Peter Kafka

Six Essays

on the Principle of Creation

and the Global Acceleration Crisis

(1976 – 1994)

The author usually publishes in German. (Last book: *Gegen den Untergang – Schöpfungsprinzip und globale Beschleunigungskrise*, Carl-Hanser-Verlag, München 1994.) Only occasionally some essays have been written in English.

The considerable redundancy in this compilation of original versions might be attributed to the wish of being understood in spite of the clumsiness of expression in a foreign language. However, the author must confess that he speaks with equal redundancy in his own language – like all preachers do in their sermons if they believe in their own ideas but know that they are far from being generally accepted …

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The ideas of this essay developed since 1968 in occasional talks about cosmology and evolution to various audiences. It was written in early 1976 at the request of the editors of "The Encyclopedia of Ignorance", a book which collected articles about open questions and speculative ideas in various branches of science. I was supposed to write about the future of the physical universe. Since I didn't stick to my theme, the editors wanted to publish only the first two thirds of the manuscript. So, I withdrew it. Copies were, however, widely spread among parts of the astrophysical community and the general public – particularly among people interested in the question of extraterrestrial life. Later, it was printed in *Munich Social Science Review* 1978/2, 91-99.

When Freeman Dyson spent a year (1977/78) as a guest of the Max-Planck-Institute for Physics and Astrophysics in Munich, we had many lunch-discussions on similar topics. He then dug deeply into relevant fundamental problems of physics, biology and information theory and published an excellent comprehensive review of his findings: F. J. Dyson, *Time without end: Physics and biology in an open universe*. Reviews of Modern Physics, Vol. 51, No 3, July 1979, 447-460.

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On the World's Ends

Looking forward to billions of years makes us long for a path of knowledge. Unfortunately, science is the path of ignorance. It is the art of asking simple questions. So simple that they can be answered, and that nature repeats the same answers whenever we ask. Most scientists adhere to the superstition that, eventually, all questions can be reduced to such simple ones.

The world around us started investigating itself less than a million years ago. Apart from problems with daily bread and daily violence, the questions asked have been the same through the ages: Whence do we come? Where do we go? And why?

Science has just reached the level of the first aspect of this trinity of questions: The world's origin.

As long as the social environment did not change significantly during the life of one generation, the ideas of a static God and a stationary world were natural. Hence, when physical science appeared, its task was considered to be the search for unchangeable laws. Like all good conservatives, many physicists clung to the eternal unchangeability not only of laws, but also of the state of the world. Even Einstein initially thought, and always felt, in favour of a static universe. If taken consequently, this concept implies thermodynamic equilibrium. Man would have to be a statistical fluctuation.

Today we know that our world – that is all we can see or experience – is not in equilibrium, but has been evolving from extreme simplicity to greater and greater complexity. It seems that there was the birth of man, the birth of life, of the stars, of matter, of space and time. Scientists of all disciplines are revealing the drives behind this procreative power of the universe. Cosmologists are already asking questions about its very beginning. For

instance, one can inquire whether basic physical laws allow a derivation of the present state of the universe from an initial state of maximal simplicity – maximal in some sense of extreme order or disorder. We may instead find that our initial conditions are *not* distinguished in such a way but are rather accidental. Then we may go in for statistics about worlds with various initial conditions, embedded (physically or mathematically) in some meta-world which lies beyond our direct perceptivity. Conservatives may even please their minds' longing for steadiness by considering the meta-world to be in equilibrium, thus making our own world a fluctuation phenomenon. But however unlikely it may appear from such a point of view, *within* our world evolution to more and more complexity must have been inevitable.

It seems possible now, and even likely, that science will answer the question of whence we come: Out of simple symmetry, or chaos, or nothingness. All we need may be some mathematical building instructions (the basic physical laws, still largely hidden), and an initial state of sufficient impetus to cause the expansion in space and time, thus preventing equilibrium. It may not be fully proven yet, but assumed as a reasonable working hypothesis, that these two provisions entail, for purely statistical reasons, the formation of increasingly complicated structures and, hence, the whole subsequent evolution.

Let us quickly go through history. Make the age of the world 12 billion years (it may in fact be a bit older) and squeeze those into 12 months. Let it be New Year's Eve today.

Remember: On last New Year's Eve the whole world which we see now was extremely near us, perhaps in one point with us, totally structureless, at least orderless, but endowed with the impetus to expand against gravity and with the rules of how to build structures. In a minute fraction of the first second of the first of January, elementary particles are created in this primeval medium. Matter appears in the form of Hydrogen and Helium. It becomes dominant after a while (on January first or second), for expansion thins radiation faster than matter. When the radiation is cool enough to decouple from Hydrogen, matter can follow its tendency to escape from the expansion and form lumps. But instead of fully submitting to gravity and collapsing into Black Holes, it has to assemble in very long-lived structures, with gravity balanced by rotation or various kinds of pressure.

Before the end of January the galaxies and the first generations of stars have formed. From now on stars brew the heavier chemical elements. Dying stars enrich the interstellar gas with such material. Laws of nuclear physics let Carbon become especially abundant, laws of atomic and molecular physics enforce the formation of organic molecules on the surfaces of dust grains in the gas surrounding stars. (During the past few years, radio astronomers have detected more and more complicated organic molecules in such conditions.)

By the middle of August, our sun and its planetary system are formed in a contracting cloud of gas and dust. It takes less than a day for the sun to achieve approximately its present properties and supply its planets with a more or less steady stream of high-temperature radiation. The formation of an atmosphere and oceans on the earth leads to an ideal environment for the kind of chemical evolution which radio astronomers find in irradiated circumstellar clouds. The earth's atmosphere does not yet contain free Oxygen, and thus ultraviolet light can reach its surface. Laws of statistics favour the formation of complexity in a system receiving high-temperature radiation and re-radiating the energy at low temperature.

Is it only due to my ignorance that I wonder whether auto-catalysis is already effective even at this level of pre-biological evolution? Does the rate of formation of some molecule in a mixture containing its constituents, and given luminous or chemical energy, grow with the concentration of this molecule? It may be a matter of taste to decide when to call the earth's surface alive. The main condition for the genesis of life seems to be that it doesn't exist yet: it would consume the primeval soup of organic molecules.

By the middle of September the oldest rocks on the earth's present surface have formed. From the beginning of October we have the first news about organisms: fossils of algae. The first vertebrate fossils date from December 16. On December 19 plants conquer the continents, and the fish form jaw-bones. On the 20th of December the land is covered with woods, and the atmosphere becomes rich in Oxygen. (Strong ultraviolet light is no longer desirable. More complexity is allowed with softer radiation!) On the 22nd and 23rd, when our coal-beds are formed, amphibious quadrupeds originate from lung-fish and conquer the damp lands. From these, reptiles are born and settle on dry land on December 24th. Warm blood is invented

on the 25th. Late in the evening there are the first mammals, living a paltry existence beside the dinosaurs during the next two days. In recesses, hidden from the mighty, intelligence prepares. On the 27th birds form out of reptiles. On the 28th and 29th mammals and birds take over the power from the dragons. During the night before the 30th, the (still continuing) formation of the Alps and other young mountain ranges begins.

Up to now, essentially all biological information is fixed in molecules of nucleic acid. On the 30th of December, storage in large protein structures – the brains – begins to supplement this genetic fixation: Learning becomes important. Soul and mind start evolving. In the night before December 31st the human twig shoots off the branch which led to the present primates. Now, we have one day left to develop ourselves. With about twenty generations per second this seems easy. But documentation is poor. Only from about ten in the evening we have the relics of Olduvai gorge. Five minutes before midnight the Neanderthal people thrive, with brains about as big as ours. Two minutes before twelve, we sit around the fire, shouting and whining and rhythmically clapping our hands, paint deer and bison on the wall of our caves, start asking our three questions, and put weapons or honey and grain into our fathers' tombs. History has been handed down for fifteen seconds in China and Egypt. Five seconds before twelve, Jesus Christ is born. One second before twelve, the Christians start the extermination of the American civilizations. How many living species do we now exterminate every day? – Gong! – Here we are in the new year. What will it bring?

In cosmology, there is one question about the future which can be answered by extrapolation from the past: Will the universe expand forever, or will it re-contract? The answer is simple: "In my beginning is my end". Like a missile that is shot from the earth's surface into space, it will go off to infinity or fall back, depending on its initial velocity. So, if the initial impetus was sufficient, universal expansion could never be stopped but only slowed down by gravity. If it was insufficient, however, gravity would win and reverse expansion into contraction some time in the far future. Our entire visible world would then return to an extremely dense state, perhaps to one singular point. Then, "time must have a stop".

Present theories say that a world which is finite in time, also has a limited space, whereas the ever-expanding world has infinite space. To decide which kind of world we live in, we need to make more observations; but if the law of gravity is that of Newton and Einstein, and if there is not much more invisible than visible matter around us, observations favour the ever-expanding model. However, should the world eventually re-contract, it would first continue to expand for at least as long as it did so far, and the subsequent contraction phase would last exactly as long as the expansion. Can it be a reasonable question what our far future would be in either of these models of the universe?

Looking forward to billions of years, we may find our curiosity withered. It does not seem possible to find our ends in our origin. The origin was too simple. What matters, is the front of evolution, here and now.

In our neighbourhood, the time-scale of evolution has become shorter and shorter: Billions of years were needed for physical, chemical and biological selection, until that beautiful organism, the system of life, covered our planet. But a few million years were enough to create man, the latest organ or blossom of that organism. And man realizes that he is not just another animal: Post-biological evolution has set in with him. In addition to genetically fixed behaviour, traditions are built up and inherited through education. Biological mutation and selection lose their governing influence. Revolutionary thinking and inventive planning are the mutative forces which change tradition. With its new organ, life changes its environment much faster and more radically than before. Technology incorporates more and more matter into the process of life. New and extremely complicated structures develop, such as libraries, or the art of the fugue. Such structures are not in themselves reproductive, but self-reproduction and, hence, personal death have gained a new quality: Whereas the essence of a plant or an insect lies in its genes, and is reproducible, the essence of man is not. In spite of communication, a great man, or a loved one, seems to take much more with him than he leaves. Even with libraries and other means of tradition, human death appears as an irretrievable loss. We would like so much to have another world for our souls.

Can we renounce that wish, and learn to love ourselves and each other as mortal parts of something unknown beyond us, evolving from us? Can't we die in peace, even if we have no biological offspring, and if we can

scarcely discover traces of our own soul and mind in the world? Our traces *must* be there and must help shape the world, contributing a tiny bit to the evolution of God, even after we have disappeared as physical and biological entities. The laws of physics and biology are no longer dominating the fight at the front of evolution. This front has moved from the level of physics through chemistry and biology to technology and noology. Further we can't see. But is there any reason to think that we are the end?

Yes there is.

Like at the last turn of a millennium, but now with far more justification, we may fear that the world's end is near. We talked about noology and hushed up the fact that *technology* has rudely pushed aside soul and mind. Within a few generations, science and technology have become rampant like a malignant tumor. Evolution rages towards a singular point in the history of the earth, a crisis which has never before occurred: Its time-scale is becoming as short as the life-span of the individuals at its front. But for our genetically and traditionally fixed abilities of adaptation, acquired in the course of several hundred thousand generations, will be inadequate or even fatal if we change our world significantly during our life-time.

It is not at all clear whether such a critical point can be overcome. As our line of life approaches it, complicated feed-back mechanisms seem to force it nearer and nearer, more and more rapidly. With an approximately exponential expansion of population and technology, every finite space will be exhausted very soon. On the other hand, as we hit the walls (or rather our neighbours), socio-economic pressure grows and accelerates technological development even further. Therefore, the psychological and sociological strain connected with the precipitation in time, must coincide with the strains due to lack of space and resources.

Do we have time to find economic, social and spiritual frames in which mankind can survive? And are we even searching in the right direction?

We certainly cannot learn from the past, for evolution was then subcritical. Extrapolation across a singular point is impossible. Therefore, blind trust in a laissez-faire ideology would be foolish. The once useful principles of evolution, our instincts and traditions, together with a degenerating technology, can now lead us only into turmoil and chaos, where we will

dissipate all recent achievements of evolution, perhaps destroy terrestrial life itself, and leave scorched earth.

Clearly, something new must happen. Evolution must circumvent the critical point by opening another path, bringing in some new laws of interaction. A new level must be climbed. But it is no longer "nature" that is responsible for evolution. It is us. *We* are the front of evolution. *We* have to do it. And what are we doing?

Looking at the activities of mankind, the physicist Max Born said at the end of his life: "Nature's attempt to produce a thinking creature has failed". In the years since, we haven't improved much. There may be some progress in behaviour, but it is usually followed by a quick set-back, and such progress is definitely much slower than in technology. As was always our usage, everybody wants to be at the top and wants to see others at the bottom. It is progress that this division is no longer inheritable. So, it has to be created anew for each generation, and this produces more strain than the old inequality. Children are bent and crippled in school to make a good bottom. Talents and qualifications are mainly used to gain privileges. The idea that they should only bring more responsibilities is not seriously considered in our part of the world.

Another example of progress: Slavery. Formerly all people were needed because there could never be too many slaves. Then, slaves were replaced by machines because these could still be owned as private property. For a while this will work quite well: Production of nonsense and waste feeds more and more people who are needed to ask for the nonsense and remove the waste. But suddenly some resources are exhausted or choked up by waste, or people can't consume all the absurdities, or the owners may simply have enough – and people find themselves unemployed. Students leave school or university and find that they are not needed, while at the same time most true tasks remain untouched.

One way out is war, isn't it? People are needed in wars, and after wars. In fact, within the rich part of the world, war without killing would be sufficient. Only the destruction of *things* is needed to create new jobs. Killing could be replaced by sex and football.

Still more hopeless, of course, is the situation in the so-called under-developed countries, where we first robbed the people of their hats and then left them alone in the sun.

But what's new with all this grousing of bad-tempered old men? Indeed, nothing new, except the nearness of the singular point.

Our planet is full, and technological growth changes it faster than man and the biosphere can adapt. If we compare the recent man-built structures with the biological and cultural wealth they replace, it seems (even if we were to forget about war) that our main activity is destruction. Within the present tenth of a second in our compressed history we are scattering to the winds all of the oil which the sun has helped us to compose during the last ten days, and we are blighting our source and our children with radio-active and chemical waste. In a Darwinian sense, technological civilization seems to have been superior. It has won. But what happens after the best has won and has closed the system? Does evolution simply come to an end if diversity has been destroyed and cannot be re-created by expansion?

Is this the hour of the conservative utopian? Can we reduce the speed of evolution by suppression? Is this, at last, the opportunity to establish the static, perfectly organized state? No! Confinement goes with rigidity. An ordered death is no better than the chaotic one which we hope to avoid. And, anyhow, a static solution would certainly be unstable and would quickly be driven towards the critical point again.

So, what we have to find seems to be a self-organization of mankind that provides for a steady non-catastrophic evolution under the conditions of restricted population and consumption. A main prerequisite will be that expansion takes place on a new level with far more diversity than economic, technological and military competition can offer. Then, the speed of evolution may become sub-critical without repression. Let us assume we succeed. Then, what will follow?

Within my limited view from the path of ignorance, two tracks show dimly far beyond the blurring abyss of the impending crisis. One leads inwards, one outwards: The development of our mental abilities, and the conquering of habitable planets.

There are hints that our present consciousness is but a poor prelude of things to come. Not only great artists or intellectuals make me feel that way,

but also the intriguing evidence of extrasensory perception, telepathic communication between minds, or even the direct influence of mind on matter. Especially in those cases where only *one* mind is involved one can perhaps ask questions simple enough to expect nature to answer in a simple way. But so far this has not been done in a convincing manner. We are still totally ignorant.

One may ask how much space and energy, and how many individuals would be needed for further mental evolution. It seems that the earth with its share of solar energy and the present population should by far be sufficient. This might represent an almost infinite spiritual space, and enough land to live on as gardeners of the world. We could easily fulfill all our needs by harvesting solar energy with some kind of biological engineering. Then, why don't we jump over to that path right now? The problem is that man is still more of a hunter than a gardener. And he loves huge dangerous machines which make him proud of his power over his progenitor, nature. The dinosaurs with their towers of protein had to vanish, and we are proud of our infinitely simpler concrete towers. Who is proud of his cancer because of its growth? Science and technology have brought us to the critical point too early. We may see the other much more attractive path of evolution very near, but it seems that we can't reach it. We don't strive to be; we strive to have. We want economic, not spiritual growth.

Then, why not try space travel, where the luxuriant growth of science and technology must be useful? Many could be employed, and all could suffer at least as hard as in war, if we were to prepare for the colonization of our galaxy. Adam was not bored, and our galaxy with its hundred billion stars would offer space to keep Adam's task for another million years – that is for about the first hour of the new year in our compressed history. Be fruitful, and multiply, and replenish the world, and subdue it. Space ships like Noah's ark would have to travel for perhaps a few centuries to find a habitable planet. Within another thousand years or so, a new home could be sufficiently populated to start one or a few similar expeditions from there. In this way, mankind could trickle throughout our galaxy and populate all favourable stars within less time than it took to develop man from apes.

This provokes wild speculations: Are we the only living society in our galaxy? If not, why did others not come here? Or did they, and leave us uninfluenced, because they have more reverence for life than we have? Or

did they interfere very cautiously? If nobody ever came here, does that show that intelligent life is always a very short-lived phenomenon? That perhaps it can nowhere evolve beyond our type of critical point? Or does intra-galactic communication set in before space travel, and one realizes that the bodies don't have to expand further in space, because the spread of information is more appropriate for the development of a new super-structure: galactic culture?

Clearly, both space travel and interstellar communication take too long to help us out of our present crisis. This path may be reachable from some safe plateau later on. Now, it is the impending, not the distant future which we have to shape. The abyss has to be crossed first. Therefore, our prospects are gloomy. Even where we seem to have a free vote we will continue to bungle from election to election. choosing mostly ambitious and irresponsible leaders who have to think in terms of four years, and the few people who dare ask radical questions will be ridiculed or pushed out of their jobs or into jail. Not only in totalitarian societies do we admire central power more than diversity. We even establish new bureaucracies in order to organize our march into the singular point more efficiently. And if we cry for jobs we mean productivity, not creativity. We don't want further evolution. We want the nice old economic growth. We are preparing for collective suicide.

If we fail, it will start again or be tried elsewhere. If we have been alone in our galaxy, it happens in others. We can't see that far, and it isn't our task. Still, it would be encouraging, or comforting, to find from cosmological observations that our universe is of the open type, offering infinite space and time. Then, physical laws would allow for an unbounded evolution. And since this type of world would never reach an equilibrium, the drive behind evolution – the drive towards more complexity – would last for ever. As the stars burn out, and one day no new ones are born any longer, as matter and radiation are thinned out more and more, it would certainly become increasingly difficult to live. But it wouldn't be us who would have to do so. Not even science fiction reaches that far. We cannot envisage the essence of structures which will be at the front of evolution after us. We don't know ourselves yet. How could we be so arrogant as to ask for the world's end? The world is open and undetermined. It has to be shaped by man. "Werelt" means "man's age". *We* have to find a way.

A clear mind of our century (my namesake) said: “There is a goal but no way; what we call way is hesitation”. Yes, with all despondency we should know what we have to do now in order to fulfill our liability for evolution. But if we look out to the coming billions of years, hoping to find support from answers to the where and why, we must turn the aphorism round: There is a way, but no goal; what we call goal is a fancy of our impatience.

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2. Time and Complexity

This text was presented in a workshop which had been organized at the Ringberg-Castle, Tegernsee, May 28 – 31, 1989 in honour of the 60th birthdays of Friedrich Meyer and Jürgen Ehlers, members of the Max-Planck-Institute for Astrophysics, to which the author is affiliated, too.

It appeared originally in: *Proceedings of the Workshop on Gravitation, Magneto-Convection and Accretion* (B. Schmidt, H.-U. Schmidt, H.-C. Thomas eds.), MPI für Astrophysik, Karl-Schwarzschild-Straße 1, D - 85704 Garching bei München.

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Time and Complexity

I shall use this “after-dinner-talk” (presented before supper) to smuggle some “soft” considerations about science and scientists into the “hard” scientific program of this birthday celebration. It seems worth while reflecting on our own position as producers or even dealers in science, since this stuff has taken over the role of “opium for the people” and as mankind’s addiction may be reaching a final state of destruction.

Of course, neither of our two “celebrants”, and none of the contributors to this celebration should be blamed. Everyone in this room deals with things untouchable, though we are still of basically two different types. Let me classify them as types I and II. (I am really aiming at type III, but this will appear later.)

A type-I astrophysicist is mainly interested in the patterns of self-organization observed anywhere between the sun and our cosmological horizon. He finds it quite natural that underlying fundamental laws exist, but he is much more fascinated by the complex structures built on them, and he wants to model them, indulging in re-creation. The type-II scientist, on the other hand, is not at all surprised that the real world has grown complexity if the fundamental laws allow for it. Rather, he is fascinated by those laws

themselves, especially by the question of how far they are arbitrary or necessary.

As usual, extreme representatives of the types can be expected to tend towards degeneracy: The one may become a collector of eye-catching real phenomena, or even just of data – the other may, in an attempt to create concepts about the real world, lose all contact with it and get lost in home-made artistic worlds of rigorous mathematical beauty. In a way, the extremes touch each other again: Unrealistic art finds its collectors, too – especially since computers provide a wealth of unpredictable artistic prodigy.

Anyway – what is reality? To quote from Helmut Friedrich's talk: "Now we have got rid of all the physics, but all the difficulties are still there". You see: Science may emancipate itself from so-called nature, but not from complexity. It has still not reached its great aim, simplification of the world, reduction of everything to graphs in a plane, i.e. what we call *explanation*. In fact, this aim may turn out to be a strange attractor: The sequence of questions and answers which generate each other may form a kind of infinite Mandelbrot set – not in spatial but in logical structure, and perhaps with dwindling self-similarity of the concepts as magnification runs on. So, the attempts to unify amd simplify the understanding of the world may in fact contribute to the growth of its complexity.

This reminds us that we don't have proper measures of complexity. There is even a sort of *relativity* involved in its judgement. The point of view of an observer will influence the measure. An old dispute with Bernd Schmidt comes to my mind: A non-rotating lump of viscous fluid, alone in an otherwise empty world, will take the shape of a ball, won't it? Is this a trivial or a deep theorem? A simple or a complex statement? Well, Bernd told me, there is still no rigorous proof for it in General Relativity. So, why not make it an axiom? But, of course, other simple things would then appear as highly complex. Remember: One must not apply the term "complex" to *parts* of a system. The complexity is in the *whole*. Even complexity-theorists have now started to realize that a "measure of complexity" cannot be based merely on internal relations within a sub-system but must somehow include the whole process of its creation. (Cf.

Rolf Landauer's recent commentary in Nature **336**, 306 on the proposals by Bennett and by Lloyd and Pagels, and the literature quoted there.)

"Relativity of complexity" also shows up in physical cosmology. We may now observe or conceive extreme simplicity for the origin of what we call our universe: Just the laws of physics, and no detailed ordered structure except the extremely well-ordered primeval expansion, i.e. some initial condition of "low entropy". But in order to discover its own basic simplicity, this universe had to evolve complexity up to our level, including mathematical geniuses and giant accelerators and telescopes. And why has all that happened? Because it was more likely than other possibilities? Obviously, the meaning of time is to let more likely things happen – the becoming of complexity, the realization of possibilities, the selection of things *realized*, among the things *possible*. You know it: The evolution of elementary particles, of galaxies, stars, living planets, neural networks, cultural networks – it all follows the same principle: The state of the world explores its neighbourhood in the "space of possibilities" by accidental fluctuations, discovers more long-lived structures, which are therefore more likely to survive longer. (The "accidents" involved are either quantum fluctuations or accidental encounters with a long history – back to the beginning, with many other accidents along the way.)

