, quite another to control our emotions. We may observe what happens to us, yet being unable to control the process. Some individuals are more prone to "lose control" entirely, many may do so under the influence of drugs, fatigue, or hormones released by something not directly related to the emotion generated – think of "runner's high", the happiness felt by the jogger after a couple of hours' running because of the generation of endorphins, the body's own morphine.

The fact that we may be knowledgeable enough about the causes of our feelings, yet unable to do much about them, indicates a challenge for education and training. Goleman has made the point that ordinary training methods do not apply in this case; they may, in fact, be counterproductive. He has also tried out some new strategies[40]. That is not to say that there are no methods existing already; we all know the wise advice to count to ten – slowly. Kierkegaard found that he had problems tolerating certain people, unable to listen to them. Until he discovered that he could always find some interesting, even fascinating detail about any one person, and now the challenge was to him, to discover that fascinating detail.

So we come to the conclusion that evolution has endowed us with a number of mental shortcuts, allowing us to make fast decisions. Everyday situations do not allow for elaborate and lengthy deliberations, and they certainly didn't during the Stone Age. Man is mentally little different now.

Herbert Simon's concept of "bounded rationality" seems to

[39] Csikszentmihalyi, Mihalyi: Flow. HarperCollins, NY NY 1990

[40] Goleman, Daniel: What Makes a Leader? Harvard Business Review November-December 1998 pp. 91-102

apply[41]. Evolution will favor developments that allow for survival and proliferation, but satisficing is enough: there is no benefit for a field mouse whose food is randomly distributed to develop sophisticated foraging strategies.

Our mental tools are simple heuristics, each dependent upon a problem. They are not part of some general tool. They do share the same structure, though. We always try to gather information to base our decisions upon, and there is thus a heuristic to direct the search. Again there is the issue of satisficing: time restrictions and decreasing potential returns imply that there must be a stopping rule: 'this is enough'. Finally, a decision must be made, speed being of essence.

One simple rule would be that we prefer the known to the unknown. This applies to food and it applies to people we meet at a party. It has been proven that if we choose what we know and recognize, then we are most often better off than if picking at random. Sometimes this even yields paradoxical results: scanty knowledge is better for making grand decisions than more detailed knowledge which we may then very often trust too much.

Thus, one stratagem is known as the minimalist. Take one simple criterion when to make a choice, and let that one be sufficient. Another is taking the very best, which instead implies going through a whole set of cues, giving them different weights, and drawing it all together. These two methods have been demonstrated to be as good as more elaborate, analytical tools such as multiple regression analysis. This may well be because in most real situations different factors are interdependent through hidden links, and the simple rules already encompass all that is relevant.

A caricature of a person is easier to recognize than the true picture of that person. Faces have been shown, the "correct" image as well as one that has been designed with a standardized, "ordinary" face, compiled with the aid of a computer, as the basis in the sense that a caricature was constructed to amplify the aberrations from that normal face. And test persons identified the original person more easily with those caricatures as starting points than the "true" portraits. This tells us something about human image processing, human memory[42] (and the process of evbolution[43]). As we know artists, especially perhaps cartoonists, regularly rely upon this feature of the human mind.

Our emotions, like love and fear, may help us make fast decisions,

41 Douglas, Kate: Basic instinct. New Scientist, 4 September 1999 pp. 32-35

42 Fjæstad, Björn: Karikatyr mer lik än originalet. Forskning & Framsteg 2/99 p. 52

43 Wilson, Edward O: Consilience. Little, Brown and Company, London 1998

or clear-cut ones. They solve the stopping problem in a very definite way for us. The toolbox handed down by evolution is not all that readymade, however. It is also honed by the culture in which we are raised, thus making for the transfer of generations of acquired experiences with a certain kind of self-reinforcement blended in.

Intuition may be all wrong

Jay W Forrester made quite some impression, and some enemies, by his proposition that his Systems Dynamics revealed that our hunches are all wrong, that the world sometimes behaves in a counter-intuitive way. But that was because of the complexity of the systems under consideration; human inability to cope with the intricacies of, e g, big city slums or large-scale road traffic. Of course a shortcut or a larger road would ease the load! Not so, and the caution was that we should realize that those systems really are complex, not transparent.

There are, however, more profound phenomena where intuition most often leads us in the wrong direction entirely. As we will see, this may have something to do with how the actual problem is formulated. Then a corollary would be that the actual presentation of a piece of knowledge or a chunk of information is very important, that this organization and way of describing it is as important as the content. That is, content does not some "bare" but rather clothed in some costume, and the costume is of importance to how we perceive what it contains.

Here is a problem for us. There are four cards on the table, each carrying one sign of E, 3, 4, and D. Which cards should be turned upside down to test the hypothesis that each vowel carries an odd number on the other side. Try to solve this conundrum before reading the next sentence! The correct answer is the first and the third cards[44]. If you have failed, don't feel too miserable, if you were successful, be proud, because only person in ten gets it right.

There is another way of presenting the problem, however. We are now at one of these dance palaces or restaurants where men have to pay an entrance fee while women get in for free. Everyone has a marker M or W on one card (or ticket) side, $ or 0 on the other. Now we have four cards with these four signs, M, W, $, and 0, visible. How may we verify whether it is true that every W has a 0? Now the percentage that comes up with the right answer is much higher. Still, the two problems, while shrouded in different dis-

[44] Biology isn't destiny. The Economist February 14th 1998 pp. 97-99

guises, are logically exactly one and the same. The explanation that has been proposed is that as social animals, we are attuned to try to discover attempts to con us.

Here is another example of what Piatelli-Palmarini calls "thinking tunnels"[45]. Just one per cent of the population has such a disposition so as to be infected by a rather rare disease. A person has submitted to a test (with a 78 per cent reliability) and has been proven positive, i e, the test indicates that he is indeed infected. What is the probability that he has actually contracted the illness? Again, try to arrive at an answer before continuing.

The obvious answer, if we quote what a vast majority would suggest, is to reiterate the reliability of the test: 78 per cent. That turns out to be very far from the actual risk. We must not forget the base rate – one per cent only of the whole population is prone to contract the disease. To arrive at the solution to our problem we need yet another figure, namely the probability that a person that is not affected by the disease responds positively to the test despite this fact – this turns out to be ten per cent. Thus the correct answer is that the person in our problem has an eight per cent probability of being infected.

Leaping to conclusions

There are lots and lots of what seems like paradoxes of this type. Some have to do with our risk taking behavior and imbalances in connection with risk. If we are allowed the choice between a hundred dollars in cash or flipping a coin for either two hundred dollars or nothing, most people prefer the sure hundred rather than taking a chance while running a risk. But if we are given the option of being given four hundred dollars first, under the condition that we then choose between either directly losing one hundred or, again, flipping a coin for a fifty per cent chance of keeping all those four hundred, the other fifty implying – you guessed it – the loss of two hundred out of the four hundred, then the majority of us prefer tossing the coin. Again, from the point of view of logic, the two situations are equivalent. The suggestion is that the base rate, the fact that we already have received four hundred, or at least three hundred, that makes all the difference.

Another fallacy is forgetting about base rates. Let's tell a number of persons that there are seventy engineers and thirty lawyers in a group; next, we describe James in words that leave absolutely no

45 Piatelli-Palmarini, Massimo: Inevitable illusions. John Wiley & Sons, Inc., New York NY 1994

clues as to his occupation. Then the likelihood is that he is an engineer. Still people would make a fifty-fifty allocation.

From Piatelli-Palmarini, we take a more elaborate example of this phenomenon, a brief sketch of a personality, Bill, 34, is intelligent but lacks imagination, stays with his strong habits in a somewhat lifeless way. In school, he excelled in math but not at all in humanistics. Which of these professions and hobbies are most likely to be Bill's:

- he is a medical doctor and plays poker
- he is an architect
- he is an auditor
- he is playing jazz as a hobby
- he loves windsurfing
- he is a journalist
- he is an auditor, playing jazz in his spare time
- he has mountain climbing as his hobby

Now make a list of what is most and least likely. Experience shows that most people put "an auditor playing..." ahead of both "auditor" and "playing jazz", despite the fact that probability calculus – and common sense – should have taught us that the probability that two events coincide is less than the probability of any on of them happening. The list of characteristics for Bill is truly very brief and vague, and most people put "auditor" as their first choice. The ad hoc probability, without any personality sketch, finds that jazz playing is much more frequent, thus likely, than being an auditor. We tend to be too impressed with the information we receive and the conclusions we think we may draw. Again, we risk forgetting the base rate – and again we see that a little information may force us into a thinking tunnel, a trap when it comes to conclusions and decisions.

Another example from the same source concerns the maternal ward of a small hospital and one that is three times larger. In both places, the number of days in a year when the number of boys exceeds sixty per cent are counted. Were there any differences at all between the two hospitals, and, if so, which one had the largest number? Asking a lot of people gains the result that 56 per cent of them come up with the answer "no difference" while 24 per cent believe that the larger hospital registers the more frequent such days, 20 per cent the smaller one.

Those days are not many, but we now learn that the days when only boys or only girls are born are also recorded. Which ward would display the largest number of such rare days? Now the response most often turns out to be the correct one: the small hospital. There have even been tests as to when there is a changeover from "equal" to "the smaller", and it comes rather abruptly at about 90 per cent.

Bad influence

Next, let us consider how we may abstain from doing what we believe we should do. Why on earth? Let us assume that I am contemplating a business trip to a city an hour's flight away but I don't know for sure that the person I need to see is available at the time I am planning to go. The problem is that I have to book my ticket now to be sure to get it. On the other hand, there are a number of worthwhile alternative activities for me to pursue at that destination if the business meeting turns out not to be feasible. Thus I have reason to go whatever the availability of that particular person. Yet most people would forgo acquiring the ticket until the uncertainty as to the meeting that triggered the idea of the trip has been resolved. I want to know for sure the reason for my trip before I arrange for it!

Piatelli-Palmarini suggests that there are a number of vices or "deadly sins" that we should bear in mind. The very first one is exaggerated self-confidence. If we are exposed to a number of factual questions, such as "who wrote the opera Lucio Silla?", "what is the name of the capital of Malagasy?", most people venture some answer even if it has to be a guess. We tend to overestimate our capacity for arriving at correct answers. For someone expert in a subject area, the frequency of correct answers increases of course, as does the confidence of actually giving the correct ones. But it turns out that this increase in self-confidence is much larger than the increase in correct answers!

Another illusion is magical thinking – we tend to observe everything that seems to verify a hunch we believe in, rather haphazardly or without considering the totality of "observations". Sometimes such thinking reveals itself in slightly (or more than so) ridiculous ways: "there was a note made in Prague: today began the 30 years' war"; "there may be one or two weak links in my proof but since history turned out exactly so, it must have been right".

During a crisis in Poland during the Soviet era, people were asked about the probability that the US might withdraw its ambassador to the Soviet Union, without any indication as to why. Then people were also asked whether there was a chance that the Soviet Union might invade Poland and that the US as a consequence withdrawing its ambassador. The latter is a chain of events; it is clearly (!?) less likely that the two incidents happen than just one of them, the withdrawal in the latter case dependent upon something else. But that is not at all how people responded; now there was a scenario seemingly making the chain of events more, not less, likely.

Anchoring is yet another factor. Let us assume that we ask the question how many African states are UN members. But before this, we have had a random number generated. If this happened to be eleven, then the number suggested as an answer would be much closer to this figure than if the random number had been a large one, like 87. This has been used in propaganda in war – after an air raid, the number of civilian victims was announced to be under ten. Skeptically, we may discount this and double the figure, but we do not increase with a factor of ten or a hundred.

The number of Americans dying from diabetes is much higher that those killed in fires. No one questioned about likely death causes would believe this, for the simple reason that fires are something covered by newspapers, the radio, and the TV newscasts. We tend to slow the car for a while after we have encountered a traffic accident, or heard of one. We are much more willing to pay for reducing a capital risk from one in a thousand than from two in a thousand to one in a thousand, though, again, the two situations are logically equivalent. This seems to be a problem especially for extreme probabilities.

Information relationships

Information seldom appears isolated; it serves some purpose. Often it might be associated with risk and uncertainty. May a risk level be defined, may information contribute to reducing uncertainty?

Daniel Bernoulli pointed to an important fact when claiming that the value of change is not symmetric. An increase in wealth is associated with diminishing returns – the first million is more worth than the second one. To lose a million is more negative than the gaining of one would be positive. A poor person appreciates a dollar far more than a rich one.

This would seem to apply to information, where problems of definition may encumber how the principles translate into practice. But it may also apply to information associated with the acquisition of wealth, of achieving something, of mastering resources.

Von Neumann, with his and Morgenstern's game theory, showed that to try to win would be self defeating against a counterpart that knew to profit from the knowledge that this person was trying to win. The best outcome that can be achieved is the one where one is trying not to lose. Thus the seeming paradox is that it pays of luring the counterpart into trying to win; two parties trying to avoid losing will in the long run develop a stalemate or an even number of wins and losses.

Bernoulli was wrong! That is, for micro decisions, his proposal does not work. Human beings are affected both by how a proposition is formulated and whether there is risk or gain involved. We are risk averse but the stakes involved are also important. Lotteries are based upon the fact that we may risk losing a small amount, with a high chance of losing, for the unlikely but alluring potential of a huge gain[46]. On the other hand, small gambles also have the best odds, certainly as consistent strategies. If the probability of winning is pit must be larger than 0,5 for you to win "consistently" and then Shannons Law for Information Capacity tells you to bet 2p -1 of your capital each time.

Kahneman and Tversky found that people would prefer to receive $3000 to gamble on receiving $4000 with an 80 per cent chance of getting it but a 20 per cent chance of receiving nothing – these may be seen as refined versions of the coin flipping we met previously. This actually held for four fifths of the respondents. But when the choice was shifted to risking something, behavior changed. Instead of the certainty of losing $3000 respondents tended to prefer taking the 20 per cent chance of losing nothing despite the 80 per cent chance of losing $4000 – this held for 92 per cent of the respondents. So when the choice is between losses, we are willing to take the risk.

The choice may be stated in several ways. Imagine a rare disease, expected to kill 600 people in a community. Program A will save 200 people, program B carries the possibility of saving everybody but the 67 per cent risk that no one will survive. Risk-averse people would prefer plan A, and so did 72 per cent of the respondents, while the two programs from a probability standpoint are absolutely equal.

46 Bernstein, Peter L: Against the Gods. John Wile & Sons, Inc. New York, N Y 1996

The problem might be stated differently. Program C, which is A in thin disguise, means that 400 people will die, program D a 33 per cent probability that no one will die, and a 67 per cent chance that 600 people will die. Now 78 per cent of the respondents went for the risky program, D – they could not stand the formula implying that 400 people would certainly die.

When pitting an unemployment rate of 10 versus one of 5 per cent against each other, and promising the latter with more inflation, a heavy majority preferred the higher inflation rate. When the choice was framed as being 90 and 95 per cent employment, less inflation and low employment was the unequivocal choice. May we conclude with Tversky that it is loss aversion that counts?

Or is it, as Thaler suggests, also the "house money effect" that is involved, the difference between being given the money first and then losing part of it and choosing between two different wins?

Mental allocations

There are many more such instances of human rationality being restrained by how we perceive the choices, i e, the context within which the information is given. The level of loss and gain is one factor, the relationships involved in general. Suppose, following another Kahneman and Tversky study, that you have bought a theatre ticket at $40, discovering, upon arrival to the theatre, that the ticket has been lost. Do you buy a new one, or do you return home? Then consider the situation where you have arrived at the theatre, intent on buying a ticket there, discovering that you have $40 less in you wallet than you thought when leaving home. Would you still buy the ticket?

In both cases you would be out of $40 depending on whether you returned home or chose to see the show. More people would be reluctant to buy another ticket, however, and about the same majority would be less concerned about buying a ticket when the $40 went missing for some other reason.

This expression, "for some other reason", may be the clue to the seemingly irrational behavior. Mentally, we allocate funds to different purposes. The lost theatre ticket already rested heavily upon the theatre account, whereas the $40 "just missing" was placed toward some "miscellaneous" item. So we might seem to have some internal accounting practices to – take into account.

To offer different accounts, and more details, also serve as to bedevil our reasoning. One group of students was asked to estimate the number of deaths from natural versus unnatural causes. Compared to actual frequencies, they over-estimated the deaths from unnatural causes. But when given a more detailed breakdown of both natural and unnatural causes, the sums of both categories went up strikingly.

Yet another effect is the one of "endowment". Students in a class at Cornell were given mugs emblazoned with the school's name. When offered to sell them, the average price accepted was more than $5. In another class, the coffee mugs were auctioned off, the average buyer giving a little more than $2. Once we own something, we find it hard to part with it. One reason would be that it is costly to arrive at new information about that which we do not own, a factor of importance at least for more complicated "endowments" like stock. US investors having placed some money in Japan and much in the US could justify their actions only with expected returns of 8.5 per cent in the US and 5.1 in Japan. For Japanese investors, however, the corresponding figures were 3.9 for the US, obviously a foreign country to them, and 8.2 for Japan, their home turf.

