Evolutionary Change

Evolutionary Change:Toward a Theory of Viable and Pathological Development.

by

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Dedicated to my Grandmother Rebecca, my mother Ida, my relatives Bluma Balter-Itsikovich, Elisabeth Feldman, Sarra Krimotat, Gregory Stolerman, and Efim Yusim, my friends Ida Abramovskaia-Shats, Alexandra Ackoff-Makarova, Alexander Ash, Ilia Blokh, Emmanuel Braverman, Michail Breev, Vladimir Dilman, Roland Dobrushin, Ivan Elagin, Frances Finkelstein, Elizabeth Flower, Emma Gurevich-Feld, Nadia Krasnoselsky, Roberta Hall-Luxenberg, Leonid Kantorovich, Tamara Libinzon-Peschansky, Wolfgang Pflugfelder, Irene Rubin, Itzhak Sankowsky, Boris Shragin, David Solomons, Michail Sonin, Leonard Starobin, Natalia and George Vladutz

victims of cancer.

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*Square brackets indicate references at the end of the chapter

INTRODUCTION

1. MAIN HYPOTHESIS

Truly amazing advances in biology, particularly molecular biology, have opened new engineering possibilities to shape the future of mankind, both in terms of "improving" the human species as well as eradicating all kinds of pathological manifestations of biological development. However, all of these promising interventions are fraught with grave dangers. The pitfalls stem primarily from the local nature of changes that are introduced, meaning that the impact of the intervention upon the overall development of the biological system is not fully taken into account. As we struggle to improve or rectify the well-being of individual human beings, we are apt to harm the population as a whole and impair the development of the human species. In addressing all of these issues, it is essential to recognize the integral characteristics of diverse biological mechanisms of change brought about by nature.

Biologists are only now starting to pay attention to this class of the mechanisms of change. The great majority of the profession persists in reducing evolution to a uniform mechanism of random mutations. At the same time, certain order exhibited by the evolutionary process of change presumes, and plausibly so, certain variety in the actual mechanisms of change. Of course, this scheme does not ignore the role of the random mechanism of change.

My aim in this book is to explore new avenues of research into individual biological mechanisms of change as well as biological mechanisms of change in their totality, i.e., as they fit in the general dynamics of biological development. The book makes extensive use of the design approach.[1]* Discovery is really a result of testing the set of constructed models against one model, which, based on all the

*Square brackets indicate references at the end of the chapter experimental data, is taken to be the model of the external, so called real world. The principle of design does not deny the role of the real world in the creative being as far as stimulating creative ideas, testing their validity in this real world, and their actual implementation (also using the example of certain pathological manifestations of these mechanisms of change).

My principal conjecture in the present work is the following: there is a somatic mechanism of change operating in multicellular organisms. It should be stressed that in speaking of somatic change I mean the entire mechanism of somatic change, i.e., the interaction of groups of specialized cells that undergo many stages of development. Change (mutations) within individual somatic cells confined to the host tissue is another matter.[1]

I set the mechanism of somatic change apart because its normal function and operation are rather poorly explored. While my focus is on the somatic mechanism of change, I would certainly not rule out its connection with the mechanism of change based on specialized reproductive cells - germ cells. In fact, I believe there is a certain relationship between these two mechanisms. Taking into account that "the genome of the somatic cells is the same as the genome of the germ cells"[2] (p.255), considerations expressed in the present work regarding the mechanism of change via somatic cells are largely pertinent to germ cells.

The following phenomena seem to corroborate my working assumption regarding the role of the somatic mechanism of change:

in terms of the evolutionary time table, the somatic mechanism of reproduction preceded reproduction based on germ cells;

the emergence of new reproductive methods on the biological scene did not eradicate previous modes of reproduction, but merely limited their scope of operation: reproduction based on somatic cells is still important to the development of living creatures. It may be argued that this mechanism is archaic, that it is not autonomous but plays a subordinate role, and that the changes it induces are not passed on to the progeny.