The concept of a "space of possibilities" which I often use in the formulation of this Darwinian tautology may remain vague. Only one line in this space is definitely known to have been possible: The realized past. The possible is only found by trial and error. Whether something compatible with the laws of nature "could have been realized" is usually an undecidable question, and whether something *will* be realized has to be waited for. On the other hand, thinking and even dreaming are certainly real processes connected with matter in space and time – e.g. in neuronal networks and libraries. In this sense, our ideas belong to that *one line*, are *realized*, even *materialized* possibilities. Who says, what we see is more real than what we think? Thinking is a very real phenomenon of self-organization, still more highly developed than seeing! The idea of reality becomes quite fuzzy when you realize that. We don't even have to discuss the EPR-paradox to shatter our confidence in concepts of "objective existence here and now" …

However, I don't want to get lost in extreme type-II reflections. If you know me, you know that I only speak here in order to excite thinking and action against a third type of scientists: Those do-gooders who not only dream of *effecting all things possible*, but who have really started doing it – with fatal consequences. These type-III scientists outnumber by far the ones of types II and III, and their *Baconian* megalomania is sweeping aside *Darwinian* modesty. They claim that they can improve the world because they have understood the laws of nature.

What's wrong with this idea? Aren't we scientists clearly the tools by which the world here and now gropes its way further into the space of possibilities? Why should more scientific knowledge be harmful in this latest version of the evolutionary process? Why do I call it "opium for the people"? Well, of course, you know: The harm is not in the "opium" as such but in its misuse. And the parallel goes quite far: The drug is applied to solve a problem, but it creates a new and bigger problem. More of the drug has to be used, and more quickly. The new problems thus created are even bigger, need still higher dose, stronger drugs, faster application … Sounds like an instability, doesn't it? How can the evolutionary path of the world (or of its subsystem Gaia) into the space of possibilities become unstable? Isn't this just a matter of value-judgement?

Exactly! "How to judge values?" is the fundamental question. Evolutionary selection in dissipative open systems has answered it: If more and "better" relations between all subsystems can be found by fluctuations (where better relative isolation of some parts may often also be a better relation), they will probably be realized. And what is "better"? The more likely under the circumstances! As we saw: "Very likely, the more probable is going to happen" – and in a complex dissipative system this is the growth of complexity as far as possible. So, the better, the more valuable, arises without any value-judgement! Or, rather, the selection process *is* the value-judgement! No God seems to be necessary to discriminate between good and evil. More valuable possibilities, i.e. more complex ones, where things fit together in a more viable way, are just more likely to be realized. All is well, isn't it?

Just one little dark spot in all this enlightenment remains to be cleared up, the role of time in the growth of complexity. And here, I must shock you,

we meet the Devil. A theorem may be proved in system theory: In a spatially finite system with unbounded evolution, the devil ("dia-bolos", i.e. he who "throws things into disorder") must at some stage appear at the front of evolution and cause a singular crisis. The mechanism is easily understood – you find hints at it already in the myths of Lucifer/Prometheus or of the Tower of Babel – but a constructive proof of the theorem lies at hand only now: One of the successes of evolution must be an increasing speed of the evolutionary process itself, because more and more efficient "languages" are found and realized in the space of possibilities. The beings at the front of evolution will, due to their own complexity, need some time to develop individually. This is their own life-time or generation-time. If they try to judge values (i.e. select new possibilities for realization) on a shorter time-scale than this, adaptation of the new and the old cannot work by definition. Hence, most likely, complexity will not grow but decrease. Under these circumstances, the *worse* is the more likely! Complex diversity will be quickly and globally replaced by universal simplicity. Reduction of diveersity, however, allows for still faster global decisions, and the next decisions will be even more likely wrong in the same sense.

You see, evolution itself defines and creates a critical time-scale, which it then tries to surpass. But thereby it must destroy its own logical pre-condition. The leading figures at the front of evolution don't give themselves enough time to judge values in the process of exploring the neighbourhood in the space of possibilities. Of course, the tautology remains valid that "more likely things will probably be realized" via the accidental fluctuations (including their more recent form of appearance, called planning) – but with a lack of time for selective adaptation, i.e. adaptive selection, the more likely is no longer a growth of complexity but rather its decomposition. In a very sophisticated way the entropy-law seems to have conquered the Earth, an open dissipative system in which we thought it wouldn't be valid. While everybody was still worrying and quarreling about the resources, we have been filling up and blocking the sinks …

Now, the news and the science-journals are full of the symptoms of this crisis. But the understanding of its origins remains poor. Most doctors recommend faster innovation and unification as the proper drug. This means that the ailment itself is offered as its only promising remedy. We cannot expect the dealers of the drug to promote much insight. Those type-

III scientists, the do-gooders who promise to improve the world by ever more contraptions conjured up ever more quickly from ever more matter and energy, have to be discredited. Perhaps the scientists assembled here are sufficiently remote from the complications of reality to be able to reflect on the role of time in the growth of complexity. Thinking about general principles of evolutionary creation of values you will discover that "devil-theorem", and you will immediately recognize that evolution toward higher complexity can only go on if we guarantee its pre-conditions at the front: Conservation of old complexity must become a kind of holy rule, and the speed of change must be bounded by the "human measure" (and, of course, still more tightly where our biological or even climatological roots are threatened).

I cannot discuss here the role of occasional revolutions which arise from hot spots in the system, where dissipation is not organized in a sufficiently complex way. But it is obvious that we are approaching one. Our mental capabilities which inevitably had to lead into this crisis also have to evolve the insight that further evolution will need self-restriction. The "pre-conditions of evolution" which had been automatically fulfilled in the past, will have to be fulfilled by social "constitutions". Those conditions, which we will have to try and re-establish, I have often characterized by the slogans "Vielfalt und Gemächlichkeit", which is roughly (and clumsily) "manifoldness and leisureliness". It means that the selection procedure, trial and error at the front in the space of possibilities, has to be left to many individuals and groups (implying very de-centralized structures) – and it means a deliberate, institutionalized suppression of the speed of innovation (– except in purely mental fields like music, poetry or mathematics). Consequences for a new organization of politics, economy, science and technology are indeed manifold. In a book which I have just written, I could only rather accidentally touch on a few of them ("Das Grundgesetz vom Aufstieg", Carl-Hanser-Verlag, München 1989).

Perhaps some of you will spare a little time from research about the last billions of years and help think about how the laws of logic and probability will influence your own remaining life-time, and all of the future. We must not leave this to the "experts" who want to sell their products. Too long, scientists have misunderstood the last sentence of Wittgenstein's *Tractatus*: "Whereof one cannot speak thereof one must be silent". We are still

misusing it in pleading for irresponsibility. But surely, Wittgenstein didn't learn speaking by being silent. The word should be changed: "Whereof we cannot speak thereof we must stammer".

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3. The Intrinsic Limit to the Speed of Innovation and its Relevance for the Question "Where are They?"

This paper was based on a talk at the 3rd International Symposium on Bioastronomy held at Val Cenis (Savoie, France), 18 - 23 June 1990. It was printed in the proceedings: *Bioastronomy – The Search for Extraterrestrial Life* (J. Heidmann, M.J. Klein Eds.), Springer-Verlag, Berlin 1991.

The question "where are they?" (referring to the missing traces of other technologically developed "civilizations" which might be expected in a galaxy with billions of solar-type stars) is often attributed to Enrico Fermi. The acronym SETI is used for the current radio-astronomical programs which **s**earch for **e**xtra-**t**errestrial **i**ntelligence.

3

The Intrinsic Limit to the Speed of Innovation and its Relevance for the Question “Where are They?”

Why has the earth not been colonized from outside, although any developed technological civilization should be able to diffuse through the galaxy within a few million years? Mainly two answers have been proposed:

(1) We are alone (or nearly so) because some narrows along the path towards our level of complexity make the appearance of intelligence or civilization extremely unlikely events. A whole universe (or even multiverse?) is then needed to let this possibility become realized on just one planet.

(2) Technological civilization itself is the narrows. Either it becomes self-destructive through global ecological (or social) disaster, or it succeeds in self-organizing technological restriction. Then, mind might be a long-lived phenomenon but renounce the spatial expansion of its own physical structure.

The first answer has been favoured by Brandon Carter, Frank Tipler and many others. Carter’s probabilistic argument [1, 2] is impressive at the first glance: A crossing of the narrows must be extremely unlikely, because otherwise it would have happened much earlier; that it happened only “near

the end" (at about half the life-time of the sun) appears then as a natural implication of the fact "that we are here".

The weakness of Carter's argument lies in the fact that many known and unknown processes on earth happen on time-scales similar to that of solar evolution. Present knowledge may not even be sufficient to exclude the possibility that the decay of some abundant radioactive nuclides was necessary before life or nervous systems could reach their present level of complexity. Similarly, the decreasing frequency of large volcanic eruptions and of collisions with interplanetary bodies might have played a role, as well as the slow shaping of Gaia's crust and atmosphere as parts of the biosphere. Therefore, the idea that "intelligence" is likely to appear on "habitable planets" after a few billion years is still compatible with Carter's argument.

Tipler [3] argued that "*the most solid experimental fact*" in this whole discussion is the absence of foreign explorers or conquerers throughout the earth's history. In his opinion this makes the SETI project comparable to ESP-research: "*Virtually any motivation we can imagine that would lead extraterrestrial intelligences to engage in interstellar radio communication with us would also motivate them to engage in interstellar travel. In particular, radio communication is colonization of other inhabited star systems by memes (idea complexes) from alien star systems. If one opposed on moral grounds colonization by genes (via interstellar travel), one would also oppose colonization by memes (via radio). Interstellar colonization either by genes or by memes necessarily implies biological evolution on an interstellar scale: The first intelligent species to originate will occupy all ecological niches available to it, a behaviour pattern adopted by all species that ever existed on the earth. …*" [3]. Obviously, Tipler assumes that mind's ecological niches would have to be found in physical space. "*What have they been doing these billions of years?*", he asks – but isn't this a childish question? Even human mind has already discovered quite different spaces for inward instead of outward expansion. And even some human minds do communicate with others without wishing to "colonize" them. Mind is a new front of evolution in the space of possibilities, not "property" of some individuals or species or cultures.

From arguments like Tipler's we can certainly not exclude the possibility that there are intelligences around and communicate with each other. Concerning the present and future attempts of search for extraterrestrial intelligence (SETI), Jill Tarter said [4]: "It's technology which we are trying to detect – not intelligence". This very relevant remark leads us to the right track to answer the question "Where are they?", even if we don't think we are necessarily alone.

I have often argued [5] that technology itself is the narrows along the way to further mental evolution, because there is a purely logical upper limit to the speed of growth of complexity, and that so-called technological civilization surpasses that limit, thus destroying the conditions for further "creation of values". Even worse, from the theory of creation, i.e. self-organization, there follows what I called the "devil-theorem": In a spatially finite system with unbounded evolution the speed of innovation must increase until a global instability sets in.

Why is that so? We do have a "solid experimental fact" (just look at the present situation of the earth), but we can gain more general insight by thinking about time and complexity. To remember what complexity is, consider the number of possible "relation structures" for a set of points with one line or no line between any two of them. How many points are needed to let the number of such possible structures surpass the number of baryons in our observed universe? The answer is: 24 points! How, then, have viable structures at all been found and kept any stability for some time? How is the history of our universe and all its details being selected? This single realized line in a practically infinite-dimensional space of possibilities? It started from an extremely special global state ("big Bang") which offered immense "fossil" resources and sinks for later self-organization. (The two main sources of free energy are "fossils of the first few minutes": Because things were thrown apart, they stored gravitational potential energy with respect to each other, which can be re-gained in the formation of lumps, and, because expansion was initially so fast, there wasn't time to go beyond Hydrogen and Helium, the fossil fuels in stars.) Ever since this unlikely beginning, the unavoidable fluctuations have been exploring neighbouring possibilities. Since there are so many of them, there are probably "better" ones found, more viable ones – if there is time enough to test the relevant relations between the new and the old. More viable possibilities survive by definition.

A hierarchy of dissipative structures emerges, with more and more mutual adaptation, which also includes relative isolation as far as possible. The tautological principle of this Darwinian co-evolution is: "Probably, something more likely is going to happen". This is the meaning of time, the drive behind the growth of complexity in our universe – up to the speed-limit.

Does this mean that the "better" (the more complex, which we find more valuable) arises without any value-judgement? No, the selection process *is* the value-judgement, and its principle is the same on the levels of physical, chemical, biological and mental evolution. One can easily see why the emerging world is hierarchical. Structures on lower levels, the viability of which has long been tested, will be used on higher levels with little modification because attempts to "improve" them must introduce many untested interactions and, therefore, probably lead to break-down. With too many new relations (remember the 24 points!) time is not sufficient to try them out, and no viable new structures will be found, even if they might be possible. Building upon time-tested feed-back loops is more successful. Still, a crisis is unavoidable.

At any moment, there is a "front of evolution in the space of possibilities", where innovation proceeds fastest. This speed is itself an "evolutionary success" and is likely to grow until feed-back with the whole becomes insufficient. Then, this front collapses, but evolution goes on with whatever diversity is left. Of course, we cannot formulate a general system-theoretical argument which would allow us to call certain developments "safe" in the sense that they will not destroy there own roots. However, even with the absurd assumption that the front might succeed in complete emancipation from its roots and the whole, a logical limit to the speed of creation of values is self-evident: The level of complexity reached has to be "relearned by each generation". Thus, the critical speed is roughly defined by "essential change within the life-time of the individual structures at the front". If the (r)evolutionary process of fluctuation and selection gropes its way into the space of possibilities faster than that, the leading sub-systems cannot even take into account their own complex value. Self-organization of global simplicity sets in and increases the speed of "wrong" value-judgements further. Within a few generations of the leading sub-structures they start destroying themselves and the viability of the whole system from which they evolved.

As I wrote elsewhere [6]: " … *Evolution itself defines and creates a critical time-scale, which it then necessarily tries to surpass. But thereby it must destroy its own logical preconditions. The leading figures at the front of evolution don't give themselves enough time to judge values in the process of exploring the neighbourhood in the space of possibilities. Of course, the tautology remains valid that "more likely things will probably be realized" via the accidental fluctuations (including their more recent form of appearance, called planning) – but with a lack of time for selective adaptation, i.e. adaptive selection, the more likely is no longer a growth of complexity but rather its decomposition. In a very sophisticated way, the entropy law seems to have conquered the Earth, an open dissipative system in which we thought it wouldn't be valid. While everybody was still worrying and quarreling about the resources, we have been filling up and blocking the sinks …*"

This kind of instability is quite similar to the "success" of a fast-growing water-lily on a pond, or of a cancer-cell in an individual organism. The characteristic difference, however, lies in the "globality". If the system is isolated or spatially finite in the sense that the time-scale for communication with the outside is long compared to the time-scale of the instability, no revival from "outside ponds" and no survival of "outside individuals" will stop or heal the local disaster. A *black hole* will remain, or *scorched earth*.

If evolution doesn't stop due to external influences, this onset of global instability is probably unavoidable. Growth of evolutionary speed itself seems to be an evolutionary success as long as the errors can be pushed to the "borders" – i.e. until the global scale has been reached. This acceleration must certainly take place when evolution on a planet reaches the level of mental structures. The "discovery" (i.e. "detection", i.e. "apo-kalypse") of the laws of nature will start technological progress because this provides more power. Of course, like in our own history, many individual minds will understand the "devil-theorem" quite early, since the *laws of logic* are more fundamental than the *laws of nature*. But in the fight between "God and Devil", dia-bolos (i.e. "he who throws things into disorder") will prevail because he is always quicker than the creator of true complexity.

Thus, any planet with intelligence is likely to run into our kind of technological crisis and to approach global ecological or social disaster. Still, I call

it a crisis, and not the end. When deadly consequences of this "progress" are felt on the critical time-scale (the own life-time) by a majority, insight into the logical pre-conditions of creation may become dominant in the global society of minds. It may then still be possible to self-organize the restriction of power and of the speed of innovation, and to shift the front of evolution to the mind – where creation of new complexity is possible without the destruction of its whole basis.

Conclusions concerning SETI are obvious. If there are others in our universe, they will not be interested in simple material structures, except during a few generations before that crisis. Mind will recognize itself as infinitely more complex, i.e. valuable. Topics like astronomy would play a negligible role in an "Encyclopedia Galactica". If civilizations transmit signals, they will probably not use "variations of something expected", as William Calvin proposed here "because radio-astronomers are interested in pulsars" [4]. For mind the only interesting thing in the universe will be other mind. Even the "acquisition signals" (though probably on "magic frequencies" – e.g. as favoured by David Blair [7] might not be perceptible on the human time-scale – another relevant remark by Jill Tarter [4].

Civilizations beyond the acceleration-crisis would not try and help others to overcome it, too. Not because they are selfish, but because such help is obviously impossible. They must know that many of us have understood the origin of the crisis, but that we can stop only (if at all) at the very edge of the abyss. The time-scale of interstellar communication is longer than that of our instability. After the development of radio-technology there is no time left for help. Earlier interference, however, before the onset of the instability, would not mean help but colonization – which is probably excluded by further mental evolution (or even by a fundamental incompatibility between long-distance space travel and a "mastering of the Devil"). Hence, there is nothing important which we could learn from aliens on the time-scale of the crisis, i.e. on the human time-scale. It's all in our minds! Still, the discussion about whether we should listen or not, and why we don't hear anything, may contribute a little to the understanding of the devil-theorem …

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[7] David Blair, in *Bioastronomy*, see [4].

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4. Ethics from Science?

This text was distributed as a “non-official contribution” among the participants of the “Workshop on Bioscience and Society”, Berlin, November 25-30, 1990, organized by Silke Bernhard in the style of her “Dahlem Conferences” for the company *Schering AG* at the 100th anniversary of their first research laboratory.

I had to act there as the moderator of discussion-group 2 (“Does bioscience threaten ecological integrity?”), and I wanted to provoke the participants a bit more than the official papers which had been distributed as a basis for the discussions. Partially, the unpublished text was used in a short summary report, which I had to present to the final panel. This appeared in *Schering Foundation Workshop 2 – Round Table Discussion on Bioscience and Society* (J. J. Cherfas, Ed.) Springer-Verlag, Berlin 1991.

4

Ethics from Science?

1. The self-delusion of risk-assessment

The four discussion groups in this workshop on interaction between bioscience and society deal with four questions. The first two of them are *"does bioscience threaten human integrity?"* and *"does bioscience threaten ecological integrity?"*.

Two aspects of human integrity may be distinguished, because man lives on two different levels. In the "biologistic" view he is defined mainly by the molecular structure of his chromosomes and those connection patterns of neurons which are genetically fixed. We may subsume this biological phenomenon, which has proven its viability on the time-scale of millions of years, under the concept of the biosphere or the "ecological system" – i.e. all the time-tested interactions within "Gaia" and, eventually, "the Universe". On this level, from physics up to the animals, complexity is already nearly infinite, but on the mental level (represented in space, time and matter by human cerebra and the cultural phenomena springing from them) it may become still very much higher.

Although, on either level, integrity cannot be defined operationally or in any other scientific sense, damage to this complex web is not only a threat

but an empirical fact. If interference on the relatively low level of chemistry has already shattered the climate of the earth, and if human activities now exstirpate one or more living species every hour, it would be absurd to claim that interference at still higher levels of complexity is more likely to create less problems than it "solves". So, scarcely a scientist will deny the possibility of threats from bioscience to the ecosphere as well as to human individuals and societies. The general answer to the first and second question will be yes – but the attitude towards the unknown threats and the proposals for action will still lie anywhere between megalomanic hope and humble modesty. Let me give two examples:

(a) "Having understood the basic laws of physics and biochemistry, we now have to improve man and his environment on the physical and biological level. Since there may be a chance of success, humanity cannot evade this task. If we weigh the benefits and risks responsibly, an overall positive result is very likely. But even if we fail, and destroy more than we improve, this is no threat to human dignity, as long as we acted in good will. The essentially human cannot be harmed by individual death, by loss of species, or even by the end of the world."

(b) "Complexity on the level of organisms and ecology is so high that hasty "problem-solving" is likely to create far more new problems. On the other hand, it is evident that in the realm of mind and culture ideas have evolved which are able to deal with such "old-fashioned" problems as need, disease and death. Therefore, let us try and restrict our activities as far as possible to the mental and cultural level and renounce all interference with mind's natural roots."

How do scientists and the society steer between such extremes? Is there a generally convincing way of finding out, which might be more reasonable?

The questions to the third and fourth diccussion group are: *"What's wrong with the interaction between bioscience and society?"* and *"What actions are required to improve the uneasy relationship between bioscience and society?"*. The discussions in the four groups are meant to be guided by the general heading of the workshop: "*Do current and anticipated developments in bioscience require a new covenant between science and society?*.

Most active scientists will feel uneasy with this question. Wasn't the old covenant sufficient, which made it perfectly clear who is the superior partner in this relationship? Society has needs, scientists offer inexhaustible hope. Natural selection within the economy of science has taken care that most of them are optimists. No wonder that, since God died of enlightenment, science had to take over the role of the "opium for the people" – which secures fat living at least for the big dealers. For them, there was nothing uneasy in this relation. And didn't it bring permanent progress?

Society wants progress – and the more it has had of it, the more it needs. Some already find it a shame that science will not find a cure against death before they die. On the other hand, the fear of "side-effects" is growing equally fast. Clearly, some kind of suppression is necessary in the fight between contradictory fears and hopes. It organizes itself in the interaction between science and society. Like with the hen and the egg, we cannot say where the process starts. Society feels a strong urge to get away from where it is, because the present state seems rather intolerable in spite of or because of all former progress. Experts offer some beneficial innovation. Society asks about possible risks. The experts describe those which they can anticipate and say society should now do the "weighing" between benefits and risks. Society says the experts must help with that weighing, and calls them into a committee for risk-assessment. Since it is utterly unscientific to talk about, or even mention, something which one doesn't understand, the problem of the "unanticipated" dangers is suppressed from the discussion. Even if a risk should become hazily visible, one can always add weight to the clearly recognized benefit which promises to deliver us from "the urgent problems of mankind", such as hunger, disease, lack of resources and sinks and other degradation of the environment.

The promised land of scientists and businessmen in gene-technology, like the promised lands behind all those other doors which key-technologies (or picklock-technologies, or even breakthrough-technologies?) are supposed to open, will be full of new problems, and more urgent ones. But this will not be due to the *"current and anticipated developments"*. The greatest threats come always unexpected. However, since this is also true for the biggest successes, the experts as well as the majority in society tell themselves and each other that the unknown very big risks and benefits will just be in equilibrium and can be left out in the "weighing". If something

goes wrong, scientists and technologists cannot be held responsible for unanticipated trouble. Neither can society. Responsible action is by definition up to the present and foreseeable standard of science and technology – which is defined by the same experts who do the risk-assessment, though usually in a different committee which society called for that purpose. (For instance, since all the mutual regulation of genes is far too complex to be ever understood, it is serviceable to declare an "additive model" the present scientific standard …)

So, what about the unanticipated developments? Society can't be held responsible. It has regulated by law that scientists and technologists act responsibly if they act according to the present standard, and the enforcement of the law is controlled by experts and other members in "ethics-committees". Everybody has done his best. Now, if God isn't responsible, and the scientist isn't, and the technologist isn't, and society isn't – who is?

2. The Devil-Theorem

Obviously, there is something wrong with the logical structure of the old covenant. A reliable concept of responsibility must be included in the common minimal basis for an ethics of science and technology. In a pluralist world-society this cannot be expected from any of the old gods. Emancipation from truth in the sence of any religious fundamentalism is certainly worth striving for. Neither can the ethical basis come from research about how our genes influence the growth and the functioning of our neural networks. A "biologistic" ethics would be as ridiculous as ethics from quantum mechanics. There is, however, a fundamental truth which is able to convince instead of indoctrinating, and which comes even before the laws of nature. This unevadable truth is logic. Surprisingly, in scientists' considerations about ethics, a very simple logical insight is usually being suppressed:

If results of a creative act are not clearly forseeable, the difference between "good" and "evil" is a matter of the time-scale and the "degree of globality" of the action. The consequence: One has to "wait and see", and old diversity must not be sacrificed quickly to "unification".