Easy to defend

It should be evident by now that these findings have caused discussions about whether humans are rational, and whether the implied "irrationality" can be exploited by those more rational (computer programs?), making human behavior self-defeating. This is not our concern here; we are interested in how we choose and treat information. But human wellbeing might have an element of "irrationality" to it, so what? Or might it be that von Neumann's finding that we should avoid attempting to win, just avoid losing kicks in, in some concealed way? We do accept to pay to reduce uncertainty when buying an insurance policy. How much can be interpreted as uncertainty reduction, with certain biases? And you might easily defend placing your fund's money in General Electric and Disney, because that is what everyone does, not in unknown stock on the NASDAQ even though volatility calculations might show this to be more rational. Your chance of winning might be considerably higher, but what is your defense if you lose?

We pay a price for this behavior, and one hopes that it is not too high. The stock that is highly valued can be borrowed on, and since everyone has trust in those values, they get rated even higher. There is an element of chain letters in this, and it works as long as trust is there – as long as we are all united in believing in those values. When they begin to be regarded as suspect, everyone will start running for the exit, and if the trust has been vested in the whole market, not just in certain stocks, then a bull may turn into a bear.

There is a term in industrial policy-making called "picking the winners". That is, if information technology, bioengineering, or what else turns out to be the next major industry, one had better promote it nationally. Or would one? Possibly, this might end in a zero sum game where all different supportive programs zero out. Another possibility is the direct opposite – just the fact that so many governments vest so much money into a particular industry is what makes it take off. This would make for a self-fulfilling prophecy, then.

It would all be based upon uncertain, incomplete information. Ex post, on the other hand, no one would be sure of causes and effects – unless there would be some nations, governments, technologies or what not that offered exceptions to the perceived program of wise action.

We may look upon human behavior, in groups, in society, as described by the formation of social fields, like magnets and electrical currents shape electromagnetic fields. Tools for human communication, like conversation, writing, the telephone, etc, would affect these fields. Under certain circumstances, field may turn out to offer positive feedback. If there is a heavy rain and there is a small imprint in the sandy terrain, that imprint is being enlarged because more and more water will be flooding this way, making for more and more erosion, causing yet more water to flow there... Likewise, an electromagnetic field in a material may affect the material's properties so as to cause the building-up of more and more concentration. What, then, has this to do with information? Let us take an example. The chairman of the Federal Reserve, Alan Greenspan, is said to believe that information technology has such effects on the US economy as to cause the GNP and inflation to be severely miss-measured. Thus there is less need for the Fed to apply the brakes on the economy, slowing down GNP development. If this has the intended effect it might be a process of positive returns, giving credence to the new theory espoused by Mr. Greenspan. The belief in information technology and its effects has been enough to have these healthy effects. A new field, a new force in the economy has been created.

Consider the fact that over 35 years, American corporations borrowed slightly more than they paid out in dividends. Since US companies have the right to buy their own stock, it would have been a better deal for their shareholders had they bought back stock instead of paying dividends, which are taxed more heavily than stock value increase. For liquidity, the shareholder might then sell a share or two, to receive the equivalent of the dividend, or, given the tax advantage, some more. But that would open the door for regret – the regret that I have just sold a stock that has increased in value! Do we pay a price to get less in the form of dividends, money that can disposed of with no risk of regret?

The truth is untrue

Haven't we all heard that with age, our memories will get much worse? Haven't we experienced the truth in that proposition? Well, it's correct only because we believe it to be correct. And besides, what does it matter? Do we ever remember everything? Isn't it important to be able to sift and sort, to judge what merits to be observed, acted on, and remembered? But the old age bad recall is just a self-fulfilling illusion, which has been demonstrated by Ellen J Langer[47].

Might there be, she asked, societies that have not included the preconceived conception about old age memory deterioration in their cultures? She found two, the American deaf-and-dumb, and the Chinese. In both cultures, the elder generation is subject to deep veneration. There are no preconceived conceptions that people will show deteriorating facilities, memory-wise or otherwise. And, lo and behold, testing demonstrates that there is no deterioration either.

A recent study performed at the University of Waterloo in Ontario gives a chilling reminder of how deeply ingrained our preconceptions may be, permeated by the media, and affecting us on a subconscious level also when we do not observe it. A larger group of students specializing in mathematics were subdivided into four groups, two male and two female. They were all given to see a handful of TV commercials. One female and one male group saw commercials with no sexist slant, the two other groups were subject, i a, to two commercials depicting women in gender stere-

47 Langer, Ellen J: The Power of Mindful Learning. Addison-Wesley, Reading MA 1997

otypes, receiving food mixers and cosmetics with innocent joy. Three of the groups scored, on average, the same – the fourth group scored much worse, and that was the group of female students who had been subjected to the stereotypical commercials.

Langer has embarked upon a crusade for mindful thinking, and through a number of simple but relevant and significant experiments, she demonstrates that a large part of our thinking is unnecessarily constrained by preconceived conceptions like the one just illustrated. To be engaged and concentrated is not necessarily the same as focusing upon only one subject at a time. It is often productive to have a broader outlook and combine the unexpected. Thus when teachers and instructors try to have us focus narrowly, they may be giving us behavioral hints in precisely the wrong direction.

Another unproductive myth is that we are inspired by rewards. Just to know that one is to be tested creates blocks to learning effectively. A reward may certainly be regarded as positive but then it should come as a surprise; the problem is that it may create the unconscious fear that next time, I won't be good enough for the reward, which again establishes an impediment to learning.

Mindful thinking

The most far-reaching observations have to do precisely with the mindfulness of thinking. By this is meant conscious reflection upon and outside the scope of the information given. We will give a couple of examples. In one test, students for business administration had to learn about the rules for a detailed technical way of dealing with certain aspects of equity trading. This was technical enough to exclude pure common sense. The text describing the regulations was introduced to one group of students with the normal "this is how it is, learn, and there will be a test". The other group, the one instructed in mindfulness, was told that these are approximate descriptions that may apply but there may be other cases as well and please reflect on when and how what you have studied may be applicable. The latter group scored significantly better on the test.

Likewise, two groups of physics students were shown a video on the workings of some of the laws of physics. One group was just instructed that they would see the film and then be tested, applying what they had just seen in the test. The mindful group received instructions that they should reflect on how what the video demonstrated might be slanted and incomplete, and how it might relate to what was not in film and how it might be complemented and generalized. The instruction for the test advised that they could well use what they had seen on the screen but they might apply other experiences and other knowledge as well. Again, the latter group scored much better.

Langer wants to underscore that intelligence is a misleading concept; we are interacting with society, playing roles and forming it actively, we are not just looking upon something that is going on separately, like on a theatre stage. Thus it is wrong to think of answers as being black and white, right or wrong. With respect to intelligence, we should draw attention to Howard Gardner's description of this as not being a unitary notion but rather a whole set of different expressions of human abilities. Thus Gardner suggests the existence of not one but seven different intelligences, which then would be related to information handling and knowledge development: verbal, logical, musical, spatial, bodily, social, artistic.

Rote learning is risky

Finally, Langer warns about the perception that we must stress rote learning and that confining routines to memory is the high road to knowledge. Here again, mindfulness is at risk, and what is preferable is a more reflecting approach. One example is a comparison of two strategies for learning how to play the piano. The rote learning one tells how to do and stresses routine repetition so that the pupil get the right movements "hardwired" into the brain. The mindful approach tells the pupil rather to try different ways of playing, to listen and to reflect. Needless to say, it is the latter way that is the most successful, both when it comes to speed in learning to play and in quality of the music produced.

In another experiment, the psychologists invented a new racketball game, with a particular type of racket and ball, plus particular rules. One group was trained in the rote way, where the coach told how one had to hold the racket, how the movements should be, and so on. This was then made into set routines. In the other group, the players were instead encouraged to test and try different approaches, listen to their bodies, experiment and observe various outcomes. Then the scientist changed the basic rules somewhat and they did this by manipulating rackets and balls so that the pure physics of the game changed, imperceptibly but with a distinct effect upon the actual play. And so we have to repeat the outcome once more: the latter, the mindful group was much more successful.

There are certainly other aspects to learning too. We learn better in a social setting, from our peers. And sleep is important to learning; without it, learning will not happen. This applies mostly to procedural knowledge, learning "how" – to play the piano, to ride a bicycle. The more shallow REM sleep (for the rapid eye movements that characterize such sleep, associated with dreaming) is instrumental to the acquisition of completely new tasks, whereas for smaller refinements the intermediary sleep stage between profound slow-wave sleep and REM sleep is needed[48]. Slow-wave sleep, meanwhile, is important for spatial tasks and creating associations, e g, between words.

48 Phillips, Helen: Perchance to learn. New Scientist, 25 september 1999 pp. 26-30

6. Turning points in information handling

Banal as it is, one of the foundations of this report is the fact, or the syllogism even, that we would never be able to predict surprising discoveries in the field of human information handling – if we were, they would not be surprising. Thus the future might, yes, it must hold any number of surprising discoveries.

What we can do, however, is to look back, and that's another banal foundation. The invention of writing, on clay tablets, in sand, on papyri, stands out as a major breakthrough. Certainly, Homer was not only blind, nor did he know reading and writing; resorting always to oral tradition as he did, though, does impose severe limitations upon the transfer of knowledge, upon the compiling of information to be transmitted from one generation to another.

The capital zero

The Inca never knew writing, but the Meso-americans did. Probably the Egyptians and the Mesopotamians were the first. Writing could take several forms, and the alphabet handed down from the Phoenicians several centuries before our era to be perfected by their competitors the Greek with the addition of vowels makes for more economy in a sense than, say, the Chinese *kanji*. There one needs to learn thousands of hieroglyphs though it is certainly true that each sign carries lots of information.

Relying upon clay would have been needlessly cumbersome. The Egyptians may have developed the more convenient papyrus already 2 800 BC, allowing the Greeks of Miletus in Minor Asia to import it around 800 BC. This was a material on which libraries might be based. Later, paper could be produced out of lump, a fairly scarce resource, and only in the eighteenth century did a French naturalist observe that wasps made their nests out of paper. What resources did they deploy to that end? Answer: wood. From this observation followed a series of processes for transforming timber into paper. A very limited resource saw its limitations lifted.

To understand the world so that we may gather information, we have to describe it in less subjective terms than those of Gods or spirits. In the fifth century before our era, Thales from Miletus made a major contribution when he described the world as consisting of, on the one hand, an eternal unchanging cosmos, on the other something which changes also and is immaterial. So we have the immaterial human sense or mind.

Somewhat later another Greek, fleeing Minor Asia for what is now Italy, made the crucial observation that some important aspects of our world, of reality, could described in mathematical terms: Pythagoras. Perhaps there were even some aspects that could only be described mathematically. The most famous Pythagorean achievement is probably the triangle carrying that very name: the sum of the shorter sides squared separately equals the square of the largest side of a right triangle. The simplest such Pythagorean triangle is the one with the sides 3, 4, and 5. But having instead the two smaller sides equal made for a singularly disturbing conundrum – it then followed that the hypotenuse had a length that was not any ordinary number, the square root of 2, √2. We have to recognize that the Pythagoreans subscribed to the belief that there was a correspondence between reality and mathematics, that is numbers. A new concept was born, that of irrational numbers, those which, for example, cannot simply be described by a single quotient, such as 8/9 or 1/123. To the Pythagoreans, since the world followed a design by numbers, they felt that irrational numbers constituted a troubling threat to their world order, to the whole world order.

Numbers and triangles might serve very down to earth purposes too, measuring the land, deciding who was the owner or how a pyramid might be designed, the stone blocks arranged. Geometry, as its very name indicates, came out of such needs, the word meaning earth measuring. Around 300 BC, when the Greek culture was about to decline, Euclid compiled a comprehensive textbook of what was known as the body of geometry knowledge. It would take more than two millennia for one of his basic, unshakeable foundations or axioms to be shaken: parallel lines may not exist, or, rather, they constituted a definition that one might choose to adhere to or not, and if not, that would be the starting point for a different geometry, the non-Euclidean, invented in the nineteenth century.

Axioms or unshakeable truths define our world view, our knowledge, and whatever information is judged to be of any value. Likewise, notations allow us to organize and treat that knowledge in a way so as to develop, remember, and organize it. 1 + 2, 2x3=6, 4/2 or 4:2 are other examples of a shorthand notation that is so familiar that we never really consider its ingenuity. What about using the Latin numbers of XXIII, IC, etc instead, what about multiplying and dividing? Though abundantly employed, that Roman notation lacked something singularly important: the 0, zero. Perhaps it was developed first in Babylon, used but not really understood by the Greeks, transferred to India from where it returned back to the Western world perhaps late in the first millennium of our era. We may find it obvious that 408 stands for 4x10x10 + 0x10 + 8 but it is no mean feat to develop such an economical and also practical notation. Add to this, then, the decimal point, and we have included not just 100 or 10^2 but 10^{-1} and all consecutive orders of ten. Information organization is key.

So the number zero, smallest of the small, is of capital importance. Without it, calculus as we know it would be impossible. Of course the abacus was relied upon in Roman times, and earlier and later. But mathematics, book-keeping, calculations in the most mundane ways of today would essentially be non-existent without the zero and the concomitant numbering system, starting from zero and going up or down, also allowing us the economic and efficient notation of 10, 1000, etc. And, mind you, without zero – think of someone proposing having zero apples, selling zero pounds of flesh! – there would be no negative numbers…

Knowing knowledge

The Greek philosophers brought up and dealt with almost all basic questions there are in philosophy. Democritus formulated an atom theory that is thoroughly modern though some of his propositions proved wrong. Socrates posed most of the important queries. Aristotle advocated a scientific approach though some of his assumptions were to prove wrong. He like Confucius advocated advancement based upon merit, which meant learning and knowledge; Aristotle unlike Confucius believed that all men were created equal which did not mean that they would develop equally, and that fundamental equality might even have to be concealed. A basic tenet, however, was that of learning; in a sense, testing for merit was an important point and thus a concomitant quest for knowledge.

Yet another invention was that of comprehensive history writing; not just reporting famous or fateful events, but rather the stringing together of the whole linear account – Herodotus and Thucydides are acknowledged to have invented this part of knowledge development. Whether the three great Greek drama writers, Aeschylus foremost, then Sophocles and Euripedes, should be mentioned here is open to question; Aeschylus introduced a real dialog in theatre that previously had only consisted of the chorus responding to a single voice. Now for the first time there was the role playing that we associate with theatre.

With Alexander the Great as Aristotle's pupil, the conqueror sent home reports to his old teacher. Here probably for the first time knowledge, knowledge about nature and social relations, was organized, and the idea of episteme or science of organizing knowledge was born. With this the proposition that we might know the world, that there is a knower understanding the knowledge, was emerging. Such knowledge, then, can be regarded as objective, constituting truth, and that truth must be independent of observer, knower, compiler or partaker in the knowledge. Thus truth would seem to be eternal, not transient or subjective. Then there could also evolve an ability to teach and to learn; pedagogy and some kind of general knowledge or curriculum.

It is of course entirely futile to guess whether Aristotle himself would have approved of how his teachings were to be applied within the culture developed with the Catholic Church – scholastic dogma where everything had to be placed in a pattern of order with an ultimate goal.

This is why Copernicus and Kepler and Galilei came to be regarded as such fundamental threats. With his telescope Galilei could observe celestial motions – nature convinced him of the motions of the moons around Jupiter that he had observed; Kepler had already calculated the elliptic movements of the planets (though Galilei did not believe in these), and, most importantly, the earth was no longer the center of the world. Galilei's actual observations regarding falling bodies invoked a new era, one where a mechanistic point of view grew steadily in importance. His starting point had been mathematical calculations, though; observations were made to confirm these. Harvey's conclusion, also based upon observations, that the heart served as a pump for the blood system was another piece of mechanics, from quite some other part of the human world. Newton succeeded in establishing the basic relationships governing the movement of material bodies, including the discovery that to every force there was an equal force in the opposite direction. That also told a story of quantity as being one part of the description – the information –, the direction being quite another, and equally important. Mathematicians were to give the denomination of vector such an entity, to be distinguished from other entities, like temperature, that had no direction, only a quantitative or scalar value.

From dogma to empiricism

Many, yes, most of the ideas and influences giving force to the development of knowledge came from such practical, empirical facts and discoveries that we would now associate with the concept of engineering. Agricola, though physician, wrote about mining and metallurgy; Vesalius did anatomy through looking at the actual human body, instead of following Galen's sermons as to how it ought to be, thus must be, man in the image of God, the body a corresponding microcosm of the world; Sea Captain Norman discovered the deviation of the compass, out of dire need; the potter Palissy experimented with clays and made important geological discoveries.