In pursuing my main theme, I explore two related issues having to do with somatic and germ cells as well as their interactions.

The first problem is the sources of change, meaning the interplay between internal and external sources of change and how ordered these changes are.

The prevailing opinion among biologists is that the sources of change are primarily external - radiation, chemicals, etc. Moreover, these changes are of random nature and are manifest in all kinds of damage (mistakes, disorders) in the genome. The utility of the damage in terms of the evolutionary process is to be determined by his majesty the process of selection. I would not discard these methods of the creation of new structures and the process of selection as the ultimate judge of the evolutionary worth of the innovations. Nonetheless, another very plausible hypothesis is that the genome supports more ordered processes of change, and it is at this earlier stage that the potential benefits, or damages, induced by the change can be ascertained. In view of the above, the term innovator shall only refer to those beings that exhibit a trend toward development prior to them being affected by the pressures of natural selection.

A number of biologists subscribe to the notion of internal mechanisms of change. The definition of this category is given by Lancelot White[3] in a following way:

> "INTERNAL (OR DEVELOPMENTAL) SELECTION
> The internal selection of mutants at the molecular, chromosomal, and cellular levels, in accordance with their compatibility with the internal coordination of the organism. The restriction of the hypothetically possible directions of evolutionary change by internal organizational factors." (p.vii)

The existence of internal mechanisms of change has been the subject of an extensive and long-running controversy. Without going into the history of science, perhaps the views descend from Bergson's[4,5] ideas of creative evolution, his *elan vita,* and the so-called *vitalist* school[6] are the principal forces in championing the existence of internal mechanisms of change. While the vitalist theory of an inner life-force irreducible to chemical or physical forces is highly controversial, its great achievement lies in its belief in the existence of an internal mechanism which makes life autonomous and self-evolving. Just as Mendel's statement of the existence of genes – long before genes themselves were discovered, had a profound influence on biology – the vitalist notion of an internal mechanism of self-evolving life can be quite conducive to current research armed with modern tools for uncovering the mechanisms of change.

The history of ideas regarding the internal mechanisms of change and described in White's book reveals that biologists who have recognized its existence tend to focus on the non-trivial links between the internal and the external (Darwinian) mechanisms of change. The internal mechanism of change itself was regarded as a black box, meaning its analysis was limited to phenomenological observations. The probe into the actual structure of the internal mechanism has only started in the recent past as biologists began to recognize the dynamic structure of the genome. We have embarked upon a long and fascinating journey into the internal mechanisms of change manifested in numerous discoveries, among which are *selfish genes* possessing definitive *linguistic patterns, transposons* (firstly discovered by Barbara McClintock, but deemed unimportant for a long time), a *computer based on the DNA molecule* designed by Leonard Adleman, etc.

In terms of a process, external sources of change operate *from the end*, meaning that they reflect external conditions (environment). Internal sources of change operate primarily *from the beginning*, creating predisposition toward future development. The joint action of these two sources of change creates the so called *tunnel process* in biological evolution. Possibly the genetic changes induced at the beginning are accumulated in the genome prior to their ultimate expressions in the phenotype.[7] Consequently, paleontologists need not seek all the intermediate changes that might be redundant or even harmful in the evolution of a phenotype of a new species. It is further surmised that internal mechanisms of change may resemble metaprograms, or programs for changing other programs, which, in turn, govern the development of an organism. Note the distinction between *regulatory* and *repair* structures incorporated into the program, as well as a program for changing the program. A program in the genome may carry regulatory, similar to the steam valve in Watt's steam engine, as well as repair genes that manage the genome's operation and preserve the program's integrity. These segments of the program should not be confused with programs for changing other programs, i.e., programs that orchestrate the performance of adjacent level programs. A formalized analysis of a similar kind of internal mechanism of change can be found in Robert Rosen's book (part 10 C, pp. 248-252).[8]

Chapter 5 explores in greater detail the modern-day discoveries in molecular biology that make the existence of an internal mechanism of change quite plausible.