It took billions of years until God "saw that it was good". Hans Machleidt, a German biochemist, active in education and in the chemical industry, a member in many committees, recently wrote: "Gene-technology has as its contents the planned new combination of the genetic material of living beings. This science has learnt from nature by patient observation, and is by now 15 years old …" He was argueing against intervention from politics which was then threatening the "impetuous dynamics of progress" and the "innovation dynamics" in our country. Mentioning both nature and the 15 years, he touches the fundamental problem but doesn't see it.

We know now that creation followed the general principle of self-organization. This principle is surprisingly trivial: At each stage, from big bang through the formation of matter, astrophysical structures, the origin and evolution of life, up to our thinking and feeling, the unavoidable fluctuations explore the "neighbourhood in the space of possibilities", and a more viable situation survives. Nobody will quarrel any more about this Darwinian tautology which does not mean more than "probably, something more likely is going to happen". Now, the more viable is likely to be of higher complexity, if there is a larger number of neighbouring possibilities to be tried via the fluctuations, and if there is time to try more and more of them until something is found where "things fit together still a bit better" and which is therefore "selected" according to the laws of probability. The proper meaning of time is the growth of complexity – which we perceive as the creation of values. Big Bang has provided time and free energy, combinatorics provides an immense number of possibilities, and the laws of physics have made possible long-lived environments in which manifold trial and error could go on.

Remember how the number of possible relation structures grows with the number of related objects: Between two points you can draw a line or not – which makes two possibilities. With three points you find eight, with four points sixty-four … How many points do you need in order that the number of possible different relation structures is larger than the number of atoms in the universe? The answer is: Twenty-four points! So, obviously, there is always an immense number of "better" possibilities in the neighbourhood – but there is practically no chance of finding them by "planning" because the "worse" possibilities are always infinitely more frequent. Even if all matter of the world were used to build a computer, and

if this would run for the age of the universe, not even all relations between 24 points could be tried. This is why “planning replaces chance by error” …

At any epoch in this process of self-organization of the universe, there will be a “front of evolution” in the space of possibilities. (Because of the isolation of stars and planets, there might be many quite independent fronts at the moment.) The speed of innovation at such a front is likely to be accelerated, because higher evolutionary speed carries a selective advantage by definition. Clearly, this will lead to a run-away instability at this front. Due to lack of time for trial and error possibilities will be realized in which things don’t fit together anymore. The front will cut its own roots to the whole and will collapse. In a spatially large system with many different local fronts this has to be judged as one of the usual errors which are absolutely necessary for evolutionary success. As long as the run-away and collapse remain spatially restricted, trial and error will go on elsewhere in space and at other fronts in the space of possibilities, too. In a spatially finite system, however, accelerated evolution must eventually lead into a global crisis. The evolutionary “success” will (again by definition) spread in space – i.e. “geographically” - until global run-away is reached. Then “the whole” (or the whole “island”) must fall back to a “lower level” in the space of possibilities.

Can such general system-theoretical considerations teach us anything about our doom? Yes. At any epoch, the beings at the front of evolution – the present “crown of creation” – will incorporate the highest degree of internal complexity. (There is probably some meaning in such a statement, although it introduces a dangerous concept. The very idea of “internal complexity” of parts would imply knowledge of their relative isolation and the time-scales of all “border-crossings”. Properly defined complexity will not be a property of parts but of the whole. Even mathematicians are now realizing that a meaningful measure of complexity would have to deal with the history of the whole …) In order to replicate this internal complexity, the individual needs a typical lifetime. This span of life (or “generation time) sets a lower limit to the time within which an essential gain in complexity (“creation of values”) might be achieved. Of course, the complexity of the whole might be damaged already at a much slower pace, but faster change will not even allow to take into account the own internal complexity, i.e. the

value of the present "crown of creation". And still, until the speed of innovation has become so high that those beings drastically change their own essentials within their own lifetime, further acceleration and global unification will be selected for. The tautology remains true that probably something more likely is going to happen – but no longer is the rise to higher complexity the more likely. Global decomposition of complexity sets in and accelerates further towards collapse.

Have you recognized the global ecological and social crisis which we are experiencing right now on the time-scale of our own life? This is a singular epoch in the history of the earth, and evolution unavoidably had to run into it after its front had moved from spelling a few new letters per generation (in the genetic code) to trying new ideas in our neural networks within milliseconds. The basic principle of self-organization is still the same as ever. The front is now in our brains and their associations, and planning is just a different word for groping our way into the space of possibilities via fluctuations. However, the rate of fluctuations in brains, the speed of interaction between them, and the speed of their interference with the environment have made the system reach the point where destruction of the old complexity becomes more likely than its growth. The broken bits are still immensely complicated, but things no longer fit together in real complexity. The blossoms at the tree of life are still beautiful, but they expand like mad, drop the leaves in order to gain space and simplify the view for planning. Attempting to fertilize the tree they poison its roots … Inevitably, evolution now seems to destroy its own preconditions: the immense diversity and the leisure for selection.

A simple objection to this "pessimistic" system-theoretical argument is the following: The mind's level of complexity is so much higher than that of any preceding dead or living structures, that the destruction or an essential reduction of the old biological complexity means a negligible loss of value. Isn't it even possible that mind emancipates itself from flesh? Certainly, this is "possible" – as one of the infinitely many ideas in the space of possibilities! But how likely is it to be reached by fluctuations during our epoch at our front in this space? Clearly, the probability is infinitesimal. So, this objection is nothing but that old insinuation of the snake on the tree of knowledge.

You see: There is an old name for the problem. No surprise, since it was so obvious to human intuition long before the critical time-scale and the global scale had been reached through the evolution of science, technology and economy. The principle has long been recognized. It is called the Devil, "diabolos", i.e. he who throws things into disorder. As an angel, i.e. as a part of the divine principle of creation, he has also been called Lucifer, i.e. the bringer of light – but then he tumbles down into hell – which we might call a black hole, the utterly simplified world, the bottom in the space of possibilities … He is the same figure as Prometheus, the "fore-thinker". Remember Pandora's box, and how its lid was taken off – i.e. its "dis-covery" or "de-tection" or "apo-kalypse" …

The Devil isn't evil. He just wants to improve the world more quickly than this is logically possible. Just like scientists and technologists and politicians.

3. How to convince the Devil

You may say, God's way is no longer reachable in our neighbourhood in the space of possibilities. We can no longer wait and "see that it was good". The Devil has lead us already so far in the global run-away that we cannot but follow him further. I hope this is not true. Can't we try a "moratorium" in all the key- and picklock-technologies? Maybe, ten times longer than that after *Asilomar*? Couldn't we use that time to reduce all the activities which we have recognized as destructive to the roots of old complexity? With a reduction of 3% per year, we would arrive at 20% of the present level of destructive activities after fifty years. This is what we would have to achieve in the burning of fossil fuels, the setting-free of chemical compounds which have not been tested in co-evolution with the biosphere, in soil erosion and in many other activities – in fact in nearly every activity which is now considered to be essential for our "standard of living" and for "job creation". If we could reach a new covenant, risk-assessment would no longer deal with detailed experiments and techniques but rather with whole branches of applied science and industry. The word "break-through" would make you think of drowning under thin ice – not of getting rich booty after a battle.

Of course, all this will not be the topic of our workshop. I don't expect the devil-theorem to be made the basis of an "ethics from science" before the ecological and social collapse has proceeded still further. Eventually, however, the "opium for the people" will no longer be able to suppress the pain; acts of sabotage will embarrass the dealers; social turbulence will counteract global simplification; big powers will collapse, and in some smaller communities people will re-discover why God could have seen that it was good. Then, they will understand that we must not try and improve the world in the language of nuclear forces or the genetic code, but in our own language. If the biosphere is conserved, or influenced only very slowly, if the front of evolution is basically restricted to our mental and cultural activities, and if diversity at this front is kept or re-gained, we may be able to organize boundary conditions under which evolution on earth can continue. The spreading of a logical insight is the only task which we have to fulfill in a hurry, and globally. The inevitability of the crisis does not mean that it cannot be overcome. The word *crisis* means *decision*..

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5. Conditions of Creation

The following text appeared in: *Entropy and Bioeconomics*, Proceedings of the First International Conference of the European Association for Bioeconomic Studies (E.A.B.S.), J. C. Dragàn, E. K. Seifert, M. C. Demetrescu eds., published by NAGARD, Rome 1993. ISBN 88-85010-11-3.

It was written a few months after a free presentation at that conference (Rome, 28-30 November 1991), which took place in honour of Nicholas Georgescu-Roegen's 85th birthday.

I had been asked to talk about entropy, but I wanted to go a bit beyond and not only touch on the question of "how to organize limits to growth" but also mention an essential point of the answer – the necessary "de-subsidization of capital" and the introduction of a *TAT* instead of *VAT* – i.e. the replacement of "value-added tax" by "trashiness-added tax" …

5

Conditions of Creation.

The Invisible Hand and the Global Acceleration Crisis

Theories in economics remind an astrophysicist of simple games, like "monopoly". Of course, there is more progress here. No longer do most economists believe in the possibility of a perpetuum mobile, and with improvements in general scientific education of the public, and particularly with the appearance of computers, the rules have become a bit more sophisticated. Even some non-linear terms may now be added in the formulation of the rules which allow for the development of "deterministic chaos" if parameters are appropriately chosen. Still, it remains a stunning observation, even in this meeting of "unconventional" economists, how few relevant facts of the real world are usually included in the theoretical thinking. If an astrophysicist would dare to produce a quasar-model containing so little reality, he would be ridiculed in his scientific community. Obviously, we have different criteria of falsification, and even different concepts of reality. A decisive difference is the strong back-action which economic theory has on its subject. In astrophysics, we cannot push galaxies or stars to behave in a theoretically preferred way. On the other hand, in economics, one cannot even demand that a theoretical model should represent essential features of a pre-theoretical world. Economics is the science of economy, where economy may be defined as a process of simplifying not only the models but the world itself until – in a climax of reductionism – it can be modeled by economists. There may be few formal errors in the theory, but even some of its "bioeconomical" versions tend to help reducing reality to money and its by-products. Since the idea that

"hard science" forbids value-judgments is still in highest esteem, a realistic theory of value – which one would expect to be a basic part of economic theory – is scarcely looked for. (Still, economists find it compatible with science to believe in the value of money …)

Embarrassingly indecent as it may seem, I shall use this opportunity to sketch a theory of value on scientific grounds which does have implications for economists, too. Since the world appears so immensely valuable to every healthy mind and heart, theory must deal with the question how all this value could originate. We have to study the creation of the world. Reductionist science has now reached a level from which it can tell the story of genesis in terms of laws of nature and laws of logic. It turns out that even a theoretical "reduction to nothing", which advanced theoretical physicists are striving for, will not reduce the value of our world but rather let it become more evident: The value of everything, including life, man and society, is not in the starting point or in the fundamental laws, and certainly not in the "use-value" for some sub-structure, but in the immense complexity which has evolved during those "six days".

We must understand the principles of this creation process (now called self-organization) if we want to answer the question why all those structures – from elementary particles to healthy bodies and minds – could come into existence and fit together in such an intricate way. I shall try and strengthen the intuitive insight that a reasonable assignment of "value" is nothing but the perception of viable complexity. Only when we know under which conditions such complexity can or must arise, will we perhaps learn to understand where the cloven hoof comes in, why the "invisible hand" can also throw things in disorder, why the principle of creation doesn't work successfully now – and why there is still hope.

1. Sources and sinks

Nearly everybody here seems to agree that present human activities endanger the survival of man and other higher life-forms on earth. The extinction of species (about one every hour!); the spread of chemical compounds which never before existed on earth or in the universe (perhaps a new one every hour?); the population growth (by more than 10 people while I count to 10 as fast as I can!) and the number of people dying from

starvation (now one child every two seconds!); the steadily rising carbon-dioxide content of the earth's atmosphere (predominantly from the so-called developed countries, where the average citizen contributes every day an amount of CO_2 equaling nearly his own body-weight!); the thinning of the stratospheric ozone-layer (which has been developed by life and allowed the evolution of higher life-forms for a billion years); the perishing of forests, coral-reefs and more and more other ecosystems … Most of us feel that these are symptoms of decline or even fall.

The recent experience – that within a human life-time the terrestrial biosphere as a whole, including man, might be seriously threatened – seems to present a sharp contradiction to the previous ascent of life, mind and culture. Since this symposium is in honour of Nicholas Georgescu-Roegen, many of you may think this all has to do with the second law of thermodynamics which states the inevitable growth of entropy in a closed system. On the other hand, this law has always been valid, and obviously up to quite recently not only did not prevent, but even entailed the evolution of ever more complex, more beautiful, more valuable structures in the world. In fact, those are all "dissipative" structures which, in a sense, form and function by means of and because of their entropy production: As "free energy" or "exergy" flows through them and is degraded to "lower value", there is a tendency to establish even more refined structures. Thermodynamically, a kind of "use-value" can be attributed to any deviation from equilibrium. Energy flow from higher to lower temperature or other equilibration processes tend to be organized in such a way that more complex structures evolve which make still better use of these flows.

Therefore, one of you said: *The problem is not the increase of entropy but the access to free energy … All problems can be solved with better technology and recycling.* One of Georgescu-Roegen's main concerns – the fact that the disequilibrium of "raw materials" in the earth's crust is being exploited to its exhaustion and complete dissipation – is then answered with the remark that "the growth of matter entropy can in principle be reversed with energetic negentropy" and that we, therefore, only need enough free energy to regain any material from sea water or waste or even from polluted soil. What, however, if the problem lies in the fact that each problem-solution creates several new problems which cry for even faster and more global solutions and for the help of still more free energy? Then,

what always had been called progress should suddenly rather be called an instability. Instabilities do not go on and on. They find an end. But how likely is the end to be found in a state of more viable complexity? Can our "technological optimist" convince us that the access to ever more free energy makes this kind of lucky outcome more likely?

You will certainly tell him, that it isn't enough to consider the sources, but that the sinks are equally important. We must get rid of the entropy which is the unavoidable waste of all that free energy. In fact, two of the most urgent global problems discussed these days, the greenhouse effect and the ozone depletion, are directly due to disturbances in the old flow equilibria of exergy and entropy from the sun over the earth into deep space. Too much free energy has been used too quickly for the production of goods and bads which now choke the entropy-sink. The earth's temperature will have to rise in the search for a new flow equilibrium, and this is now happening on the time-scale of a few decades. At the same time, and even faster, the ozone depletion raises the flow of a particularly valuable kind of free energy: More and more of the hard ultraviolet radiation can reach the earth's surface.

Well, our optimist might throw in, if terrestrial life is so stupid that it cannot make sophisticated use of such innovations, can't human intelligence help with a little more spirit of enterprise? Of course, he will say, he did *not* forget the "other end" of the problem. He clearly meant to include it in the concept of *better technology and recycling*. We just have to endeavour global environmental engineering, "geo-engineering" as it has already been called! For instance, among the infinitely many possible combinations of old genes (and new home-made ones) we must find some which let amoebae or plants remove CO_2 from air, or bring ozone into the stratosphere, or use hard UV to produce food for more people. True – more free energy may not suffice. But isn't everything else just a problem of good will and more money for science and technology? With better education, nicer laboratories, larger computers and higher salaries for scientists the experts will be stimulated to create even more fabulous gadgets and drugs, and weigh their risks and benefits even more responsibly before they may be sold and spread and start saturating air and water and soil, and souls.

Of course, mistakes will be unavoidable. Much and perhaps most of the old world will disappear. But this has always been so. Nearly all species which ever existed on earth have died out and have been replaced by superior ones. This process will always go on, only faster – because now the source of innovation is no longer the accidental mutation of nucleic acids but fluctuations in the firing pattern of billions of neurons in billions of human brains. Compared to that tiresome reproductive diffusion of new genes within a species (with that unbearable limitation through boundaries between species!) this new principle of evolutionary progress is immensely more effective. If the old-fashioned kind of life has been able to find not only sources of free energy but also proper entropy sinks, mind will certainly succeed, too, and much more quickly!

A year ago I asked a scientist, in fact a social scientist: "How many new options do you want every year?". "Stupid question!", he answered, "of course, as many as possible!". "And every day?", I went on, "and every hour? and every second?" – Can you imagine the answer? No, there is no answer; just frustration; likely to turn into hate if I don't smile and go away.

2. Probably, something likely is going to happen

Do you find the value-judgment which shines through my skepticism disgustingly unscientific? Let me put it on firmer ground! Access to free energy and sinks for the entropy are clearly essential prerequisites for any creation of values. But there are *more* necessary conditions. The *time-scales* and the degree of *diversity* in the process of trial and error are decisive for the probability of "success". We shall see that there are *limits to speed and globality* of evolutionary processes. If they are surpassed, progress degenerates into that instability in which people try ever faster to escape from their mistakes and make ever more new ones, and more and more quickly. Of course, they ask so-called specialists to take care of the prevention of mistakes. But how many possible "side-effects" of innovations do the experts have to consider in order to exclude later severe damages to human society or ecosystems, or to the whole biosphere? When can the process of "weighing the risks and benefits" be declared finished? As an example, think of a few trace-gases in the atmosphere which are involved in a few geological and biological loops. Let us assume we know the reaction rates between these gases under various conditions of

density and temperature, in the presence of various kinds of radiation and with all possible combinations of the geological and biospherical partners. A rather complex network of interactions will appear – but does this offer a real problem to modern computers?

In order to answer this, let us simplify the picture and represent each partner in this net by a point and each possible interaction between two of them by a single straight line, neglecting all details of kind or strength and "catalysis" or other synergisms of the interactions. You are all mathematically educated. You see the disaster coming. But for other readers let me add: With two points there are two possibilities (you can draw one line or none), with three points there are eight (three pictures with one line, three with two, one with three, and one with none), with four points you find sixty-four … Clearly, the number of different possible relation-structures of this simple kind is rising rather steeply with the number of points. Now the question: How many points do we need in order to let this number surpass the number of atoms in the observable universe? – Mind your breath! The answer is: Twenty-four!

You see, there is a problem with the "weighing of risks and benefits". Benefits are usually obvious – but how does one weigh risks if there are so incredibly many possibilities? The risk is scarcely ever what comes to your mind via calculations. It comes as the experience of something unexpected but very real. And this must necessarily be so in all complex situations. The unknown is simply too much. If the whole matter of our universe were organized as a single big computer, and this would run for many ages of our universe, it would not even be able to just *count* the number of possible different interaction patterns between a quite moderate number of partners – not to talk about a calculation of probabilities for their realization in a "chain of unfortunate accidents". Thus, reliable risk-assessment is impossible in complex systems. Planning and risk-assessment cannot have been parts of the process of creation of our world. Planning of creation is out, like planned economy.

You know that the alternative is not miracles but the "free market" of evolutionary self-organization. This paper shall summarize its logical structure which many scientists and economists have difficulties to accept because, at least subconsciously, they still stick to the belief that mind is not subject to the laws of nature. However, if a scientist looks at the world as material

structures in space and time he finds only one kind of world. Even ideas influence the world only through some materialization. The introduction of a "metaphysical" difference between matter and mind doesn't seem to make much sense. Therefore, the scientific working-hypothesis is: All laws which govern processes in the world – like the formation and functioning of elementary particles, atoms, galaxies, stars, life, mind and societies – have evolved via "self-organization" from a single germ which we call *big bang* and which includes *the fundamental laws of physics.* Whether these laws are themselves the result of evolutionary processes in the earliest stages of our universe, and how "simple" the world really can or must have been when it all started – such questions remain open. However, for a sketch of the logic of all subsequent evolution this does not seem to be very important. For the purpose of this paper, we may start the story when the fundamental laws have been fixed for what we call our universe.

A basic insight of our century is: Besides logic, *chance is the only necessity*. Chance is enough to make the evolution of complexity likely for a wide range of initial conditions. The essential reasons are the vast number of possibilities and the fact that the laws of quantum-mechanics make everything in the world fluctuate. One can say this although the fundamental laws are not yet known, and not even known to exist in a conventional sense. The observational facts which led to the theory of quantum-mechanics will never allow a step back to classical concepts of reality. Any "phenomenon" or "event" or "realization of eventualities" contains stochastic elements. I put all these words in quotation marks because their meaning becomes blurred at the horizon of present physical theory. But, believe me, the cognition of the decisive role of "accidents" in the history of creation will not become obsolete with further progress in fundamental theory.

If any realized structure fluctuates, this means that a large number of its "neighbouring possibilities" are realized for some time. If among them there are "more viable" possibilities, that is if they are likely to survive longer, they will probably survive. This Darwinian tautology is the principle of self-organization, as creation is called nowadays. *"Probably, something likely is going to happen"*, or: *"Something more viable is likely to survive longer"*. As far as the principles are concerned, nothing but these

tautologies is needed in the free market of evolution from the birth of matter to our own innovative thinking and acting.

How does it all start? What kind of “everything” or “something” has to “be there” initially in order to go through our “six days of creation”? Obviously, we cannot start in thermodynamic equilibrium – where it is most unlikely that microscopic fluctuations ever reach something more interesting. Indeed, we do quite convincingly see that it all started in extreme disequilibrium! Everything which we call our universe was once very closely packed together, flying apart in an extremely well ordered way. All those galaxies and their precursors which now fill the space within our horizon have been created out of this simple initial state near the “big bang”. Our horizon is at the distance which light could travel during the about 15 billion years since this beginning. That means, we nearly see the beginning! “Nearly” we must say because the red-shift approaches infinity as we try to look nearer the beginning. Thus, in a sense, red-shift manages to make the finite distance to the present horizon infinite. But this also has the consequence that the (still unknown) fundamental physics of the big bang is not very important for the present discussion. It is enough to say that we came from “something with practically no detailed structure except the unavoidable fluctuations”. Let me leave this blurred here.

Some scientists have been puzzled by the fact that matter and radiation were close to thermodynamic equilibrium when they were born from the “original substance”. This seems to mean high entropy, and all the subsequent formation of structure might then appear as a miracle. But this is only so, if we forget gravitation – which plays the dominant role in the beginning, and even today. With respect to gravity, the world is in extreme disequilibrium, near the minimum of entropy. The presently observed entropy of roughly 10^9 natural units per baryon has obviously arisen in the first fraction of a second in the formation of matter (perhaps in a so-called inflationary period), but this seemingly large number is totally negligible if we compare it with the entropy which would be gained by gravitational recollapse. This point has been made particularly clear by Roger Penrose in his book “The Emperor’s New Mind”. (For physicists: In order to calculate the entropy of a black hole – in units of Boltzmann's constant –, measure its radius in units of the “Planck-length” and take the square of the result. The radius of a black hole is proportional to its mass, and is 3 kilometers

for the mass of our sun. The Planck-length is about 10^{-35} meters …) All this talking about the low-entropy start of the universe may to some of you appear as theoretical fantasy. But let me remind you of the surprising experience that even without knowledge of the laws which govern the very beginning, present physics can successfully extrapolate back to the first minute and e.g. "predict" the abundances of Hydrogen, Helium and other light nuclei which have actually been observed in the oldest stars. And we have good reasons to say that before the first millisecond there were none of the present types of elementary particles "in existence". Thus, it may turn out that physicists come to a conclusion which theologians have always known: *As a creator, God did not have any realized properties.* What, however, were his *possibilities*? And how was a selection among them made and *realized* ?

3. The Space of Possibilities

The beginning of the universe offers an immense store of free energy for the subsequent formation of dissipative structures and an ideal sink for the entropy they produce. The energy source consists basically of two types of "fossil energy from the big bang". First, the regular expansion created (and still *is* creating) gravitational potential energy of matter which is eager to form lumps under its own gravity when irregularities develop; second, the fast expansion in the first few minutes prevented matter from trying out more than a few initial steps into the periodic table of elements. Matter could not reach full nuclear equilibrium in such a hurry. It was, therefore, likely to attempt this again later in stars, i.e. after the formation of lumps which stabilize themselves against further collapse for a long time while they slowly burn this kind of "fossil nuclear energy" in self-regulating processes. On the other hand, the sink for all the entropy from collapsing lumps and from "friction" (in the ensuing long-lived dissipative structures like galaxies, stars and planetary biospheres) is the dark sky. This nearly bottomless sink is due to the cold horizon – i.e. the low temperature of the background radiation (only 2.7 degrees above absolute zero) – which is itself a consequence of the universal expansion, i.e. again a consequence of the big bang. (If our universe has enough swing to expand forever, this "bottom" will sink deeper and deeper. If the world should fall back into a "big crunch", the story will be diffe–rent, but this must not bother us for many

billion years – and, for the moment, allow me to leave this topic to John Barrow, Frank Tipler and other disciples of Pierre Teilhard de Chardin ...)

