

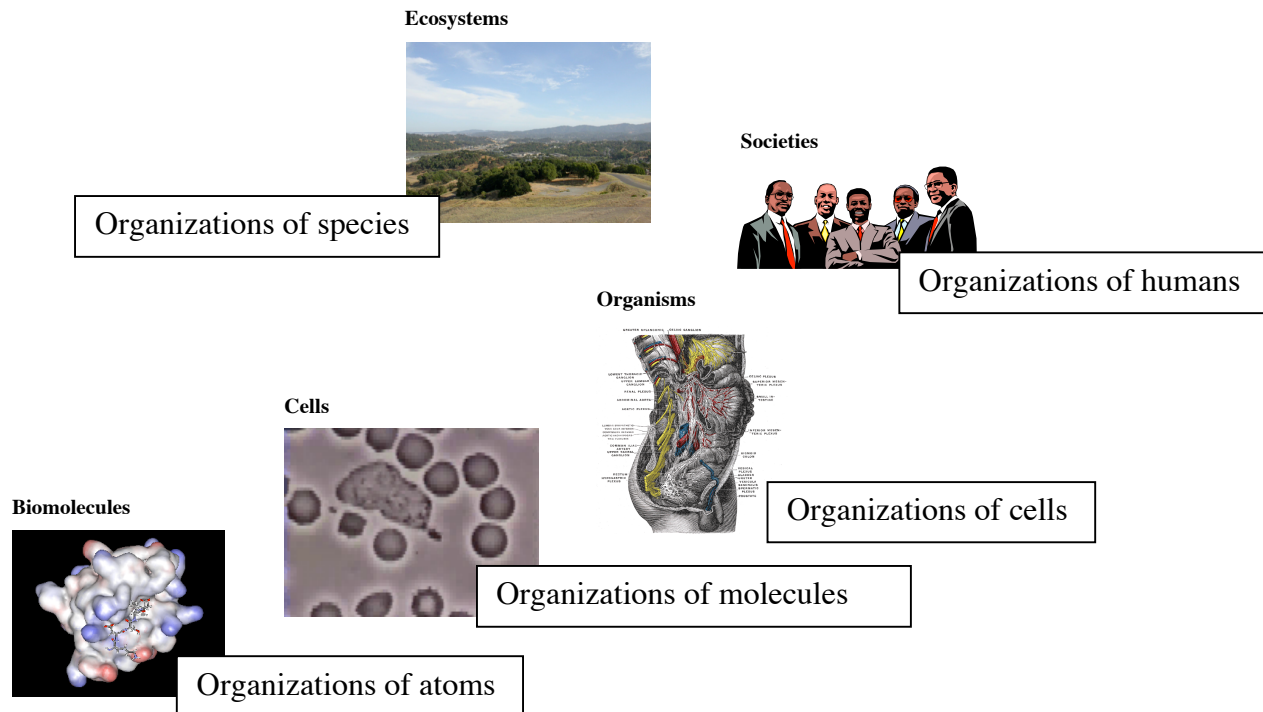
Lecture #6

Watchmaker versus Self-Organization.

Part I. Critique of The Newtonian Worldview.

Alexei Kurakin

The topic of today's lecture is a critique of the Newtonian Paradigm, or a critique of our all-pervasive and sub-conscious habit to interpret and represent the World surrounding us in mechanistic terms. The purpose of this lecture is to facilitate a paradigm shift in our current world perception. The shift from a reductionist, mechanistic and deterministic perception of the world to a dynamic, holistic view of the world, the view of the world as an ever evolving system of interacting, interconnected and interdependent complex systems that co-exist and co-evolve on different spatio-temporal scales.



Slide 1. Organizational hierarchy.

On one scale different molecules, through their specific interactions, are self-organizing themselves into cells. On another scale the cells through their specific interactions are self-organizing themselves into tissues. The tissues and the cells, in their turn, are self-organizing into human and other organisms. Humans, through their social interactions, are self-organizing themselves into organizations and societies, etc. All these different scales are interconnected and interdependent, and constantly

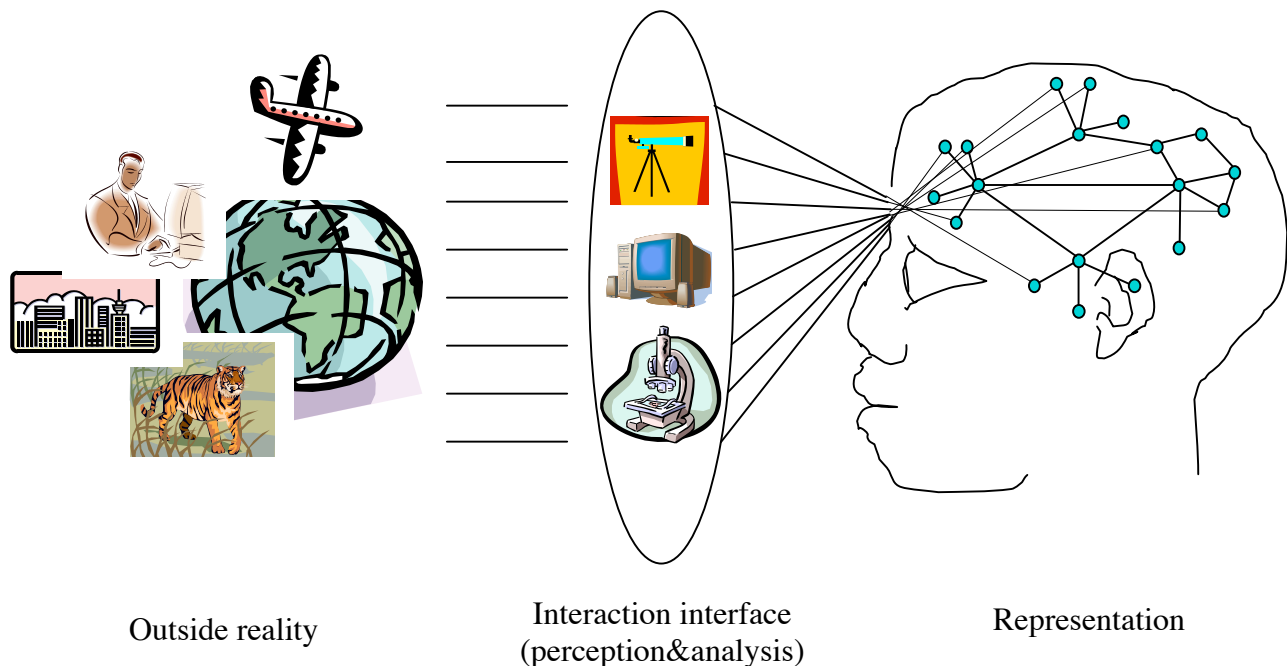
influence each other. In fact the division and separation of these scales are just convenience products of our reductionist mind, which cannot operate otherwise, but by taking a whole apart and considering its constituents separately.