To doubt what is being taught can well be regarded as scandalous, even blasphemous; we recall Bruno, Galilei, and others. Doubt is of course the basis for every apostasy, but scepticism as a way of life, as a method of philosophy is quite something else. The doubting Thomas strives to find some new foothold; the sceptic may well relish his own aptitude for weighing pros and contras. Of course there were sceptics among the Greeks but it was only the Reformation, with the competing ways of interpreting the Bible and dogma that it inspired, which allowed for a return to that lost tradition: Erasmus is quoted as the forerunner. And it was Montaigne, with a Catholic for a father and a Jewish mother whose family had converted to Protestantism, who made a point of underscoring how little he knew. The idea of tolerance met with little tolerance initially; sometimes it still does.

This all goes to reinforce the necessity for a certain information and knowledge infrastructure to exist for discovery to take root. Thus Leonardo was a pioneer in a profound sense: but he lacked in his era the scientific infrastructure that might have allowed him to become truly influential, not just the object of posthumous admiration. The same can be said for Ramon Llull before Leonardo; almost equally versatile, his combinatorial method was rediscovered centuries later; in the meantime, he had, with his reputation for sagacity, come to serve to legitimize astrologers and alchemists which he had himself despised in his lifetime. Science was not yet invented, certainly not in the thirteenth century of Llull's, and not yet in Leonardo's time two centuries later.

Yet another turning point can be said to have been the advent of something not quite engineering, something as mundane as book-keeping. Yes, some book-keeping was necessary for risk to be shared and rewarded, for example when trading expeditions set out to follow the silk road to Central Asia and China, or down along the African coast, or eventually when travelling West, to the Americas. No methods for calculating the trade-offs existed initially, but certainly there had to be rewards to compensate for risk-taking.

And so, in the seventeenth century, not earlier, probabilistics were discovered or developed[49]. Again, we may be surprised to find that the actual calculations of chance are so recent. Some statistics and conditional probabilistics are no doubt tough going but much of it – "fifty per cent of fifty per cent" or the probability of your bridge partner having two spades instead of three – would seem pretty straightforward. On the other hand, on some other occasions probabilistics theory runs contrary to our common sense beliefs and intuitions, and that might well be one of the most important long-term features of human information handling[50].

The law of large numbers: the larger the number of experiments, the likelier it is that the outcome will be closer to the average. Sampling – how may we design the selecting of test samples so as to represent the whole: more information from less, extrapolation, and so on? How may we depict the likelihood, like with the bell curve, the Poisson distribution, etc?

Bayes proved his point, the starting one for what became

49 Bernstein, Peter L: Against the Gods. John Wiley & Sons, NY NY 1996

50 Piatelli-Palmarini, Op cit

Bayesian statistics, in a particular way. We look for the place where a particular billiard ball on a billiard table is. Shooting one new ball after the other, we note which balls are to the right and which are to the left. From these indirect measurements, we may infer the location of the particular, searched after original ball. In other words, new information is used to revise probabilities based upon old information. There is the continuous revision of estimates.

Symbol dependence

Information is measured in bits, and it is represented in a machine, in a computer. Information handling, information treatment is thus intimately linked to computation, therefore to mathematics. To quote: "Second only to the mother tongue, the language of number is … the greatest symbolic creation of man."

Let's take stock of what we have said about mathematics, which is closely linked to logic, to proofs and proving, and to another important concept, algorithms, i e, schemas for going through a procedure to achieve a particular result from some input. Like much other human information oriented endeavors, mathematics resorts to symbol, to symbol language. Symbols allow for shorthand representations and for making detailed retracing of previous attempts redundant. Generalizations are also made possible – without which development would grind to a halt. On the other hand symbols also constrain – an advantage mostly – and lock in, which may hamper creativity and thus also restrain development – a disadvantage. We will see how conundrums and paradoxes may jolt mathematical scholars out of such rewarding and alluring confines.

This is not the place for a thorough historic review of the history and development of mathematics. Of course excellent such descriptions already exist[51], and we have here relied upon some of those for what is our subject: the basic rules for information and knowledge development, the basic underlying structures[52]. History may just help in explaining and discussing those aspects. General histories of knowledge, of human thought, and of scientific endeavor cannot but include the field of mathematics, thus often providing linkages to the general development of society and culture[53].

Early on, mathematics, and geometry especially, developed out of – as we have seen the name hinting – a necessity to measure land. Another important factor was the urge to develop calendars. In hydraulic societies, depending upon the regular differences in wa-

[51] E g, Swetz, Frank J (ed): From Five Fingers to Infinity. Open Court, Chicago, Ill. 1994

[52] Dahl, Kristin: Den fantastiska matematiken. Fischer & Co, Stockholm 1991

[53] Taylor, F Sherwood: A Short History of Science & Scientific Thought. W W Norton Cpompany, Inc., NY, NY 1949

ter availability, and possibly the fertility boost from floods, economy of a particular sort had to evolve. Later, major influences came from the needs of astronomy, navigation, architecture, and military engineering, with more abstract economic forces arriving later on, with needs emerging out of trade and barter, the establishment of rents, stocks, and insurance. All the same, discount tables were available already among the Babylonians.

Here we may see mathematics as developing from the concrete, physical reality – how many sheep or fingers are there? – to the abstract – because initially the signs for four sheep were distinct from those for four fingers. Eventually emerging were notions like not just irrational but even imaginary numbers, and also with physics being inspired by mathematical theory, alternatively demanding new mathematical developments.

Inside and outside the system

Let us propose four different driving forces for the formation of mathematical thought, and also for logic, and let us suggest that when it comes to examples they will intertwine with each other:

- the interaction between formal, abstract mathematics and reality
- the development of notations
- the inspiring, irritating, and demanding force of conundrums, problems, and paradoxes
- the opportunities offered by transformations

New concepts have been developed to transcend existing borders. Just the number of 0, zero, is, as we have stressed, such a concept, and an important one. To have one or two sheep – yes, but none? Furthermore, this is a dangerous number: if we divide with 0 we may get any result; it is, in a way, what the mathematicians call a singularity. Here the abstract evolved out of the tangible.

When we have zero, we get infinity ∞, the result of dividing any number but zero itself with zero. This is an even more difficult concept, and then zero also begets something which is not so difficult to us now: negative numbers. We may take out a loan, the negation of saving the same amount, but what is the meaning of negative fingers or sheep? Irrational numbers, transcendental numbers, imaginary numbers – there has been quite some refinement going on, and all those tools are essential for our handling of information. If we are involved in mathematics, many of these concepts offer us no problems. We really have to think hard to understand how numbers like $\sqrt{2}$ or π originally made for deep philosophical problems; we might say traumata, because they seemed to be too far from the reality known and comprehensible.

We have just used symbols like $\sqrt{}$, π, ∞, and we might add +, = (a seventeenth century creation!), !, Σ, e, i, . (the road to the decimal point was long enough) n_i, n^e, $\int$, and so on and so on. Mathematical treatises from times before the invention of every such shorthand notation are almost intractable to the modern reader. In 1545, for example, Cardan wrote[54]

32.quad.p16.p1quad.quad. æqualia 48.pos.
for
$32x^2 + 16 + x^4 = 48x$
in our current notation.

Again there is the link to other sciences. Physics also has its notations, and so has chemistry, and many of the notations are used in several disciplines, like +, =, indices, etc (their meanings and interpretations are different, however). One should perhaps add that notations, like all systems, tend to further development within that particular system but might well hamper development out of it or outside it because creativity of a more radical type is reigned in[55].

There also seems to exist a development sequence for the establishment of a formalism: first a search, then an understanding, based on existing language, and only after that, the creation of specialized language. It is then structured, rule based, and not malleable as ordinary language.

The power of problems

As mentioned, an important factor – the third one after interaction between the abstract and the real, and notation development – has been the discovery or concern for paradoxes or mysteries. Again, we have to constrain the discussion to a few examples. Zenon's paradox has it that Achilles will never overtake the tortoise, and it has something to do with what mathematicians would call expanding series. We have introduced infinity, ∞, but it turns out that there are even more than one category of infinity; some infinities are much larger than other infinities.

[54] Sällström, Pehr: Tecken att tänka med. Carlssons, Stockholm 1991

[55] Sällström, Op cit

Most important is of course the Gödel theorem of 1931, proving that there may be true statements that cannot be proven within a consistent logical system – yes, there will always exist such statements for any sufficiently sophisticated, i e useful, system. Turing's solution to the halting problem, which gave us the Turing machine concept, is a variation to this theme, and also a major step in the introduction of the algorithm, a crucial concept for information handling if there is one. Furthermore, it underpins another important effect of Gödel's work: there may be problems where we can never tell whether they have been completely solved, and there is something that can be seen as proof and solution to a problem.

An application of what Gödel put forward was already well known, and we have broached it previously. Euclid had established, or at least organized and written down, a consistent geometry, with a number of statements defining the whole system. Early on, one of them, however, was perceived as something of a problem: the statement about parallel lines never meeting. Is this something that can be proven from the other axioms, thus a theorem, or is this something more fundamental? Generations of mathematicians had attacked the problem before it was solved in a way foreboding Gödel some two centuries ago: there may, in fact, be several different geometries, of which the Euclidean is but one. Others may suppose that no parallel lines ever exist but that straight lines will always meet somewhere, though perhaps far away, and that also creates a self-consistent system, but a different one. And that is then a system where the sum of the angles in a triangle is never 180° – a theorem that we acquire from Euclid.

We might dispute whether mathematical transformations really are on the same general level as the three previous driving forces. An important development was the right angle coordinate system, called Cartesian because Cartesius (or Descartes) was the one who popularized it. Difficult equations may be transformed into geometric curves in such a system and thus solved geometrically. A description in a Cartesian coordinate system may be transformed into one where the two coordinates are angle and radius or distance from origo (the mid point), respectively. Among those disturbing singularities that might be regarded as conundrums, some may be made more tractable through other mathematical transformations, be those of the Laplace, Fourier, or some other type. In physics, string theory is plagued by singularities that may be resolved through a transformation from strings to membranes.

Crude as it may seem, encoding or encrypting a message is an example of transformation, and such encoding may well make a mathematical treatment easier. Another example is when you look at the three-dimensional rendering provided by a hologram. Here information allowing for a three-dimensional reproduction has been reduced to a recording in two dimensions. The underlying mathematical transformation is made visible through the physics of optics, the properties of coherent light.

Tools that keep us constrained

It is not just notations that keep our minds in a bind; it might also be the very tools that exist for solving problems. Like geometry might come in handy when looking at equations, going back, as it were, from the calculus and the differential equations developed by Newton and Leibniz to difference equations instead, Jay W Forrester created systems dynamics, and a way to attack previously "impossible" problems. The other ingredient was an import from control theory, one of these refinements or branches of mathematics.

There are several more of those refinements or spin-offs, and control theory is a latecomer among them. Group theory is focusing on groups of elements that share the same properties, like symmetries, as distinct, then, from the rest or the world, or from other groups. Set theory takes up the idea that "four" is the common denominator between four sheep and four fingers, and develops generalities and distinctions in another direction. The pioneer Boole has lent his name to Boolean algebra, a symbolic logic related to set theory. An odd number belongs to the set of odd numbers; though if it happens to be, e g, 1, 5, or 9, it also belongs to the set of numbers smaller than ten.

Another type of system or generalization is the one offered by probabilistics and statistics. Again concept development, basic and important principles, and an efficient notation go hand in hand. Game theory and stochastics are other related developments.

Recent years have seen the development of a couple of branches of mathematics with highly suggestive and important results. They have all, to be sure, roots further back. The three are catastrophe, chaos, and complexity theories, referred to already. The latter two, especially, are closely related. There are possibly more variations to the themes, such as self-induced criticality.

Catastrophe theory stems from yet another refinement, a generalization in a particular direction of geometry – topology. Topology looks at geometries in any number of dimensions, and attempts to find symmetries and commonalities structures that are topologically similar or dissimilar. In three dimensions, a topological structure would be some kind of surface, possibly closed into itself – a thorus, a cigar, a Möbius ring, the inner and outer surfaces of a coffee cup. Topological structures exist in any number of dimensions but then they require quite some training before they present themselves to you as familiar and accessible to thought. They can also be projected as "shadows" or "projections" onto spaces of less dimensions, notably three, then represented on a piece of paper as a sketch seen in perspective.

Catastrophe theory is a way to describe, mostly but not always entirely in a qualitative way, connections between a number of independent variables, those variables spanning the space depicted. A change in variables is described by a movement along the topological surface created by the actual values of the variables. The surface may well be folded so that one part of it covers another part with a distance, the distance continuously and smoothly as the apex of the pleat is approached. This means that if the wrinkle exists only in one part of the surface, the development history will be starkly different when the combination of variables is such that there is no passage over the cliff constituted by the outside of a fold as contrasted by the forced jump down from one part of the folded structure down to another. The catastrophe mathematics pioneer René Thom has described the limited number of catastrophes types existing. A number of phenomena and interdependencies, such as in the economy or the ecology, can be described in catastrophe terms. Apart from making for an explanatory toolbox, the importance of the sequence of events (”path dependence”) is highlighted.

The advent of chaos theory highlights how the availability of particular instruments may distort our world view. There were forerunners, most notably Poincaré, but the real breakthrough came when, in the 60s, an American meteorologist with a strong mathematical bent, Lorenz, made efforts to simulate the weather. One day, instead of starting his simulation from zero, he took his previous effort and started mid way through it. He contented himself with rounded off but sufficiently exact numbers – sufficiently, that is, within established mathematical dogma. The shocking revelation was that the tiny change effected by the rounding off made a world of difference.

So this is the famous butterfly effect: the initial conditions in a chaotic system make a whole world of difference. In Lorenz' case, one thousandth of a difference made for en entirely different weather development. This is because while only linear equations may be treated mathematically, the weather equations turn out to be non-linear, one effect being that initial conditions are all-important. With some delay, it dawned upon physicists that instead of the governing principle of linearity being the all-encompassing rule, non linearity the exception, it is the other way around.

This, then, establishes some limits for calculations, forecasting, etc. The full expression for the phenomenon, however, is actually "deterministic chaos", which means that there are rules, the only problems is that it is impossible to know those initial conditions well enough to make for reliable calculations. On the other hand, there are also limitations to chaos, and one can describe those limitations accurately with the tools of chaos mathematics. Medium term weather will be inaccessible to forecasting but summers will stay summers, winters stay winters. So instead of us having a mistaken idea about our world being linear, we now know it to be more intricate but we also master more relevant tools for handling the more complex situation.

Emergent phenomena

If you arrange a pattern of dots on a grid, starting along one line and generating the next by some simple rule based upon the absence or presence of dots in adjacent cells, then, sometimes, with particular rules and starting patterns, there will be the generation of "meaningful" patterns. It might be like the generation of a series of look-alike aeroplanes, or the constant generation of certain letters, even words – or it might be entirely meaningless.

So far, no one has succeeded in explaining or generating some formula for the generation of these patterns. They are classified as belonging to emergent structures, structures not easily deduced in a formula dependent, reductionist way from the previous layer of the whole system. The individual dots, yes – the patterns, no. This could be a model for the mathematics of complexity which can be employed in the study of expressions of human endeavor also – the economy, the ecology, the development of cultures, even, it seems, the emergence of biological life. The common denominator is that there is a system consisting of a large number of components of just very few types – in our grid dots or absence of dots – and simple rules that describe their interactions, like the ones for generating the next line in the grid. Sometimes, and possibly too glibly, this is described as dealing with "the edge of chaos" relying upon chaos mathematics where equations often do have limited domains where one may use a linear approach with success, because those non linear effects are insignificant enough. Then there is exactly an edge of chaos, the borderline between linearity and non-linearity.

Self-induced criticality is something akin but not quite the same: think of a pile of sand – as more grains of sand are dropped on to the top, the pile grows, while a number of smaller and larger avalanches contribute to the pile having the same general shape, growing at the top and at the base at the same time. The avalanches, number versus size, follow a power law, a straight line in a log-log diagram. Similar equations, power laws, describe a vast number of natural phenomena, including the frequencies of words of different lengths.

The generation of that geometric pattern could best be left to a computer. The computer may also be programmed to emulate the evolution processes in an ecology. In this way, different organisms, represented by small programs, will follow rules akin to those of real life and equivalent to procreation, mutation, competition, selection, etc. The programs may well have utility, and if we apply the right combination of selection rules and other input parameters, better programs or solutions to particular problems may evolve. Such problems include some that are practically intractable by ordinary algorithms, not because of any impossible equations but because of the sheer vastness of solution space. The odd thing – from an ordinary problem solving point of view – is that while the solution eventually arrived at outperforms any solution arrived at in some other way, there is no possibility of proving that it is the best solution – and perhaps it is not. But it is just "good enough"; had we continued the sequence of mutation–competition–selection, something infinitesimally better might have evolved. Since this is a process mimicking evolution, we might claim to have come to better grips with one way of accumulating better adaptability, actually one aspect of knowledge management though perhaps not the one that comes first to mind when evolving the concept.