This simple beginning of the history of creation has laid the foundation for everything to come: The sources of free energy, the sink for entropy, a huge number of nearly independent places for further trial and error – and a lot of time. The nature of time, and especially its "arrow", has puzzled many physicists and philosophers. I like to speculate (like others) that time does not have "a direction in itself". I hope that in a more fundamental theory the *acts of realization* may turn out to be a proper basic concept, and that they create more space and time and space of possibilities as they "happen". But I think that even in the incomplete theories of today the direction of time is by definition that of the growth of entropy. The second law of thermodynamics is just a special case (for an isolated system) of the tautological statement that "probably something likely is going to happen".

If there is a stochastic element in the realization of possibilities, any process becomes practically "irreversible" after very few steps. It is infinitely unlikely to find the way back by chance, but there is always a new way opening into the immense realm of possibilities. The "difference between past and future" is a consequence of the large number of possibilities which the world has, and of the fact that it started with a most special one, near zero entropy, which could not but become more complex. "Being" doesn't define a direction of time. "Becoming", however, does.

All this modern poetry about the idea of time is variations on one and the same theme: Start from a uniquely simple beginning, with immense swing, into a realm of inexhaustible possibilities. On the other hand, it is also this character of the common beginning which via the high global symmetry of our universe allows the choice of a universal time coordinate. (This would not be guaranteed by theory alone. Remember the theory of relativity and its consequence that the time-interval between one and the same pair of events may not only be judged as long or short by two different observers, but that in special situations involving black holes even the difference between *finite* and *infinite* duration disappears! The concept of *eternal existence* becomes *relative*. …)

Now, what could possibly happen in our universe once it had taken off and started wriggling? The longevity of matter and astrophysical structures

(in their "proper time" or in universal time) can be understood from the laws of physics. To some degree, we are able to calculate probabilities for their formation and survival under the typical fluctuations during early epochs of universal expansion. We can not yet do this for the *very* early period, because fundamental theory is still incomplete. And certainly, for the much later stages, e.g. when life and mind have been reached, a mathematical treatment will forever be impossible because there are too many possibilities of configurations and interactions. But there is no good reason to doubt that the *principle of innovation* remains the same: *Random fluctuations, as organized by already existing structures, try neighbouring possibilities, and more viable ones are more likely to survive.*

Talking about "neighbourhoods" implies some concept of space. One might think of the "phase-space" of all states of position and velocity of particles in a "classical" physical system, or of a more modern idea like "the wave-function of the universe". However, with present physical theories such concepts cannot yet be clearly defined. Therefore, I prefer to speak rather vaguely of a "space of possibilities". Clearly, such a space has practically infinitely many dimensions. Remember the example with the number of different relation-structures of only 24 things, or the fact that there are probably no two identical molecules of the same type of protein in one of our bodies, or even in all living beings on earth! (Considering the number of possibilities, small variations which do not influence the "functions" seem extremely likely in the formation of any enzyme …) It is also clear that *nearly all possibilities never have been and never will be realized* in the history of our universe. Every moment in history is just a point in this space, and the whole history is a single path. It springs from a region (or point?) corresponding to the "simple" big bang and runs "upwards" to ever higher complexity, realized by more and more refined dissipative structures which feed on the flow of "fossil energy from the big bang" and dump the entropy in the sink of the horizon (and, partially, in collapsing black holes).

At any moment in the history of creation, the "upper" end of this path, the "presence" at that time, is groping its way further into the space of possibilities via the fluctuations. Near the beginning the more likely choices were simple enough to allow us to "understand" them or simulate them on computers. But as more and more dimensions of the space of possibilities

become realized, diversity is growing so much that this is impossible. The tiniest fluctuations, very small "accidents", can influence the path decisively. (Just think of the story of your own life!) Further up the path of world-history, when many complex sub-systems have evolved, we may for some of them and for some time neglect most of their "outside" interactions (except some feeding and relieving flows of energy and matter) and look at them as "isolated systems". "Subspaces" corresponding to relatively isolated parts of the world – like a galaxy, a planetary system, a biosphere, a species, a living individual, a human brain, a society – are themselves practically still as "infinite" as the whole space of possibilities. ("Even a tiny fraction of this kind of infinity is nearly as infinite as the whole".)

Is there any general principle which governs the choice of the realized future among the immensely many different neighbouring possibilities? Does perhaps the concept of entropy offer a guide?

4. The uselessness of the Second Law

Some of you may ask for "selection rules" which might tell us why the increase of complexity is so obviously more likely than a direct evolution towards configurations with the highest entropy. For the whole world, in case of a closed universe, the answer is simple: Its final configuration, with maximum entropy, would be the "big crunch" (– mind the essential difference between the initial and final "singular" states which have minimum and maximum entropy respectively!), but this would only be reached after gravitational attraction has stopped and reversed the universal expansion. This would take about fifty billion years. Obviously, comparing entropies is not sufficient for judging the likelihood of somewhat nearer possible futures of the whole world. And the situation is not much different when we ask for the future development of sub-systems! Why do galaxies or stars not straight away collapse into black holes although those have an entropy many orders of magnitude larger?

Just look at such dissipative structures, and you see that their rate of entropy production is not determined by the "distance" from ultimate thermodynamical equilibrium (including gravity!), but by much more intricate features. In astrophysical structures those are e.g. the transport processes for angular momentum and various kinds of radiation. Entropy

production in a confined region creates a flow of “waste” energy, directed away from its source, eventually towards the horizon. In the surrounding, this represents a flow of free energy which will help the fluctuations to reach and try out more complex possibilities. In a star, e.g., the flow from its centre excites the surrounding material into a state in which the central entropy-production itself is regulated and (for light stars) extended over billions of years. Relatively weak interactions in the outer layers manage to control the strong interactions in the centre. Further outside the flow is used again, and this is, e.g., why astronomers find clouds of quite complex organic molecules around young stars. On planets, as we know, more and more sophisticated details can come into play. The flow of energy (which appears as free energy from one side and as entropy from the other, and which comes ultimately from the big bang) finds more and more twigs and twiglets in ever new dimensions of the space of possibilities. The “decisions” in all the bifurcations are made by fluctuations, but the “transition-probabilities” depend on many properties of the realized structures and their reachable neighbourhood.

Clearly, the non-viability of our present economy has to do with the entropy production in the wasting of energy, the squandering of resources and the choking of sinks. On the other hand, dissipative structures *live* on entropy production. Whether a given production rate is viable or not, cannot be concluded from the second law of thermodynamics. This does not even offer help in understanding the drive towards higher complexity and its successes and malfunctions. Neither does the formulation of a “fourth law”, tailored for judging the chances of mixing and unmixing matter. Georgescu-Roegen’s motives in proposing this, and his understanding of the destructive consequences of our present dealings with resources and sinks of raw-materials are certainly to be welcomed, but it does not make sense to introduce several kinds of entropy and formulate separate laws for them. In principle, there is only one kind of entropy but in the realm of real complexity this concept is anyway quite impracticable because one does not know which degrees of freedom have to be taken into account and which “coarse-graining” must be chosen in the definition of the system and its “macroscopic states”. The situation is particularly unsatisfying in economics, where one uses the word “system” even though

one knows that the most important degrees of freedom have been neglected in the theoretical modeling.

One may be tempted to think of some extremal principle. Doesn't better viability mean longer life through more economic use of the resources? So, shouldn't the use – and, thus, the rate of entropy production – be minimized? Obviously, this is not true. Even black holes do occasionally form. But neither is the contrary true. Because of the immense number of possible dissipative structures it has been likely in history to find some with relatively long internal time-scales, i.e. long-lived ones. (In this context, life-time does usually not mean that of an individual material structure. The concept of individuality, which is lost at the level of particles, has its difficulties at the more complex levels, too. In more general kinds of metabolism not only matter and energy are exchanged and "consumed" but all sorts of "individual" structures. We may e.g. also speak of the life-time of species or even of a planetary biosphere.)

Of course, if we think of all possible paths in the space of possibilities, there are certainly always quicker roads to ultimate equilibrium. But in the labyrinth of so many other paths with long delays in "stations", such direct roads are unlikely to be found via accidental fluctuations. Therefore, the speed of approach towards equilibrium does not necessarily have a positive selection value. On the contrary: If possibilities with slower internal dissipation can be realized (and protected from external disturbances) they are likely to survive. On the other hand, such structures are so stable because they have less internal fluctuations. (An extreme example is the proton, which is perhaps also a dissipative structure, but with a practically "eternal" life-time of more than 10^{30} years …) The long-lived structures cannot play a "creative" role in the "invention" of a more complex future. They will rather be used as building-blocks by "higher" structures, which organize weaker interactions between them. Viability has a wide spectrum from maximum stability to maximum evolvability. (Please, be startled by that word, which suggests limits to growth! Are we, at last, making headway towards economics?)

I am afraid we must accept that there is no reason to expect any general "selection rules" in the evolutionary process, except those of logic. Logic implies, of course, the generalized entropy law, i.e. the tautology that "probably something likely is going to happen" and that this will be the self-

organization of something viable which can be found by fluctuations among the neighbouring possibilities. But how should such trivialities teach us how to judge values? Is the *new* more valuable, or the *old* ? Stability or speed of change? You may have become aware that the time-scales are important in some way. But wasn't it pretentious to promise you a better understanding of the concept of value – just from logic? It's true that from a tautology there follows everything, or rather everything *possible.* But isn't it cheeky to claim to have understood something? Allow me a few more fluctuations between views of the space of possibilities. Perhaps we find the invisible hand … ?

At many moments a huge number of neighbouring possibilities may be nearly equally likely to be reached – and, therefore, in fact each extremely unlikely. But one of them *must* be realized. Something *must* happen – which is just another way of saying that time does not stop. If there are many possibilities which can be reached with similar but very small likelihood, the result will be very sensitive to small fluctuations. Then, in spite of the weakness of a system's external interactions, it may be a poor approximation to consider it as "isolated". The viability of its complexity might be founded in relatively weak interactions with many different parts of the whole. If complexity evolves very far in this direction, its viability is threatened by chaos and collapse. As we saw, viability and evolvability are intimately connected on more complex levels. A higher organization of trial and error increases not only the chance of success but also that of failure. Still, this kind of failure isn't likely to lead to deep fall if there are sufficiently many independent trials. (Nietzsche's collapse did not yet mean the end of mind …)

If we try to visualize the history of the world in the space of possibilities as a single line, we loose practically all intuition. We cannot think of all dimensions at the same time. We rather imagine infinitely many sub-spaces attached to the line in each moment, and view the complex dissipative structures as bundles of nearly closed loops in such sub-spaces. Then our "world-line" consists of hierarchies of intricately interwoven narrow spirals. Nearly everything repeats itself again and again in nearly closed "orbits", i.e. loops which have been established as viable in the long process of trial and error. But there are "accidental encounters" which occasionally cause radical changes, and with extreme resolution we should be able to follow

the history of such accidents back to tiny wriggling motions which represent spontaneous fluctuations. At the "present" momentary end of all those spirals, the random events give the whole bundle a chance to gain essentially new structural features, but this evolutionary progress through smaller and larger revolutions, the "Darwinian upward-drift", is very slow compared to the essential internal time-scales of the spiral loops. Isn't it? (It is no longer – and this is why I am talking here!)

5. The Invisible Hand: Self-Organized Chance on Complex Attractors

I have insinuated that complexity and value are practically synonymous. But does this help us to understand what value is? Even the concept of complexity is difficult to grasp mathematically. The essentials of a complex system cannot be analyzed or synthesized in a reasonable time – not even by the largest computers which might ever be realized. Of course, mathematicians have been able to invent abstract measures of complexity – which may e.g. in principle assign a single number, some "degree of complexity", to a given message or system – but for real systems the calculation of such numbers would either take practically infinite time or miss all the essentials, i.e. the true value. In fact, the practical determination of a degree of complexity of a real system would have to follow the immensely many accidental bifurcations along the path of its origin, i.e. the whole "wriggling-process" of trial and error in co-evolution with nearly everything else in the world which influenced the probabilities of choices.

The complex value of a genome or a poem does certainly not lie in the correlation structures of its letters but in their "context" within the whole world of life and culture. If we look at some "strange attractors" in the phase space of a simple dynamical system or if we let a computer "zoom in" at some micro-region of the fractal edge of the Mandelbrot set, or let it draw contours of the Lyapunov number of the simplest non-linear systems of difference equations with two parameters – we are overwhelmed by a feeling of immense complexity which we sense as beauty. But in a way, these are all still extremely simple structures, because they arise from trivial iteration processes, the rules of which can be written down with a few

symbols, and because in their construction there enter no external interactions (except the random motion of the eye or the thought which decided where to look). What we call *the functioning of a cell* or *the health of an organism* or *the viability of the biosphere* or *the value system of a society* – all these *attractors in the space of possibilities* are infinitely more complex than such visualizable patterns.

Do scientists really claim that the whole beautiful complexity of our world evolved from the utmost simplicity of the big bang via random fluctuations, i.e. "pure chance"? Yes, this is the working hypothesis! But we must understand that the evolution of viable structures implies an *increasing organization of random fluctuations* ! Any viable "gestalt", a type of dissipative structure of matter and energy in space and time, can be looked at as an "attractor" in the space of possibilities. Considering the number of possible relation patterns in the world, this space must be full of infinitely many more or less attractive ideas of structures which are consistent with the fundamental laws. The question is, whether and how a *specific* attractor can be reached, how it reaches out for others, and how in an immense number of such steps the "Great Chain of Becoming" is realized – this one and only real history of our universe among infinitely many possible others which did *not* happen, and never will. (Of course, the concept of a universe becomes itself doubtful at this stage, and one must start speculating about a "multiverse" of infinitely many universes. Their conceptual position in the space of possibilities is not very different from that of the unrealized histories of "our" universe …)

You often hear, the real world could not arise through chance because the probability of "success" would be negligibly small: "If an ape played with a type-writer, many ages of our universe would not suffice to let one of Shakespeare's sonnets arise by chance". But there is a fundamental misunderstanding in this argument. Chance is organized on a very much higher level in human mind. Some complex features of this organization we name by the words "consciousness", "intuition", "wisdom", "free will", "responsibility". But chance is still at the root of all this. An identical twin of Shakespeare would have written quite different poetry – if any at all. And if you would have "clones" of Shakespeare, born and brought up elsewhere and in other epochs, the probability for the appearance of one of his sonnets would be infinitesimally small – similarly small as with that ape and

type-writer. And even with the real Shakespeare there is the same problem: Infinitely many random events have gone into each line of his poetry – every single line is, therefore, infinitesimally likely, i.e. extremely unlikely, namely one possibility out of practically infinitely many. However, once this level of complexity had been reached in his mind, something *had to* happen at this new front of creativity. And, no surprise, it turns out to be something very attractive for other highly organized minds – which does not mean that from now on all minds move exclusively along the sonnet-attractor.

An attractor is a pattern in some sub-space of possibilities which attracts the path of a subsystem when it happens to come near. With a less fashionable word we might call it the "idea" of this pattern. Any realization is only an approximation. It is fluctuating in its basin of attraction due to internal and external random events – which may be spontaneous quantum fluctuations on a microscopic scale or accidental encounters on larger scales. The latter have a history, but if one could analyze this history, all accidents could in principle be traced back to microscopic fluctuations – at least in the big bang, but usually in the much nearer past. (Remember the "butterfly-effect" in meteorology!) As random fluctuations let the path of a system cross the border between the basins of neighbouring attractors, the tautological principle of creation ("survival of the more viable") takes care of a statistical tendency to evolve in the direction of higher viability, which is the "better idea". This quality must be ascribed to the attractor – not to the realized path. It is, therefore, again a tautology if we say that more viable attractors organize the statistical patterns of their internal and external fluctuations in such a way that *typical* fluctuations and accidents are less likely to lead outside the basin of attraction.

All possible ideas, i.e. attractors in the space of possibilities, may be thought of as fixed and timeless. Time is, so to say, the counting of steps in the process of realization which draws a path into the space of possibilities and tries and proves the viability of more and more attractors. An attractor which has proven its viability is likely to be used as a building-block in the evolution of still higher structures which derive their own viability from the fact that they organize the fluctuations of their constituents even better, protecting them from all stronger interactions, and thus stabilizing their "attractivity". Higher attractors organize relatively weak

interactions of their constituents. Successful “enslavement” of sub-ordinate structures in more complex higher ones does, therefore, usually not mean a loss of all their individuality, i.e. their proven viability. Molecules don’t try to change atomic nuclei, life doesn’t try to change the genetic code, mind didn’t – until recently – try and change the biology of the immune system or the climate of the earth. The obvious hierarchy of attractors is not a hierarchy of “power”. Evolution is co-evolution. “Fitness” of a part is a property of the whole. The Darwinian drift towards “higher” attractors is not at all based on some mysterious “drive” of the attractors to “push aside” and replace others. It is a logical consequence of a large number of independent trials of possible attractors, with slightly different realizations at many places and times.

In summary, we may say: Self-organization of complex systems is the necessarily accidental organization of accidents, the organization of chance by chance – in which more viable systems must arise if they are possible in the accessible neighbourhood in the space of possibilities. We saw that in our universe the inexhaustible offer of “fossil” free energy from the big bang makes it likely to reach higher states, i.e. a higher organization of the fluctuations, via random fluctuations. Therefore, “it is likely that extremely unlikely possibilities are realized”. This entailed the co-evolution of ever higher complexity, from big bang to consciousness. Of course, in this general sense, minimized interaction, i.e. better isolation, of certain parts is included in the concept of complexity as well as intricately organized co-operation of others.

At this point you may have started thinking of your own brain, well kept in your skull – and of the realm of ideas which are approached in very weak interactions in and between our brains. Attractors of the mind become physically realized in the self-organized growth of connections between neurons (Gerald Edelman’s “Neural Darwinism”), in the firing-patterns of those neural networks, in language, gestures, music and all other sorts of communication between people, in libraries, in houses and all other works of art and technology. Due to internal fluctuations and accidental encounters in souls and minds and cultures the path wriggles upwards through attractive ideas. There is no difference in principle to the “pre-mental” earlier stages of evolution. However, on the new level of complexity it becomes even more evident that attractors in the space of possibilities

can be "realized" only approximately by matter in space and time. Think of mathematical ideas – like the set of natural numbers, or categories of infinity, or the Mandelbrot set. What is *their* place in the space of possibilities, and their relation to the line of reality which time draws through it? And where are the Brothers Karamasov, or The Art of the Fugue, or England, or I myself, or my dead mother, or God?

Where do we place all our customary fancies about differences between "physical" and "metaphysical" realities and possibilities? If you are philosophically minded you may resume the quarrel whether "*universalia sunt realia*", which occupied outstanding European minds for centuries. But more urgent questions have developed since. Though the overwhelming majority of possibilities in our neighbourhood is of this "ideal" kind, more and more very material "hard-ware" is being selected for realization. The probabilities in the decisions at impending bifurcations seem to be determined by rather compulsory motives and motions. More simplistic ideas seem more likely to win. Let us try and reveal the nature of this invisible handicap!

6. The Visible Foot

Can you see why all this worked beautifully as long as mind had many independent areas for trial and error which were sufficiently weakly connected with the rest of the world? And can you see why there arises a problem when quick brains start effecting decisively their own roots, down to the nuclei of atoms and cells, and up to the global cycles of climate? What about the viability and evolvability of systems which try and plan improvements of their environment and their own "building-blocks" in a hurry, and globally? *Why* in a hurry? And *why* globally?

I think I don't have to explain to economists why speed and global unification have a selective advantage. This is a logically unavoidable trend in the evolution of evolvability in a spatially finite system. Attractors on which the wriggling is organized at higher speed, are likely to conquer new frontiers in the space of possibilities more quickly than others. At any epoch in history, and in any region in physical space, some types of attractors are the most successful in this sense. We may say that such structures are locally "at the front of evolution". However, the definition of

this front of most successful innovation may depend decisively on the time-scale on which the success is judged. In all that trial and error it must often be likely that some attractor is very successful on a short term but destructive in the longer run. Clearly, this will be more likely to happen if there is a higher speed of innovation at the "front". Important interactions with underlying "sub-attractors" (which may be internal or external) or with more encompassing, larger attractors will later turn out to have been neglected. The trial may then turn out to have been an error which can no longer be mended by more trials in the neighbourhood, and this front collapses.

This kind of mistake is a normal constituent of the evolutionary process. Think of a cell of your body which undergoes a small genetic fluctuation – e.g. from some radiation or unfamiliar chemical agent. Perhaps it is successful, and the cell discovers that it can multiply much faster than in its old organization. It wins the competition with your immune system, attracts more and more of the free energy available from your metabolism, grows into a tumor, conquers new frontiers in other organs, and swamps you with its waste – which is deadly poison for you. So what? This is probably a negligible event in world-history. You must die anyway, and there are many others to continue with trial and error. – We can see the same type of phenomenon at an even lower level of organization: Think of the water-lily on an pond which has become over-fertilized in some chain of fortunate accidents. What a fantastic offer of free energy! The lily grows and grows, covers the whole surface, blocks the sun for the biosphere underneath – and lets it die. Of course, now the lily dies too – and again it isn't a lack of free energy which causes its death, but the poisoning of the whole system by the waste, that is by entropy production. But again, this isn't a catastrophe in world-history. There are other ponds from which life will trickle back. And, in fact, much of the deadly entropy produced in this instability will be used as free energy by many micro-organisms. So what?

Are there other planets in our neighbourhood from which intelligent life could come back to the earth if we let it collapse into a state similar to the Jurassic or the Precambrian? Probably not. Or would there be a chance to try again with more success? Well, the sun will offer its flow of entropy, i.e. the earth's free energy, for approximately another 5 billion years. Creation would go on. But we have understood by now, that it would have to find a totally different path in the space of possibilities. Only the features which

are inevitable or very likely for purely logical reasons would have to become realized again. I claim that the present global acceleration crisis belongs into this category. It is not due to a chain of unfortunate accidents, but intimately connected with the level of complex organization reached in us – and with the fact that planets, the sites for long-lasting trial and error under relatively stable environmental conditions, are round and isolated. The selective advantage of a higher speed of innovation is very unlikely to be constrained via self-organization before trial and error approach the global scale. The reason is, in short, the success of what we call power.

We saw: Faster "wriggling" in the space of possibilities means faster progress. So, the speed of wriggling will increase and so will, correspondingly, the speed of innovation at the front. As an example for the organization of higher speed in our history, think of the "invention" of sexual reproduction. The old-fashioned simple splitting – i.e. copying with a few mistakes – was replaced by combination. This inflated the rate of "accidents" – i.e. the speed of wriggling in the space of possible genetic structures. Without this acceleration it would have been too unlikely to evolve the richness of our biosphere, especially the animals with their brains and nervous systems. Still more revolutionary, of course, was the evolution of the cerebrum. This shifted the front of trial and error from the molecular structure of DNS and proteins to the patterns of "firing activity" in huge neural networks. Remember the number of different possible relation-structures of twenty-four points – larger than the number of atoms in the universe! Our brain contains tens of billions of neurons, and each of them is connected to tens of thousands of others …

Among the possibilities of this system there is what we call soul and mind – attractors of very much higher complexity in newly opened dimensions of the space of possibilities. The exploration process does no longer have to wait for a quantum of cosmic radiation or some poisonous molecule to change a gene in an egg or sperm-cell. There are immensely more fluctuations in the firing pattern of brains. Even the thermal fluctuations may come into play (– think of fever-fantasies!). And more than that: The principle of combination gains far more influence now. Via language, a sort of hypersexual exchange, more and more individuals share their experience while they develop. The time-scales of loops in the leading attractors and of their innovation become comparable. Soon, 10 billion brains will be

connected by a few TV-satellites and evolve as one. What a step forward in the organization of the tools of exploration! What acceleration! Now, how many new options do you want to be offered every day? There doesn't seem to be a limit! Isn't the globe being conquered by better and better ideas, ever more quickly?