Now a few words about the second issue related to the principal topic – the emergence of germ cells and their interaction with somatic cells.

It seems that change can be more effectively implemented via the germ cells if the genetic material which defines the development of a new organism is collected in one compact space. Over the course of evolution, germ cell based reproduction has undergone fundamental shifts. Evolution first gave rise to sexual cells, and then separated the carriers of these cells.

There is no agreement among biologists as to the origins of the sexes. One necessary condition, frequently deemed sufficient, for the formation of the sexes is their ability to create diversity of genetic combinations generated by crossing over between homologous chromosomes. I have tried to elaborate a general approach to sexual differentiation, not necessarily limited to two sexes, and to show that specific functional attributes of compatible organisms, directly participating in crossing, represent another condition needed to define different crossing types. It cannot be ruled out that change is not merely limited to germ cells, but also takes place in somatic cells. The latter may eventually migrate to germ cells via the female reproductive system, which is easily penetrated by somatic cells (at least pathological ones). On the other hand, invasion of the male reproductive organs by somatic cells is problematic.

By focusing on the less explored mechanisms of biological dynamics, the theory proposed here might help future research into the mechanisms of evolution, both under normal and pathological conditions. I hope to further the understanding of the somatic mechanism of change in the norm by focusing on its pathological manifestations. My basic hypothesis is that cancer represents a pathological attempt to reconstruct an organism via the mechanism of somatic change. The omnipresence of cancer - from plants to various cells in complex creatures - seems to corroborate the one condition necessary to make the above claim, namely that a pathological systems-oriented dysfunction in the mechanism of change is universal to all life.

Furthermore, cancer cells might turn out to be innovator cells of the radical variety which flourish under a weakened immune system. Although there are obvious external sources of cancer, I believe the main causes of this pathology are rooted in, or at least linked to, the internal mechanism of change. The similarity between transposons, which I beleive belong to the latter mechanism, and cancer causing virusis can be viewed as a minor confirmation of the above statement**.** During the last two or three decades, we have witnessed unprecedented progress in molecular biology which has shed light on the various stages of the malignant process: the role of telomeres and telomerase in immortalizing the cancer cell, malfunctioning genes responsible for slowing down cell growth, patterns to metastasis, etc. Recent research has also provided an opportunity to probe the normal process of somatic change. However general theories of cancer are lacking.[2] Biologists involved in cancer research tend to focus on isolated features of the disease, slighting more global concepts of this category of disorders. The empirical branch of cancer research is fueled by one very important consideration, namely that even if one single stage of cancer can be fully dissected and controlled, then the progress of the disease can be stopped. In other words, in order to destroy something, it is sufficient to eliminate one necessary condition of its existence.

It seems that the lack of comprehensive understanding of the nature of cancer will make it very difficult to eliminate even one of its necessary conditions. I shall elaborate upon this statement in the main body of the book. To reiterate, what distinguishes the concept of cancer expounded in this book is its totality.

I believe the proposed approach that attempts to explain cancer in its totality will benefit if we view cancer in terms of the general development of life, i.e., immerse cancer in the general evolutionary framework. Unfortunately, the evolutionary approach to cancer has not been adequately explored. In fact, theories of cancer rooted in the evolutionary framework tend to focus upon the *justification* of cancer and its devastating effects, thus fostering a conflict between the positive role of cancer in terms of evolution and the need to eradicate it at the microlevel (single organism).[3] My approach is predicated upon the notion of cancer as a pathology that ought to be overcome, both at the micro and the evolutionary levels. Recent progress in fighting cancer is fraught with certain dangers arising mainly from a lack of elaborate theories of cancer in terms of general evolution, thus pitting progress at the level of an organism against that of the species as a whole.

Thus, I believe the above argument is grounds for the following hypothesis: cancer belongs to a class of systemic diseases stemming from the malfunction of the normal mechanisms of change in the cell. The great majority of disorders, including infectious diseases, poor organ performance, etc., stem from the dysfunction of a normal mechanism that merely reproduces a cell.