Relativity and fleeting nature of “truths” and “facts”. The world as an evolving representation.

We habitually underestimate the powers of our mind. And we grossly underestimate the powers of the sub-conscious part of our mind, largely and successfully ignoring it. Meanwhile, the ignorance in this regard may constitute one of the main causes of the misperceptions and the misunderstandings plaguing our world. Our mind is a very powerful thing. In fact, it is everything. The world is nothing else but our representation of it. Which is a product of our mind. There are 6 billion people on this planet. It means that there are 6 billion different representations of this world. Which means that there is no such thing as “truth”. Any “truth” is nothing more but a representational consensus of the majority. Which is subject to a constant change and, increasingly often, intended manipulation. Most of the time we ignore the relativity of truths and facts. We tend to forget that any event or phenomenon communicated to us as a fact is always only someone’s interpretation. Consider the fact that our planet is round. It is only an interpretation built-in in our sub-consciousness by our culture. For a very long time our ancestors held as a fact that the Earth was flat. Today this interpretation has ceased to be the truth, but still remains as a practically serviceable approximation. Now imagine that in the next century our developing scientific theories and their practical applications will find it economically imperative and, hence, much more adequate and truthful, to interpret our existence in four dimensions, instead of three. Then the planet as a globe will be considered only as a three-dimensional projection from the next century’s four-dimensional world and only as a practically serviceable approximation for a certain and limited set of phenomena. The Earth as a four-dimensional object will become the fact and the truth obvious for everyone. If your imagination permits you to perceive clearly the fleeting nature of such seemingly unshakable fact as “the planet Earth is round”, then you are probably able to conceive our world not so much as a growing collection of facts and truths, but rather as a turbulent and ever evolving flow of emerging, competing and vanishing opinions and interpretations.

The current consensus of the majority regarding the global arrangement of the world constitutes the current paradigm or model of the world, the worldview. It is not constant on a larger time scale. It evolves. But, because it changes very slowly in comparison to a human lifespan, it is normally perceived by any individual as constant, except maybe for those rare historical periods that are commonly recognized as worldview revolutions or paradigm shifts.

The evolution of the individual mind is fueled and defined by its interactions with the reality.



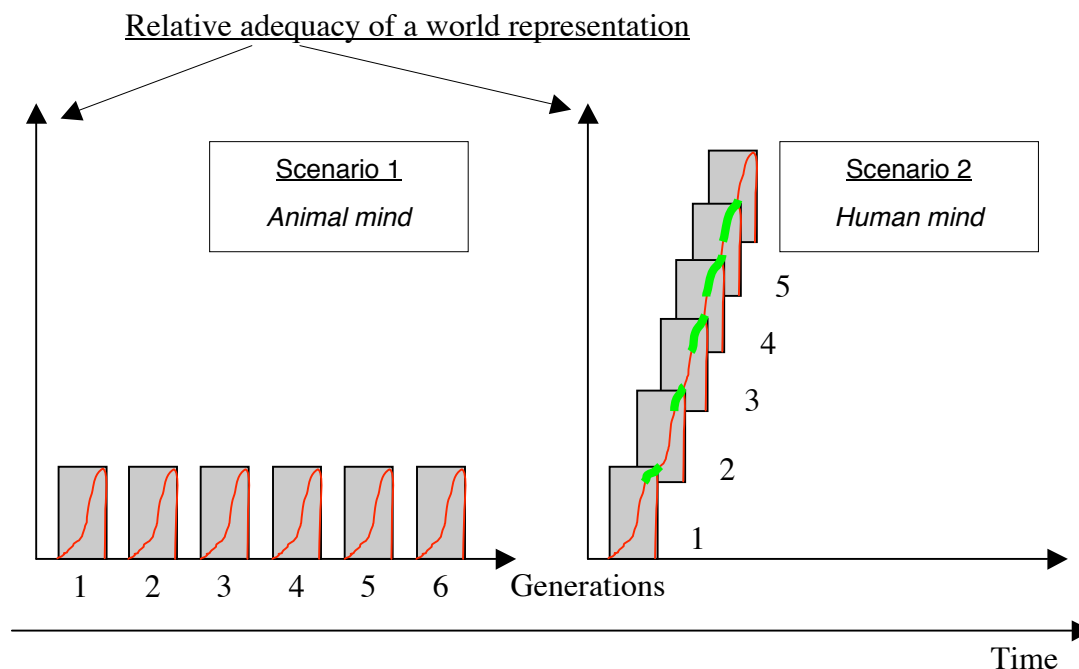
Slide 2. World as a representation.

Shown on the left side in *Slide 2* is a symbolic representation of the world surrounding us. It is an ever evolving system of interacting, interconnected and interdependent complex systems. On the right is a symbolic image of our cognition or our mind, which can be thought of as another ever evolving system or a network of interacting and interconnected concepts, ideas, notions, beliefs and feelings that represents the outside world inside us. In other words, one evolving system or process, our mind, is trying to make a proper representation or to model another evolving system or process, the outside world. Even assuming, just for a second and only for the sake of simplification, that the outside world is static, it is still too complex and too immense to be comprehensibly and adequately represented in all its minute details by our mind. Our ever developing mind does, therefore, its best. It generates during our short lifetime a chain of progressively more and more adequate representations, or approximations, or models of the outside reality. One representation becomes obsolete and inadequate with time and is replaced by a newer, more adequate one. Compare, for instance, your current ideas about the world and the ideas of your children, or your own ideas when you were younger, and the ideas of your parents. One may clearly see from this comparison, that our representation, or model of the world is a dynamic evolutionary process.