So, for a long time, we were prisoners of a firm belief in the predominance linear systems. What other mistaken beliefs color our perceptions of reality? Statistics may help us describe the evolution of an epidemic but catastrophe mathematics may give the explanatory tool to understand it, and to do something about it. Systems dynamics, like complexity theory in an entirely different way, has provided some important lessons about the non-intuitive behavior of complex systems. It may improve traffic conditions if you close off a shortcut road; it may make for a more rapid emptying of a sports stadium if we introduce some obstacles, like pillars, close to the exit gates. What, then, may be the less well-known structural properties of knowledge and information handling systems?

New ideas about proofs

The importance of the nesting of systems within systems implicit in Gödel's result has already been indicated. This established a more secure foundation to the notion of mathematical proofs, going back to Euclid and discussed by Hilbert though for ever completely destroying Hilbert's dream of a self-contained, all-proving, completely substantiated mathematical system. That is why we now have the solution to the apparent impossibility of the old paradox "all Cretans are liars, said the Cretan" or, more succinctly, "this sentence is false" which so bothered Russell, as it had many others. We know, thanks to Turing, that there are problems where the calculation process will never know when to stop by itself, because it is not possible to tell when the calculation is complete – another take on Gödel's theorem.

We have also recently learnt, it would seem, that there have eventually been developed solutions to some of the problems where only hunches were existing, like the four color problem (four colors are sufficient to allow all neighboring countries to have a different color on any map however designed) and Fermat's last theorem (about prime numbers) – but in both these cases, the proofs are so convoluted and in one instance so dependent on computer calculations that we can only say "they seem to be flawless, but intuitive they are not". This represents another leap in knowledge development and we might speculate that it would inspire some development in notations or formula that will eventually make one or the other proof less cumbersome, at least for the initiate.

Notations more generally

Now let us briefly broaden the view to other notations than those of mathematics, even outside physics and chemistry. There is a fine line between notations and concepts, of course. There are notations for music and dance, for typography and language, for maps and the weather, for mechanics and architecture. The fine line becomes clear if we think of something as mundane as color. There are a number of color atlases, striving to make for a system that is adapted to the human way of perceiving colors, which has to do with perception and thus with psychology, whereas a physicist might be tempted to think in categories of wavelengths. It is an important discovery that the brain does something with those wavelengths, and this is one of the basic facts of human information handling. Interestingly enough, we all have a distinct idea as to what constitutes an ideally yellow color, characterized by the absence of red, green, black, and white, and we also have an exact notion as to what is a yellow-red color that is as yellow as it is red.

Another intriguing discovery is that different languages may contain different numbers of color words. There are some languages that only recognize or offer descriptions for two colors, black and white, lending some credence to the proposition that early, color did not exist, only a scale of shades of grey. When there are three colors only, the third color is always red – red like blood is the guess. And so it evolves, following a clear-cut scheme[56].

Could we see a color that we couldn't name? The question is philosophical: what do we mean by seeing – and can we see things that we are unable to describe? Yes, certainly – that is the problem with qualia: how may I be certain that we two experience the same degree of red, of "redness"? Answer: we cannot.

But we may experience the taste of wine without being able to describe in any other way than by analogy. The wine language is often flowery, sometimes verging on the odd and amusing. That is precisely because there has been no notation developed, and so far, there are few clues as to how such a system would be designed.

The point here is, then, that when there is a notation system for wine tasting, possibly linked to what seems to be the commanding phenomenon, smell, then there may well be some kind of break-

[56] Kay, Brent & Berlin, Paul: Color Terms. University of California Press, Berkeley CA 1969

through in human information handling. This is because it has been demonstrated that we humans are strongly affected by smell signals, even though we are not fully aware of it, and there may even be smell signals that are picked up by some extra organs at the back of the nose that are completely subconscious but certainly important enough.

Here is a conundrum to ponder. A blind person has been brought up to experience geometrical figures like the circle, the triangle, and the rectangle with her tactile sense, say, her fingertips. If given the faculty for seeing for the very first time, would she recognize the geometrical figures now drawn on a paper?

In general, then, new and more efficient notations, as well as new discoveries, would be something to be on the lookout for since they may herald important changes in human information behavior.

7. The power of perception, the power of the power

Initially, the Gods were present, we have claimed, as we highlighted the switch from cult to belief system as a major change in world view and attitude versus knowledge – and versus what power should be regarded as legitimate. Stalin's famous question 'How many divisions can the Pope muster?' points to the relationship between the powers of this world and the other – as if had not Islam's Jihad already proven the point.

What information we take in, what information we judge valid, what knowledge we strive for are all dependent upon our cultures and belief systems. Here we must also regard whatever frameworks that rule our lives, material as well as informational, interdependent and inextricably intertwined as they are.

Heavenly ordained

In the early days, in many cultures, the Gods (mostly plural) were represented by priests, also serving as princes. As we see it in ancient Egypt, with the pharaoh also in charge of ceremony, in the Bible's priest-kings, or in Aztec Mexico, where the king fulfilled much the same (bloody) duty, they were the masters of the vital cult. Chieftains served as priests, assuring good contacts with the Gods, commanding magical powers. In some cultures or as a result of shifting perceptions, they were or became Gods – or, when having conquered, they had themselves erected to godly status. Later, they might be crowned by the Pope or the archbishop, or at least governing by God's grace, their legitimacy confirmed by the highest authority.

It would be all too simple to suggest that all societies develop along the same lines, in parallel. Rather they influence each other through communication. All the same, there are common subthemes emerging seemingly without direct connections but spontaneously and independently in several places, reflecting natural yearnings or eternal contradictions in all explanation of reality. Thus it has been suggested that there are deep similarities between Gnostic thinking (existing before and after our era also in Persia, linked to zoroastrism), the cathars as their descendants, the Sufis, and some strands of Buddhism, most typically of the Zen variation. There are certainly great variations, from the almost if not entirely pacifist cathars to the sometimes militant Zen warriors, with the jokes of the Sufis setting them apart – well, what about the koans and the knowledge, or wisdom, they set out to convey. Their common denominator, however, would be the belief that there is another reality out of this world, another truth, a truth unavailable to human logic, to scientific discourse, to analysis, even to description. It is revealed, partly, through paradox, koans, mystical experiences, to sentiment and intuition and inner experience.

To the Western mind, the discovery or invention of monotheism was a great event, perhaps a defining moment even. The Jewish people had a covenant with God, not just a particular king. With the development of Greek thought, particularly with Alexander's successful transmission of this civilization and the subsequent competition between different creeds, rulers and citizens of the Roman Empire were increasingly beset by doubts as to the coherence of their old Pantheon. Since their Empire encompassed most of the world the Romans knew – the Barbarians did not really count – it seemed almost natural to turn the tables: why not establish the Emperor as God?

If a Pantheon or a Valhalla consisting of a team of specialist Gods, hierarchically organized and with its members quarrelling between themselves, had been untenable, the idea of the latest soldier to have emerged victorious from inter-army cabals suddenly also claiming heavenly status was hardly less so. At times, turnover rate at the very top was rather high. Various more sophisticated religions, most notably manicheism, depicting life and universe as the battlefield of a fight between good and evil, alternated between underground and more official status.

The effects of the studies of the great Jewish philosopher Maimonides are illustrative. In his Guide for the perplexed, he tried to deconstruct biblical antropomorphisms but he expressed himself enigmatically because it was regarded dangerous to teach the layman esoteric knowledge. One question that he dealt with is whether resurrection would apply to both body and soul or just to the latter. In southern France, there was a movement among the Jewish that this tract should not be allowed, and they mobilized none other than the Inquisition which duly had the book banned and burned. This, however, brought such disgrace upon the opposition to Maimonides that his teachings or rather his name became sacrosanct, and all further attacks were directed on his followers only. The upshot, after a quarter of a century, was that only men more than 25 years old were to be allowed to study philosophy, after having passed through talmudic education.

Religion carried not only notions of princely legitimacy and origins of the universe but also of ethics. The Old Testament contained its severe law “an eye for an eye” which might be and thus was implemented; it was instituted by God. Christianity brought something new (if we discount the Essenes), with the Sermon of the Mount. Buddhism teaches a particular approach and respect to all living, all nature. The Koran like the Bible contains rather detailed instructions on certain aspects of human life, such as diet, and much more. Differences in interpretations, in, e g, attitudes to interest payments were to cause many attempts at re-interpretation, and much agony. What were the limits to interpretation, to knowledge allowed or forbidden?

Christianity, initially of course a revolutionary upstart, got established through associating itself, eventually, with the governing powers, or perhaps the other way around, or maybe there were mutual benefits to be harvested. It got this position in an Empire of twilight years, but succeeded in conquering the souls of Franks, Goths, and other conquering bodies. Thus it was no longer one Empire with one Emperor that held society together but in Western Europe the Church claiming universal powers. The scene was set for the battle between the Pope and his Church, and Emperors and other princes. In the Japanese history, there are some examples of Emperors having tried to emerge from their long-time position as religious and national symbols above the fray to retake their formal position as real governors. It always ended in failure, even threatening the symbol position. As in Europe, quarrelling factions have been eager to harness the support of the Emperor, to become formally anointed. In the Moslem world, division was caused, initially, by the dispute as to whether one should follow the descendants of the Prophet's family or not. The battle for supremacy between priesthood and state powers is played out to this day in Iran. A religious claim for power, then, is based upon a claim for superior knowledge and interpretation of what is supremely ordained; a prince would base his claim on social networks.

Networks of loyalty

Those social forces were the loyalties created in a feudal society. Families and clans and personal relationships, trust, and allegiances have always played a role. In an economy where arms technology suddenly became very expensive and created great inequalities – the armoured knight on a strong horse versus the peasant or day laborer – there was the need for some kind of "food chain" and legal and belief system sustaining a balance, however precarious.

The Pope tried in vain to forbid the crossbow since it was too fearsome, killing at a distance, and the truces of God, briefly a success in the eleventh century, preventing warfare on Sundays and holidays, were soon forgotten. There were forces in society that would indeed have had the Pope call for some military divisions of his own.

With Macchiavelli, expedient princely behavior got, if not a blessing, at least a how-to-do manual, serving also to some extent as an underpinning of rather ruthless behavior. Several ways of reading Macchiavelli have been suggested; his book was eagerly studied and its lessons emulated by a large number of princes all around Europe. Theories about government were of course nothing new in themselves. One could study Plato; the Koran contained ample instructions; and the idea that the Emperor should have his due was frequently invoked. In Europe, the production of Macchiavelli's manual coincided with the emergence of the idea of "the kingdom by the grace of God". In some way, God had bestowed power upon the governing prince, and thus he was the liege lord to his feudal barons as well as to all his underlings.

Until the advent of print, churches had served as bully pulpits, for religious dogma to be sure, but also for political propaganda, as long as the Church was coerced into participating in its propagation – and also as means for the transmission of official information, including information on going prices for various goods and utilities, i e, officially declared prices when free, self-organizing markets and price systems did not exist. From time to time, the Catholic Church – as any administration of a creed, just recall the regular upheavals in various parts of the Moslem world – had gone stale or developed behaviors alien to its true message. Sometimes the criticism had been silenced by weapons, sometimes by co-opting the critics, sometimes by the Church mending its ways.

Knowledge is not just that which is discovered in words or preached but also embedded in tools. Observing mass, and the call for labor duty, also in monasteries, changed fundamentally with the invention of the mechanical clock, a tool to boot.

A chasm

As we know, in sixteenth century Europe, conditions coincided to create a real and surviving rupture. It was a question of interpreting the Bible, thus a kind of knowledge, in dogma and in practices, it was a question of power, over the Church and its property and also its personnel, and it was a process where new media, i e, the book, the pamphlet, and the printing of pictures played a major role. More people were brought into the religious and political debate, the two being intertwined, some of the results showing in the German peasant revolts, or the English civil war.

While the esoteric knowledge of Gnosticism and Sufism and Zen would always be attractive, its opposite, rationality, reason, and analysis now got more firmly established. There is also the claim that some knowledge is tacit or even silent, some truths never available to be expressed or transferred directly in an organized way. This standpoint is not at all necessarily one of mysticism, however, but rather the underlining of the fact that we experience and express ourselves by all our senses, and that the pronouncement "I had a headache for three ours" is not the same as experiencing what the sentence describes. Sometimes modern physics with its conundrums of quantum indeterminacy and immediate uncertainty reduction at large distances (Bell's theorem, Aspect's experiment) would be interpreted in such ways.

It is an irony often underlined that those philosophers eventually preparing the way for the philosophy of democracy during Enlightenment were admired and supported by Emperors and Princes that certainly did not stand for rule by the people, only their rule over the people. “We the people” first became an incantation in a nation that severed the bands with the prince, the tyrant, but preserved slavery. Power, most importantly taxation power, could only emerge from the people, this being an idea already established in the country the prince they abandoned was ruling. The young United States declared not only independence but also that state and religion were to be kept apart; the government should have nothing to do with the creed of the individual citizen.

The French took this one step further, in creating its own newly designed religion, in fact the belief in Reason, with the Supreme Being (l'Etre Suprême) as the substitute for God, and with most of Church dogma (”superstition”) discarded. It was, in effect, a belief in Man. This particular consciously designed social construction was still born. Utilitarianism, with the largest amount of happiness possible for mankind as its goal, was to become a mainstay. But who would know, who would measure, who would judge? How were trade-offs to be made?

More slowly than Enlightenment would have it, the link between religion and the state, the government, has changed, implying a separation between the two. At the same time, we may note occasional recurrence of movements with religious underpinnings and political claims.

Consent by those Governed

Thus societies had tried and tested different ways of establishing legitimate and efficient ways of government. Legitimate and efficient are not necessarily equivalent; Macchiavelli was certainly concerned with efficiency, but on whose behalf? The idea of the people electing the prince or a governing body was nothing new; it had worked in small clans and townships. Why would a particular family inherit the position as chieftain? The most able might rather fight for the title, a process that would not be to the tribe's advantage, however. Better, then, to elect the person seemingly most endowed with magical powers, with the best relations to the Gods, or the best warrior (which might be the sign of the Gods' consent or favor). Perhaps there was not much balloting, but would-be soldier emperors in the Roman army tried to curry favor with their electorate and power base, the soldiers. Likewise in many feudal states, it took some time before a particular family had succeeded in creating a hereditary governing family. Most often, the governing prince tried to secure support for his oldest son (though not necessarily always the oldest) while still living, and of course lobbying and vote buying is nothing new: land, taxation rights, distributing favor to or in competition with other barons, and betrothal were some of the means that might be used. In the Viking lands, kings initially were elected, though those eligible for election and for voting were a restricted number of noble families, much like the oligarchy in Venice. In Venice, an extremely intricate way of nominating the electoral assembly was developed to avoid vote selling and nepotism, involving a series of lotteries as the nomination procedure.

In ancient Greece, or, rather, in some city states, the principle was that all free men might vote. The same applied to the newly born US, and to the French Revolution, which happened in a country with no slaves. Carried by revolutionary zeal, the French tried to export their democratic ideas, eventually resulting in national awakenings across Europe, and the idea of constitutional monarchy, and also of Republic, taking roots.

It is worth noting that all the different ideologies of the last century have kept to the principle of "the people's will". But according to Marxist "science", there are "objective" conditions and various distortions that, in its Leninist interpretation especially, calls for a revolutionary vanguard, the party, to represent the "true" interests of that majority group the proletariat which is not itself aware of those its true interests. Thus there is the need for a transition period of the proletariat's dictatorship carried out by the elite few. That is because only the (party) elite has the ability to interpret the objective realities, needs, and future oriented wishes of the people, in this case the proletariat. In fascism and nazism, the people is a mystical entity with roots in the past as well as a future still to be created, which calls for the formation of a unified force instead of factions fighting each other. Communism claims an analysis that goes deeper than an ordinary one, fascism limits to analysis in the face of feeling, action, and experience, of shaping the future through acts of will. Here the one in power is right because he is in power; a consciously circular reasoning.

Nothing is ever unproblematic

As all decisions, political ones are based upon insufficient or incomplete knowledge, uncertain dynamic (or systemic or social) effects, path-dependence, seemingly impossible trade-offs, time lags, and complex interdependencies. Non-democratic ideologies have judged democracy unable to handle these intricacies, criticisms and problems that of course have been discussed by firm believers in democracy. Political parties might turn into political machines, offering "solution packages" as well as having interests on their own, vulnerable to lobbying and behavior on the verge of sophisticate vote buying – "pork barrelling". Not all democracy is representative, and a balance has to be struck when it comes to the amount of direct voter participation. Yet another problem might be instability, the courtship to swing voters, and the possible instability in coalition building. The result might be frequent policy reversals, inconsistent or untenable decisions, and less concern for the future impact of decisions taken. Propaganda will aim to tell who is right and who is wrong – how information should be interpreted and what trade-offs are valid.