To summarize, the present book contains four classes of problems: the axis problem is the somatic mechanism of change with three other problems rotating around it - internal mechanisms of change, sexual reproduction, and cancer.

In terms of content, the present work resembles a monograph.[4] It is written in the key of contemporary ideas from systems theory, adorned with ideas expressed in the old-fashioned style of natural philosophy.

In keeping with the systems approach, the study of biological mechanisms of change ought to be immersed in the more general system which, in this case, is the universe.

A considerable number of works[9,10] have surfaced that attempt to examine biological evolution from a more general perspective, namely in terms of its link with the evolution of the inorganic word as well as its place in the social evolution of mankind.

Scholars of the holistic evolution of the universe strongly support the notion of a certain order governing the evolutionary process and reject the idea of randomness as the major driving force.

As noted by Ervin Laszlo:

> "It is reasonable to conclude that pure chance did not (and does not) dominate the evolutionary process: there must also be a significant degree of non-randomness.
> ...Given the ordered complexity that meets our eye, the reasonable assumption is that, somehow, preferential interconnections must exist in nature."[11] (pp.4-5)

The described general concept of cancer is made more concrete through the use of a new discipline termed General theory of evolution that emerged at the beginning of 1990s.

The champion of the new discipline, and one actively involved in promoting publications in the field, including editing World Futures: The Journal of General Evolution, was Ervin Laszlo[12], well known for his work in general systems theory. A major contribution to the development of this field was made by Ilya Prigogine.[13] One of the cornerstones of the new discipline is Prigogine's concept of nonequilibrium thermodynamics. Its applications extend beyond the realm of physics and chemistry to the evolutionary processes in biology, social systems, etc. Other interesting ideas of interdisciplinary significance contributing to the development of the general theory of evolution were expressed by Vilmos Csáni.[14]

The guiding principle of the general theory of evolution is the exploration of the general features of complex dynamic systems that exhibit development and the emergence of new structures. I believe that many of the ideas elaborated on in the present book that are pertinent hinge upon this guiding principle, e.g. the relationship among survival, viability, growth, and development, the interplay between the emergence of new entities, (expansion of diversity) and order, the tunnel process, evolutionary goals - to list a few.

While much of the research on the general theory of evolution examines the general characteristics of systems' evolution, a number of authors have probed specific systems, such as biological, social and economic ones.[15] Therefore, my analogies between the mechanisms of change in biological and socio-economic systems, as well my general deliberations on the nature of change in biological systems, also conform to the spirit of the general theory of evolution. In fact, the following topics touch upon new facets:

a) deliberations on the biological mechanisms of change (specific ones, as well as their collective behavior) that were initially based on somatic cells, then on a specialized reproductive cell, which, in turn, was transformed into differentiated germ cells with a subsequent separation of host/carriers of these cells;

b) my hypothesis that such a systemic disease as cancer is a manifestation of a pathological operation of the mechanism of change which appeared over the course of evolution; furthermore, based on this pathology, one can try to reconstruct certain less explored normal mechanisms of biological change that touch upon new facets of the evolutionary process and may contribute to the development of new branches of the general theory of evolution.

2. MECHANISMS OF EVOLUTIONARY CHANGE: IS THERE ROOM FOR NEW IDEAS?

Having done some reading on the subject of evolution, I have come to the conclusion that the basic research into the mechanisms of biological change addresses the following issues:

1) Is there one uniform mechanism of change, or a variety of such mechanisms?

2) Does change evolve in small disjoint steps (piece-meal), i.e., in the evolutionary manner, or does it unfold in broad comprehensive stages, i.e., in the revolutionary manner?

3) Are changes that take place random, or do they exhibit some sort of order?

4) Assuming there is some order in genetic changes, are these changes governed by rules pertaining to individual parts of an organism, or to holistic development?