We have reached the seventh day of creation. Remember, how God looked back every evening and saw "that it was very good". Very natural, we may think, when we imagine how much time his wriggling fingers had in order to try and find more attractive shapes. The six days in the old myth of creation are about fifteen billion years in the new. The old myth didn't take numbers so seriously. In fact, the shaping of man took only the last minute of that whole week, and written history is a blinking of the eyes. But I am puzzled now. It doesn't seem to be clear which day it is *today*. Didn't a leading German specialist of genetic engineering recently announce the dawn of the *eighth day of creation*? Can someone tell me what happened on the seventh? Wasn't the Sabbath meant to be a day of rest? A day for contemplation, i.e. for the unfolding of possibilities of soul and mind, for the evolution of arts, of ideas, of happiness, of love? How do the more and more accelerating restlessness and the demolishing of past works of creation fit into this picture? What has happened?

Excuse me for reminding you of old stories. There was that angel who had watched it all. He understood the laws of nature: How elementary particles function, and atoms, molecules, solid bodies and the genetic code, and neural networks, and societies with well-organized advertising. He even attempted to understand markets … When we became curious, like any intelligent child, he enlightened us. Therefore, he was called "the bringer of light", that is *Lucifer*. (In the Greek myth, he was called *Prometheus*, i.e. the "fore-thinker".) He isn't at all malicious or evil. He just wants to improve the world – do exactly what God had done, and with the same means. However, he wants to do it in a hurry.

He has not realized that the laws of logic come before the laws of nature, and that the logic of creation, i.e. of self-organization, implies some simple conditions of success: There must be sufficient diversity in trial and sufficient time to eliminate errors before they have destroyed the viability of the basis. Otherwise, it is *not* likely to find more complex attractors in the space of possibilities, and the wriggling at the front of evolution becomes

unstable. More and more free energy is turned into entropy via quite complicated dissipative structures. Locally, and for a moment, they may still seem very attractive, but they wriggle so quickly and extensively that the coherence of that bundle of spirals gets lost. Complexity falls apart, turns into complicatedness. Problems are being felt. You know the answer: No problem! With faster wriggling they can be solved! You know the result: Several *new* problems have been created, which are being felt on a larger scale, and which have to be solved still a bit more urgently. The answer: No problem …

You see why that race between problem-solution and problem-creation had to set in, down the road to hell, which has been paved with so many good intentions. Now, after his fall, the enlightening Lucifer has a new name: The Devil, i.e. *dia-bolos*, i.e. "he who throws things into disorder". Why? Because he wants to improve the world faster than it is logically possible. You see: The theory of value which I promised is nothing but the well-known *system theory of God and Devil*. Can we seriously apply it to economics?

7. Are We Free to Constrain the Devil?

Since the global acceleration crisis is implicit in the principle of creation, we cannot say that it started at any well-defined moment with one specific error. We may, however, say that the global aspect became manifest with the conquest of the globe by our own powerful system of attractive ideas. We are just celebrating the fifth centenary. What we call modern times, is the 500 years of self-organization of this enlightened power. Modern economy has a dominant part in this process. In short, it is the incessant discovery of more deviations from equilibrium which can serve as cheap sources of free energy to be used for the detection of new attractive possibilities. Exploitable sources of this kind have been serfs, slaves and whole subjugated people, as well as the energy sources proper and all the other resources – ultimately the whole realized creation. They allow "problem-solutions" which let more people of each generation live like kings of the preceding one – until the globe drowns in the entropy production of so many kings.

(Remember that *dis-covery* and *de-tection* mean the same as *apo-kalypse* – namely "taking a lid off". And *Pan-dora* means "the all-giving one"!)

The majority of economists either ignore the threatening collapse-singularity, or pin their hope on faster and more unified efforts of the same kind – i.e. faster innovation and global unification. However, those are *symptoms* of the devilish disease, and cannot be its *cure*. Some have understood that the world has been seized by an instability, but they tend to consider this as an unstoppable consequence of the laws of nature. If this were so, it wouldn't make sense to call it a "crisis". The proper words would then be "decline, doomed to collapse". In fact, the cancer-cell and the water-lily are certainly not able to stop their progress with their own means. In their case, the fluctuations are organized in such a way that they scarcely have a chance to escape from the unstable attractor once they happened to stagger into its basin of attraction. But such accidents don't make the whole principle of cells or water-lilies unviable – because there are so many organisms that immune-systems could evolve, and because there are so many ponds. These are qualities of the biosphere which don't have to be, and cannot be, organized by cells or lilies. Will the biosphere take care of *our* problems, too?

Scientists are easily taken in by the "biologistic" view in which "man is a species like others". Since biochemists, biologists and ethologists have found out so much about the principles of life and even the behaviour and "psychology" of higher species – and because scientists have been taught to talk and think only about subjects simple enough to be studied scientifically – they tend to push aside the fundamental difference: The essential level of man is his mind, and mind is realized on a very much higher organizational level than life! The essentials of human life happen in very different dimensions of the space of possibilities. We must not confuse the human species and mind. Their relation rather resembles that between life and matter, or between matter and the big bang. Mind is not a "property" of the human species. It has been growing on it, like life grew on matter, and matter grew on the "original substance" (which physicists may one day even describe as nothing). The threatening collapse of the biosphere must not be thought of as a "biological event". It is not due to a chain of unfortunate accidents of mutation and selection. It is, so to say, a spiritual event,

namely an expression of that mental disturbance which the ancients called the Devil. Inescapable, but superable.

There must be many recent approaches to theoretical studies of processes in what I call the space of possibilities. (I don't know them because I don't read much.) One of you quoted Richard Dawkins' concept of general structural ideas called "memes". Those are considered as analogs of the genes in biological structures. To the biological phenotypes, which continuously replicate the genes and try out their mutations, there will then correspond analogous "interactors" for the memes on the structural level of mind and its cultural and economical stage. One may then talk about mental, cultural, technological and economical evolution in a quasi-biological terminology. Progress – the generalized Darwinian upward-drift – is then due to the selection of more successful memes in the "meme-pool". Of course, this scenario is similar to what I have described with the visualization of "attractors in the space of possibilities". This similarity will not surprise you once you have understood the tautological character of the Darwinian insight. However, no matter which words and images we choose, we won't find help in judging values and choosing reliable paths from such pictures, unless we consider the question of time-scales and discover the logical inevitability of the global acceleration crisis and the logical conditions for overcoming it. Otherwise, any generalized evolutionary theory will remain an empty frame, or it will – more likely – be misused for a still more effective self-organization of the forces leading *into* this crisis. Like all science, it will serve very well as "opium for the people". Just imagine how much more effective advertising might become under the more promising and distinguished scientific name *memetic engineering*!

I have the impression that all evolutionary theorists shy away from one simple thought which leads immediately to what I called the "devil-theorem", i.e. the basic insight into the character of the acceleration crisis. When somebody claims that something is going too fast, the reaction of a scientist must be: *Too fast in comparison with what*? The answer seems to lie far outside the reach of scientific knowledge about the time-scales in the processes involved. Indeed, the answer is "pre-scientific" and comes from logic. Among the many evolutionary processes in a spatially finite system like our biosphere there is that fastest one, at "the front of evolution", defining the time-scale of innovation. But there is another time-scale invol-

ved at that front, namely the life-time or reproduction-time of those "leading structures". This will not become shorter in the course of evolution, because the internal complexity of the most highly evolved structures requires that minimum of time for maturation after reproduction. Therefore, due to the selective advantage of speed of innovation at the front, the two time-scales will approach each other until they coincide. This is the system-theoretical, "purely logical", origin of the acceleration-aspect of the crisis. It is obvious that it must become global, and that rush and global unification amplify each other.

It is very unlikely that this devilish attractor can be overcome by self-organization before the crisis has become manifest in both its aspects. Its prophets will be ridiculed or smashed by the successes of power. However, when the symptoms indicate the approach of catastrophe, there is still a chance to realize the idea of the "seventh day". The selective advantage of speed and globality may be constrained by conscious organization of mind and society. The idea may be overcome, that the "good" is something "better" which can easily, quickly and globally be found with the good will of a majority or the expertise of some elite. It sounds like an internal contradiction, that the same idea should then help us to overcome the crisis. It is again a tautology that a rapid global instability can only be overcome by quick and world-wide action – if at all. However, constraints may be more easily developed than all the details of a complex system. We don't have to and we must not design society, but only better boundary conditions for its development.

The devil is a highly organized attractor. It interweaves practically all other realized attractors of the mind, because mind fluctuates so fast. But if you are old enough to have a little experience with your own mind, you may have realized that the same can be said about God. The fact that the road to hell is so well paved does not necessarily mean that it has to be followed to the end. All along, beautiful paths can be found away from it. We have a word to describe those manifold possibilities of bifurcations: We speak of our freedom. But this does not mean chaotic fluctuation. As we saw, the ascent to viable complexity is due to the more refined organization of chance on ever higher levels. The history of human mind is *the self-organization of freedom.*

8. The Cloven Hoof in the Market

Liberalism is at the intellectual foundations of modern economy, but the idea that freedom has to be organized smells of dirigisme. Constraining the Devil is by many considered as a fiendish act of enslavement. To be sure, the ideological war of words is not very helpful if we want to approach the questions of economy from the point of view of logic and general system theory. On the other hand, ideology is an unavoidable guide in the world of ideas. We can never discuss decisions in all details, because those are not known, and not knowable. So, self-organization of freedom will always mean trial and error with a very blurred vision.

The usual scientific type of mathematical formulation and computation doesn't help here. It is mainly intuition what we need, and this does imply ideology, in a modified sense. Our various ideological principles have to be checked in the light of basic insights about self-organization, which I have tried to sketch here. Although the working hypothesis behind this picture introduces no other kind of realized mental phenomena beyond our own mind, it keeps a little bit of the traditional "dualism" in the discrimination of reality and possibility. In a way, the whole spiritual world lives in the space of possibilities. Doesn't this offer the chance for a *re-unification of materialism and spiritualism*?

Because of its irrefutable logic the evolutionary theory of the invisible hand and the visible foot may be acceptable for ideologists of many schools in science, philosophy, religion and even economy – possibly with the exception of some fundamentalists who claim that God or the rules of the stock exchange tell them directly which way to take at each bifurcation. All others might perhaps agree that God *is* the attractor which leads "higher" in the space of possibilities, but that he is found in the course of physical time via the worldly interactions – beginning with "quantum-fluctuations of geometry", through elementary particles, molecules, life-forms and, for the present, the abilities of our minds, which are wriggling in that basin of attraction. *Praying* is then a good word for our attempts to allow the self-organization of better sub-attractors. Successes are stored in cultural loops, and even in stone. If you worry about uniqueness, you must remember our first visualization of the space of possibilities, in which *reality* is a single line. If you are intimidated by too many dimensions, stay

in your homely subspace. In fact, I am doing this here right now. This doesn't mean that I deny the possibility that I know and use only a small selection of human mental abilities – but I am glad to say that even the known ones leave us a lot of hope.

We have the freedom to choose – not only as individuals but also as democratic societies. E.g., we must choose which dealers should be admitted to the market. Who should be responsible for this? Adam Smith already told you that the invisible hand cannot even build the light-houses, needed to show safe waters. Nobody but informed and conscientious people can take care of this. They must struggle to convince everybody. It is a misunderstanding of the idea of equal political rights, when such people leave the responsibility with the less informed majority. If you see rubbish and poison and weapons being sold and bought in the market, *you* must shout and act and try and stop this. The most important section of the market must be the free exchange of ideas, and exactly this cannot be regulated by money. If the view of the masses makes you wash your hands of it, your cowardice may cripple or paralyze the invisible hand. The front of evolution is in the individual minds. The ideas of a personal soul and of equal human rights have their roots in this insight. God can defeat the Devil and realize higher parts of himself only through *our* wriggling. Now we understand the peculiar notion, that God has to be *served*. Just one tiny complication arises. Someone said it: *Ye cannot serve God and mammon.*

Once a global instability has set in, you will find its organizational principle acting everywhere. Nearly everything which happens on earth today, is organized in a wrong way! This sounds ominous. However, since nearly everything develops from good will – and not from malice, as we saw – it will be possible to find a few "leverage-points" in the organization of society, from which changes will spread easily to many other points of that complex network. I think the monetary system, land-law and other so-called property-rights are such leverage-points from which the self-organization of freedom, i.e. the organization of the necessary impediments to "size and speed", might start. Of course, this can and will not happen in one mind. I shall only give a few hints and leave the necessary research to you, the experts. (I have said a little more elsewhere, also in my last book: "Das Grundgesetz vom Aufstieg", Carl-Hanser-Verlag, München 1989.)

The basic ideological principles of the present organization of society are called democracy, free market, and capitalism. People have needs, demands, wishes – often very "selfish" ones – but all this is supposed to come into a viable quasi-equilibrium with a Darwinian upward-drift if (1) everybody has the right of vote and thus can every few years influence the choice of the main figures in the administration, and if (2) everybody has access to the free market of ideas and goods which organizes itself via supply and demand. These ideas are summarized in Adam Smith's image of the invisible hand. The idea of democracy sprang from an intuitive insight into the evolutionary principle of self-organization, supported by the experience that we don't have reliable means of classifying people according to the quality of their aspirations. So, in its root, it is a good idea. However, future thinking must turn to the long-neglected question which scales are optimal at various levels of democratic organization, and how the relations between these levels should be organized. Much of the present "constitutional" state of our planet and its regions, and much of the recent developments in the political organization is clearly "wrong" from the point of view of viability and evolvability, which would require more diversity. Size and speed will have to be constrained in the world's *political* organization, too.

The idea of a free market is, at first sight, exactly what evolution needs. Everybody participates in the political and economic trial and error, and if improvements are possible and can be reached by present activities, they are likely to be realized. The main defect of the so-called socialist system – which just collapsed at last – was the attempt to replace the free markets of opinions and goods by planning in small groups of "those responsible". Now, everybody admits that "planning replaces chance by error". Originally those systems were "devilish" not because of bad intentions but because of good will – like with Lucifer. We must not forget that socialist ideas formed at a time when children were forced to creep through mines and chimneys in order to survive. But degeneration of good will is inevitable if principle flaws block the chances to reach improvements. Then, the "evil" side of the Devil tends to show up – which is a very subtle feature of that attractor. Atrocities certainly accelerate the recognition of the non-viability of a system. Unfortunately, the fact that the other system collapsed does in no way prove a much longer viability of ours. In fact, the largest contributions

to the ongoing destruction of atmosphere, soils, water, species etc. – as well as the weapons for most of the brutal violence in the world – come from the richest western democratic societies. The ideology of the free market does not guarantee viability. The spread of cancer-cells is a free-market phenomenon, too. When the immune system of the organism has been overcome, freedom becomes unlimited – for some participants at the cost of others. So, which constraints should be taken into consideration as an immune system for the free market?

A critical shortcoming of present realizations of democracy and markets is the extreme economical inequality. If people cannot even satisfy their fundamental human needs through relatively simple own efforts, they can be easily exploited. In order to properly feed and house your family and bring up your children, you need a "job", and you only get the job if you do what the "employer" wants. As a result many people are working hard to help producing goods which they have long recognized as rubbish or poison. But they must help producing and selling *something* – with the means of production owned by others. So, a majority depends on producing and selling rubbish and poison. And on advertising it! Demand is often created by supply – like in the drug-scene. Science and technology do their best to supply more "opium for the people" and let themselves be paid by the producers of poison to supply the wanted "risk-assessment". It is cynical to talk of a free market when people are not free to do something less destructive, and can satisfy their basic demands only with so many "side-effects". The democratic idea – to define value via demand – must then lead to break-down.

Economic inequality is still increasing – in practically all nations as well as world-wide. With small variations the present distribution is like this: The first tenth of the people owns half of all property, the second tenth owns one quarter, the third tenth one eighth … and so on in the geometric progression. This means that the vast majority of people own scarcely anything. One might think that this "injustice" is at least steadily being corrected when there is so much good will everywhere. It isn't. The distribution is changing, but still further in the wrong direction! This means that the majority of people work for their bare life or even starve in order to make a minority richer.

Increasing inequality is organized via the idea of capitalism. Capitalists tend to confuse this concept with that of the free market, but it is something quite different. The basic idea of capitalism is income from property. A very attractive idea, admittedly, if you own something! But in fact it is the most effective suppressor of the individual and collective components of the mental immune system, the main organizational principle of the global acceleration crisis. Why that? As an economist, one must not talk about the problem, you know, because Karl Marx wrote so much about it and is still being blamed for the consequences. As a physicist, I may be forgiven a few remarks: If some people are allowed to appropriate the foundations of living of others, the vicious circle of growing inequality sets in. The owners let the non-owners pay for the unavoidable use of their property. So, the property grows, which means that the owners become richer and can appropriate more of the foundations of living of others, even further away.

Since people are no longer the main means of production, it is useless to own them directly. It is much more rational to own just the foundations of their life. The old-fashioned kind of slavery could be abolished. But most people in the world are still forced to misuse their mental abilities for bare survival. This is not what those were "meant for" in their evolution. (Remember: Like life is not there for the functioning of molecules, mind is not there for the functioning of life.) The degeneration is not always a consequence of brute force. Unobtrusive gifts can lure you into deadly addiction. A particularly vicious feature of this attractor loop of appropriation and expropriation is the fact that capital ultimately also controls the foundations of living of university professors, including economists and even moral philosophers. This is why there is so little scientific and ethical discussion of this obvious and very effectual phenomenon. It is considered as a law of nature. Perhaps you are right, then, to leave its exploration to physicists?

Modern history is dominated by consequences of this fault in the self-organization of society. It is tempting to write volumes like Marx, but I cannot go into details here. I must, however, at least mention the obsession with the growth of gross national product. It has been clear for decades that the contributions in the GNP which are related to damaging activities are growing fastest. But whatever has been paid for with money, is still simply added up in the GNP, as though economists had never heard about

negative numbers. So strong is the general feeling that money is something positive! Something which has not been bought or sold is worthless. People with zero per capita income are, in a way, considered as non-existent – although the majority of all ancestors of economists were among those, too. Recently, many of you may feel a bit ashamed about the misuse of the GNP, and rather keep silent about it. But it isn't enough to be ashamed of dangerous stupidity. You must name it and attack politicians and media whenever they talk about growth without mentioning entropy or cancer. Economic progress has become a cancer of the mind, and it metastasizes throughout the biosphere. When it has become so overwhelmingly clear that most economic activities are damaging our roots, why don't you admit and loudly demand that the GNP must *shrink* ? We know the answer: Because the whole political and economic system would break down! And that seems unacceptable – until one has understood that this system organizes a far more encompassing collapse, along that unstable attractor which I called the global acceleration crisis. Once you have realized this, you will of course try and help break down this system to let a more viable one grow.

9. Reduction Strategies

First, forget about GNP and its "sustainable growth". Second, forget the idea that you have to replace GNP by some other "welfare-indicator" which should grow. The devil can only be defeated if we stop doing things which we have recognized as wrong. The concept of "qualitative growth" must be taken seriously! The first steps towards qualitative growth mean quantitative shrinking in the areas which we have recognized as most damaging. E.g. the production of such chemical compounds and materials must be reduced, which are probably incompatible with the viability of our biosphere (because they didn't co-evolve with it) – no matter how many people profit from the investions, the jobs, the trade, the application and consumption, or the attempts to heal the damages. Most of such wrong activities cannot be stopped over night. Reduction strategies have to be developed, where the time-scales will depend on the present speed of destruction due to each activity.

Sorry, there will be *planning* involved. Not for the design of some saleable good, but for the *reduction* of sales, especially for the greatest runners. So, the kind of thinking necessary will appear as "counter-economical". But economy *has to* be countered when it organizes collapse. Let me illustrate this with only one example – the energy problem: Practically all climatologists agree by now that the continuation of the present world-wide energy consumption would overthrow the earth's climate in about 5o years. Due to many unknown or ill-understood positive and negative feed-back mechanisms the time might be longer or shorter, but most experts agree that it would be very foolish to rely on good luck in this case. So, a reasonable energy policy should set the aim of reducing the present consumption of fossils by about a factor of five within the next fifty years. Today, four fifth of mankind do practically not contribute anything to the consumption, and the population is still rapidly growing in exactly those "under-developed" countries. Therefore, if we assume that we (the "developed" countries) manage to reduce our energy consumption to, say, 20% of the present German one, and if you give justice a chance in 50 years and allow the rest of the world to approach the same level from below, world energy consumption will roughly remain the same as today – namely about 10 Terawatts. With the about 10 billion people living 50 years from now, this would mean about 1 kilowatt per capita – as compared to more than 5 kW in Germany and more than 10 kW in the US today. (This means the *daily production of your own body-weight in carbon dioxide*! One human generation scatters to the winds what the biosphere stored from solar energy on a millionfold longer time-scale!)

1 kilowatt may sound like utmost poverty to some of you. But, believe me, nearly all our present energy consumption goes straight into entropy. With more intelligent use, to be developed by the next two generations, 1 kW will be comfortably enough. However, even this radical reduction of the worst sins would not bring the earth one step nearer to viability! The same two generations which must achieve this tremendous task of saving energy, will at the same time have to develop alternatives to fossil energy at the scale of the global consumption, i.e. 10 TW. Huge advertisements in all newspapers tell you that *there is one good plant in the greenhouse*, namely the *nuclear* one which produces no direct CO_2-emissions. Some of its proponents still rant about a nuclear future, in which they will supply even

all the fuel. But you need little more than counting, to recognize the nature of such dreams. To supply 10 TW within 5o years, with plants of about 1 GW each, which live for about 30 years, you must set in operation *one big plant every day*, for *50 years*, from *now* on. This shows the size of the so-called energy-problem. But nuclear energy is not only out because of this order of magnitude, but because the radioactive inventory of even the safest reactor makes you play a sort of "Russian roulette" with cities and whole regions. Those infamous "chains of unfortunate events" can never be excluded in a world with so much good-willed megalomania and so much stupidity, not to talk about wars and terrorists. Therefore, in a viable society, any large-scale technical use of radio-active nuclides will become for ever taboo.

The only remaining alternative is solar energy in the widest sense (which also includes wind and water), used in manifold ways. Many of them can already be seen, many new ones will be found and developed by our children and grandchildren. In Munich, where I live, the sun delivers on each square meter annually the energy content of 100 liters of oil. With realistic efficiencies an average area of about 100 square meters will be needed for each inhabitant of the earth to "harvest" his share of energy – a fraction of what is needed for his food. (Perhaps it is helpful to think of an example of a particular piece of land of 100 square meters, say in Kenya. The former owner has sold it to a land-lord who produces *cash-crops.* He could buy a used TV for his family, and he is now working for the new owner. The harvest is a box of beans which can be sold for about 1 British Pound to an export firm. On the next day it is on the European market, where the consumer pays about 13 Pounds. Exercise: What is the growth of GNP in Kenya and in Europe, respectively? How much energy has been spent? How many people have been fed, and what is their body-weight? …)

From what I have said about energy, it is clear how the reduction strategy has to begin in Europe: In order to reach 20% of today's consumption within the next 50 years, we should reduce it by 3% every year. It is worth thinking about your own possibilities of reduction – when you buy a car, when you choose the type of vehicle for your way to work or for a voyage, when you buy electric household equipment or energy-intensive food or consumer goods, when you build or renovate a house. You will see that for the first few years you and everybody can easily save 3%, and it will turn

out that this doesn't even have to cost you money. On the contrary: Even money will be saved, and we just have to take care that everybody gets a fair share of these savings. In later years this will, of course, change. It will cost a good part of the efforts of two generations to “solve the energy problem”. But what does this mean for economy? It means that people will have something *meaningful* to do. There will be plenty of jobs which do not accelerate the destruction of the biosphere and regional cultures. If we are able to find a better type of “division of labour”, those jobs will not be organized for the growth of capital but in order to achieve a long-term co-existence of mind and biosphere on earth. It’s worth trying! We are getting a bit nearer to the concept of real value ...