One criticism of democracy is that it not just makes for too little concern with the future but that it preserves the present, is self-perpetuating: the future has no constituency, and new constituencies have to make do with, e g, old party structures. Media are important, as are the machineries of political parties. These existing systems, and the elites linked to them, certainly fight and undergo change, but within limits, "within the system". It is by virtue of the efficiency of these systems, this indoctrination that we may even fail to see – some would claim – that we are prisoners, that the democracy is phoney rather than real.

This is the criticism not only of Marxists but more acutely of Anarchists. Anarchism dwells on an idea that is extremely different from that of an elite party realizing the dictatorship of the proletariat: self-organization. Instead of voting – something Anarchists are against – people represent just themselves, and they should associate freely with other people on all those issues that interest them. Associations should be loose and temporary, people just acting freely and spontaneously, much activity in society based upon freedom and voluntarism. An important requirement, obviously, is sufficient ability to process information, i e, education. Thus Anarchists stress education but an educational system allowing for and stimulating criticism rather than indoctrination.

Some have suggested that Anarchism will get a second wind from cyberspace, where enthusiasts like Kevin Kelly declare the open space for self-organization and systems that are clearly out of (central, that is) control. Another stirring comes from the communitarian movement, stressing the need for a civil society beyond laws, regulations, and formal organizations, a civil society based on trust, and on common interests. There are parts of this creed that might be tilted so as to lead to fascism, others that touch upon wishful thinking, and many which quite reasonably resonate with age-old village community cohesion. Then there is the proposition that the market too is self-organizing, seemingly functioning much like biological evolution.

Self-organization – what does it mean?

The proponent may suggest any number of indications that self-organization is on the increase as a governing principle, though it will never be the sole one. New, or differently phrased, questions as to knowledge structure – i e, sometimes, power structures – are being generated. What are, for example, the “primitives”, the fundamental entities of human interchange? Which are the forces or procedures leading to self-induced stability? Some examples of the reverse would be when, in the former Soviet Union, there was a market for spent electric bulbs. The person disposing of such a bulb could try to exchange it for a working one while no one, in the office, in the factory, in the supermarket lavatory were present to see and prevent what was happening. This was because working light bulbs were a rare commodity. Or when in the same economic system innovation was encouraged, innovation equated with such change that was deemed reasonable – but lacking any proper measure, read: profit, various planned variables were optimized: electricity if that was in short supply, this or that raw material, but without any concern for the general public good. The market looks after this general public good just because no one in particular is in control – and of course there are deficiencies, “externalities”, such as environmental effects.

Sedentary populations meant cities and specialization, implying complexity and fragmentation in the sense of diverging faculties and interests. So many micro decisions have to be taken, so many balances have to be struck, constantly, time and again, that no central planning is feasible. Perhaps spontaneous and dynamic balancing is a better proposition than self-organization?

Information technology has been harnessed to improve upon co-ordination, balancing, and market mechanisms as well as to make up for its deficiencies, such as measuring and monitoring and controlling environmental impacts. No market is perfect, not least because of information defects, genuine uncertainty, and transaction costs. A perfect market assumes perfect information, and the first problem is that information carries a cost, the second that it may just not be available because uncertainty reigns. Transaction costs may account for as much as 30-40 per cent of the costs. They are constituted by contact costs, the establishment of quality, and contract costs. Quality means both qualities, i e, features, and "raw" quality, i e, robustness, reliability, smoothness and nice touch and sight, etc. Contracts may have to be very elaborate, calling forward an army of lawyers, after sales inspections, etc.

Trust is less expensive than courts and lawyers

The communitarian movement makes the case for trust. Trust may depend upon tradition and culture. Thus transaction costs may be affected by the general cultural and social framework, as has been pointed out by students of, e g, the Japanese way of doing business. There are also, most importantly, signs that trust is substituting or complementing paid in capital stock as the "stock" in collaborative efforts, substituting or supplementing the limited liability corporation. The efforts to establish measurements for trust or quality, with the Malcolm Baldridge Award and its concomitant check lists, or the ISO 9000 quality standardization, with its reviewing and auditing procedures, offer further examples of how trust is being operationalized. Trust in Japan may constitute long permanence, ISO 9000 certainly not. Trust would lessen contract costs but other costs might well increase.

More generally, IT promises to affect costs associated with all these factors, contact costs, quality ascertaining, and contracts. The Internet is today's demonstration of contact opportunities offered, where also, e g, consumer groups may self-organize, as may all groups sharing a common interest, without necessarily having to buy into a larger package of opinions or interests or services. Descriptions of features, including the necessary instruction and education to make it possible to appreciate and affix a value to them, may likewise be facilitated, simulation being a case in point. It has actually been suggested that simulation, the ability to imitate reality in fine detail, implies a sea change, affecting *la longue durée*. Quality, contracts, and eventually trustworthiness or reliability may be researched through polling over the Net; there are also "quality assurances" of sorts, like those offered by TRUSTe and Better Business Bureau or the audit performed by Pricewaterhouse-Coopers. An experience exchange may develop as a quite natural quid pro quo in a society more geared towards self-organization. Ideally, the Internet offers less transaction obstacles in principle, less costs and delays, more opportunity for interaction.

What are the political equivalents of contact, quality, and contract? The agenda and in what order different propositions are pitched against each other and then eliminated often turn out to be of capital importance, yet there has proved to be no logically preferable way to establish the proposition order. Furthermore, there is no guarantee that the mechanisms in place result in compromises that in some sense maximize the total good (the consolidated happiness of utilitarianism, for example) rather than what the formal proposition order and temporary coalitions resulted in. There is also the problem of establishing a coherent package of decisions, where all ends meet.

It might be suggested that the requirements implicit in the last few sentences are impossible. Democracy is a mechanism that provides some reasonable compromise, reasonable perhaps in the sense that people regard it as fair. It has even been proven that there is no objective correct way, more correct than other ways, to vote between several propositions until a final decision is taken; likewise, if A, B, and C hold different views, there is no sure process for obtaining the best compromise. The question is whether compromising might be improved through improving democracy. The rules of the market, the laws underlying contractual arrangements are established through a political process. So are law enforcement procedures and structures in general, and the framework for agreements between different groups, e g, in the labor market. Perhaps in future the political process will be more engaged in establishing such rules, then leaving to self-organization forces to self-adjust reasonable balances, relying upon feedback mechanisms.

A concern for self-organizing or self-balancing co-ordinating structures will bring up the question whether there is a convergence, whether there are universal behavioral patterns which automatically and eventually lead to basically the same stable outcome.

The key word here might be "basically". Languages are very different, still they share certain commonalities, thought to be embedded in the deep structures of the human brain – or in the evolutionary process of "efficient" language structures. Likewise, cultures may differ considerably but still offer a deeper coherence.

Trust, i e Behavior, is Linked to Culture

From within a culture, however, other cultures look very different. Cultural imperialism is not regarded as liberating. Might it be that different cultures are geared differently to, e g, decision making mechanisms such as democracy or economic mechanisms such as those associated with free and competitive markets?

Much before becoming the Prime Minister of Malaysia, Dr Muhamad Mahathir wrote an explosive book, "The Malay Dilemma", so explosive, in fact, that it was banned at the time. The main thesis of the book is that there is a cultural discrepancy, a chasm even, between the Malay and the Chinese cultures. Malays are steeped in a culture of sharing, of openness, of hospitality, of always inviting strangers and visitors as honored guests when they arrive – something which characterizes some other cultures as well. Since everyone in a pure Malay society behaves like this, there is automatic and natural reciprocity: someone who is a guest now will himself be entertaining guests at some other time. The Chinese, however, belong to quite a different culture, where reciprocity is needed only if contracted, as within a family or a clan, but else what is offered is just taken and nothing, for want of contract, is returned. This also works well within a "pure" culture since, again, everyone is aware of the tacit rules. The problem arises when the two cultures are brought in contact. Then the Chinese will automatically profit from their own behavior versus that of the Malays (Dr Mahathir claims), exploiting, in effect, the latter, mostly without realizing what is happening, since they would not understand that there might exist any other behavior than the one they are steeped in, the only one natural for them. Thus, Dr Mahathir concluded, the Malays must be protected from the negative side effects of their own culture.

France and Sweden are often described as Europe's two most centralized countries, based on a tradition going back, respectively, to Philip le Bel in the thirteenth-fourteenth centuries and Gustav Vasa in the sixteenth. The relationship between citizen and state in the Soviet Union has been suggested to have been modelled, more or less unconsciously, on the Tsar's personal "ownership" of all Russians. The Japanese keiretsu are said to embody the same feudal principles as the samurai of the Medieval Ages. The question then arises whether such long-term cultural patterns may also influence attitudes and aptitudes vis-à-vis information and knowledge.

Fernand Braudel has provided a "dictionary of cultures" but it is hard to do much more that speculate on the possible effects of different traditions and cultures on the ways in which information and knowledge are developed and accepted. Yes, the Chinese have traditionally venerated knowledge and wisdom. Yes, the Japanese display little of the "not invented here" syndrome, readily accepting new ideas from any source as they do. Yes, the Americans and the British have fostered dialog and the adversarial process whereas the Japanese are striving for consensus, accepting that there are no simple truths and falsehoods but rather a scale in grey.

By and large, this would seem to be a potential, and a potentially important, avenue for future research, rather than just speculation. There are of course a number of investigations that more than touch upon the subject, such as Simon Schama's "Landscape and Memory", dealing with the mythic content of the forest in a number of cultures[57].

The question, then, is what other imbalances and inequalities may arise when technology and globalization, especially perhaps the Internet and other future cyberspaces, force or allow people from different cultures to interact much more frequently. That there are cultural misunderstandings is one thing, and quite an established problem or phenomenon. What we are speculating about here – and speculation it certainly is – is something larger: cultures tending to act as predators when they get in contact with certain other cultures, offering "prey" features relative to the predator.

[57] Schama, Simon: Landscape and Memory. HarperCollins, London 1995

8. Money, Markets, Marriage

Today, the market, that self-organizing structure, seems to reign supreme. As a concept, and as something to have to work smoothly, it is seen as a generator of wealth. It is often even sometimes called The Market, as some new major Deity.

The market, like money and marriage, is a social construct that works simply because we believe that it does work. Of course all three of money, marriage, and markets may be said to rely upon contractual obligations and even laws with their concomitant sanctions. That just means that these social constructions are linked into yet another such construct – the system of law and its upkeep. They all display a certain circularity in the sense that we trust these institutions because they work and they work because we trust them: they are recursive. History has seen occasions of breakdown of them all: reckless promiscuity (where the word "reckless" obviously makes a value statement indicating a particular stance), runaway inflation and the subsequent return to a barter economy, and markets collapsing for want of functioning mechanisms such as trust, money instruments, etc.

Instruments for economic transactions like money, but also checks and the modern credit card, are so mundane that we seldom ponder the wondrous fact that they work at all. They demonstrate the self-fulfilling power of social institutions, social constructions. They are recursive, depend upon themselves: "for recursive, see recursive"[58].

[58] Dyson, George: Darwin Among the Machines. Allen Lane, London 1997

Start with Barter

The very first markets were of course for barter, thus barter economies; they can be said to have been direct, not socially constructed. Tools were exchanged for food, different foodstuffs were also exchanged, the utility to the bartering parties deciding the "exchange rate". If there were several sellers and buyers, a real "market" on, most probably, a very direct and concrete market*place*, then there would also be a "market valuation" of the various products. There must have developed a need to assess quality and quantity, calling for the development of measuring instruments. How many fishes would equal one horse but then what type and size of fish, and how prim and proper the horse? Early on, laws were created to make the market safe from cheating, like doped horses and fish stuffed to carry more weight, thus an artificially inflated value. Archimedes discovered his famous principle while researching a method to test whether a piece of rare material was fake gold or not. (It turned out to be fake: eureka.)

A number of quantitative measures evolved, some of them not the same but still often enough related in several regions of the world. These measures were the measures of man, the length of a finger or an arm or a stride, the weight of a stone or a piece of grain. Quality was – and still is – another matter entirely. Experience held high value, sometimes laid down in proverbs and sayings. Tools required certain competency for their adequate application, and guilds emerged, taking in their own hands to guarantee artisanship quality. At the same time, this created closed societies, controlled monopolies.

Land and possibly traps for hunting would require a social contract, a supreme power that enforced property rights. That power needed mechanisms and servants – police, soldiers, prisons – seeing to it that rights were upheld: a social construction. Sometimes guilds got established through royal privilege. Rivers did not allow an infinite number of irrigation canals nor mills of various types everywhere; here was sometimes the marriage between the guild of millers or blacksmiths and the secular power controlling, say, water resources. Some craftsmen were so skilled and the power depended so much upon them that they were allocated a certain defined latitude of power, like prospectors-miners, often allowed a self-organizing or at least self-governing type of society structure.

A live horse or camel might be transported a long distance if food and drink could be provided. Fresh food, however, could only be bought and sold just after catching or harvesting, thus, given slow modes of transportation, only within the vicinity of the cultivation. Local circumstances would be most influential on local price patterns, on the information guiding the market, and there might be large variations from season to season, from year to year. The possibility of preserving food, through salting, sugaring, smoking, or drying, made for an important change in the geographical size of a market, thus also for the information concomitant to that market.

Some foodstuff was less perishable and also fairly easy to transport and at the same time sufficiently valuable to serve as an exchange medium – cocoa beans in America and pepper around the Mediterranean. Still, it would be difficult for anyone to acquire too much wealth with such a medium – it was rather the size and quality of land that would constitute the foundation of "financial" power in a time when "financing" would have carried little of the meaning of today. Geometry was created to allow for the exact measurement of land, not just to serve the landowners but also to make for an important collaborative endeavour: the management of irrigation, of water resources, of canals.

Several Tiers of Money?

Pepper grains were certainly transnational. Some resources were even less perishable – metals of value. Here emperors or kings might make their imprints, with faces, texts, symbols, and indications of value.

Money as we use it is one-dimensional. It carries one single value; how could it be differently? Well, there have been cultures utilizing different currencies for different exchange spheres, so that, e g, food was exchanged against other types of food, prestige goods against other prestige goods, but not food against those show-off things. Consolidating value in one single currency equals levelling systems with different characteristics such as turnaround times, tendencies to perish, or spatial extension.

Early on, animals, beads, cowry shells, and weapons served as monetary instruments[59]. The units had to be rare enough to be valuable, at the same time with some utility and ability to reach common acceptance. Rare metals like silver and gold were then interesting; they held utility, and they carried a favorable value to weight and volume ratio; they also sometimes acquired a mystical

59 Histoire de la Monnaie. Air France magazine Janvier 1999 pp. 86-87

quality that fits the idea of a social construct nicely. Its diffusion and acceptance took a long time but the concept of paper money originated in China just after the year 1000. Prior to that, the Chinese had adopted coins in the 6th century BC[60] – if the state is guaranteeing the system of law and order, then it was perhaps natural that it should guarantee that the coins could be trusted for their metal value, too; it was not for everybody to perform Archimedes' test. An alternative to coins with fixed values would be to cut up sheets of gold or, e g, copper.

Some princes, like Philip le Bel in France, cheated; they lowered the percentage of valuable metal. This would help mint Gresham's Law, an information law of sorts – the lesser metal or the lesser coin will always drive out the more valuable. When, e g, both silver and gold were used, there were sometimes arbitrage, hoarding, and speculation. Because of the need for trustworthy value, old coins had a long lease of life: Roman coins were current for centuries and the Maria Theresa-thaler was relied upon for trade in places far away from Austria, such as Arabia and East Africa.

The American dollar was created just before the war of independence, in 1775 – in earlier times, the colonists had relied upon tobacco, shells, strings of beads, and Spanish coins. For a long time, many banks in the new Federation minted their own dollar bills which is why all greenbacks look the same apart from the denomination. The fact that, e g, Bank of Scotland notes are used in Britain is another reminder of the fact that there was not always one central bank controlling the issue of money.

Today, out of a total French money supply of some 1800 B FF, just less than 300 B is paper money, the rest intangible. This serves to tell that there are several other important inventions in the field of value exchange, one being credit. This requires trust; it might mean security, and then the legal system takes on further responsibilities. Usury, charging a cost for the time value of money, used to be regarded as a sin by the Church, as it is still in Muslim countries. It may be seen as a prerequisite for economic development or at least the smooth functioning of the financial system, however. It is obvious that we here have a case of complex information relationships, including some displaying uncertainty, and thus (?) speculation or hedging.