The adequacy of our current model of the reality is constantly tested through our interactions with the outside world. Every time we interact with the world, and we interact all the time except maybe when we are sleeping, we have a model of the situation in our sub-consciousness. We anticipate a certain

development of the situation. It is important to remember that though very often we may not be consciously aware of the model and our anticipations, they are always there, residing in our sub-consciousness. If the responses of the outside world fit our current model and are anticipated by this model, there is no confusion or surprise. If there is a persistent anomaly in the anticipated reactions from the outside world, we tend to adjust our model or even discard the old model and replace it by a new one.

Of course, the real situation is more complicated. The outside world is changing. So our mind generating a chain of progressively more adequate representations strives to do two things simultaneously: 1) to keep up with the changing world and 2) to model relatively slowly changing aspects of the outside reality to a more and more precise degree.



Slide 3. Temporal evolution of a world representation.

First, let us imagine a fictitious living creature that has a mind able to model the world. Let us plot then along axis X the time and along axis Y the adequacy of the creature's world representation, the adequacy of its worldview or the maturity of the creature's mind. The imagined creature through its unique experiences and interactions with the outside world builds up a better and more adequate model of the outside world in its mind as its life progresses (red line in box 1, left chart, Slide 3). The mind of the creature matures through its experiences. With time our creature becomes old and wise. And then it dies. The last and most adequate world approximation of our creature dies together with it. Its descendant, or second-generation creature, starts from scratch (box 2, left chart, Slide 3). Again, through its personal experiences and interactions with the outside reality, the second-generation mind builds up a chain of more and more adequate representations of the outside world until the second-generation creature dies

together with its worldview. In this scenario, the adequacy of the worldview remains relatively primitive, never exceeding a certain level limited by the creature's lifespan and its experiences. That is how, in a crude approximation, the animal mind works. The mind of every newborn cat or dog starts building its model of the world through its unique personal experiences from scratch. And at the end of their lives, their worldviews die together with them. For this reason our domesticated cats or dogs do not appear to be much smarter than cats or dogs which lived 100, 500 or 5000 years ago.

The humans, on the other hand, have developed a trick. They have invented culture, arts and science. A first-generation human mind, in the same manner as an animal's mind, develops a chain of more and more adequate models of the outside reality during the short span of human life. But the latest, most developed model does not die together with the first-generation humans. Instead, it is deposited outside the physical human beings as products of culture and science. As language, writings, arts or skills that are passed by imitation. The second-generation human minds during their first, developing, learning phase (thick green line in *Slide 3*) are formed and molded on the cultural template left by the first-generation human minds. During this early and relatively short phase they adopt and implant in their sub-consciousness, largely uncritically and as given, the latest model of reality left by the first-generation human minds. During the rest of their lives the second-generation human minds, through their interactions with the outside world, test the adequacy of inherited worldview, adjust it or replace it altogether by a second-generation model or paradigm of the outside reality. The improved model of the world is again deposited, as products of culture, to form the paradigm template for the third generation. In this last scenario, therefore, the development of a progressively more adequate model or representation of the outside world is dissociated from any physical human being, becomes independent of any individual and of the constraints of individual lifespan.

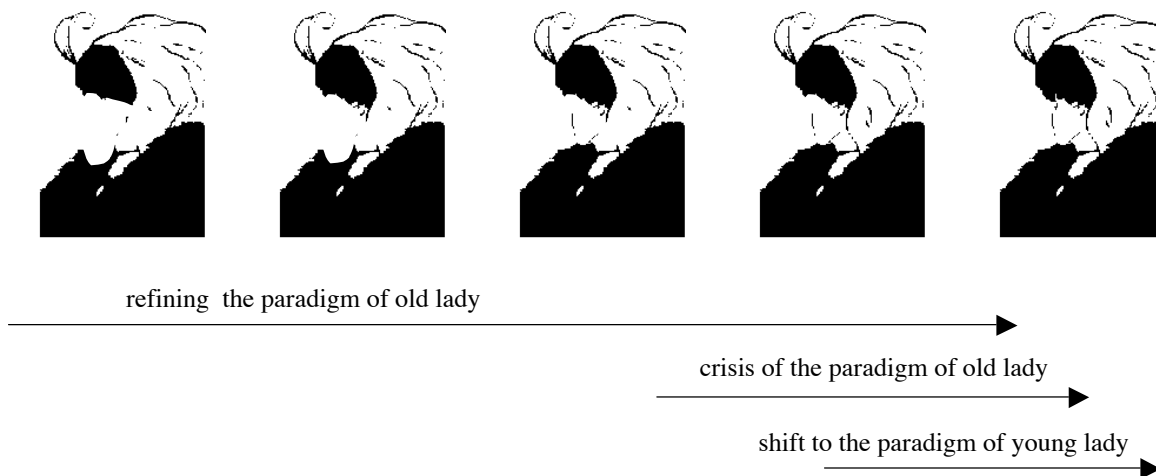
Of course, this is a very simplistic and crude approximation of human cultural development, meant only to convey principles, not details or variations. For instance, a particular model or paradigm of reality can exist in an essentially unchanged form and mold generations and generations of human minds. As an example, a largely constant religious worldview dominated over and molded European minds for more than 1000 years during the Middle Ages causing the cultural, political and economical stagnation of the human civilization in Europe. Another important point to keep in mind is that even though the graphical representation of human cultural development shown above is suggestive of a purely cumulative process, this impression is not exactly correct. For, as we discussed on previous lectures, during cultural and scientific revolutions the paradigm shift or replacement of the old and inadequate worldview by a new, more adequate one happens in a Gestalt-switch-like manner. Therefore, a cumulative process punctuated by avalanche-like perceptual transitions would be a more adequate image of human cultural development.

The development of human culture is conceptually equivalent to the development of the individual human mind, but happens on a much larger scale. Propelled by individual developments of individual

human minds that come and go in successive generations, the human culture as a whole builds up an increasingly more accurate representation or model of the outside reality.