5) Is there a special internal mechanism of change within the genetic structure, or is the genetic structure geared entirely to reproduction of the same organism? If so, are changes due to external perturbations?

6) Does as much change take place in somatic cells as takes place in germ cells?

7) What are the reasons for one germ cell (*spore*) that is sufficient to produce an organism, to evolve into gametes - specialized reproductive cells that must fuse to produce an offspring - and the subsequent separation of the carriers of these cells?

8) Are there players who intervene forcibly in the process of change, or does change evolve based on local interactions of equal participants?

The following dichotomies represent a concise summary of research into the aforementioned problems of biological mechanism of change:

A. 1 - uniformity, 2- diversity;

B. 1 - small disjoint steps, 2 - big broad steps;

C. 1 - randomness, 2 - order;

D. 1 - only via a genome, 2 - organism as a whole;

E. 1 - special internal mechanism of change, 2 - disturbances in genome structure;

F. 1- somatic cells, 2 - germ cells;

G. 1 - recombination, 2 - different functions;

H. 1 - vertical, 2 - horizontal mechanisms.

While the above parameters are not completely independent, each one underscores a specific aspect of development.

Figure 1 is based on these dichotomous variables. The cells, generated in a deductive manner, correspond with the various theories of evolutionary change. There are 256 different theories possible under the outlined scheme.

Generally speaking, the prevailing theories which conform to the scientific mind-set answer the eight questions posed above in the following way: (1) the mechanism of change is uniform, (2) changes unfold in a piece-meal fashion, (3) randomly, (4) via the genome, (5) lacking a specialized internal mechanism geared specifically toward change, and (6) implemented through the germ cells, (7) that are recombined, and (8) interact as equal participants.[5]

My personal perspective on the outlined problems of biological evolution runs as follows: (1) there are diverse mechanisms of change, (2) change is carried out piece-meal via minor isolated innovations as well as in a comprehensive sweeping fashion, (3) changes may be random or ordered, and (4) be implemented through the genome as well as the organism as a whole, (5) contain specialized internal structures to implement changes, (6) these mechanisms of change are incorporated into both somatic and germ cells, and the latter ones (7) are functionally distinct, and (8) interact as equals.

These issues will receive a detailed treatment in later chapters.

FIGURE 1. Combinations of different parameters defining the process of biological change.

A	B	C	D	E_1								E_2							
				F_1				F_2				F_1				F_2			
				G_1		G_2		G_1		G_2		G_1		G_2		G_1		G_2	
				H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
1	1	1	1																
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3. A SYSTEM'S VIEW ON THE BOOK

I believe that the best way to summarize the present work is from the *systems* perspective. In keeping to the systems approach, any problem involves at least five dimensions: function, structure, process, operator, and genesis.

The development of this approach is heavily indebted to Jamshid Gharajedaghi.[16] His analysis of a system incorporates three dimensions - function, structure, and operation. I have added two more dimensions to this list - operator and genesis. As a result the system to be analyzed is subjected to the following dissection: the purpose or what final product will actually implement a given objective – function*;* ordering the elements into a totality – *structure*; transformation of primary ingredients into the final product - *process*; tools used to implement the process - *operator*; and the impact of the prehistory of the system upon all the above variables - *genesis*. In principle, all these variables are *independent*.

The majority of scholars, however, attempt to find one single dimension which determines all others. This is typical of functionalism, structuralism, operationalism, etc. Unnecessary arguments among scholars in the same field frequently arise as a result of some system being viewed from a single narrow perspective.

Using the above mentioned multidimendional methodology, the present book, from the *functional* point of view, represents an attempt to show that each stage of the evolutionary process - change, selection, and heredity - incorporates a multitude of interwoven mechanisms that differ in the basic principles underlying their operation. My focus is upon the possible somatic mechanism of change and cancer as its pathological manifestation.