You may think, society must first find a better way of organizing the committees which discuss the probabilities of “risks and benefits” of technological or economical activities and make recommendations to politicians. I agree. As the experts for technology assessment one should no longer call the people who invented a technology and want to sell it. And as experts for constraints to economy one must not ask the money-growers. I think, however, that even more barriers must be found against the fast offering of “new options”. The organization of freedom must lead us in a direction where it becomes less likely to find buyers and consumers for more and more fast world-wide innovation. Under present conditions it appears illusionary to try and stop the spreading of fashions of ever more sophisticated gadgets. Not only will soon every child want to carry a “game-boy” with his “walk-man”, but everybody may wear tiny computers, perhaps under his skin, which can receive messages of his own voice via microphones, and via radio from other people or from libraries and big computers anywhere in the world – and probably from the “administration”. Your “personal computers” will then really be part of your person and assist your little brain by processing all incoming information in microseconds and supplying the output as words in your ear-phone, or showing it on screens which cover the back of your hands or the inside of your glasses. Who is laughing? Thousands of the brightest young men in well-equipped laboratories are working hard to let even you, but certainly your children, participate in such blessings of “AI” – which stands for *artificial imbecility*.

Wouldn't a high-tech development of this kind be one of the most instructive examples of "qualitative growth"? Yes, indeed – if it happened in some Silicon-Valley, and *we* wouldn't mind. But obviously, such innovations would conquer the globe within a few years and would change everybody's way of life and thinking immediately. And a good part of the people would only find a job in this branch of industry – if at all. This is the characteristic of the global acceleration crisis. Am I telling you, we must try and constrain such developments, which are as democratically legitimated as anything? Who is "we"? Who am I, that I dare challenge the free market of evolution?

10. Optimal Scales of Property?

You may think, with me, that human mind and soul are the highest structures realized in the space of possibilities – the "crown of creation". But it takes our generation-time or our life-time to experience this complex value and let it blossom and bear fruit. The attempt to improve basic features of an attractor before it has run through just one cycle, is doomed to failure. This is a logical, not an ideological statement which summarizes once more the essence of the crisis. In fact, we are changing essential features not only of society, but even of climate and the whole biosphere *within our own life-time.* This is the system-theoretical climax of the crisis, in which everybody at the front will feel it, because he doesn't recognize the world of his youth any more when he has grown up. Life-long experience has become worthless. This hurts, but old people's pain does not count. They can't move much. Midlife-pain, however, and the pain of the youth, will cause wriggling. At this point, that is in our children's generation, today and tomorrow, it will be decided whether it was a crisis, or whether we go to hell.

One of you asked "whether the shift to qualitative growth should be left to market forces or to rational, conscious, democratic decision". Isn't it a fascinating psychological phenomenon, that an economist can ask such a question, when it is so obvious that *both* the market forces *and* the democratic process are organized predominantly by that "invisible foot with a cloven hoof"? Market forces are the collective result of processes in many human minds under environmental and psychological constraints, as well as political and economical constraints which are of chiefly ideological nature. The imminent task is a more rational shaping of those ideological

constraints via democratic decisions, with the aim of increasing the likelihood of evolving viable societies of free citizens in a viable biosphere. This is certainly not an impossible task. (Remember the number of possibilities!) So, let us ask many rational, conscious, democratic citizens: Which constraints does the so-called free market need most urgently, and which have to be taken away from it, in order to foster relatively slow qualitative growth with a lot of diversity?

Probably, the first thing which comes to everybody's mind is the monetary system. In its present organization it takes care that the value of anything is defined by the amount of money which somebody will pay for it. On the other hand, the system takes care that money grows by about a factor of twenty per generation. (Let me neglect inflation here. Taking it into account would only strengthen my argument.) What can all that money buy and turn into more property? After the abolition of slavery there aren't many really valuable things for sale, are they? We have already seen what the second-best is: Appropriation of the foundations of living of many others! Or should we rather call this "misappropriation" or "usurpation"? Who can explain why such property rights are right? If you don't own much more than you need, however, don't be frightened to hear the war-cry "property is theft". The self-organization of freedom will certainly include the concept of property, perhaps even innate and inalienable property, for everybody on earth. But there must be limits to the *size* of property.

Legal limitations to the size of property will probably suffice to change the world in the right direction, and awaken the kind of market-forces which deserve that name. The continuation of slavery by appropriation of the essentials of other people's lives will simply become impossible. The discussion about the idea of interest and capital gain can be followed from Moses through antiquity and the middle ages to Karl Marx, Joseph Proudhon, Silvio Gesell, John Maynard Keynes, down to our time. The mainstream of economics has, of course, always shown little interest in such unscientific topics. Nowadays, only a few outsiders have tried to keep the discussion alive. I should like to mention the German constitutionalist Dieter Suhr, who recently died in an unfortunate accident. His thoughts about *neutral money* are certainly worth further consideration. (His last book was *The Capitalistic Cost-Benefit-Structure of Money*, Springer-Verlag, Berlin-Heidelberg, 1988.) The "wrong" ideas about the creation of

values are focused in the institutions of interest and capital yield. Real progress in the space of possibilities cannot run at a speed corresponding to that factor of 20 per generation. This kind of growth rate enforces exploitation. Actually, the pauperization of the *third world* was not sufficient to render all our development possible. Through exploitation of all resources and sinks, *nature had to be reduced to misery, too*.

For those of you who still believe in the money system, let me add a remark on the discount rate. This is a perfect symbol for the "exploitation of the future", typical for an instability. One of you showed a table here, in which a discount rate of 12% had been assumed! At that rate, one dollar which has to be paid in 10 years is valued today as 28 cents, a dollar in 30 years as 2 cents. You see why it doesn't itch us today if we prepare the annihilation of the GNP of all times and nations just a few generations from now. Shouldn't the discount rate rather be negative? (Again, inflation doesn't mend this flaw. Its expropriative effect hits only the small owners. The big ones own the "foundations of living" which don't lose value.)

A reformation of the money system and of property rights will have to run parallel to more general constraints which must prevent "everything big and fast" – like the size of companies, organizations, nations and what else you may think of on earth. The earth is round, and since the creation of values needs many independent trials and errors, most structures which tend to grow must probably be limited by laws and taxation long before they approach the global scale. Optimal scales between the individual and the globe will have to be found in the imminent process of organization. The only global structures which mankind must soon establish will be a world-constitution which must guarantee those constraints and regulate the co-operation of political sub-units in finding, implementing and defending this constitution. A "world market" will scarcely play a role in the longer run, and the idea of international competition will be ridiculed as one of the most absurd manifestations of the global acceleration crisis: "Who is first in the collapse-instability?"

The other day I had a dream: Our parliament found leverage points for some of our seemingly insurmountable problems. The usual taxes were abolished and replaced by a tax on money and taxes on goods or activities which are known or suspected to be damaging. Imagine: This included a tax on *size and speed* in many areas! And an old idea (of Silvio Gesell's, I

think) was realized: *All rent from land would regularly be distributed among all children*! Billions of pages of coded results of bureaucracy were pulped. The hopelessly complicated legal system was suddenly not needed any longer. Its radical simplification, relying more on boundary conditions than on detailed regulations, opened paths for the self-organization of highly complex societies of free citizens. More and more countries followed as the viability of the new values became obvious. In a loose world-wide cooperation of such societies, our planet started blossoming again in many different colours and patterns.

You may smile about this unrealistic sermon of an itinerant preacher. I find it quite ridiculous, too, that a physicist must try and teach economists how to judge values, and tell them why *the liberation of the free market from capitalism* is a basic condition of further ascent to viable attractors. Fortunately, mind is still alive, and creation can go on and realize unreal possibilities. Many economists, who are still theoretical assistants in the organization of the crisis, will have difficulties to imagine that the necessary is possible. But this lack of imagination is quite normal before revolutions. The climax of the crisis is quickly bringing forth a revolutionary situation. Managers in industry and finance, and even professors have begun to realize that our economic system is not viable without some basic changes.

We have seen: Entropy and Free Energy are certainly not sufficient concepts for a discussion of why economy ruins the earth. The question of the *scales* is the decisive one. But you may still be waiting for the announced "theory of value" – or be angry that I dared to use this word at all. Have I been able to offer a better understanding of the invisible hand? Maybe you have a wrong idea of understanding! I have tried to make clear: Viable complexity is valuable because it *cannot* be understood or planned. At the present front of evolution, new value is something that may grow in and through ourselves under proper boundary conditions. Those conditions, however, can be easily understood. They must guarantee *diversity* and a *leisurely pace*. This will mean the end of history for all sorts of power which organize the global acceleration, and for many activities which are called economic but are, in fact, destructively wasteful. In the new realm of possibility, where we must succeed in the self-organization of our freedom, history may just be beginning.

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6. What is Beauty?

A presentation of the following ideas had been planned for a Conference of physicists, philosophers and theologians in Venice (December 17/18, 1993) which took place under the title ***The Beauty of the Universe*** within the series ***Venice Conferences on Cosmology and Philosophy***. I could not participate because of illness, but nearly a year later I wrote this version for the proceedings. The Original is unpublished.

An Italian translation by Alberto Bragaglia appeared as: "CHE COS'È LA BELLEZZA? – SULLA TEORIA SISTEMICA DELLA CREAZIONE" in: La bellezza dell'Universo (Eds. F. Bertola, M. Calvani, U. Curi, M. Donà). Il Poligrafo, Padova 1996 (ISBN 88-7115-057-0), pp. 43-83.

6

What is Beauty?

On the System Theory of Creation

1. A preposterous approach

Pulchritudo splendor veritatis. Beauty is the splendour of truth. These words are attributed to Augustine. We might stop here, if we were satisfied with a contemplative life – but scientists have to go on and ask: *What is truth*? They are searching for it, they say. What have they found, so far?

When we look into the world, we find reality. We find it beautiful if it stirs emotions related to happiness or awe. Considering the natural history of feeling, this may seem natural with lovely faces and friendly landscapes – but why does a regular spiral galaxy appear more beautiful than a very disturbed one and, on the other hand, the pattern of a snow flake more beautiful than a regular hexagon? Would Augustine have seen more truth in one than in the other? Are our aesthetic value judgments related to any "objectively true" features of reality? Can we find some general principle behind attraction and repulsion of real or possible structures?

Scientists often confuse truth with reality. They claim they are striving for truth when, actually, they want to introduce a new marketable gadget into reality. Dazzled by the glittering of the money which springs from this kind of creativity, they may feel tempted to speak of *the splendour of reality*. On the other hand, even "observational" scientists and engineers usually agree

that the concept of truth should be reserved for something less transitory than the phenomena realized by matter in space and time – especially now when, sub specie aeternitatis, even the proton is suspected to be ephemeral.

Asked for an example of what he means by the word *truth*, a scientist will certainly mention the *Laws of Nature*. Those are cast or forged in mathematical formulae, after a proper mapping between observable phenomena and quantitative theoretical concepts has been found. A particularly fascinating experience has been that some kind of truth often sparkles in wrong theories: Phenomena seem to follow mathematical formalisms even if there are obvious internal contradictions in the underlying conceptual and mathematical systems. As "the laws" are discovered piece by piece, they may never be "the truth" – and still they seem to approximate it in some sense. Obviously, before we can speak about beauty, we must think once more about the relation between truth and reality. Unavoidably, this will take most of the space for this article which isn't about phenomena but about ideas.

By definition, or by arrogation, the true laws of nature govern everything which might be realized in material processes – from the formation of elementary particles in the early universe to the neuronal activity of my cerebral cortex while I write this sentence. However, realizability is a difficult concept even if you don't believe in miracles which transgress or "transcend" the laws. Just now, the discussion about the interpretation of quantum mechanics is receiving fresh impetus from physicists quarreling about "the nature of reality", but there are still no generally accepted scientific ideas of what it means when we say that something "is there" or "is happening" or "is possible".

Of course, my own wrestling with such questions over five decades was accompanied by similar processes in many other heads, which occasionally came to my attention, and my terminology has developed in contact with many older ideas. But I have never been interested in the question when and where a thought was first thought or spoken out or printed. The evolution of human ideas cannot reasonably be viewed as the spreading of discrete "memes", which might be traced to a specific article in some journal. The obsession with "originality" is a disease to which we will eventually come back, because it has even infected the idea of beauty. The process of mutual adaptation across the borders of "expertise" seems

more important to me. If I would quote anybody in this “article about everything”, this would only tell something about my memory, but nothing reliable about the history of ideas. So, I shall rather not quote at all, and leave the book-keeping to others.

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Mathematical truth may be defined in a rather clear sense. Reality is fuzzy. Rigorous physical theories do not pertain to reality but to abstractions of it which are called truths as long as no contradictions have been discovered. As the physicists of our century struggled down to ever deeper levels of abstraction, the idea of a “history of the real world” as a sequence of “events” has become more and more blurred. For decades it has even been fashionable in quantum mechanics to reserve the concept of an event for “observations” in which that metaphysical “collapse of the wave function” should take place. Thus, oddly enough, observers were thought to take care that something “real” happens at all. This way of splitting the world into material and mental reality still resembled traditional divisions into *res extensa* and *res cogitans* or “outside and inside”. If we want to draw ethical or aesthetical conclusions from a scientific world view, we should perhaps first try and reach some *re-unification of mind and matter*. Can’t we see ourselves as parts of “natural” reality? Everybody does this in front of a mirror. Only when it comes to feelings and consciousness, many people are in doubt how those could belong to the material world in space and time.

Occam’s razor is a proper tool to cut out such dubitations at this point. If soul and mind appear as infinitely more complex than all other experiences, this is no reason to shift them into “another world”. In order to strengthen your belief in the possible riches of complexity in a material world, let me ask a simple question: How many points do we need in order to let the number of their different relation structures (via straight lines) surpass the number of atoms in the observable universe? The answer: Twenty-four! This trivial example shows that there must be a practically infinite potential for complexity in the activity patterns of ten to hundred billion neurons, when each of them is connected to many thousands of others – and even more so, when many brains cooperate in the form of societies. Obviously, there is enough *res extensa* to house every imaginable

reality, including the *res cogitans* and all its activity. The problem is not one of capacity but one of organization, that is creation.

So, doesn't the question suggest itself, whether the known laws of nature and the findings about the evolution of the universe from big bang to consciousness teach us something about the process of self-organization in people, too? Haven't we learnt a lot about how matter, stars, life and brains came into existence, even though we know that the laws used in all that "understanding" are not yet really fundamental ones? Newton's theory is not obsolete for the use in a planetary system, and the results about the structure of atomic nuclei or molecules will not stop making sense if we find a deeper "unified theory of everything". Let me assume that our present ideas about mental processes as physical phenomena do not critically depend on further progress at the front of theoretical physics. Of course, it remains an open question whether the "wrong" laws of nature, which we have to deal with on the present level of theoretical concepts, are near enough the truth which is steering the organization of soul and mind in our cerebral activity. But this question must not divert us from a more urgent one: What follows from what we have understood already? What follows for ourselves if we assume that the creation of man, and all subsequent human creativity, obeys the same laws as pre-human creation?

Let us see what happens if we, with that crude reduction to incomplete scientific terms, dare to approach the idea of beauty. Is this a preposterous approach? Well, remember the episode from Heisenberg's biography, when some of the most brilliant theoreticians washing the dishes in an Alpine refuge were startled about the result: With dirty water and dirty towels they produced beautifully shining glasses! This may encourage us to try and re-approach the realm of ideas and the system theory of God and Devil in terms of more modern language. In spite of the unsatisfactory conceptual basis, let me offer some thoughts about the process of creation and about conditions under which its results are likely to be beautiful or ugly.

2. Is there a universe ?

We shall now put on quasi-classical spectacles to look at the "obvious" reality of cosmic structure, of the earth, of its biosphere, of human brains

and of their interaction in society. We neglect the vexations which quantum mechanics has generated for the concepts of history and reality. And if we really live in a “universe”, we neither have to worry about the relativity of time, if the overall uniformity is sufficient to introduce a global cosmological time coordinate. Then, we may talk about universal “moments” and a universal history in our fuzzy image of an evolution of physical reality.

Cosmology and fundamental physics have now reached a stage where speculations about “the nature of the laws of nature” are not quite meaningless, even though no fundamental theory has yet been found. The laws themselves may be looked at as a “part of reality” – in the sense that they are perhaps not given as “absolute truth” but that they are consequences of the early history of our universe. Among the thinkers who have started brooding over “the egg of the universe” – i.e. the very beginning where the concepts of space, time and matter start making sense – there are basically two species, which tend to prefer different answers to Einstein's question, whether “God could have made the world different”. There are those who expect that proper concepts can and will be found from which the laws governing our universe follow inevitably – including the “constants of nature”. In this case, the laws of physics would be determined by pure logic. There are, however, others who suspect that the ultimate logical foundation of our world lies much deeper and would allow for universes with very different laws. Then, the details found in modern physics would not have more “necessity” than the phenotype of the elephant or the wording of this article. The principle of evolutionary self-organization would then govern the rise of complex structures not only on the “six days of creation” but in the very first idea of our universe.

Fortunately, for the choice of our own will between good and evil, nothing depends on a decision of such questions. It does not matter, whether our universe is the only possible one or one among infinitely many others – if only the concept of a universe makes some sense at all. And the belief in a universe is well supported by observational hints: Wherever we can look in space and time, matter obeys the same laws and seems to have come from that common early state of extreme uniformity, that we call the “big bang”. All subsequent creation seems compatible with the notion that our world started without any detailed structure and came out of just one idea: The greatest possible density and uniformity with the fastest possible

expansion. Indeed, our most important cosmological experience is: *There is* a universe – defined by common laws and a common early phase, perhaps with a common "point of origin". The "age of the universe", around 15 billion years, is still uncertain. Even with a more reliable measurement of the "Hubble-constant" (the speed of global expansion) it will not yet be fixed because there seems to be a lot of invisible but gravitationally active material, and also the so-called vacuum might influence the spatial expansion via some unknown force, like Einstein's "cosmological constant".

This beginning is extremely "special" in the set of all imaginable configurations. Without deeper insight from some more fundamental theory it appears as infinitesimally likely, i.e. practically impossible. We can only speculate whether this special choice is logically unavoidable or rather the consequence of some early evolutionary selection process. Uniformity could have been immensely amplified when our universe was "inflated" from a tiny bubble in an infinite chaos. Anyway, it has turned out that the appearance of man in our universe sets quite narrow limits to the laws and the order of its early stages: "Our world must have allowed for human evolution in order to let such questions come to our minds". This truism is called the "anthropic principle". However, it is probably not sufficient to enforce the extreme order of the early universe which finds its expression in the low entropy of only a few billion photons per baryon in the cosmic radiation background. That number may not sound small, but it appears as extremely unlikely in the immense number of possible more disorderly states if one includes gravitation. Roger Penrose has made this evident in his book *The Emperor's New Mind*.

In a deeper theory, though, space, time and matter might "spring from nothing" in a single "fluctuation of the vacuum". Then, there might not be any other possibilities to be counted in the beginning. Isn't it "new-born" space which is coming into our view in the course of time as we "see" the origin at our cosmic horizon with infinite redshift? Isn't it tempting to speculate that after a re-formulation of the fundamental concepts, the extreme initial symmetry might turn out to be a necessary consequence of the fact that "everything came out of one"? In a way, this hope has always resonated in the word "universe". If it came true, one might say: "Fundamental laws, perhaps even the laws of logic, enforce the absolute uniformity

of the egg of the universe", or "God as the creator does not yet have properties but only possibilities".

On the other hand, many theorists suspect that at least some features of the laws of nature may be the outcome of an early selection from a wider range of possibilities. The observed universality of our laws, or at least that of some numerical constants contained in them, should then be due to some process like inflation. A whole "multiverse" of other worlds might then be thought to "exist" beyond our range of possible observations. To be sure, the concept of existence would become quite fuzzy at this point: Should we grant a higher ontological status to such "other universes" than to unrealized possibilities like, say, the history of the earth without that cosmic accident which killed the dinosaurs – or, say, the history of my family if my mother had died as a baby?

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Obviously, for a tiny fraction of a second after the origin, our present knowledge of the true laws is still insufficient. But, as physicists know, we can already calculate what must have happened a few minutes later, when the first nuclei formed – and the results compare well with observations! Thus, the quasi-classical view on the "history of reality" as an evolution process of matter in space and time seems to make good sense. The "quasi", however, has to be added in order to incorporate the most important new experience of our century which has lead to quantum mechanics: There is a stochastic element in all history! Reality is not strictly determined but influenced by accidents. For instance, if we keep a hundred atoms of the radioactive Cesium-137 in a box, the laws of nature and all past and present realized structures do not determine how many of those atoms there will be after one year. At any time, there is only a probability distribution given for that number, such that after roughly 30 years the "expectation value" is half the original number. This kind of reality is not uniquely determined but selected "accidentally" among the more or less likely possibilities lying within reach of unavoidable fluctuations.

In the conventional interpretation of quantum mechanics, the stochastic selection was thought to take place in the "collapse of the wave function" due to an observation. The wave function itself, which defines the probability distribution, behaves deterministically. As I said, we shall avoid this

conventional split between mind and matter, because we want to consider the observer's consciousness itself as a part of the material process in space and time. So, we cannot clearly say where and when the "quantum mechanical events", the "acts of realization" happen. However, this is probably not a shortcoming of reality but rather one of present physical concepts. Like the concept of an empty space-time with test bodies, that of an isolated system and its observables does not tell the full story. Such ideas formulate important features of certain processes of measurement, but they are not "the truth" pertaining to reality. In fact, in spite of quantum-mechanical dogma, most physicists are inclined to call the decay of a radioactive nucleus a real event, even if no observer is there to register it. For our present purposes, without better fundamental concepts, we can hope that our rather naive realism is a reasonable approximation to the truth – with the implicit assumption that "there is" some truth about "process and reality".

The world-view within which we now want to discover beauty is that of naï ve cosmologists, geologists, biologists or historians. In this approximation we say: There really is a universe, and its reality evolves through events, which it creates itself in its intrinsic spontaneous fluctuations and encounters. In each event the new reality is chosen within the set of available possibilities. This choice is not arbitrary, but accidental within a given momentary probability distribution. Probabilities are determined by the present and past reality, and by the available possibilities. Of course, both reality and possibility are assumed to be subject to logic and to the laws of nature. With the events, however, "pure chance" is coming in. One might be tempted to call those stochastic events the "acts of creation" but we shall see that this would be misleading.

From "chaos theory" we have learnt that even strictly deterministic laws of nature would not make the behaviour of most systems predictable in practice. Tiny "non-linearities" in the equations governing the processes can produce an exponentially increasing divergence of histories which started with arbitrarily small initial differences. You know that "butterfly-wing-effect" from long-range weather forecast. As a simpler quantitative example, mathematicians have calculated how sensitive the balls in an idealized frictionless billiard game would be to minute external influences. If one computes the paths of a few balls which collide with each other and with

the cushions, it turns out that after a surprisingly small number of collisions the motion-picture on the table might be totally different if one explicitly included the gravitational action of a single electron at the edge of our milky way! I think I remember that the resulting number of collisions was smaller than the 24 in our former example – and again this throws some light on the number of possibilities of quite simple systems. Clearly, the state of my mind when I have finished this sentence would not be predictable in any sense, even if the momentary firing rate of every single neuron in my brain and all underlying molecular and atomic activity had been continuously registered in some huge, "super-universally" huge, library – and if their evolution were governed by absolutely deterministic fundamental laws.