Model of the paradigm shift. How to change the world.

According to the scenario described above, our minds were molded on the paradigm template that we inherited from previous generations. It is crucial to remember that, during the formational or molding phase, our minds adopt and incorporate in our sub-consciousness the inherited world paradigm largely uncritically and indiscriminatingly, as a given.



Slide 4. Model of the paradigm shift.

The gestalt picture was kindly made available by Dr. Korb, The Gestalt Center of Gainesville, Inc. <http://www.afn.org/~gestalt/fignd.htm>

Metaphorically speaking, we have been taught by our parents, teachers and our culture to see the outside world as the portrait of an old lady that can be recognized on the slide partially hidden behind white spots. The white spots symbolize the yet-uncharted or unexplored patterns of the outside world. According to the paradigm of the world as an old lady, which has been embedded in our minds by our upbringing and education, here is the mouth of the old lady, here is her chin (see first picture on the left in *Slide 4*). Now it is our turn to live, to interact with reality, and to improve the inherited model of the outside reality. We do some experimentation and research to uncover patterns under one of the white spots, which presumable covers one of the eyes of the old lady. And we do see the eye. More precisely, we interpret as an eye the pattern we have uncovered there. We do not interpret this uncovered pattern as an ear, for example, for it would not fit the paradigm of the old lady. And we do not waste our time investigating the white or the black areas of the picture, for according to the paradigm of old lady, there is nothing there.

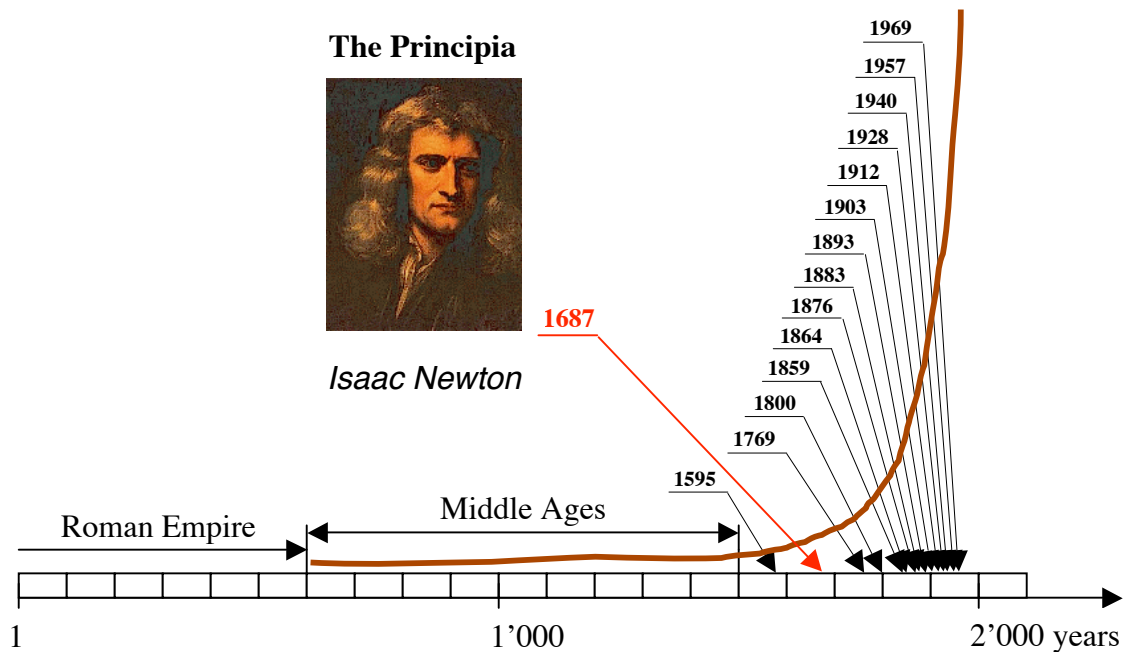
We continue then to uncover, through our interactions and research, other hidden patterns and to interpret them according to the paradigm of an old lady. This way we refine the image of the old lady, or refine our inherited worldview. We see her eye where we expect to see her eye, we see her nose where we expect to see her nose, and so on. But at one point a few people start to challenge this paradigm and its interpretations. They say: “The old model of the world, the paradigm of the old lady is wrong. This is a portrait of a young lady looking away from the screen. And this is not the eye of an old lady, this is the ear of a young lady. And this is not a nose, it is a chin. And this is not a mouth, it is a necklace. And the world is not an old lady, it is a young lady!” But as I mentioned before, the truth is nothing more but the interpretational consensus of the majority. As long as the majority continues **to interpret** the outside reality as the portrait of an old lady and **to act** correspondingly, the world **is** the portrait of an old lady, whatever the minority claims might be. Only when the majority of people’s minds will have learned to see the patterns of the outside world as a portrait of a young lady, then only the world will become the portrait of a young lady. The World will change. In a certain sense, the reality of the world we live in is essentially our mental problem. You can choose the world you live in. You can choose it individually. But you cannot change it individually. Only together we change the world we live in. Individually, however, we can help each other to see a new and better world.

Our current worldview in a historical perspective.

The current paradigm of the world, the one we inherited from previous generations, is a mechanistic and deterministic Newtonian interpretation of reality. It has been built in our minds as the default worldview by our education and our culture. And because it is a default, it does not require any mental or intellectual effort and comes “naturally” and automatically from the depths of our sub-consciousness. We naturally interpret everything around us as machines or mechanical devices. Worst of all, because this default resides in our sub-consciousness, most of the time it is inaccessible to the critique of our conscious rationality. The portrait of an old lady discussed above can be seen then as a metaphor of the Newtonian worldview.

It is a very good habit to consider everything as a process. Therefore, let us look at the dynamics of scientific and technological development in a historical perspective. This will help us to understand where our present paradigm comes from, its past and current worth, and its limitations. Let us limit our analysis in space and time and consider only Europe, starting from the year when allegedly Jesus Christ was born up to the present day. We shall not consider the dynamics of the Roman Empire with its cultural, scientific and technological raise, triumph and eventual decay. Somewhere from 500 after Christ till the 16th century there was a long historical period, of more than 1000 years, called the Middle Ages.