To obtain a loan to acquire a piece of land, or food to preserve,

[60] Monnaies du monde et d'aujourd'hui. Air France magazine Janvier 1999 pp. 92-93

is one thing; another problem is that of transporting the equivalent of money over a larger distance. There is the real risk that the traveller will be robbed; for larger sums of money, liquidity might be cumbersome because of its sheer weight, particularly before the advent of paper money. So in retrospect the invention of the check, of a paper instrument of a designated value that might be translated into currency again, seems like a foregone conclusion. The problem and the point is, like with the functioning of money, that the instrument must carry trust – a social construction thus. That trust might not exist between the traveller and the money men he dealt with. The trick was that the money men operated in larger networks and that they issued receipts or value instruments that could be cashed at some other office or node in the network.

Trust is Key

There is still a Lombard Street in London and a rue des Lombards in Paris, as memories to the traders from Lombardy who in the Middle Ages established a network for trade, including banking facilities, covering much of Western Europe. Many of them came out of a few families; they had frequent businesses with each other within a family; they moved from one office in the network to another. Thus they knew with whom they dealt, and cheating would have cost dearly in lost business. Within the self-reinforcing monetary system, this is an example of a self-reinforcing network of which we have seen many more. We might have mentioned the Florentine bankers; another system was, at about the same time, the network of installations of the Chivalric Order of the Temple. The Knights Templar too had lots of offices, the commanderies, and they too were propertied and had lots of business deals going on, basically with the aim of purchasing weaponry and supplies for their men fighting the infidel in the Holy Land.

The fact that a money order was created in one country to be redeemed in another offered a convenient way out of the risk of being accused of usury. There were no established, much less any official, currency conversion ratios; thus the concept of a conversion loss would have been empty; but the Lombard paying cash for the money order might be sure to record a profit.

These money men could be trusted, princes not. While kings relied upon them, their riches, real or imaginary, sometimes attracted both envy and protest from ordinary, poor people, and greed from kings constantly in need of more gold for war and impressive exuberance. The competition might use such feelings to have the successful money dealers, and traders, suffering being robbed by princes, often enough on trumped up charges. The Jews were the ones in the most precarious situation.

As we have noted, money is a rather one-dimensional information carrier and a great equalizer in a sense: it tells of its value, period. The networks mentioned also operated as carriers of more complex information, indeed of knowledge. Religious orders, including the Knights Templar, developed a number of trades and industries in which they were involved, like agriculture, and with the acquisition of new lands, they themselves served, in their very persons, as vehicles for technology transfer. Likewise, since the Lombard families circulated their family members between different places where they had offices, they acquired a lot of knowledge that could be brought from one place to another. If they did not always master everything themselves, they would serve as recruitment agencies, telling someone in England what type of Italian artisan to recruit. It is often said, and sometimes proved by research studies, that technology transfer is most efficiently carried out through the physical transfer of people; this was possibly even more true in past times.

Intimate information links

Money doesn't smell; in fact, it is anonymous. In contrast, a letter of credit may mention the persons involved; if it has been traded, there might be a record of its whole history. The aggregate amount of money in a society tells something about that society's wealth; thus it gives us information. As has been well established, there are now a number of measures for the amount of money circulating in society, this being so because of the existence of a plethora of monetary instruments, including government bonds, credit card credits, hedging funds to reduce currency risks, and much more. The market for securities offers a number of different options, derivatives, junk bonds, and other instruments, sometimes related to the second differential of the change in security value.

This is all information, telling about those many relationships between those very instruments and the underlying economic actions and "real values". The problem, some would say – the point rather – is that such real values don't exist, perhaps they never did.

Already in the exchange of a fish for a sweet potato, the exchange value was in the eye of the beholder. The element introduced in a much more sophisticated way by today's more complex financial systems is the time dimension. The degree of subjectivity or expectation involved in the fish for potato trade was small, certainly compared to what is involved in the selling of futures or investing in, e g, Internet companies. There is the risk for a vicious circle – the virtuous circles are less often mentioned – where people borrow against their securities and then buy more securities that then increase in value – or is it not rather price? – and so on, until the trap springs. That is, there is then a fall in share values, making the lender call the loan that is no longer fully secured, causing the speculator (who did not see himself as a speculator) to sell his shares, making for a further fall in prices, etc. And then there is no guarantee that the fall stops at some "real" value threshold: real value does not exist, only what the market decides. The economic crisis may have reached such far-reaching effects so as to have factories come to a stop, transportation companies file for Chapter 11, and farms drowning in their own produce.

This is a well-known enough mechanism, chilling as it is. The point is underscored by the fact that the amount of international money transfer is about a hundred times that of the value of international trade. Speculation of those dimensions? Not at all, it's insurance, it's all those attempts to balance out currency exchange and other risks and uncertainties.

Money serves as a social institution, functioning through the established spiral of tautology. We need money; without money, transactions would become overly cumbersome, costly, often enough impossible. It is a construct that seems to have been pretty robust over the years, despite the fact that there is a real risk for manipulation. One reason may be that there are several countries and not all of them would attempt, even manage, to manipulate their currency or the value of their money or the state of their economy at the same time. Several Latin American countries have opted for the American dollar, to save themselves from the temptation to devalue and recreate runaway inflation. In several countries that American dollar has become the currency of preference, just because of its relative stability, something which serves to underscore the point about trust.

Do we know of any examples of economies where money has lost its trustworthiness completely? The answer seems to be yes – one case in point was Germany of the 1920's, with runaway inflation making people use apple charts to transport billions of German marks with a value close to that of the paper in the notes. With the collapse of the Soviet Union, even non-smokers accepted cigarettes to be the more stable and efficient currency. In Italy, chewing gum and local transportation tickets have served to substitute coins in an inflationary economy. In Israel, at the time when inflation was running at 400 per cent a year, the joke had it that one should only travel with transportation means that allowed for payment on arrival because then the same sum of money carried less value than at the outset.

9. The framework of economic and technical development

Why did it happen where it happened? Why did agriculture develop in the fertile crescent, why did Europe come to conquer and reign, however briefly, large parts of the world? Most importantly from our perspective of changes in information behavior, why did the industrial revolution take place on the Western fringe of the Eurasian continent and not, e g, on the Eastern?

There are several answers to this, all linked to human organization, thus to the development of knowledge. We will start with the very long view, following Jared Diamond[61], and then turn to the question of technical development and industrialization more specifically.

Eurasia is large and goes East-West

This is the brief version of Diamond's 'Short history of everybody for the last 13,000 years'. For an agricultural civilization to emerge, there must have been advantages superseding those characterizing existing hunting and gathering society. This meant a number of wild species suitable for growing and domestication, as well as the availability of several animals that might be domesticated. These conditions are not present everywhere. In addition, to allow for such a new society to take root, the exchange of seeds, experience, and animals would be advantageous. Here, the Eurasian continent holds a unique advantage in that it has a large contiguous area ori-

[61] Diamond, Jared: Guns, Germs and Steel. Vintage, London 1998

ented in the East-West direction, which means that the climate is about the same for a long stretch. Thus Italy and Japan display climates that are not too dissimilar. And so the transfer of plants and species was possible – in contrast to the conditions determined by the North-South axes of Africa and the Americas. Furthermore, some of the animals, notably the horses, where particularly efficient in transporting warriors as well as merchants and colonizers. Trade routes could develop, furthering exchange and specialization.

Large and dense societies could thus be sustained. They were sedentary and, in comparison with their forebears, they displayed a booming population. They allowed for the development of cities, for the stratification and specialization within themselves, for example in a number of guilds, and since they were dense enough, epidemics might flourish. These were often contracted from animals, mostly from domesticated ones. An epidemic might be a disaster temporarily but as a trade-off it offered immunization in the longer run. Thus the combination of domesticated animals and population density (ten to a hundred times larger than before) made for surviving populations less prone to be infected by diseases. Again and again, we meet in the history of colonization the virtual wiping out of whole populations by diseases brought in by the Spanish, the British, or others.

Agriculture, storage of food, and stratification meant something else also. There was the development of a need for calendars and bookkeeping, for administration, law, and taxes. The construction of a written language is a huge step and it seems to have emerged gradually out of bookkeeping, with symbols like “two sheep” and “two sheep from John”. Writing might be based upon single sounds, syllables, or whole words – though very often there would be a combination, like we use letters but also % and &. In two places, writing developed without any predecessors – in Sumer and in Meso-america. It is possible that this holds for China also, and possible but less likely for Egypt as well. In all other places there was at least the impetus of inspiration from knowing that writing should be possible because others were known to master it.

Alphabets, then, are based upon the principle of signs corresponding to sounds, even though there is no exact correspondence – a C may be pronounced as a K and TH in English is needed for a particular sound. The second important feature was to standardize the order and the pronunciation of letters, originally using a particular word for easy recalling – arch, ball... In Semitic languages, these objects corresponded also to the forms of the letters. The last innovation was to provide for vowels as well as for the consonants preceding them.

Most of the inventions crucial to the industrial revolution of the nineteenth century had already been made, centuries before, in China. Newton and Leibniz, inventors of differential calculus, had a Japanese forerunner. Africans seem to have mastered iron production, including preheating the air blown into the furnace, much ahead of this "Western" invention, patented in Britain in the 1820s. Much invention stems out of imitation, improvement, and tinkering – building upon what already exists. Thus technology begets more technology, and the process might take on the face of an autocatalytic one, each step necessitating or calling forward the next.

The question probed here – why in Western Europe? and what do we learn from it? – has resulted in what Diamond terms a "laundry list" of explanations, one, e g, being longevity so that an inventor would have time enough to gather experience and make use of his or her knowledge. One might expect eyeglasses to play a subsidiary role here. More generally, modern medicine should then be of importance. Cheap slave labor would be a detriment, individualism a positive factor, as would a scientific outlook. Many factors, not just one, seem to have been of importance.

A question of philosophy?

Still, and yet again, the industrial revolution did happen in Europe, not anywhere else. It seems to have been closely linked to the availability and dissemination of information, including, and occasionally transcending, rules and organizational undertakings to further such processes. What begot a virtuous circle where such rules and organizations might evolve instead of locking up in their own success or just in fright of failure?

As we have stressed, there have indeed been many attempts at explaining the advent of the industrial revolution. It has been claimed to have its roots in a change in profound values: in earlier times, development was either regarded as cyclical, so that history would repeat itself, not any exact repetition to be sure but with a limited number of basic features succeeding each other in a preordained order. Seven fat years would always beget seven lean ones. The rulers felt secure within existing structures and any change was to be regarded as threatening – this certainly was the dominant thinking in ancient Egypt[62]. Or so history was regarded as a slide downhill; the thrust should be to return to Paradise, a Golden Age lost. This striving to return to a lost era would also calm discontent, would serve to comfort those suffering from illnesses, those who were starving, downcast, oppressed. There was a return to Paradise for the meek, and there would be a day of Judgement.

The philosophy of Enlightenment changed this. For the first time – this is at least the claim – there was an idea of progress, of humankind on its way to something better. Later progress was translated into growth, economic rather than moral growth, and into wealth and welfare.

Ideas need underpinnings. The Enlightenment philosophers had keen followers and sponsors among despotic rulers such as Catherine the Great of Russia or Frederic the Great of Prussia. And while Voltaire wanted the Church to be crushed, Christians found the new ideas foreshadowed in Biblical sentences: yours is the earth to exploit... Earlier on, in the early part of the second millennium, laws and legal thinking had been compiled into an integrated structure. This created the basis for rationalism, for organized reasoning, and also for a self-described elite at the emerging universities of Europe.

A detour to writing

It's very expensive to produce a new design but fairly trivial to copy old designs. Thus any copying device is of importance.

A pair of scissors is not just a product of intelligence; it also transfers intelligence in a direct and intuitive sense. An individual endowed with a pair of scissors is andowed ewith a larger potential repertoire of smart avenues for action. A tool transmits intelligence (Dennett). So what about those tools provided by language and words and copying through printing?

”The ease of alphabetic reading and writing was probably an important consideration in the development of political democracy in Greece; in the fifth century a majority of free citizens could apparently read the laws, and take an active part in elections and legislation...” “The writing down of some of the main elements in the cultural tradition in Greece... brought about an awareness of two things: of the past as different from the present; and of the inherent inconsistencies of life as it was inherited by the individual

[62] van Doren, Charles: A History of Knowledge. Carol Publishing Group, NY, NY 1991

from the cultural tradition in recorded form". "Lacking the resources of the unconscious adapatation and omission which exist in the oral transmission, the cultural repertoire can only grow". " The mere size of the literate repertoire means that the proportion of whole which any one individual knows must be infinitesimal in comparison with what obtains in oral culture". "One way... is to see the literate society as inevitably committed to an ever-increasing series of cultural lags... [A]ny particular individual... becomes a palimpsest composed of layers of beliefs and attitudes belonging to different stages in historical time"[63].

The literate mode of communication does not impose itself as forrcefully or as uniformly as is the case with oral transmission. Obviously, an oral culture has no texts. How coud it, then, bring together organized material for recall? How is it possible to learn and to go back and check on previous attempts, successes, or work in general? One way is mnemonic patterns, with restrictions associated[64].

McLuhan too stresses the importance of tools, and as extensions of man, to him, they may qualify as media. He even suggests that electric light being amedium though mostly an empty one; thus we do not recogize it as such. But it is necessary for much of informed behavior. Thus historians tell us that electrical light developed as a necessary respoonse to the operational needs of large manufacturing halls. Broadening the perspective, breakthroughs in construction, transportation, city and social organization are bound to affect needs for and patterns in information utilization.

63 Goody, Jack & Watt, Ian: The consequences of literacy. Pp.48-63 in: Crowley, David & Heyer, Paul: Communication in History. Longman Publishers, White Plains NY 1991

64 Ong, Walter: Orality, Literacy, and Modern Media. Pp. 63-69 in Crawley... Op cit

If not philosophy – what about competing alternatives?

In a lifetime of studying Chinese history, philosophy, and society, Joseph Needham developed what he saw as the key difference between powerful China and Europe. China was, despite warring factions and local warlords, monolithic; Europe represented pluralism. An artist and engineer like Leonardo, a preacher like Calvin, an inventor like Gutenberg – they could change allegiance as their liege lord was interested in sponsoring their works or not. Of the six important ingredients in Gutenberg's innovation, paper and movable type existed in China, whereas the press (borrowed from wine and olive oil making), inks, metallurgy (a particular one, for style metal), and scripts (i e, a limited number of letters instead of thousands of signs) did not.

We have now outlined a number of institutional aspects of the industrial revolution, and several more will follow. Gutenberg's breakthrough would seem to have indispensable for the various informational functions involved. When it is pointed out that the Chinese invented the printing press much before Gutenberg, there is one fundamental caveat to observe, and that is that the Chinese signs are hieroglyphs, not letters. Thus the limited number of movable types that make Gutenberg's printing press so efficient would have to resort to thousands of kanji in China and Japan. Whether the Phoenician script was alphabetic or sign based is disputed but the Greeks started writing in letters around the time when they got papyrus from Egypt. Thus this event had repercussions more than two thousand years later.

If we look behind these examples, we also find different types of states: royal dictatorships, trade republics, self-governing cities, small independent sees, feudal federations, military orders, oligopolies. The Eurasian land mass, including Northern Africa, offered the globe's largest assortment of competing societies – competing, conquering, exchanging, amassing knowledge and technology in the process. At the same time, development had to begin somewhere to be able to really start, to get off the ground – the autocatalytic process is imperceptible at first. We may, but only in retrospect, discern it in several strands of the full development landscape, just like with the Gutenberg press: Leonardo was too lonely to get to scientific breakthroughs – invisible or visible, a college, a society, an academy had to exist, to make for those giants on whose shoulders Newton claimed to be standing. Even Diamond in his Epilogue quotes power concentration in China as a reason why the Chinese merchant fleets were called back: the party at the Imperial Court that was dead against such adventures had come into power, and power was absolute, and without any challenge or competition. That decision became irreversible, since no shipyards were maintained. By contrast, Columbus succeeded in his fifth attempt to find a sponsor, after having been turned down by a number of other princes, and also the king and queen of Spain, before they changed their minds.

Diamond's argument having much to do with geography, he links the chronic disunity of Europe, and the long history of Chinese unity, to this feature also. In Europe, there are many more lakes and seas, islands and, especially, peninsulas; there were straits, mountains, coastal indentations, and forests to establish barriers and protect or at least mediate against such powerful Imperial designs as could be exerted in China.

Those different forms of government mentioned evolved into each others which means that different power centers claimed influence, not always winning or monopolising all of it. Thus the long battle between Crown and Parliament in England resulted not just in two revolutions and one military dictatorship but also in a reigning in of Royal discretionary power at a much earlier stage than in most other countries.

A Royal patent extended a monopoly, granted, and revocable, by the Sovereign. Patent rights might cover a monopoly on all milling in a particular region; on trade with a specific part of the world or port or for a particular goods; pirating; and then also inventions. Patents were awarded to royal favorites, to those who had lent or were expected to lend services to the King, and possibly to those who paid for it, another way of lending a service.