Scientists and philosophers used to think that the difference between strictly deterministic and stochastic events must be essential for our ideas about freedom. However, in our present picture of the universe, even this difference becomes fuzzy: As the billiard example shows, what happens in my brain, must be influenced by microscopic events near our cosmic horizon, that is near the "original act of creation". So, even if there were no local spontaneous fluctuations at all, and if even the decay of radioactive nuclei were somehow "determined", there would be infinitely many tiny influences which could by no means be distinguished from purely spontaneous accidents. For the practical way in which we look at the history of our universe and at our own history, and for the perception of our own freedom, it does not make much difference whether the selection of reality within the realm of possibilities is influenced by "initial fluctuations" near the actual cosmic horizon or in infinitely many spontaneous local accidents during the whole long history and in the pattering and flaring of our present brain activity.

Our experience with microscopic phenomena suggests the latter picture – but we don't have to be dogmatic about it. The essence of creative freedom is not to be found in the detailed character of the wriggling but in its sheer presence. Random initial conditions which enter any region in space and time at its momentary horizon would be as effective in the process of "trial and error" as spontaneous fluctuations at many space-time points. Creativity is due to the principle of evolutionary self-organization, which means: Wriggling among a lot of possibilities makes it likely to find more attractive ones. If there is or if there ever was a stochastic element in the

history of the universe, creation is going on incessantly. It has now reached the level of our “freedom of will” – the source in which (as even the etymological roots suggest) a chaotic “welling-up” organizes itself along the attractors of mind and culture.

3. Attractors in the space of possibilities

The larger realm within which reality is being selected I like to call the “space of possibilities”. Of course, philosophers and theologians of all times have given many different names to closely related and similarly vague concepts. “Heaven”, “the realm of ideas”, “the spiritual world”, “eternity”, “eternal truth”, “the beyond” are some of the words used in our western tradition for a larger province, of which reality is a part or a shadow and from which it seems to be being steered or receiving creative power.

When I consider the realm of possibilities, I obviously include at least all material structures and processes which might in principle be realizable because they do not contradict the laws of nature. When I call this set a “space”, I must think of some concept of neighbourhood for its “points”. We may imagine a picture quite similar to that of the phase-space for a classical system. There, any momentary state is specified by the positions and velocities of all particles or, if those are restricted, of the “degrees of freedom”. As a point-like particle in three-dimensional space is free to move in three spatial directions, its phase-space is already 6-dimensional. The momentary state of a gas with N such particles would have to be specified in at least 6N dimensions. Clearly, if such ideas can be applied to the real world or any part of it, this dimension is practically infinite. Still, theoreticians liked the phase-space picture because every possible momentary state of a system corresponds to a single point, and deterministic laws of nature define one single line through each point as its past and future history. So, the “dynamics” of a system could be visualized by the properties of bundles of lines in its phase space – that is by all its possible histories.

In this classical picture, the “freedom” of a system lies only in the choice of initial conditions. For a given state, i.e. a point in phase space, the whole preceding and subsequent history is a single fixed path, connecting all the

state points which become realized according to the supposedly deterministic laws of nature. In principle, those laws allow the exact calculation of the path into the future as well as into the past of each state. All the other possible states and histories of the system, namely all points in phase space which do not lie on that one single line, will not become realized. In this type of classical physics, there is really no "freedom" of a system, except in the free will of an experimenter who chooses and fixes initial conditions. ("Initial" they are only in the sense that they pick a path from the bundle of possible histories; usually, there is no beginning or end of lines in phase space, unless they run into a point-like attractor …)

If we dare to think of something like "the space of possibilities of our universe", any real or possible momentary state of the whole world, including all brains, books and computer-storages, is considered as a point in this space. With all the complexity and beauty of the world, this may appear as a huge step beyond the classical phase-space picture. This step does, however, not lie in the larger number of dimensions. "Nearly infinite" as it is, the number of particles in a brain is not larger than in the same volume of water. So, it cannot simply be the "size" of the phase space, its practically infinite number of dimensions, which is responsible for the appearance of all that beautiful complexity in the world. It is the organization of correlations, which seems so incredibly unlikely to be found and kept and evolved further – whether by "planning" or by "accident". Still, it is obvious that all this is possible. *There it is* – really: this one single line in the space of possibilities, the real history of our world, from big bang to the state at this moment. And your reading of this text is a tiny filament of this history in a sub-space which is infinitesimally small in comparison with the whole, and still practically infinitely large. Isn't that stupefying? But our stupefaction is not due to the fact that this is possible but to the fact that it has been found among the immensely many other possibilities in the course of history. Somehow, this line seems to have been more attractive than others.

Everybody must have seen by now some of those surprisingly beautiful coloured computer graphics in which phase-space attractors of simple non-linear dynamic systems are projected into planes or sub-spaces. One of the most impressive features of such pictures is how basins of attraction which are well separated in certain regions of phase space can be interwoven in

other regions in incredibly sophisticated ways. Like the infinitely filigreed edge of the Mandelbrot set, such patterns are usually produced from extremely simple iteration processes with just a few mathematical symbols. So, we shouldn't be surprised that the space of possibilities is full of attractors. They are lines (or, generally, manifolds of relatively low dimension) near which real processes tend to accumulate when they have somehow got into their basin of attraction.

Relatively simple ideas of that kind we find everywhere as elementary particles and atoms. Progressing to higher complexity we find galaxies and stars, organic molecules, all forms of life, the whole biosphere, human brains and cultures. Some features of the simpler ones we can represent by formulae and simulate in computers, but when we think of the number of possibilities with our "24 points" we see why this becomes impossible higher up in the "great chain of being". Still, we have our eyes, our telescopes and microscopes, our thoughts and dreams, to find out what is there! All those beautiful structures and processes – and some ugly ones, too. It has turned out that everything in the universe, and the universe itself, is a dissipative structure – i.e. some arrangement of matter exchanging energy and matter with similar and other structures such that the pattern stays near the same idea, i.e. near the same attractor in the space of possibilities. The basic attractors are of a cyclic nature, and reality runs through them again and again for such a long time that even Einstein loved to think of a stationary universe – although he knew about evolution of everything else and certainly realized transitions to more attractive ideas in his own mind.

What makes an attractor attractive? Obviously its mathematical structure, its embedding in the bundles of all paths in phase space – but even for quite simple systems this is usually so complex that it can only be discovered by trying. In the deterministic picture of classical phase space one has to try a large number of points, distributed over a wide range of phase space, and use them as initial conditions for computer calculations. The corresponding bundles of histories may then accumulate in certain regions and make you suspicious that there is an attractor. With more trial and error you may then confirm or refute this assumption. This is why there was so little mathematical thinking about "deterministic chaos" and attractive structures "between order and chaos", before we had fast computers – although in principle the insight into such phenomena had been around long before.

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What about the "existence" of reality and possibilities? Let us contemplate the example of the Mandelbrot set a bit more thoroughly. *Is it there*? Does this structure *exist* in any sense? Penrose said *it is there like MtEverest*. But mountains are very short-lived phenomena, whereas mathematical structure is there beyond time, in the "realm of ideas". Isn't it obvious that we should, in some sense, include the Mandelbrot set in what I call the "space of possibilities"? It has been approached by material space-time structures in the course of the history of our universe, though only lately – perhaps first in activity patterns of Benoit Mandelbrot's brain, and then in computer print-outs and on millions of colourful book pages. True, it has not been "realized". Not only because of its infinity this is for ever impossible. Thus, it makes good sense to extend our concept of "heaven" and include not only what might in principle be realized by matter in space and time but also all possible "limit points". For mathematicians this is a very natural procedure (like introducing the "real numbers"), but engineers will accept it, too, since they have always known that machines are not identical with their blueprints and, still, in some sense quite near them. To be sure, it isn't the realization of a blueprint in ink on paper, or in the memories of computers or people, to which the realization of the machine is near; it is the idea – an attractor in the space of possibilities, beyond the reality of space-time, i.e. a spiritual "gestalt".

Will not, at this point, philosophers and theologians also become interested in the mathematical trick of attributing "existence" to accumulation points? I don't ask them to resume the old dispute about the "reality of universals" – but I think it makes some sense to say that the unrealizable attractors of reality "are there"! They pervade the space of possibilities everywhere densely. Heaven and earth touch each other in infinitely many points. Our reality comes quite close to the "impossible" idea of a Newtonian planetary system, and our thinking and longing is really quite near the philosophical and spiritual ideas of our ancestors. Not even scientists can deny that God and the angels are back in Heaven, and quite near reality, when so much cerebral activity and culture has been wriggling about those attractive ideas!

Do I really have an immortal soul? Does God exist? Are the angels real? Perhaps these are the wrong questions, when not even the "gestalt" of a

proton is real – although the realization of all protons in the world is wriggling very close to this idea (the mathematical structure of which has still not been fully discovered, though). Man, of course, the most complex phenomenon so far realized by matter in space and time, follows more complex attractors than elementary particles. But this does not make soul and mind or the whole history of philosophy and religion less real than such more primitive phenomena. Here I am – and I don't mean the cells or the molecules in my body and brain! I mean reality as it is organized by my own attractors in the space of possibilities. The process of finding them is the self-organization of my freedom along my individual "gestalt" which I experience as my soul and mind, embedded in the ideas of our culture. "Praying" is an old word for my wriggling in this process. God and the angels help by being around, and attractive.

4. The logic of creation

You know many attractors which govern our present reality. Just look at "Gaia", the idea of the earth and its biosphere – that immensely complex dissipative structure in the stream of sunlight. The earth's reality is near all sorts of more or less cyclical sub-attractors with very different cycles. There are the elementary particles, nuclei and atoms with their extremely short internal periods and very long lifetimes. They cooperate by weaker interactions to follow the attractive ideas of certain molecules, which again cooperate with still weaker interactions via the exchange of energy and matter to follow the ideas of the genetic code, the living cell, the organ, the organism, the society. Among all possible chaotic histories of our atmosphere, the earth's climate attracts the weather, our health attracts the activity of all our organs, ethics attracts our thinking and behaviour. No two individual cells are identical, no man is like any other, and still everything seems to be near its attractors in the realm of ideas. However, considering how fast man is changing life and even climate, we recognize that the recent front of Gaia's evolution in the space of possibilities lies in the wriggling of our minds. Thus, with my present attempt to re-unify the split world, let me include in the figure of "Gaia" not only the human bio-mass but also our mental and cultural activity, that is the earth's "noosphere".

Although in classical physics attractiveness is a consequence of the laws of nature, this "consequence" must mean a sequence of trial and error, when we look at the path of real history with its infinitely many decisions between possibilities. (And remember: Even the laws of nature might be the result of a process of evolutionary self-organization under more fundamental laws of logic.) The full structure of the attractors, the underlying truth, can scarcely ever be reconstructed when something shows its attractivity. We just have to admit: It works! In spite of infinitely many deviations, in immensely many sub-spaces corresponding to local reality, the projections of the phase-space path run through similar cycles again and again without leaving the old basins of attraction. Evidently, the attractors of local reality are *viable*, and their viability means repetition, reproduction – in atoms, cells and people. The Greek *ethos*, from which *ethics* is derived, means *custom* – i.e. what has proven its value in generations, i.e. in the repetition of cycles.

When we look more closely, we see that viability is not just a matter of local internal organization, but that the global and even universal context is essential. For instance, terrestrial life and climate take care of each other's viability. And the global structure of the universe is essential for the viability of all its complex dissipative sub-structures. All free energy used by them is in fact "fossil energy" from the big bang. Why? Expansion creates gravitational potential energy which is later partially regained in the formation of lumps; and the stream of energy from stars, which helps create complex molecules and life around them, is due to the fact that the early universal expansion was too fast to allow all possibilities of the nuclide chart to be realized; this could be achieved only later in the centres of stars. Thus, the ultimate source of all free energy is the origin of the universe with its very low or even zero entropy – and the ultimate sink of entropy (for all practical purposes) is the dark night-sky, i.e. the cosmic horizon, i.e. the simple origin again.

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We still haven't explicitly answered the question how reality is selected among the inexhaustible filigrees of heavenly possibilities. Don't expect the revelation of a secret, please! The answer is trivial, and it is contained in what I have said so far. It is the tautology that "probably something likely is

going to happen". We saw that the stochastic element in all history, that "wriggling of reality", introduces fuzziness into the phase-space picture. Perhaps, in a future fundamental theory, the "state-points" themselves will be described as fuzzy, but anyway, at any point, the continuation of history is not strictly determined but subject to "accidents" which make a choice within probability distributions. This means that there are transition probabilities between attractors in the space of possibilities. Now we understand more clearly what the "viability" of an attractor is: It means that due to its internal and external organization the usual accidents are unlikely to lead out of its basin of attraction. In other words: The probability distribution is sufficiently sharp to make the continuation along that attractor very likely. But now it is also clear that with a large number of accidents in a neighbourhood where the basins of attraction of many different attractors are near each other, there is a chance – and with enough trial and error even the logical necessity – that local reality leaves this region and follows a still more viable attractor. "The more viable is more likely to survive". Again a tautology. The principle of creation, from the origin of space, time and matter to the co-evolution of our biosphere and noosphere, is nothing but Darwin's tautology.

It is obvious that there are two general features of viability which seem to contradict each other: Isolation and connectivity. Physical isolation of local systems is attractive, because it helps to prevent strong fluctuations caused by external interactions, under which the transition to other attractors would be likely. For example, matter which has collapsed into a black hole forms a very attractive island. No outside activity will be able to pull out anything again, and the time-scale of its dissipation through quantum-fluctuations is practically infinite. This is an example of an instability which finds the simplest possible attractor, completely defined by just three numerical values: mass, angular momentum and charge. But also the more complex dissipative structures, an atom, a galaxy, a living cell, an organ in an organism, an individual in a species or a person in a society have features of an island: External influences are not likely to critically disturb and totally destroy the internal organization. – On the other hand, interconnection, i.e. manifold interaction with the whole surrounding, is also attractive if it is organized with sufficient complexity. Complexity means that "things fit together" such that the interactions are likely to increase the viability of both the parts and the whole instead of disturbing it. I usually discriminate the

terms “complex” and “complicated”: Complexity is meant to include viability; complicatedness arises when viability is disturbed or destroyed through excessive interactions. Then, history tumbles through the space of possibilities, along complicated unstable attractors, towards less complexity or even ultimate simplicity. With sufficient diversity this isn’t harmful to the whole – but there is a problem to which we have to come back …

In a sufficiently rich space of possibilities, like that of our universe with its streams of energy and entropy, competition between the two tendencies of isolation and interconnection takes care that hierarchically organized complexity is most attractive. In the evolution of matter, this has to do with the fact that there is a hierarchy of elementary physical interactions. In a deeper theory, though, this fact might itself be attributed to the process of evolutionary self-organization. After all, on higher levels of complexity, the ways of interactions are themselves discovered in this process. As reality in various regions of physical space follows its sub-attractors, the local histories are more likely to “fit together” if their basins of attraction are adapted to the probable sizes of internal fluctuations and external accidents. Viability for the parts and the whole is closely linked with “evolvability”, since disturbances which lead to further transitions must be rare but not totally excluded along the “best” attractors likely to be found.

The delicate balance between permanence and fluctuation favours specialized “species” of structures with a hierarchy of rising internal and external complexity and a hierarchy of interactions with decreasing strength. In a sufficiently rich space of possibilities, attractors of this kind are likely to be selected by reality if there is enough space and time for trial and error. The reality of our biosphere and noosphere illustrates this perfectly. (I don’t know, whether general theorems of this kind have been proven in a mathematical system theory of evolution, but it seems intuitively clear and I would be surprised if this tendency towards hierarchical discretization, diversification and specialization would not be found in expensive numerical simulations of evolution in sufficiently rich artificial spaces of possibilities.)

If this is what we find in ourselves and around us, it does not mean that there are no other lines in the space of possibilities. “There are” infinitely many possible histories with different patterns of organization, and many may be closely approached occasionally, but nearly all of them are not likely to be continued in the process of accidental wriggling. If reality tries them

in some spatial region, they turn out to be “errors”. This means that they are soon abandoned again – usually because they lead into instability and local collapse. Although most transitions to other attractors will turn out as errors, with enough trials in many different regions of physical space-time, there is a very good chance (as good as necessity) to find still more viable and evolvable ones. Via “auto-catalytic” spatial interactions this increases the chance of finding the same ones in other places. Good ideas spread in space. Near the simple beginning of the world, the “legal structure” of the attractors may determine reality to a large degree. That is why the same types of nuclei, astrophysical structures and molecules are realized in space-time regions which scarcely interact. (As we saw, the riddle of the universality of laws is still unsolved.) With rising complexity, however, the choice of viable attractors becomes so large that the realized ones appear as accidental in immensely many aspects. In most evolutionary transition steps the realized forms of higher life or culture have probably not been much more attractive than many other possible ones. Various “good choices” must be available, but realization of one of them often makes the others practically unreachable. E.g., if different possibilities of evolvable chemical codes for life may “exist”, and may even have been within reach after the formation of the earth, only one was likely to be realized globally in the end. How likely “it was in the beginning” that our level of complexity is reached, with the realization of what we experience as soul and mind, we cannot say. Do just a few planets have to try? Or a whole universe? Or even a “multiverse” … ?

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As I have tried to picture the space of possibilities in close analogy to classical phase space, one may have been tempted to think that the attractivity of an attractor should be fully determined by the laws of nature. However, since the probability distribution for “what is going to happen” is influenced in a different way by reality and its neighbouring possibilities, the actual attractivity of lines in the space of possibilities in any present moment also depends on the past real history and, therefore, on immensely many past accidents. This suggests a bold assertion: Not even in this sense “is God almighty”. Viable and evolvable attractivity is not fully determined by the “heavenly truth” of attractors. Hasn’t this been understood in all myths of creation? What else do the words at the end of each day in Genesis

mean: “And God saw that it was good”? He didn’t know beforehand! And he didn’t always know for sure while he was kneading and moulding in the tohu-wa-bohu and in the clay. He needed a lot of time. Viability, the beauty of reality, was tested all the time but became particularly obvious at the end of a day, when adaptation had been achieved on one of the hierarchical levels of complexity and had proven its value – that is its viability. (Sorry, the tautology lies in the principle of creation …)

Now we see why it wouldn’t be fair to call the *accidents* “acts of creation”. If one likes this word, it should rather be reserved for the processes of transition between relatively durable attractors. Locally, it may often make sense to speak of those as single successful acts, because many types of transitions between sub-attractors (e.g. typical phase-transitions described by physicists and chemists, or even some revolutions in societies) appear as straightforward on some “macroscopic” scale. But such acts of “spontaneous self-organization” are always accompanied by wriggling on smaller scales, and spatial spreading may happen with a lot of “fighting” for adaptation. The value judgment is contained in the whole process of wriggling and finding. – To summarize: Creation is the evolutionary self-organization of reality, the process in which the “freedom” of the accidents is organized by the attractors in the space of possibilities. However, as we saw, not only the finding of attractive histories, but even the very definition of their attractivity occurs only in the course of history. Reality and the “spiritual world” are inseparably intertwined.

5. What is truth ?

Have we gained more insight into the connection of truth and reality? At a first glance, the word “truth” seems to suggest itself for all structures in the space of possibilities. However, reality also belongs to this space; it is the line connecting all momentarily realized state-points. We know that reality doesn’t always and everywhere shine with beauty. To count it as a part of truth might not fit with Augustine’s idea of beauty. Lies and ugliness would also be true in this sense. In a way, we would be confronted with all the frustrations of the “theodicy”. Can we avoid this problem if we don’t use the word truth for the structural ideas of arbitrary assemblies of “points” in the space of possibilities, but reserve it for attractors? Well, even this turns

out to be quite unsatisfying. Isn't a black hole particularly attractive – not to talk about the devil? Since we identify the space of possibilities with the "realm of ideas" and the "spiritual world", doesn't the attractivity of evil belong there, too? Should we, perhaps, include *viability* in the definition of truth, in order to exclude evil? But this would immensely complicate the concept, since we have just seen that evolutionary viability is not a purely intrinsic feature of attractors in the space of possibilities or its sub-spaces. The actual viability of an attractor does not only depend on its internal structure and its embedding between the basins of other attractors; it cannot even be defined without relation to reality. If reality had chosen a different path, the truth of a chosen attractor might be different, perhaps depending on intricate real details due to historical accidents. Shouldn't truth rather be something "eternal", i.e. something exclusively defined within "heaven", i.e. by intrinsic properties of the attractors in that realm of ideas?

If we try and keep reality outside the definition of truth, we seem to be quite close to what Augustine meant. Can't we say: "Truth is a property of any cyclic attractor in the space of possibilities"? Isn't it exactly the property of being cyclical? Doesn't this include a kind of "abstract viability" which we experience as beautiful? If some part of reality would follow such an attractor, undisturbed by any fluctuations, it would live forever. In a sense, this kind of truth would be "beyond time". To be sure, the cycle is meant to be "run through in time", but time is only a mathematical parameter here, and there is no discrimination between future and past. The cycle could be run through in both directions. This kind of time, like that in the phase-space picture of classical mechanics, doesn't have an "arrow". It is, so to say, the "time of being", not the "real time", which is the "time of becoming". Reality, which is inevitably suffering from fluctuations, cannot stay on such permanent "reversible" attractors. Reality must be creative. Not even elementary particles and black holes are eternal, although some of them live long compared to the age of our universe. But for a theoretical physicist their beauty does not depend on that lifetime. It lies in the joy which he feels when he is able to "understand" how complex attractors can be "explained" (i.e. flattened out, made flat, on a sheet of paper, or a view-graph). So, isn't beauty just the splendour of the eternal mathematical truth of cyclic attractors, which can be approximated in the evolutionary wriggling of material space-time structures, including that of our cerebral activity?

Very disappointing! It looks as though we haven't at all come nearer an answer to our initial question: What is beauty? Didn't physicists know beforehand that the fascination with cyclic phenomena and their spatial patterns in atoms or galaxies is of the same kind as the fascination with mathematical structure? Similarly, for a modern biologist the fascination with the cycles of genes and proteins in a living cell may be of that nature. For a scientist, something is sufficiently "explained" when it has been reduced to tautologies – that is what all mathematical truth is, in the end. No mathematical theorem is more true than any other. If there is no truth but tautologies, however, the various degrees of beauty which we perceive cannot be due to different degrees of truth. The beauty of a rose, the beauty of a face, the beauty of a poem – what makes the different splendour of their truths? What about the aesthetic difference between the beautiful simplicity of a black hole and the beautiful complexity of Bach's "art of the fugue"? And why do most of us find the rose so disgusting when we are told that it is made of plastic? There must be an intuitive perception of something like a "complexity index" which determines the splendour of truths and leads us to value judgments.

True, complexity is itself a complex concept, and when you start thinking about it, you discover a kind of "relativity of complexity". Is the Mandelbrot set complex like its representation, or utterly simple like the algorithm for its generation? More generally: Whether a mathematical theorem appears as complex or as simple, depends on the starting point. You may choose a theorem, which needed a long proof, as an axiom, and one of the old axioms may then become a complex theorem. In a way, complexity is never the property of a part but always of the whole. Still, if beauty lies in the eye of the beholder, we may ask: Which axioms lie behind our intuition? The plastic rose is far more complex than a Kerr black hole, and the process leading to its production includes not only the evolution of complex flowers but even that of still more complex *people*. On the other hand, the *discovery* of the Kerr black hole involved a lot of people, too – maybe people of higher mental complexity. Thus, the complexity (– however defined –) of mathematical truth in an attractor doesn't seem to be a sufficient measure for its splendour. We seem to sense some other kind of truth behind the beauty of an axiom or a theorem, a black hole or a galaxy, a rose or a face, a cathedral or a poem. What is it? It seems to have to do with the viability of our own attractors in the real process of creation.