The largely constant worldview dominating the human minds during those over 1000 years was religion and irrationality. There was an omnipresent, omnipotent and incomprehensible in principle God that



Slide 5. Dynamics of scientific and technological development.

created this world and run it by his “inscrutable decrees” through his earthly governors, the Church and the clergy. The economic power, additionally, was concentrated in the hands of kings and nobility. The interests and powers of the Church and the nobility, though internally competing, readily and naturally allied when the management of the vast and extremely poor majority was being considered and executed. Those over 1000 years are also called the Dark Ages. Relatively nothing much happened in terms of scientific and technological development during those years. I reflected this fact respectively as a flat line on the slide. Europe started to wake up during the historical period that followed the Middle Ages and is called the Renaissance. Starting from the Renaissance all aspects of human life such as arts, science, technology, politics and economics, underwent an explosion-like development and progress. This explosion continues up to the present day. I included below a rather accidental and far from complete list of various scientific and technological achievements of the humanity during the last 200-300 years to convey the explosion-like character of this revolution.

Almost everything that surrounds us today are the products of the application of physical and other scientific theories that were invented, introduced and developed together with their practical applications within a remarkably narrow, in historical terms, window of time. Essentially within 200 years of the 19th and the 20th century. The question then: what is the underlying cause of this explosion in

development? The answer - a global paradigm shift in the worldview. The shift from the image of the world as dark, incomprehensible, uncontrollable and irrational, to a new image – the world as a perfectly

Random sample of scientific and technological achievements
of 18th, 19th and 20th centuries

1595 Jansen invents the first microscope
1769 English steam engine introduced. Industrial Revolution begins
1776 Adam Smith's "Wealth of Nations"
1800 Luigi Galvani invents the first battery
1820 Ampère inaugurates the birth of electrodynamics
1824 Sadi Carnot: The Carnot cycle is introduced
1827 Ohm formulates the Ohm's law
1836 Telegraph is patented
1850s Clausius, Kelvin introduce "energy" as a unifying concept
1859 Charles Darwin's "The Origin of Species"
1864 Louis Pasteur: All living things are produced by other living things
1864 James Maxwell "A Dynamical Theory of the Electromagnetic Field"
1866 Gregor Mendel places foundations of genetics
1867 Karl Marx: "Das Kapital"
1870s Kelvin, Clausius, Planck: The second law of thermodynamics
1876 Telephone arrives. First gasoline engine
1883 Edison patents the light bulb
1893 Koch, Pasteur: Fermentation process patented
1903 Wright brothers: dawn of air travel
1905 Einstein's special theory of relativity
1910 Morgan: genes are carried on chromosomes
1912 Radio arrives
1928 Flemming: penicillin discovery
1932 Television arrives, the electron microscope invented
1940 First human trials of antibiotics
1953 DNA structure uncovered
1957 USSR launches Sputnik
1969 Birth of Internet
1970 Isolation of the first restriction enzyme
1975 Microsoft founded
1976 Apple founded. Queen Elizabeth sends out an e-mail
1978 First human hormone is produced by using recombinant DNA
1981 First transgenic mice
1983 First field trials of genetically modified plants
1986 Internet. 5'000 hosts
1989 Internet. Number of hosts breaks 100'000
1991 The World-Wide Web (WWW) arrives
1997 Dolly the sheep is cloned
2001 Draft of the human genome is announced

ordered and logically functioning machine or the mechanism that has been designed and triggered into motion by a highly superior divine intellect. Though prepared by many brilliant scientists and philosophers, this paradigm shift was precipitated and is historically associated in large part with an individual effort. In 1687 Isaac Newton published his "The Principia" or "Mathematical Principles of Natural Philosophy". In this work, that has become the foundation of modern sciences, Newton defined the concepts of absolute time and absolute space, as well as mass, momentum and three types of forces: inertial, impressed and centripetal, as he called them. He formulated his famous laws of motion in a rigorous mathematical form and deduced a number of important laws. In addition to fundamental scientific contributions, the Newtonian paradigm triggered a Gestalt-like switch in the world perception of the whole western civilization.

In the Newtonian view, God, in the beginning, had created fundamental material particles, forces between them, and the laws of motion, and set the whole universe into motion. The world, or any part of it, can be understood then by reducing all phenomena to the motion of material particles in the void. The motion governed by fundamental and immutable laws that were given by the divine lawgiver. Therefore, the world that was seen before, during the Middle Ages, as incomprehensible and inscrutable in principle, was turned by Newton and his exponents into a gigantic, fully deterministic mechanism, something like clockwork, designed and triggered into motion by God.

"An intellect which at a given instant knew all the forces acting in nature, and the position of all things of which the world consists – supposing the said intellect were vast enough to subject these data to analysis – would embrace in the same formula the motions of the

greatest bodies in the universe and those of the slightest atoms; nothing would be uncertain for it, and the future, like the past, would be present to its eyes.”

Pierre Simon Laplace

The Newtonian representation of the world proved to be more adequate than the religious model of the Middle Ages. It provided a fruitful conceptual framework for the rapid advancement of physics and technology. And thanks to the Newtonian paradigm, we have and enjoy today what we have and enjoy. Basically it is everything human-made around us. We tend to forget, however, that the Newtonian paradigm is only an approximation of reality. It is by definition transient and limited. Any our model of reality sooner or later exhausts itself as a representational framework upon increasing amount and diversity of our experiences. The more we learn about the reality around us, the more hidden patterns of nature we uncover through our observation and experimentation, the faster the aging of the paradigm in use. The more inconsistent and inadequate it becomes to explain the reality we experience. Besides, the world is not a frozen construct. It evolves. The world we live in today is significantly different from the world of 1687 in many respects! The Newtonian paradigm became inadequate even for physics, and already in the last century. More precise experimentation with and modeling of reality necessitated the introduction of quantum and relativity theories in physics. Their introduction, unfortunately, has not affected the general worldview, which remains essentially unchanged for the last 300 years.