This kind of differentiation/integration analysis of evolution is rather foreign to biological science. While evolutionary theory has undergone change over time, each historic period has advanced its own reigning doctrine which proclaims one single universal in time and in space principle that governs the process of evolution. The currently prevailing doctrine is the neo-Darwinist theory of evolution, which takes the following fundamental principles for granted: change is random, i.e., based on chance; selection is rooted in the struggle for survival; and heredity is encapsulated in the genome. These basic principles are untouchable and are not subject to evolutionary development. Certainly, there is some marginal, but extensive, research spearheading new approaches to biological evolution outside the traditional framework. These approaches, however, also tend to proclaim a single governing principle of evolution as being universal in time and space.

From the *structural* point of view, the book is divided into three parts with some parts preceded by an Introduction and followed by a Conclusion. Part One presents the analogy between societal and biological systems. It is more common for social sciences to appropriate ideas from the natural sciences, especially from physics, engineering, and biology. There are well-known and wide-ranging analogies between society and a machine, an organism, or a biological colony. While the reverse analogies are infrequent, they could be quite informative. One well-known example is Darwin's use of the idea of the struggle for survival, borrowed from Malthus's treatise on political economy. I know of only a single work written by a Russian-Ukrainian scholar, Michael Tugan-Baranovskyi (1865-1919),[17] which examines in a *systematic* fashion the impact of the ideas in social sciences on the natural sciences.

I have employed concepts derived from social systems in my analysis of both the macro and the microlevel of a biological system. By spotlighting the R&D sector as an intrinsic component of the economy's overall structure, we can draw interesting parallels with biological systems which might also incorporate an analogous internal, ordered, or, more precisely, semiordered, sector of change. Our nebulous analogy becomes more concrete when we examine the multi-stage process of R&D and the diverse mechanisms including the mechanisms of random mutations) associated each stage.

My approach toward the definition of a sex and the feasibility of multi-sexual reproduction was suggested by an analogy to the division of powers. Analogies to the socio-political systems at the microlevel are more relevant in the analysis of cells.[6] Just as there are social deviants, there are cells which either induce a positive change in the organism or cause its demise. The reader may have surmised by now that I regard cancer cells as deviant type cells that might attempt a drastic and rapid restructuring of an organism and be particularly successful when the organism is under stress and its immune systems is weak.

Part Two examines the general characteristics of two plausible normal mechanisms of change based on somatic and/or germ cells. It also explores specific characteristics of the internal mechanism of change and the related topic of the emergence of sexes over the course of evolution.

Finally, in Part Three, I elaborate upon my hypothesis that cancer is a pathological manifestation of the somatic mechanism of change. The somatic mechanism of change itself has been poorly explored. Therefore, my discussion is based primarily on the well-documented pathologies of this mechanism. The sequence of analysis from the pathology (cancer) to the normal mechanism of somatic change was turned down in order to make my analysis more coherent. A reader who may be unnerved by my approach can return to the chapter on the normal operation of the somatic mechanism of change after reading about its pathological expressions.

In the Conclusion to the book, I have tried to bring together all the individual hypotheses which I have advanced in the course of analyzing my main hypothesis.

My other aim in the Conclusion is to provide some justification for my intervention into the complex world of biology. Perhaps the arguments expounded in this section might be of interest independent of the actual discipline explored in the present work.

The *process* oriented aspect of the present book is closely tied to its methodology. The crux of my methodology in probing into the mechanisms of biological change is the systems approach. I have borrowed the idea of finding isomorphic structures shared by different systems and expressed rather loosely via analogies. I spotlight the parallels between biological and social, especially economic, systems, but I also embrace such fields as origami, music, etc. I have also made extensive use of other methodological devices, namely the multidimensional (function, structure, process, operator, and genesis treated as independent variables) analysis of the problem and the integration of the various facets into a holistic structure. The currently prevailing trends tend to reduce the whole to a single dimension regarding other dimensions as dependent variables.