We had just tried to discard such a connection of truth with reality, in order to avoid conceptual complications. But this was a mistake. Obviously, we assign *values* to truths, even though truth is tautological, and the value judgment doesn't seem to be just a matter of counting possibilities or bits of information in eternal mathematical structures. What is it, then? We forgot that our individual and collective mental activity is part of the process of creation. Our aesthetic value judgment is part of that selection process in the wriggling of evolutionary self-organization. It must have to do with the discovery of viability, which happens in this process. As reality is groping its way through the space of possibilities, it "feels" rewarded when it finds a viable attractor. For the reality of a human mind this re-ward is re-cognition. Clearly, this already plays a role in the "psychology" of higher animals, e.g. when they feel comfortable "at home", and restless otherwise. So, a disposition for the recognition of viability is guaranteed by the bio-psychological realization of human mind. The beauty of the universe, as perceived in a starry night and with the cycles of the sun, the moon and the planets, the beauty of the biosphere and one's homeland, and the beauty of one's kinsmen and their language – as the consciousness of mankind awakened, all this was unquestionable, like it still is for every awakening child. Any healthy mind realized that the universe was the mother's womb, that the biosphere was paradise.

Then, further biological organization of cerebral attractors, i.e. their discovery in the space of possibilities via the wriggling of reality, brought a new front within reach of the fluctuations. On these roots more and more attractive ideas of culture and civilization have been found, very slowly over a million years, much more rapidly over the last few thousand years, and like in an explosion during the last few decades. For most of the time, nobody would have asked what beauty is, like nobody asked why customs were good and right. Habits were usual, beauty was beautiful. Nothing mysterious. Just the rewarding recognition of viable attractors. Why, then, should at last such questions have come up: What is truth? What is beauty?

6. The devil-theorem

There is a conflict built into the very principle of creation. Evolutionary self-organization through accidental wriggling of reality along its attractors

does not necessarily favour the discovery of complex viability. There are those powerful "unstable" attractors which find a viable cycle only after an essential reduction of complexity. In fact, this kind of collapse must often happen locally, but (except in the extreme case of a black hole) that devastated region will soon serve as fertile experimental ground for further trial and error, starting from attractors still realized in the spatial neighbourhood. Their ideas survive and expand, unless they also come too near a more attractive unstable one. However, spatial expansion is necessarily accompanied by contact with new possibilities. (Not "new" in the realm of ideas, of course, but new in real time.) Adaptive wriggling must then lead to other reachable attractors.

In the competition between various regions in real space, more evolvable attractors, the organization of which allows for faster and wider "wriggling", have a selective advantage. As an old example, remember the invention of sexuality: Via accidental combination the number of trials in each reproduction cycle is immensely larger than in the old procedure of sheer division and mutation. Therefore, this new principle quickly conquered the front in the space of possibilities. More recent examples are the invention of neural networks in the brain and, at last, of language and conscious thinking in the cerebrum accompanied by the development of cultures and their mythologies and systems of slavery, which still brake the free expansion of mind. At last, there comes that explosion of civilization with writing, long-distance weapons and long-distance traffic, scientific enlightenment with more and more technical gadgets and "media", and economic enlightenment with globally convertible currencies and with terms of trade and property rights which permit and, therefore, enforce the buying-up of the livelihood of ones fellow-citizens and whole nations – with total liberation from the old kind of slavery and the organization of much more powerful enslaving ideas which take care that everybody follows the same attractor, once called *mammon*.

We see: For purely logical reasons, there must be an "evolution of evolvability", i.e. an increase of the speed of innovation. Simultaneously, the "faster" ideas must spread to increasingly larger scales in real space. In an isolated spatial region, like on a planet, this ongoing evolutionary progress must approach a global unstable attractor – again for purely logical reasons: There are upper limits to the organizational scale and to the speed of

innovation. As they are approached, a decomposition of viable complexity must set in. Globalization reduces the diversity of trial and, together with the increasing speed of innovation, diminishes the chance of finding "better" attractors. And the faster an attractor is left for a new one, the less likely is it that it has been sufficiently tested for viability. So, there is no reliable basis for the next trials. The creation process becomes globally unstable. Acceleration and globalization amplify each other, until essential global features change on the critical time scale. When even Gaia'a oldest and most reliable attractors are being left, the crisis reaches its climax. As that singular epoch in planetary evolution, the tumbling of biosphere and noosphere near a catastrophic instability, must inevitably be reached for system-theoretical reasons, it deserves a scientific name. I call it "the global acceleration crisis". We start realizing that we have reached its climax. Why? What is the critical speed of innovation?

Mind has long realized that it is in danger of falling sacrifice to attractive ideas which are not viable. Etymology suggests that "evil" is related to "uppishness". The uppishness of scientific enlightenment lies in the belief that progress leads upwards if it is produced in good will. But this isn't enough! While scientists are looking for the intrinsic truths of all kinds of attractors, they have neglected that other kind of truth which lies in the very principle of creation. Like all truth, it is of a tautological nature: A cyclic attractor in a rich neighbourhood of possibilities cannot even be suspected to be viable, before reality has run through it at least once. Scientists claim that their business is to discover more attractive structures and to offer them as "new options" to everybody. Society is then supposed to make a reasonable selection. However, there is a problem: At what pace of innovation is evolutionary progress likely to find viable attractors? With how many new options can people, individually and collectively, be confronted within a year and make reasonable decisions? or within a second? or a picosecond, with faster computers?

In the general obsession with the successful acceleration of progress, it has been overlooked that there is an intrinsic time-scale in the problem! What is the cycle of reproduction of the highest value which has been realized so far? Which attractor of reality am I talking about? Of course, it is the attractor of a viable person, God's image. That this is "the crown of creation" has been understood not only in Western culture. It does not

seem to be an error that the idea of "human rights" is becoming one of the leading ideas on the whole planet. One might be tempted to assign an even higher value to viable cultures and to the whole system of biosphere and noosphere. But this would only strengthen my argument. The cycles of cultural attractors, in which the individual ones must be embedded, are necessarily much longer – not to talk about global biospherical cycles. But man is able not only to destroy himself by his own wriggling – he can even introduce global innovations on very short time-scales. This is why we say he can be trapped by the devil. He is able "to sell his soul", and jump on to unstable attractors. This isn't new. The new development – with the global acceleration crisis – is that nearly everybody does it, and has to do it. The leading idea of global civilization has become that we can and must improve everything within one generation and even faster, before even one cycle of the relevant attractors has been completed.

That this should be logically impossible, contradicts the most attractive ideas of our time, but it follows from what I have tried to explain here. After we have understood it, we shall grope for different attractors – and not in arbitrary directions, with the hope that "anything goes". What we have found out about the process of creation, will allow us a clearer vision of good and evil, of beauty and ugliness, of essential values which used to appear as indiscernible to "value-free" science. A closer look at spatial and temporal scales of evolutionary processes will introduce value judgment as a scientific argument. The arbitrariness, which up to now seemed to result from the enlightened world view, from the tautological truths of science, will become transparent. Behind it, we shall discover not only the seductive attractivity of the devil's haste, but also a more consolatory "transcendental certainty", namely the fact that system-theoretical logic provides commandments which may help us to put the devil in chains.

Lo and behold: There are logical conditions for "successful" creation, which define the difference between good and evil, between beauty and ugliness. Our wriggling between the ideas of truth and reality wasn't useless. Scientific enlightenment is, at last, going to bear fruit in the fields of ethics and aesthetics. Considering the "tautological" self-evidence of our findings, though, we must not be surprised if we find similarities with images and imaginations from older myths of creation.

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We have understood that in the course of evolution nearly all trials must have been errors. Failure is the most essential constituent in the creative process and can't be "devilish". Why, then, does the figure of the devil play such an important role in nearly all myths of creation? Clearly, this has to do with the fact that man is capable of more than the usual kind of mistakes. He can destroy himself, his society, and even his roots in the earth's biosphere. This is recognized, e.g., in the stories of Prometheus, the *fore-thinker* who brought fire from heaven, and of Lucifer, the *light-bringer*. That angel had watched creation and seen how it worked. He had understood the functioning of elementary particles, of nuclei, atoms and molecules, of the genetic code and the living cell, of organs, organisms and species, of brains, societies and markets … Why, then, should he not be able to improve the world much more quickly? We know: He tried, and he fell, and he received a new name, *diabolos*, which means "he who throws things into disorder" – though all was done in good will, with the best intentions, which still pave the road to hell.

One might think that in our "reductionist" phase-space picture the Devil cannot be an attractor, like the idea of the proton is, or the idea of "Gaia", or that of a man and his individual soul. Isn't the truth of God and the angels of a different nature? It lies in the logical principle of creation, and not in a specific "gestalt". Isn't this why it is forbidden to make an "image of God"? But this would be a misunderstanding. In conscious human cerebral activity the logical principles of creation can be understood, and this means that God and Devil are actually approached by material reality! On our level of mental complexity, they do represent very effective attractors. This is why they have been around for at least several thousand years, probably since the evolution of free thinking started in gifted individuals. The truth of those attractors is essential in our own creativity, i.e. at the present front of evolution, in the self-organization of human freedom. After our re-unification of mind and matter we can even try and talk about them in scientific language. What I am presenting here, is the sketch of a "system theory of God and Devil". And the statement about the inevitability of the global acceleration crisis I have occasionally called the "devil theorem".

Why does our creation myth allow the devil to become active only on the last day, when man had appeared? Because all the previous beings were not

yet able to destroy the highest values, i.e. the most complex viable cycles, which had been reached so far. An animal can make a mistake and die, but this is a negligible accident in the co-evolutionary wriggling of the whole biosphere. A species may develop abilities which are harmful to many others, but the diffusion of profitable genetic mutations or sexual combinations into the whole population necessarily takes many generations. Before a dangerous innovation can spread over the whole earth, other species have had time to adapt through frequency-shifts in their own gene-pools. And although higher life forms necessarily have much longer generation times than the micro-organisms, they have been able to cope with them through their own diversity and via an "immune system" which is able to evolve counter-forces on similarly short time-scales as the potential enemies. Therefore, fatal large-scale accidents which could have critically reduced the complex diversity of the whole, were extremely unlikely to happen as a consequence of biological evolution itself. They could only occur "from outside", e.g. when a stone the size of *Mont Blanc* hit the earth 65 million years ago – and more often in the early history of our planetary system. If this had been likely to occur much more frequently, the biosphere might not have been able to reach noospheric attractors. On the other hand, the death of the dinosaurs created more evolutionary freedom for the mammals with their brains …

Only the human brain has reached a level of internal complexity on which the self-organization of speed and size of innovations must become the basic problem. Whereas in biological evolution the necessary steps of mutation, reproductive mixing and phenotypic selection set a limit to the speed of innovation, such that essential global changes can take place only within many generations, the biological limits to the inventiveness in mental processes do not forbid us to change the world within a few years. Of course, this needed time to become obvious. For most of the time of human evolution and the early history of culture, the groping of individual minds couldn't reach very far in the realm of ideas. Viability demanded that the cultural attractors sufficiently constrained the individual ones. Only culturally accepted truth or beauty was true or beautiful. If exceptionally gifted people stepped too far in their individual wriggling, the organization of social attractors probably took care that they were soon eliminated. However, with very attractive ideas it was also likely that some disciples were already trying them. Mind was such a successful invention, that its

freedom could not be suppressed indefinitely. It started groping in more and more new areas in the space of its possibilities – very slowly at first, but accelerating – and more and more quickly after globalization of the fastest leading ideas had been achieved – until it was by no means clear anymore, what was beautiful or ugly, good or evil.

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We cannot go into details about the system theory of leading ideas in the history of mankind. It is, of course, fascinating to look for branching points in the past, because they may give us hints to viable attractors which are still near. Just one more question: Why did the idea of "equality of all people in front of God", and the corresponding idea of democracy become attractive just before the climax of the crisis? This is not an accident! There is a very powerful "wrong" attractor next to both ideas, a devilish trap, a very probable "misunderstanding" which is self-accelerating. Along the old viable attractors of culture, nearly everybody had the same opinions, formulated in taboos, myths, proverbs, poetry, laws. So, majority was usually "right" in judgments about good and evil or beauty and ugliness. As the individual mind becomes more and more liberated, this is unfortunately no longer true – if we want to uphold the notion that "goodness" and beauty are associated with complex viability. As social reality reaches unstable attractors, the more deeply rooted attractors of our time-tested psychological heritage take care that the majority thinks it is right because it is the majority. So strong is this idea rooted in us, that even some political philosophers still believe in its truth. But clearly, near the climax of the global acceleration crisis, majority must be wrong in nearly every respect. We see again that the truth of attractive ideas cannot be judged without reference to their embedding in the whole neighbourhood in the space of possibilities, including reality. On unstable attractors political "conservatism" may lead into collapse, whereas "revolutionary" wriggling towards a few selected old ideas may bring the rescue.

Faster change has become the main attraction of the conservatives. The only generally accepted custom is innovation, the replacement of all the usual habits by more useful ones – in world-wide competition, which means world-wide collaboration towards the same aims, of course. Newly discovered ideas attract more and more quickly every spot on the earth – from the centers of the Western world to the people of the last hidden islands

and valleys. At last even the biosphere has to adapt to new attractors. We set free more heavy metals than all weathering processes; about every hour we invent a molecule which may not have been realized before in our whole universe; also about every hour a living species is disappearing, perhaps even up to ten; this means an essential reduction of the biosphere within one human life time; we change the climate of the earth on that same time scale, and the ozone layer, which was built up by life within the last billion years and which brought more complex attractors into the reach of life, is being decomposed still more quickly. Right now, as those problems have become obvious even to conservative scientists, they have started to discuss the possibilities of "geo-engineering". There are so incredibly many attractive ideas within reach!

Now, however, with that speed of global innovation, the "solution" of a problem is likely to produce several new problems which are felt on a larger scale and which need a solution still more urgently. A larger scale and a higher speed of innovation still have a selective advantage in this process of evolutionary self-organization called progress. This is a euphemism for the kind of system behaviour that scientists would call an *instability* in any other context. It is exactly the selective advantage of size and speed, which made it likely, practically necessary, that we ran into this crisis. And still, it must not mean final decline and fall. Crisis means decision. The choice is between further tumbling down, perhaps back to Precambrian attractors, and the successful self-organization of human freedom. Of course, this is just a sophisticated wording for what one used to call culture. – Why should there be a chance of viable self-organization, when all present tendencies promote the instability? But this is the essence of an instability! This is how we recognize it! And therefore, there is still the chance that the majority understands it, too, if the symptoms become even more visible. Then, new attractors may strengthen different interactions.

I used to say that I didn't recognize the world any more when I reached the middle of my life. For our children this experience came at the end of childhood. People of our time may find it "unjust" that the crisis becomes manifest while it is our turn to live. Many sulkily refuse to look at it. But it had to be reached sometime, unavoidably. Now, here it is. Soon nobody can deny any more that man is changing not only his social environment and his culture on the critical time-scale, but even the earth's climate and

other essential features of the biosphere. It is becoming incontestable that within two generations all that would collapse if we go on with what we call our civilization. In this situation, more and more individuals start searching for remnants of viable ideas. Trends which are right now scarcely recognizable in the rapid stream of the instability will suddenly lead to the self-organization of patterns which dissipate and break its impetus. Reduction strategies for unsustainable customs will be developed. Many majorities on smaller scales will suddenly start following similar attractors because their truth is practically self-evident under the conditions of the crisis. This will happen on the level of conscious mind, the leading structure – as the instability is not a biological but a mental disease.

After we have understood the principle of creation, including the devil theorem, we shall be able to work for the self-organization of our freedom. It is immediately obvious where more viable attractors are to be found, and if this insight spreads fast enough – i.e. also on the critical time-scale of a generation – viability may still be achieved. It does not represent an internal contradiction, but lies in the logic of instability, that we must try and constrain speed as quickly as possible, and that we must co-operate globally to restrict global power. It is self-evident that the new attractors of society must organize constraints to nearly everything "big and fast". This will become constitutionalized as the governing principle in politics, technology and economy. So-called realists call this "utopia", because they lack the sense for all neighbouring attractive possibilities except the smooth, broad road to hell.

7. The beauty of the seventh day

Wasn't this supposed to be an essay about beauty? I am sorry, we had to take that long deviation to clear up the relation between reality and possibilities, and between realism and idealism. And now, space, time and everybody are exhausted. Anyway, of course, we are still not able to say what beauty is. No surprise! The essential feature of complexity is that it cannot be analyzed quantitatively. (To defend this statement against naïve optimism, let me again remind you that the number of different possible relation structures with straight lines between 24 points surpasses the number of atoms within our cosmic horizon.) Insofar, scientists were right to refrain

from value judgment about details of the filigrees in reality and its attractors. However, if they accept a single proposition, they will be able to make quite general judgments about the relative "survival value" of attractive ideas in technology, economy and other social activities. That single proposition is: The front of terrestrial evolution in the space of possibilities should not fall back to pre-noospheric or even pre-biospheric attractors. This demand certainly deserves to be called "ethical". If human mind accepts it, it will continue the "ethos" of our universe, its custom to find viable attractors of beautiful complexity.

Of course, the creation myth which I have sketched here, is not "proven" – it is a proposal, an offer especially to scientists, meant to encourage value judgment. In this framework, scientifically correct judgments about necessary constraints of human freedom – namely my general statements about spatial and temporal scales of viable social attractors – are unavoidable, of a tautological nature, like the principle of creation itself. No doubt, the majority accepts our "ethical" proposition. In the imagery of our myths, we may say: This shows that the devil has not won yet.

Where are we in the process of creation? Which day is it? A genetic engineer announced the morning of the eighth day, recently. A beautiful day it might become, he hoped, because he wasn't able to judge the probabilities of seeing beauty or ugliness at the end of the day. In fact, he thought he would make the weather himself, with his best will. After we have understood the conditions for successful creation, we can tell him: If mind would try to improve its own biological roots within a few generations, chaos would be the probable result, with a probability extremely near one. The beauty which we can imagine in the realm of ideas, if we allow for arbitrary combinations of genes from the pools of all species, is overwhelming. Marvelous children, men and women, beautiful, healthy and joyful for more than a century, living in a world full of sophisticated gadgets and a moderate selection of fantastically useful and cheaply produced other creatures … For fun, we may even make animals which Hieronymus Bosch might have painted! Why should all this be devilish?

We have understood now: With too many trials at a front near the old time-tested attractors of our material roots, the probability of reaching new viable attractors is practically zero, whereas the probability of losing the old attractors and of starting to tumble and become unstable, is nearly one. The

example makes it perfectly obvious where human creativity is likely to succeed, and where not. In our imagination, in poems, novels and pictures, we are certainly allowed to try other worlds – if their interaction with the real one is sufficiently weak. Our creativity must concentrate in our purely mental activity, which leaves the old world intact. We are still on the seventh day! God's rest does not mean that creation has stopped. This is impossible, as we have seen. The front of creativity has moved to our mental abilities. But our main task on the seventh day is "to praise God". In the clumsy language of this article that is: "Let your mind come near the truth of complex attractors which it can reach". This includes the attractors of pre-mental reality, God's creation of six days – which must not be abandoned, of course – and it includes all human ideas and works of art which are not in destructive conflict with those. We are back with Augustine. As mind wriggles near this kind of truth, it perceives beauty.

Creation and perception of beauty are both creative processes. In a first step, some part of reality has been created by the organization of accidents near complex viable attractors in the space of possibilities, i.e. in heaven. This may be part of the "outside" world, produced by the cosmos, the biosphere or by people in the form of works of art and craft or as communicable ideas, like poetry or music. In perception, the other creative step, a human brain interacts with this reality, and its neural activity, the mind, wriggles about the resulting patterns. If the fluctuations between newly excited patterns and the memory reach cycles in this process, this does not necessarily lead to the perception of beauty. If such "recognition" is reached too fast, it may even cause boredom.

The perception of beauty only arises when the wriggling goes on for some time and touches many neighbouring attractors in the memory. This is accompanied by a feeling of continuing surprise, and even excitation. It is, so to say, the sparkling of the complex truth of all the attractors touched in that trial and error of mental activity. In the end, though, this sparkling may give way to a steady splendour, when more adaptation has been reached and mind follows the complex attractor with reduced fluctuation rate. This is accompanied by a feeling of satisfaction. As far as I am concerned, after my long wrestling with the text of this article, my excitation about Augustine's words has given way to a kind of satisfaction, but I still find

them beautiful, not boring. Some wriggling is going on. Creation is not finished around this idea.

A complex mental process in productive and perceptive creation is not necessarily connected with a complex structure of the motive. Simplicity and symmetry often excite the mind to higher receptivity for its own internal beauty, its own viable complexity. Even simple geometrical patterns, and "monochromes" or extremely monotonous music may, therefore, cause long-lasting sparkling – as in a theoretical physicist – or inexhaustible splendour – as in a meditating monk.

In the history of art and music, which is part of the general progress towards the climax of the global acceleration crisis, we can see how the very concept of beauty changes. More creative minds wriggle faster and faster, and abandon the traditional ideas more and more quickly. In those purely mental activities innovation on our critical time scale, defined by a generation, must not yet mean decline. Here, the new can add to the old without fully destroying it, as it now often does in the biosphere and in many traditional cultural ideas which need more "hardware" for their expression. In the perception of art and music, some people may even follow the old attractors more often than new ones – e.g. in museums and concerts. Near the climax of the crisis, though, innovation in the production of art has long passed the critical pace and has reached the time scale of the most short-lived fashions. The very concept of beauty disappears. World-wide success of the fastest possible innovation, called originality, becomes the main selection criterion. Eventually, sparkling and satisfaction are no longer correlated with the "motives" and the skills in a work of art, but exclusively with the money involved.

Since the search for attractive structure takes time, thus hampering faster innovation, two tendencies must evolve naturally: For the invention one may use computers. They can do certain things in fractions of a second, which a human mind cannot do in a lifetime. Clearly, due to the selection criteria in the instability, the aesthetic value of such things is likely to rise, even more so, if the computer is very expensive. On the other hand, particularly modern people will become accustomed to finding *chaos* beautiful. Chaos seems to allow perfect freedom of the mind in its perceptive wriggling. However, this is an illusion. If mind finds complex ideas from chaos, they

must in fact have been very near subconsciously. Only the chaos near proven complex attractors is likely to be fertile in the creative process.

I do not want to insinuate that computer-produced pictures, like bits of the Mandelbrot set and many other fractals, cannot be extremely beautiful. They can stimulate mental activity in quite unexpected ways. Haven't we just used the Mandelbrot set as a guide in the discussion of what "existence" and "being there" might mean? The very language of this essay, admittedly still clumsy in its wriggling for a combination of exactness and freedom, would not have evolved without the acquaintance with the theory of deterministic chaos and the complex filigree structures of attractors and their basins of attraction in the phase space of simple dynamic systems.

Though, in a way, intuitively gifted minds must long have known that complex order can only exist near the "edge of chaos", and that self-organization of viable complex structures is impossible without accidental fluctuations around the attractors near that border, the consequences for human self-constraint could scarcely be made accessible to most people in a culture moulded by science, technology and "materialism". Now, with the popularization of chaos theory and ideas of modern physics and biology, there is a chance that the principles of creativity become familiar to many – and, eventually, to a majority. Perhaps my attempt of a "re-unification of mind and matter", of "earth and heaven", in the space of possibilities can help to find a language, in which scientists, theologians, economists, artists, and maybe even politicians and people in the "media" can talk to each other about the logical roots of the global crisis.

There is no reason to lose hope. The fundamental structures of our brain and of its drives are not changed by the evolutionary instability. Man isn't a failure in the process of trial and error. Children still enjoy beauty and abhor ugliness and evil. We must not be blinded by exceptions. And the adaptability of societies to changing circumstances is obvious from the history of culture. The only difference is that now the new constraints will not come from outside, but will be consciously created by the majority of all people after they have understood the principle of creation. The world has really become "man's age" – i.e. what the old English *werelt* for *world* means originally. The necessary self-organization of human freedom on viable attractors is certainly possible, and it will become likely as soon as more people start talking about the phenomenology and the logical roots of the

global acceleration crisis. Of course, this cannot happen if most gifted people run after more money, or want to solve the problems of mind with more material gadgets, or lean back peacefully or cynically to watch what evolution or God are going to achieve. But as we approach the climax of the crisis, more and more people will not feel satisfied. The wriggling will increase as more and more of the ugliness of our age becomes visible and felt. We can be sure that beautiful attractors are near.

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