Though the Newtonian representation will continue to serve us well as the most *convenient approximation* for a limited set of phenomena, especially in modern technological applications, it is ceasing to be the *best approximation* of reality and it certainly cannot be considered as adequate in explaining everything. We tend to forget somehow that the Newtonian paradigm was never perceived as especially adequate in application to the life phenomena. In fact, voices against the mechanistic interpretation of life were raised already in the times of Newton. At the height of the Newtonian triumph Denis Diderot wrote:

“Look at this egg: with it you can overthrow all the schools of theology and all the churches in the world. What is this egg? An insensitive mass before the germ is put into it... How does this mass evolve into a new organization, into sensitivity, into life? Through heat. What will generate heat in it? Motion. What will the successive effects of motion be? Instead of answering me, sit down and let us follow out these effects with our eyes from one moment to the next. First there is a speck which moves about, a thread growing and taking colour, flesh being formed, a beak, wing-tips, eyes, feet coming into view, a yellowish substance which unwinds and turns into intestines – and you have a living creature... Now the wall is breached and the bird emerges, walks, flies, feels pain, runs

away, comes back again, complains, suffers, loves, desires, enjoys, it experiences all your affections and does all the things you do. And will you maintain with Descartes that it is an imitating machine pure and simple? Why, even little children will laugh at you, and philosophers will answer that if it is a machine you are one too! If, however, you admit that the only difference between you and an animal is one of organization, you will be showing sense and reason and be acting in good faith; but then it will be concluded, contrary to what you had said, that from an inert substance arranged in a certain way and impregnated by another inert substance, subjected to heat and motion, you will get sensitivity, life, memory, consciousness, passions, thought ... Just listen to your own arguments and you will feel how pitiful they are. You will come to feel that by refusing to entertain a simple hypothesis that explains everything – sensitivity as a property common to all matter or as a results of the organization of matter – you are flying in the face of common sense and plunging into a chasm of mysteries, contradictions and absurdities.”

In this fragment the French philosopher Denis Diderot expressed the protests and confusion of many scientists, philosophers and professionals dealing with the so-called animated matter. The impressive success of the Newtonian paradigm that provided a framework for the development of physical sciences, and, what is the most important, the rapid economical advance as result of technological applications of physics, suppressed these voices of protest and pushed the life sciences on the periphery of scientific development. The industrial age of machines and domination of physics followed. What do we have now? Today the life sciences are revitalizing and moving into the mainstream of research and development. And, what again is the most important, they gradually acquire economic power. Moreover, economics itself is increasingly perceived as a life science. The Newtonian paradigm has never been fruitful in application to economics. Nevertheless, our minds, molded on the Newtonian paradigm template, continue today to sub-consciously interpret everything in the terms of mechanical devices or clockworks.

Clockwork as allegory of Newtonian paradigm.

Let us consider a mechanical watch, the symbol of the Newtonian worldview. We provide mechanical energy through the winding stem (5a) and store it in the mainspring that is situated inside the main barrel (1). The stored mechanical energy is gradually released causing the extremely slow rotation of the barrel. The slow motion of the barrel is transformed into the relatively rapid rotation of the last gear in the gear train (2). The last gear is coupled to the mechanical oscillating device that divides the constant motion of the gear into a quantal motion (4), which is passed through the dial train to the hands of the

watch (6). No part in this watch is redundant or accidental. All the gears, their radiuses, external and internal, their stems and all the interconnections between them are carefully designed and manufactured with high precision to insure the proper performance of the watch. All the individual components of the watch and the whole device have their respective purposes and, before their manufacture, pre-existed in the heads of engineers and designers and were put on paper as project charts. The watch can be disassembled down to its



Slide 6. Mechanical watch.

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individual components and readily re-assembled by an intelligent person who is unaware *a priori* of the watch design, but has more or less clear ideas as to the functions of its individual components. Importantly, the re-assembly of a functional watch can be achieved in a unique way only. Primitive variants of clockworks are often available in toys shop departments as sets of individual components, ready for assembly. Our culture seems to take special care to foster this type of intelligence in our children, thus molding and training their developing minds to operate in mechanistic and deterministic terms. Clockwork is a good analogy of how the Newtonian paradigm sitting inside our sub-consciousness sees or models all the phenomena of the outside reality. That is how we perceive the world surrounding us.

Reign of Newtonian paradigm in biomedical sciences and its lamentable consequences.

We all have been brought up and educated in the tradition of Newtonian Science. And we continue to live and to see the world through Newtonian glasses. It means that, consciously or sub-consciously, in everything around us, we are trying to see mechanical devices and deterministic processes. Our descriptions of the cell are full of mechanistic analogies. We see proteins produced like cars on assemblage lines according to programs encoded in the DNA, motors moving molecular complexes pre-assembled for specific tasks to defined destinations along microtubule tracks. Power stations producing and supplying energy where and when it is needed. Recycling factories of proteosomal machines, etc. And all of this is assumed to be organized and interconnected like cogs and nuts in a watch mechanism. It is very illustrative and helpful to look at the titles taken from our most respectful bioscience textbooks, scientific presentations and publications, to realize the all-pervasiveness of the mechanistic interpretation. A random sample: A. Sub-titles in the chapter "Making Machines Out of Proteins" from the popular textbook "Molecular Biology of The Cell" (Ed. B.Alberts et al., 3rd edition, page

211): “Energy-coupled Allosteric Transitions in Proteins Allow the Proteins to Function as Motors, Clocks, Assembly Factors or Transducers of Information” and “Proteins Often Form Large Complexes That Function as Protein Machines”; B. Title on the cover of “Nature” magazine (issue 421, no. 6924, 13 Feb. 2003) reads “Power Stroke: Electron Microscopy Shows Dynein Microtubule Motor Action”; C. Presentation title from American Society for Biochemistry and Molecular Biology (ASBMB) annual meeting (April 2003, San Diego, CA) reads: “Macromolecular Machines and Assembly Lines”.

What is the main idea underlying the most fashionable research today in molecular and cell biology? It is to make a comprehensive list of all components of the cell, see how they are connected and interlocked with each other and to draw comprehensive engineering-looking charts as if the cell was clockwork and the molecules were gears and springs of a watch-like mechanism. The hope is that those charts will allow us to infer “the design” of the cell as soon as we have learned the functions and properties of its individual components. In other words, in biomedical sciences, we sub-consciously perpetuate the image of the cell as a clockwork and follow today a traditional reductionist approach disassembling the cell to individual basic units in order to understand the whole through the study of its isolated individual parts. One cannot help comparing this whole image with the behavioral habits of infants disassembling toys, and toddlers struggling with assembly sets.