What the King had given, he could also revoke. To vie for a monopoly, to cater to the whims and the arbitrary ideas of the Sovereign was better than to work diligently. Someone might be awarded the monopoly right to tax, to rip of the diligent worker.

So this was in a sense corruption in the highest of places. The King could be induced, by nice words, sex, political services, money, power, or real estate to extend rights – rights that impacted on the functioning of the economy and that so affected a number of people not given those rights, and whose rights and actions were thus restricted and made more costly. As with all corruption, bribing in a broader sense than the literal tended to be more profitable than long range planning and investing.

The selling of monopoly rights gave the Crown a source of income independent of Parliament. Inasmuch as individuals' inventions were covered, it seemed patently unjust that the King should have the right to hand out the patent to some favorite who had had nothing to do with the invention. It seemed also evident that people would not be induced to come forward with ideas if these where, by Royal fiat, appropriated by someone else. So, in 1624, Parliament passed a patent law, lying down objective and global requirements for the issue of patents, substituting the previous arbitrary regime.

We might note (again) that this was not the very first patent system. In the early fifteenth century Brunelleschi, responsible for a number of inventions crucial to the completion of the building of the cathedral in Florence, had succeeded in convincing the Signoria, the government of this city republic, to grant him rights roughly similar to patent rights. And the oligarchic trade republic of Venice had also developed a patent system early on, while still trying to keep secret the methods applied in its glassworks. We might further note that an important early patent item in Italy seems to have been food recipes.

The Venetians tried to keep the secrets – secret. This is not at all the idea of the patent system. *Patere* is a Latin word meaning "lay open". The patent holder has to pay for the patent, which is fair enough since the claims have to be established beyond doubt by some impartial and powerful authority. It is a legal document, required to offer descriptions making it possible to apply and defend: delimitations, clarity, unambiguity. But there is a definite quid-pro-quo in the sense that the patent, once granted, is made public.

It was only in the late last century that an international patent agreement was created. Prior to that, a patent owner might see his patent "stolen", i e, copied by someone else who took out a patent on his patented invention in some other country. This was entirely legal and quite a few people sought to exploit the opportunity for this type of arbitrage. Thus we may see the Bern convention on immaterial rights as an important step in the further development of an international industrial society.

The quid-pro-quo underlined would be of little importance if this information could not be made available. Thus the printing press and the media for dissemination came to play a pivotal role in the industrialization process. As we shall see, pivotal in several respects.

Patents begetting machinery

Quite obviously, the first century of patents is dominated by agricultural inventions. Ploughs play a predominant role. Energy machines are emerging. And now we may give a few examples underscoring the importance of the patent system in furthering innovation and the industrial revolution. We may start precisely with an energy machine, THE energy machine, the steam engine that James Watt developed in the company of Boulton & Watt. (Fernand Braudel sees industry as having an older history, as something emerging very gradually – again, we might speak of scaffolding and autocatalysis even though Braudel does not use such metaphors.)

Watt's was not the first steam engine, it had predecessors like the Newcomen machine that seems to have been so inefficient that had today's profit calculations applied it would never have made sense economically. But under a different economic regime, this "the miner's friend" was regarded as important in that it could pump water out of mines which else would have been impossible to exploit. Watt was given the task of repairing a Newcomen machine, and he ended up designing his own much more efficient contraption, eventually incorporating a number of new principles.

Watt learnt as he advanced, and like with other breakthrough projects, this was badly delayed. Boulton and Watt concluded that they would not be able to have the product on the market before the expiration of Watt's patents on it, so they would never be able to reap the benefits, the profits to pay for all development expenditures. So they took their case to Parliament, asking for an extraordinary prolongation of Watt's basic patent so that they could finish the work and start producing, getting a few years of grace. Otherwise they would have to discontinue their efforts.

Parliament was sympathetic, and the motion was granted. Boulton & Watt got two decades more to exploit their patent. The resulting machine was far from perfect, however. Watt never succeeded in getting it leak proof; that had to wait for another invention – as he himself had built upon his experience with Newcomen's system.

Another but in a way flip side example of the importance of patenting stems from the early days of photography. Daguerreotypes have some features in common with today's photography in the sense that light is employed to record a scene, but the photochemistry involved is entirely different. The layer in a Daguerreotype was metallic and developing and fixating involved cumbersome chemicals such as mercury. The photography was a positive original; no copies could be made from the metal sheet.

The invention had a huge impact and Daguerre managed to negotiate a state pension for life for himself and his colleague Niepce (the nephew of the older Nicephore Niepce, the real inventor, who had not lived to see the realization of his invention) from the French state. Instead, the patent was made available to just everybody, for free. There was still an incentive for professional photographers and for further development in that the process was so cumbersome.

In allowing free access to his patent, Daguerre made an exception for Britain. Here, he intended to exploit the invention directly, charging licensees a license fee. But, fortuitously enough, precisely in Britain, there was a person who had been thoroughly shocked by the news of the Daguerre-Niepce invention. This was Henry Fox Talbot, who had, quite independently, also invented photography.

Fox Talbot's process, though, was not at all akin to Daguerre's; it was, in principle, the same type of negative-positive photochemistry process that we use today. And because there was the licensing costs affixed to using the French method, Fox Talbot had the incentive to develop his own – patented – process, which he also exploited.

We may provide a final example of the importance of the temporary monopoly rights that a patent comprises, and now on a more systemic level. The system at issue is the one concerning development projects launched by various US government agencies and thus paid for by the American tax payer. In the 70's, there was much talk about spin-off effects from such projects, especially the space program. But researchers, performing an analysis, found that there was astonishingly little such spin-off – despite the fact that new technologies, new ideas, new breakthroughs were available for free, there were no takers. And yet, the ideas did not seem anything but very enticing. How come?

Further investigation provided the clue. The crux of the matter turned out to be precisely the fact that the ideas were available for free. The basic underpinning for this policy had been that since they were already paid for by the taxpayer, they should be freely available to the whole American society. But firms and inventors knew all too well that very few ideas are ready to be applied just as they are. They have to be refined, there has to be developed a production process, customers must be enticed to try the new, markets have to be tested and developed. There is a whole set of uncertainties and risks to be resolved before any profits just may emerge. With the monopoly power of a patent, there is sufficiently often enough of an upside to compensate for these risks. With an idea free for all, it would rather be better to just wait for someone else to overcome these various uncertainties and reduce the risks, because then there would be little or no barriers to follow only the successful examples.

The outcome was a slight change in policy. Ideas "in the public domain" would henceforth be patented and exclusive licenses granted, at reasonable conditions. As far as can be evaluated, there was a very marked upturn in the exploitation of such ideas after the implementation of the new policy. No one complained; there was no one who identified as a loser.

No man can make it alone – media are key

From the space program, we return to the time of Newton and before. It was not only patent information that got disseminated, it was scientific knowledge too. So let us backtrack. We claimed that Leonardo was too lonely, he had no social framework to interact with, no sounding board nor any established channels for his scientific endeavors. This would have to wait for another century and a half. The two countries that have figured most prominently in our early history so far, Britain and France, saw the creation of learned societies such as the Royal Society in the seventeenth century, and they were associated with a new type of publication, the scientific journal. Such journals may be said to constitute a true invention: it has ever so often been underscored that printing the Bible was a reason why Luther and Calvin could challenge the Catholic Church, while early concerns about printing actually turn out to have been directed at the new opportunities for disseminating X-rated texts.

The late seventeenth century is often seen as the starting point of an accelerating wave of scientific discovery. Of course it can be traced back to Bacon, Brahe, and others, but Descartes, Fermat, Newton, Huygens, Leibniz, Gauss, and others now laid the foundations for a mathematics that is fundamental to physics and also technology. At the same time, physics itself, with Galileo, Huygens, and of course Newton made great strides. We have already, in a context associated with a change in value structures, mentioned the Enlightenment and its philosophers. Of great importance were the encyclopaedists, with their drive to compile, to organize, to disseminate, and to utilize all human knowledge.

The obvious has been mentioned: that printed documents, printed journals, printed encyclopaedia need printing technology. There existed, however, another problem holding development back. There was simply not enough material to print on, paper supply was not sufficient. The Greeks had learnt the trick when they had started importing papyrus from Egypt around 800 BC. The raw material used for paper production in Medieval days was rags, implying that with the advent of print, there was not enough of worn and torn cloth to make for a sufficient volume of paper production. A French eighteenth century scientist made an observation that laid the foundation for another breakthrough: he realized that wasps made their nests out of wood, out of cellulose, and these nests were nothing else than paper.

There is a continuing discussion as to whether growth, the creation of wealth and a democratic system are interdependent. Rule by law rather than by whim, open and general constraints and conditions rather than corruption and favoritism were some of the factors behind Parliament's creation of a patent law. One way to uphold such a regime is through achieving the consent of those governed, i e, through democratic means, another, though closely linked, would be by open discussion, furthered by investigating journalists and freedom of the media. So the need for more paper was really fuelled by the emergence of popular pamphlets, leaflets, and eventually newspapers.

The printed newspapers as well as billboards and mail order catalogs served to create a real market economy where previously lots of restrictions, including monopolies, trading conditions, customs, and a bewildering maze of taxes had applied. Thus organizational undertakings such as the German toll and customs union, unification of weights and measures, and a realignment of taxation systems were important – as were emerging postal services and the invention of the letter stamp.

Nor should investors be alone

There is one organizational innovation, however, that stands out, and again it is closely linked to the availability of information. Most countries now have a legal and procedural structure governing the conditions for establishing and operating a limited or anonymous company. Again, there was a long slightly tortuous development: trading companies that most often lasted just for one journey, with someone at the home base partnering with the sea captain; the Florentine and Lombard trading houses, based upon families and family connections; the British Muscovy company for trade with Russia in the 16th century was certainly not the first. The term "limited" as in the British version of an incorporated company points to a salient feature: the owners of the corporation, the share-holders, carry a risk, but this is limited to the amount of capital they have put into the undertaking. They may lose it entirely, but they are not legible for any other losses that the corporation may have incurred. This evolved out of an earlier type of company, the partnership for which one of the partners took unlimited responsibility.

In some countries such as France and Spain, the term is S.A. instead of Ltd., S.A. for anonymous society; that is, there can be a number of owners, many or even all just participating with a small share of the entire capitalization of the corporation. This is yet another important feature. It is thus possible to raise a very substantial amount of capital without any one person or organization risking but a limited sum. A number of undertakings might have been all but impossible had not this risk-sharing device been invented.

But this anonymous, conceivably large group of risk-sharing share-holders must be brought together, must be established. Here again, printed media are key.

The investors must be able to judge the merits of the proposed investment, and of management. There must be a reporting system, and prevention of insider trading. Information must be standardized, which means that accounting procedures must follow certain rules and accounting itself be open to outside scrutiny. Owners need their shares to be liquid, so there should preferably be a market for selling and owning shares – some kind of stock exchange. This whole system has been developed into a set of rules for owners and managers describing functions such as the annual meeting; the Board of Directors; and management. Auditing is also a separate process. The responsibilities of the Board and the CEO are differently defined in different countries, however, as are accounting practices and bankruptcy rules or regulations as to whether a company may buy its own stock back or not. However unpleasant bankruptcy may be, a law regulating it is necessary so that owners, creditors, employees, and the government know which rules to play by.

In all of this information is what makes the system function at all. The requirement is that information processing is not too expensive, hampering the whole process and making it too cumbersome. Since time advantages create opportunities for arbitrage, time constraints and rules regarding timing are mandatory.

Invitation to speculation

Sometimes limited, anonymous companies were started to exploit inventions. There are obvious links between the kind of information technology that Gutenberg represents and a number of the organizational structures that seem to have been instrumental in bringing about the industrial revolution. It goes without saying that this was a spontaneous development in the sense that no one foresaw or planned for any industrial revolution. The patent system, scientific societies and journals, science itself, the limited company, printed media, philosophical turnabouts, and a free, critical press developed more or less independently of each other, and their linkages stand out only in retrospect.

This leads to the obvious and rather critical question: what can we expect to foresee and trace of future developments and, especially, where these are interdependent?

The only answer is: we may speculate. We may offer some parallels to this history. We may also search for early signals on new developments, using the past as a template indicating what to look for, qualitatively.

10. Technology, embedded information – emerging how?

Like mankind – or, rather, a European part of it – for a long time was looking back to that lost Golden Age, science was not always footed primarily in observation or what is called rationality. As we have seen, the world was looked upon as prescribed, prescribed by some old sages like Aristotle. Or some would have regarded it as endowed with magic properties combining religion and mathematics, perhaps available through the magic of numbers, the harmony of the spheres, the kabbala.

The emergence of science as we know it

Galilei's idea of empiricism (if his it was) was not sufficiently obvious to take root: in medicine, for example, old books rather than observation held sway and so it took a long time for the blood vessels, the heart pump, and the connections network of the nervous system to be understood – even to be allowed to be understood. Empiricism got combined with rationality, the art of reasoning that would allow observations to be put into context, to be linked together[65].

To understand nature required more and more of sophisticated measurement. There is a classic figure describing the development of surface finish during the last century. The gradual improvement displays two abrupt knees where development suddenly accelerated. These two knees are linked to the introduction of better measuring equipment rather than to that of finishing tools.

[65] Taylor, F Sherwood: A Short History of Science & Scientific Thought. W. W. Norton & Company, NY NY 1963

Like in mathematics, physics and chemistry development is much accelerated by symbols and notations. But before the design of these, there was a need for some stepping-stones even more fundamental for reasoning: concepts. The harmony of the spheres propagated by the Pythagoreans turned out to be ephemeral, the atom of Democritus to be recurrent. Concepts like beauty, truth, and ethics have become mainstays, and they point towards something even more important: rationality in action requires some values, some intentions, some ladder of priorities – indeed, often several ladders, with value conflicts as a possible result.

One of the most important concepts in physics turned out to be energy. How was it possible to discover that on the one hand mechanical energy and on the other thermal energy, and later light and electrical energy, were in reality all one and the same? And how to explain the phenomenon of action, where, e g, light takes the shortest route and, generally, there is a striving for efficiency, and a resulting one single solution to non-quantum equations?

Thermodynamics evolved and, in correspondence with energy, the concept of entropy could to be invented – invented or discovered? yes, invented – and, well, introduced. The two phenomena of electricity and magnetism turned out to be two embodiments of the same force, the same field, and, later on, light was observed to fall into the same category. Today, there is the ongoing effort, so far unsuccessful, to integrate the different forces of nature into one single formula, that famous theory of everything.

Observations, empiricism, mathematics, rationality[66] – but, then, how does new technology come about? This is not another attempt to answer the impossible question of technology push versus demand pull, just an effort to look back into history. Here we see, as Daniel Bell claims, how technology for a long time was invented haphazardly and in an experimental way, Galilei's empirical way.

[66] van Doren, Charles: A History of Knowledge. Birch Lane Press, NY NY 1991

No link between science and technology

For the oldest inventions, we don't know any names of inventors. That might be because wheels and fire and hammers were more like discoveries, based upon nature, happening in several instances, cultures, and locations and perhaps roughly simultaneously and purely by chance. Levers, measuring, mathematics, and especially geometry are associated with the Egyptians and, probably even more, with the Greeks, like Pythagoras and Archimedes. Experience and experiment dominated, but mathematics played a role, especially, as we have seen, with Pythagoras and his school. The Romans provided construction technology, fish breeding, heating of buildings, and much more to a substantial extent through the transfer of know-how across the Empire. There was no science underlying, most of it was, as Bell claimed, trial and error, including Medieval cathedrals, sometimes crumbling – though mathematics might always be relied upon to serve a purpose.

Forgoing various earlier attempts, by the Venetians, Brunelleschi and others, to establish a patent system of some sort, we arrive at the 18th century. Early on, Leibniz and Newton laid the foundations for mathematical analysis, for integral and differential calculus. Later Diderot and the encyclopaedists strove to establish a catalog of human knowledge, of different solutions to problems, of established technologies. About the same time, James Watt attempted to harness steam power in a more efficient way than had Newcomen with his steam engine. More and more, scientists came to depend upon the knowledge exchange made possible through that ingenious invention, the scientific journal. For the practical inventor, patents had the double function of protecting and laying open (as the word initially stands for), of telling what the patented designs really were.

Apart from the protection of an innovation, a temporary monopoly giving impetus to development, and the fact that competition among nations and individuals and, eventually, organizations might further development, what were the driving forces behind? The alchemists where hunting for deeper knowledge, for something much more profound than the transmutation of materials – esoteric knowledge, a transcendent understanding, the truth about what is behind the existence of earth, nature, human beings, ethics. Almost by accident they created some important tools for chemistry, the destillation of alcohol, etc. Thus an endeavor that we – and isn't that a social construction? – would classify as irrational begot results that were to further empirical science, especially chemistry. That which we name irrational came to serve rationality.