Many scientists nowadays are obsessed with the usage of an aircraft, a car, or a computer as an analogy to describe the complexity of the cell. These scientists, however, stop short from asking themselves the following logical question – if the cell is a mechanism like a car, or a Boeing 777, who is the designer then? For any mechanical device implies the existence of design behind it, and, therefore, a Designer. Or Watchmaker. Newton himself was very explicit about it. He postulated that God designed and created the universe, gave laws of motion, and triggered this motion. The purpose of science, according to Newton, was then to try to understand the divine design and laws in order to predict the behavior of the world. Therefore, Newton was consistent as a scientist. Many modern researchers are not.

Developing increasingly better instrumentation and methods to probe and to study the outside reality, we accumulate an enormous amount of awkwardly piled data trying to interpret these data as if biomolecules, cells and organisms were clockworks, and the confusion grows. The more in quantity and better in quality data we get, the more these data are inconsistent with a mechanistic interpretation of biological reality. Any novel and seemingly unifying concept or theory emerging in the field, consider as examples programmed cell death, theory of cancer, theory of aging or theory of degenerative diseases, quickly diverges into multiple sub-theories, often competing and contradicting each other or at best artificially held together in consistency with the help of multiplying *ad hoc* assumptions. This precise state of affairs has been described as a paradigm crisis by Thomas S. Kuhn in his philosophy of science classic “The Structure of Scientific Revolutions”. The much debated these days shift to and legitimacy of the “discovery” science as opposed to traditional hypothesis-driven research is yet another symptom of

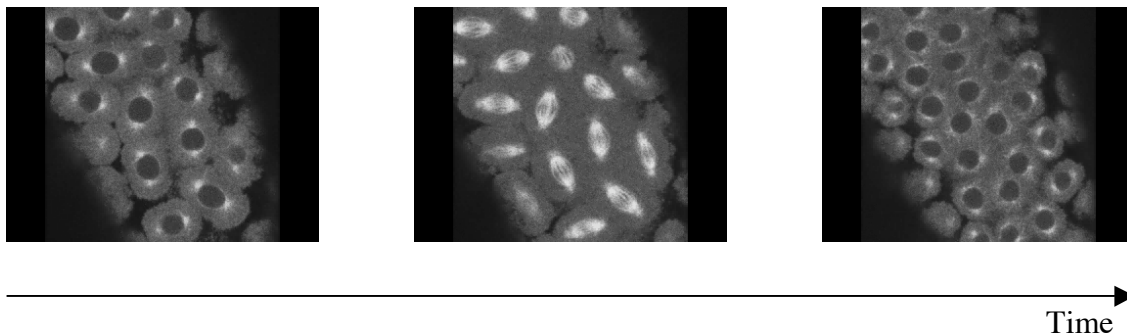
the paradigm in crisis. It is essentially an indication that random discovery science and “fishing expedition”-type experimentation are increasingly more fruitful than paradigm-based hypothesis-driven research.

But the paradigm of biology, or, generally speaking, life sciences, has never existed. It still remains to be developed. Therefore, it is just natural that we have been trying to apply to biology the best of what we had, the mechanistic and deterministic Newtonian paradigm. It is this paradigm that is in crisis today. And it is irrational and in the long run ruinous to insist on the wrong and inadequate interpretations of the failing paradigm. Even for someone with a vested interest in maintaining things how they are. Biology and biomedical sciences are of prime and special concern. Drugs and treatments, food and consumer products that are coming in increasing amounts as products of science based on misconception are applied to you, your children, your beloved and your environment today, and more will be delivered tomorrow. One may certainly ask why I am insisting on a paradigm crisis in the biosciences today when they enjoy an unseen-yet-in-history popularity and intense attention from society – from media, general public, investors, government and politicians. When almost every year brings a new discovery bordering a miracle. That is exactly the point. The discoveries are miracles. Even for professionals. Because most of them are *accidental*. As a rule, they do not arise or are predicted as a result of the application of a theory. And some of them, like cloning, or producing differentiated embryos and animals from cancer-derived genetic material, cannot even be explained by, or directly contradict the existing dogmas. Nevertheless, and perhaps not surprisingly, they are quickly and without much noise assimilated by and retrofitted into the old paradigm with the help of *ad hoc* hypotheses by the vested interest. Miraculous discoveries regularly and increasingly arise largely because an increasing amount of resources, both private and governmental, are being shifted to biosciences and biotechnology. As you, on average, hit “six” once, while throwing conventional dice six times, you have a good chance to hit “six” twice by throwing the dice twelve times. In addition, some miracles are real. And each miracle promises more mind-boggling discoveries coming tomorrow. It is a perfect scene for a speculative capital. Which brings even more resources to the field. The reader who starts doubting this description as being too good is, of course, right. The real picture is far from being idyllic. Theory-independent discoveries, theory-dependent pseudo-discoveries and *credo quia absurdum* promises, thoroughly mixed at ratio 1:10:100 – is what seems to be at work today. For each unaccounted-for by theory but useful discovery we have 10 misinterpreted discoveries, or pseudo-discoveries, born because of the wrong paradigm used for their interpretation and sustained by the irresistible pressure from the vested interest to believe that they are real and will make it to the market. And who is the end consumer on this market? You are. But not in the sense you are used to. You can return, sell or discard almost any conventional consumer product you are not satisfied with. Bioscience’s products, in large part, are targeted to your body and your mind. They directly affect and irreversibly change you upon consumption. And you will be left living (or struggling) with the consequences of this consumption, you like them or not. In addition, those products tend to be

prescribed by authoritative opinions you cannot possibly test or challenge, and, therefore, prefer to accept on faith.

Emergence of the alternative paradigm.

Fortunately, the minds of increasingly many scientists, artists and general educated public are pregnant today with a novel, alternative paradigm of the world. It is not well articulated yet. It is emerging. We are on the brink of the birth of a new world. We are living through a global paradigm shift, though it may be difficult to appreciate it because it is so slow when compared to our human lifespan. This novel view of the world is associated with a number of modern and explosively developing theories, such as network theory, complexity theory, chaos theory, non-linear thermodynamics and self-organization. These theories are bound to evolve and to fuse into a unified theory of Life and probably sooner than we might expect. Especially if we help.



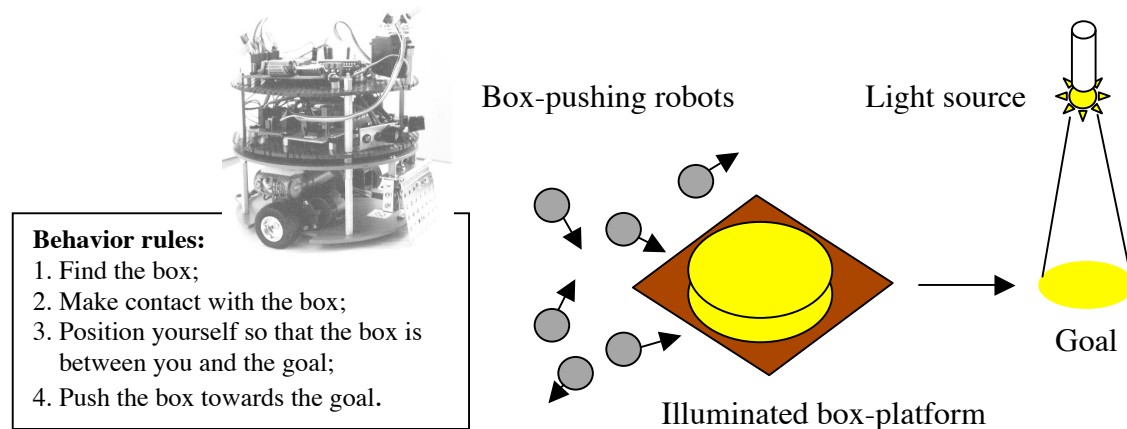
*Slide 7. Synchronous nuclei divisions in the early *Drosophila* embryo.*

The movie source: <http://www.welc.cam.ac.uk/~brandlab/movies/brand1.mov>

Brand A.H. (1999). Microtubule dynamics during cell division in the *Drosophila* embryo. In GFP in Motion, Trends in Cell Biology, 9, (no. 2; CD-ROM supplement). Reproduced with permission from Dr. A. Brand, Cambridge University, UK.

Consider a movie showing synchronous nuclei divisions in the early *Drosophila* embryo (*Slide 7*). Highlighted in this movie is the dynamics of the cytoskeleton during divisions. If we take 100 embryos and make 100 movies we will see approximately the same pattern emerging each time. The old paradigm would say: “Of course! The cell is clockwork! What else would you expect? We provide energy and it moves in the way pre-determined by its design. You can repeat this experiment 1000 times and you will see the same.” The novel paradigm, the paradigm of self-organization would answer: “No, the cell is not clockwork. It is an evolving system or evolving network of molecular interactions. If you repeat the shown experiment 100 times, the evolutionary outcome, nuclei division, will be repeated over and over again, but the evolutionary path of each one of those 100 repetitions will be unique.”

Let me illustrate this point on the example of the “box-pushing robots” movie, which we saw during our previous lecture on swarm intelligence (*Slide 8*). The box-pushing robots are relatively simple electro-mechanical devices designed to model the intelligent behavior of social insects. There are six of



Slide 8. Self-organized cooperation: performance of complex global task by following simple local rules through.

The movie source: <http://www.cs.ualberta.ca/~kuba/crip.cgi>. Reproduced with permission from Dr. R. Kube, Univ. of Alberta, Canada.

them in the movie. They have a task – to deliver a heavy box to the illuminated area in the room. Each one of them is too weak to move the box on its own. The robots are unaware of their global task. They do not communicate with each other. They are even not aware of the existence of each other. They are programmed to adhere to four simple behavior rules: 1) find the box; 2) make contact with the box; 3) position yourself so that the box is between you and the goal; 4) push the box toward the goal. In the movie you can see that the robots self-organize themselves in a rather chaotic and unpredictable ways to deliver the platform to the illuminated area. The global task, which is not comprehended at a local level, is achieved, nevertheless, by following simple local rules. The system is non-deterministic, flexible and robust. If you repeat this experiment 100 times, 100 times the box will be delivered to the illuminated area. Thus, the evolutionary outcome will be the same, but the evolutionary path will be unique for each

of those 100 repetitions. The same happens inside the cell. Molecules follow local physico-chemical rules in their interactions, unaware of each other and their global goal. They self-organize themselves in chaotic and unpredictable ways in what we observe as the dynamics of nuclei division in our example.

The principles underlying this self-organization we shall discuss in another lecture. Here I would like to stress that if we learn to see the cell not as clockwork, but as a process, as an evolving network of molecular interactions, we will ask very different questions and design very different set of experiments. We will not be asking then “What protein interlocks with what and how do they form together a gear train to transfer a signal along the pathway?” But, instead we will ask “Why is this particular evolutionary outcome repeated over and over again, and why it is preferred over millions of other possible ones? Why does an evolving system of interacting molecules self-organize itself in scale-free networks and not in other network types?”

In other words, looking at the same patterns of world we shall not ask: “Why does she look so grumpy?” or “Why the skin under her eyes is flaccid?” But we shall ask: “Why is she wearing a necklace and dressed up?” and “Why does she look away from us?”



References and acknowledgements :

1. Picture of the neutrophil chasing bacteria in *Slide 1* was reproduced from <http://expmed.bwh.harvard.edu/projects/motility/neutrophil.html> with permission from Dr. T. Stossel, Harvard Medical School, Boston, USA.
2. Laplace's citation was quoted in “The Tao of Physics” by F. Capra (SHAMBHALA/2000, p.57).
3. Diderot's citation was quoted in “Order out of chaos” by I. Prigogine and I. Stengers (A Bantam Book/1984, p. 81).

I gratefully acknowledge permission to reproduce the original works used in this lecture and encourage the interested reader to explore the cited sources for additional information.

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