Newton spanned the old and the new, with his calculus, his observations, and his many treatises on alchemy. Gradually, the "invisible college" of scientists providing "peer review" was to develop, step by step norms for "good science" were to establish themselves. In historical works on great breakthroughs we do not read too often about inspirations and ideas that we today would judge irrational and unscientific, but those have been filtered away only with the advantage of the rear-view mirror; the future will certainly pass such judgements on us, too.

Many of the early scientists – scientists in our view – were, like artists, dependent upon princely protection and support. Magic and worship, utility, first in agriculture, then in military endeavors, then in construction works, but also play, showmanship if we like, and purely intellectual stimulus were some of the driving forces behind a prince's interest in a mathematician, who might also – broadly educated as he were – serve as a tutor to the next generation of the prince's family. In that sense, there was little to distinguish that mathematician from the court musician. Watt, however, was driven by the profit motive, while Robert Fulton first obtained Napoleon's, then Britain's support because of the perceived military applications of his schemes to develop a steam boat, and also a submarine; trials were performed on, or under the surface of, the river Seine.

Thus military concerns constituted a prime force behind "high technology" development is nothing new. By contrast, magic and the idea of getting to the bottom of esoteric knowledge would seem to have lost its impetus – though not if we broaden the view to take into account basic science in, e g, physics, which certainly is far from the mystical incantations of the past but still striving for the establishment of the final laws of nature, possibly one single law integrating all different laws of physics into just one grand scheme, connecting all those still separate, seemingly incompatible strands. Another part of magic was the enchanting tricks of the magician, foreshadowing the current experience industry if we like. As for economic motives, they might be found everywhere, also at the bottom of military or experiential endeavors.

As Bell[67] suggests, it was not until the late 1800s that technology development slowly started to rely upon theory as well as practical experiments, trial and error in the workshop or the laboratory. There, Niepce and Daguerre – the latter originally a show man and an artist, like Fulton – learnt how to make a photograph the hard way, much like Fox Talbot, not through calculations and chemical formula. Chemical formula were rather established on the basis of prior experience of a practical nature.

The industrial revolution has sometimes been described as

[67] Bell, Daniel: The Coming of Post-Industrial Society. Heinemann, London 1974

linked to the innovation of inventing. People like John Ericsson, inventor of, among many other things, the ship propeller, the Monitor ship, and an efficient heat engine, and Thomas Alva Edison incarnate this era. They also saw the birth of the new epoch with inventions becoming more dependent upon scientific results – first in the chemical industry. Alfred Nobel is an early exponent of this trend, establishing as he did a scientific laboratory from which emerged several pioneering inventions in the field of explosives.

There are still a great many practical inventions made, based upon empirical observations. There are still even occasions of practice confounding theories, causing brand new theories to be formulated or older ones to be corrected. As indicated by Nobel's example, the fact that theoretical concerns have moved to center stage has meant the institutionalization of research and development, in government and, more importantly, in business corporations. Very substantial private and public investments into innovation, and the realization that research and development were major forces to growth and prosperity, caused a surge of research on creativity as well as on innovation.

Given this historical background, we may now spot a number of important changes, not all of them limited just to information technology development. What will follow here is, as will be clear presently, heavily tainted with speculation.

Copyright protection has been extended to cover software, whereas patent protection applies to biotechnology. Copyrights are much stronger than patents in that they last longer, but there are also difficulties in interpreting what would merit a copyright. Biotechnology is linked to IT in the sense that the DNA code may be seen as a computer program, and also since information technology is just indispensable in mapping the genetic code.

For the future, there are bold suggestions for biologically based computers, DNA computers, a concept that has been successfully demonstrated. Only fantasy may cope with the opportunities existing for long term combinations between these to "high technologies". Life certainly evolves at a time scale completely different from that of current IT so we may be in the beginning of a long term change to a, comparatively speaking, more turgid development, holding great importance nonetheless. Another possibility might be friction and conflict caused by the differences in the time scales involved.

There is a certain irony in that computer games, a sub category of the experience industry, seems to have overtaken the military industry as the driving force for leading edge information technology: the fastest, the most powerful chips. Since the conditions for military procurement projects are decidedly different from those of the toy or games or amusement park businesses, since time scales are different, we just might expect a number of distinctly new practices to develop.

A change in the invisible college

Scientific papers are proliferating, and scientific laboratories are running out of funds to subscribe to all the new (and old) scientific journals catering to ever new sub-fields of scientific endeavor. The peer review process guarantees good reliability, relevance, and quality in general, but it takes time. It takes time and causes delays in a world more and more obsessed with gaining time.

The reference journal was developed in the field of chemistry in 19th century. It evolved quite naturally into data bases and data services – third tier services, with peer review articles constituting the first tier, and the printed abstract the second. With the advent of the Internet, originally intended precisely for the collaboration between scientists, it was quite natural to do two things: to work on joint papers over the Net, and to "publish" on it. There are various problems associated with both these suggestions. What about false rumors, "publications" introduced only too early to gain priority, or just plain sloppiness and bad quality? What about responsibility, for results, publications, proper credit, effects of premature publication? What about the effects of short-circuiting the peer review quality insurance process? A number of remedies have been suggested but no one has emerged as the standard procedure so far. Whatever the resolution, or lack of it, of such concerns, the speeding up and the subsequent generation of more "noise", but perhaps also a diminishing of duplicative research as a potential upside, are bound to change future research and development profoundly.

Virtue and vice of abstractions

We saw the development from empirical practice to theory and formula as the primary basis for much technology. In a sense, we may now witnesses further development in that direction, or in a particular way the return to practice, but then in an entirely abstract setting. Previously, practice gave birth to theory – now reality is generated form theory.

This, then, is a virtual reality, something that has already been happening for quite some time with, e g, computer aided design relying upon simulation, a design process that might well comprehend the design of chemicals, pharmaceuticals for example. It is possible to tell the computer what data and various laws govern a particular part of reality. With differential equations, friction and other non-linearities may be brought into the picture. Solutions may be conditional or fractal or provide branching out, but they reflect reality as much as our real world, as long as the laws and data mirror the latter (or do they? may there be exceptions?).

Problems may arise when we try to graphically describe those phenomena that defy every day experience but lend themselves perfectly to mathematical formula, such as various aspects of the quantum world. That, then, is one of the challenges facing those designing the interface, the actual presentation, the interpretation.

With the advent of the pocket calculator, people could relax the need for their own on "manual" calculating abilities. Many are those who have been somewhat annoyed by clerks now using a computer, that perfect tool, to calculate something like 3+5. The possibly serious problem is that they seem to have lost their ability to judge whether the result is credible or not; if they get it a bit wrong, like with 3+.5 that makes 3.5 instead of 8, they may not react to the ridiculous result. Still, what power of ten should apply does matter, obviously!

In a classical elementary physics experiment, pupils are dropping a bag of small lead balls from a known height, and, after several drops, measuring the temperature increase in the bag. This is to establish what was such a revelation initially, that there is an equivalence between mechanical work and heat. Likewise, they perform practical experiments with light rays and lenses, and with electrical resistors and electrical current, and so on. In this way, practical experience is involved in establishing an understanding of various well know physical laws, the classical way also to physical intuition.

It is certainly feasible to drop a bag lead balls in the computer, the very same laws that were governing reality now hidden in the background of the computer program, for the pupil to discover, "experientially". Likewise with optics and electricity. The question is now whether there may be the same loss of direct contact with tangible physical nature as the loss of basic mathematical “intuition” caused by the pocket calculator. There are reports on city children being amazed to see that a cow is “that big”, their perceptions formed by TV programs and the only animals normally encountered, like cats and dogs.

To some extent, we see the dissolution of the comprehensive laboratory as a physical entity. Despite the potential for simulation and virtual reality, people may still need access to physical means, but collaboration may far transcend the walls of the buildings close by. Given the breakthrough effects of such limited means to collaboration as, e g, scientific journals, one can only speculate about the eventual results of this “globalization of the laboratory”. As has been demonstrated with some types of “groupware”, there is also the possibility of enhancing group creativity with the assistance of clever software – and in some instances, results represent quantum leaps in problem-solving achievements.

It is perfect but can’t be proven

There is a particular and very promising way of operating a computer that at the same time calls into question the absolute reliability of a computer program. Instead of programming rules, e g, describing natural laws, directly into the computer, it might be submitted to a learning process akin to that of human beings. The computer, probably with a neural network design, would learn from experience, having the laws of nature inferred from a large number of learning experiences: when there is an input, the computer suggests an output, and then learns and corrects itself through comparing its suggestion with the actual case. As its experience grows, the computer also grows in competence.

This is a method now harnessed to solve problems that would otherwise be just intractable. The one problem is that the computers or the programs cannot tell why they arrived at a particular solution nor can we know for sure that this is the best solution existing – though we may be unable to come up with something better, which in a practical case may be good enough. So, if we teach by relying upon this type of experiential “program”, we can only tell what is inferred by the knowledge so far collected – by the machine – but not whether it holds in the practical case, nor what the precise formula is. And then the question: the computer would calculate everything as correctly as its experience would allow but could it also explicitly state Ohm's and Maxwell's laws?

Ordinary software is formed by a number of instructions, at the core depending upon some logical procedure. How does the programmer think, how do we ascertain that the logic is correct, and that the rendering of that logic into code is perfect and free from bugs? One attempt to produce bug-free software relies upon a particular type of formal logic.

Since much research, development, and innovation now imply software development, we need to know how such development takes place, may be planned and managed. If the fundamental basis for software is human logic, it is not necessarily a very advanced such logic but often enough a series of tedious descriptions of various routines. There is no practical reality to test the result on, as when a car or as hi-fi tuner is developed, though certainly the software is being tested. If a machine breaks down, we may observe that a ball bearing is overheated. No such directly observable link exists between the nature or location of a bug, and its effect.

More importantly, though, we lack the kind of knowledge body that exists for hardware development, established methods for planning and execution. One example is the mythical man-month syndrome[68]: if we are lagging twenty man-months behind schedule, then let us get another four people to make up for it in five months. But first they have to undergo training to be introduced to the project; there is now a larger group of people to keep informed and collaborate within; so after those five months, we are twenty-five man-months lagging.

Another example is the obvious lopsided relationship between development and production costs. This may be the case for an ingenuous pharmaceutical preparation too, but it still requires some kind of drug that has to be distributed and administered, possible prescribed. For software, however, not only is the diskette an insignificant cost, it might be (and is) scrapped entirely in favor of distribution on a network, or it might be inserted into a number of computers, and so the results of a huge investment in development might be available for free.

Yet another example is the fact that programmers differ in productivity, not just by a factor of two, but really by orders of magnitude. Certainly some people are much more creative than others, but when it comes to the laborious tasks of etching master boards

[68] Brooks, Frederick P, Jr: The Mythical Man-Month. Addison-Wesley, Reading MA 1982

or titration solutions in the chemistry lab, there are no such enormous discrepancies.

The point here is simply that software implies a very different development paradigm from the well established paradigm of hardware development. Patterns from this latter field will work with difficulty in the former or perhaps not at all. It will require the development of a new thought style and new methods for planning and calculating.

Also within the large family of "software" there are huge differences. Some software is dedicated to tasks in the background visavi the end user, who might experience them only when they cause a machine to work slowly or when they cause conflicts. Others, however, are dependent on displaying an attractive and efficient user interface. Here creativity and development efforts would focus less upon the logic behind and the production of the particular software code, more upon interaction design. So concern would be with understanding, planning, and managing a design process, perhaps also an artistic endeavor of sorts. It is easy to see that hardware, software, interface, and application experience at times may become interdependent and amalgamated.

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Afterword

This book is the result of work starting in 1995 so I have every reason to show my gratitude to Bertil Thorngren and Telia's Telekon for their patience. I also owe a lot to the early input from the Teldok editorial Board, apart from Bertil Thorngren and PG Holmlöv, Göran Axelsson and Agneta Qwerin also offered valuable suggestions that I have tried to act upon. The Teldok Editorial Board is actually responsible for me writing the report in English since they wanted it published in that language.

Bertil Thorngren's rationale for supporting my study was that it would serve as background material for future research efforts, presumably supported by Telekon and KFB, the Board for communications research. Thus it might seem somewhat ironic that these two bodies soon will be extinct – but it's not all that ironic, since successors will be in place, and the whole field of study and research of paramount interest.

The basic idea of the report is to try to discern fundamental patterns in human information handling. Some of these are cognitive and perceptual, some are social and organizational, some have turned out to be physical. To use a quote from the Swedish 19th century historian and poet Geijer, the challenge is 'to discern that which happens in what seems to happen' and to discover what we do with regard to information without knowing that we do it because it all comes so naturally. Consequently, if that which is so natural so as to regarded as something given and unchangeable actually were to change, that would be most important.

The thrust has never been to duplicate defining works on what information and knowledge are (such as those classics by, e g, Machlup) or how they are changing, and changing economy and society (such as, e g, Castell's seminal work), in the short term. But is is hoped that here the reader and the researcher will find lots of threads, trends, and mechanisms to further explore in the setting of whichever is the newest economy or the new new thing.

The book has been written so that the chapters can be read separately (a few of them have, in fact, been published in scientific journals during the term of the project). The flip side is that there certain important developments are described repeatedly. I have discussed with myself whether the degree of repetition might indicate importance but settled on the suggestion that it's rather the issue of perceived importance; and sometimes it might be that one observer's judgement as to level of importance has become dominant, other efforts being relegated to the doldrums. That's another story than that which is mine here to tell, however. As long as the breakthroughs are the right ones, whether Brunelleschi developed artistic perspective or rather some other Florentine is of no consequence.

Bengt-Arne Vedin
May 2000

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Dr Bengt-Arne Vedin (vedin@stockholm.mail.telia.com)

The treatise discerns fundamental patterns in human information handling – some cognitive and perceptual, some social and organizational, others physical; because, if these patterns actually were to change, this would be most important.

TELDOK Report 135E

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Ed by Dr Bengt-Arne Vedin (vedin@stockholm.mail.telia.com)

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Mr Weje Sandén (weje.sanden@va.se)

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Ms Maja-Brita Mossberg (maja-brita.mossberg@alfa.telenordia.se)

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Via TELDOK 34E

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Dr Åke Sandberg (Ake.Sandberg@niwl.se)
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IT växer (även) i skogen (IT [also] grows in the wood]
Mr Arvid Höglund (arvid@tivore.se)
Information technology has long been used in Swedish forestry. The report primarily deals with how IT is put to use, now and in the imminent future, to help controlling and coordinating the flow of logs from woods to plants.

Via TELDOK 39

Egendeklaration av programvaror (Evaluation and certification of software)
Mr Bertil Håkansson (bertil.hakansson@infocomab.se)
As long as programmers cannot adapt their software to real-life users, corporations stand a lose billions in time lost and fees for consultants. The report documents a unique Swedish method for software evaluation – Spi2000 – and the experiences of some early users.

TELDOK Report 134

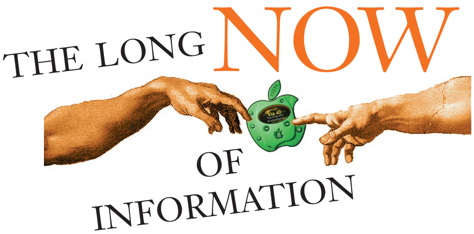
Privatliv & Internet – som olja och vatten? (Private life and the Internet – like oil and water?)
Mr Anders R Olsson (anders.r.olsson@swipnet.se)
Deals with problems related to privacy protection in today's "IT society", delineates the risks, and discusses possible ways to protect one's privacy with legal, technological, and practical means.

TELDOK Report 133

Interaktiv underhållning inför framtiden (Interactive entertainment for the future)
Mr Erik Fjellman (ericfjellman@yahoo.com) & Mr Jan Sjögren (jansjogren@yahoo.com)
The report describes and explains how computer games and computer gaming work, and looks at how interactive entertainment/edutainment is likely to impact us in the near future. Genres and types of games, usage and users, technology and business are dealt with, as well as the ongoing debate on violent computer games and their effects.

TELDOK Report 132

Den digitala fabriken – Verkstadsföretaget som IT-företag (The digital factory)
Ms Christina Johannesson & Mr Peter Kempinksky (info@fba.se)
Based on extensive interviews with four engineering and machinery manufacturers and their partner companies, the case studies of this report show ample proof of innovative and insightful IT use, serving to fuel growth and collaboration.



What are the most fundamental patterns in human information handling? And how do we know when these really are changing?

The basic idea of Via TELDOK 40: ***The Long Now of Information*** is to discern fundamental patterns in human information handling – some cognitive and perceptual, some social and organizational, others physical. Consequently, if these fundamental patterns actually were to change, this would be most important.

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