As multi-faced as I have tried to be in my presentation, my focus on the single issue of the mechanism of change in biological evolution, in fact, the very controversial somatic mechanism, is not without certain flaws. The reader might get the impression that I am trying to enthrone *one decisive factor* governing biological evolution and subordinate the development of the living creatures to this one factor. I realize the pitfalls of such a one-factor methodology. Examples of Freudism, Marxism, etc. reveal the harm that can be inflicted by such a narrow approach. However, my focus upon this unique factor skewed my analysis of biological evolution, and I hope the reader will be understanding.

In my analysis of the biological system, I have also drawn upon certain philosophical categories, and I have elaborated upon those categories associated primarily with indeterminism. It is in connection with the category of indeterminism that I consider the idea of a tunnel process, which seems highly pertinent to biological systems. Essentially, the tunnel process connotes the idea that development is a two-way process: from the end, i.e., adaptation to demands imposed by the environment, as well as from the beginning, i.e., internal restructuring of the genetic make-up aimed at creating the potential. Eventually, over the course of many unforeseen events, this potential can give rise to structures which will respond to the demands imposed by the environment.

I further believe that natural philosophy can be a powerful methodological tool if used at the appropriate stages of the investigation of new problems. Generally speaking, natural philosophy connotes speculative meditations on natural phenomena. Based upon certain facts, speculations of this sort may not require direct experimental verification. History of science, on the other hand, has demonstrated the virtues of the experimental method in molding new scientific theories so most scholars feel a deep-rooted distrust for natural philosophy.

A number of reputable scholars are also vying to rehabilitate natural philosophy. For example, Ernst Meyer acknowledges the crucial role of natural philosophy in preserving and developing the concept of a complex organic world during the reign of Newton's mechanistic reductionist methodology.[18]

It seems to me that natural philosophy fertilized by contemporary ideas on systems' organization (ideas born of specific disciplines or, indirectly, via the general systems theory) can be very helpful in the analysis of natural phenomena. Natural philosophy provides Weltanschauung, or a broad perspective, into the essence of the problem. It becomes indispensable at the *initial* stages when the foundation for a new concept is being laid and the most fundamental issues in the respective field are being explored. Under these circumstances, we must start with certain axioms, meaning certain assumptions must be taken on *faith* Here, natural philosophy helps steer us in our choice of axioms and subsequent course of research. And, since a developed society allows for multiple philosophical paradigms to coexist, different axioms picked by different scholars preserve the pluralism in respective field and help prevent a false course of research from monopolizing all resources.

As the new theory takes shape, there is a need to formulate more mature hypotheses that will be ultimately amenable to formal mathematical representation and experimentation. The issue, therefore, is not some abstract validity of natural philosophy, but the stage in the investigation of a specific problem at which it ought not to be discarded. To repeat, I believe that natural philosophy is helpful in dealing with the early stages of completely novel investigations. The more a given field is explored and the more a given hypothesis follows a trodded path, the less need there is for philosophical speculations. Moreover, the use of natural philosophy, especially its early stages, is fraught with superficial vulgarization if one overextends its use to analyze specific facts and thus bypasses certain crucial intermediate stages such as the formulation of experimentally verifiable hypotheses.

In the present context, the *operator* is the book's author. I have made the reader familiar with the author's person in order to make the point that, in spite of the book's lofty subject matter – cancer and the mechanisms of biological change – it is written by someone who, while not a specialist on the subject, is not a charlatan.

Finally, the *genesis* of the book - the history of how it was written. This aspect reflects the *source material* and *preliminary publications* of my hypothesis regarding the mechanisms of change.

Much of the material I have used in the book is concerned with molecular biology and the various stages of cancer, and was published in professional books and journals as well as in the Science, Nature, Science Times section of The New York Times, etc. I recognized the need to discuss my ideas with professional biologists before they embarked upon their own publications. I did just, that gaining much insight from many valuable discussions with biologists. Certainly, the people with whom I discussed my ideas cannot be accused of unrestrained admiration for my views. I would venture to say, however, that the majority of my colleagues did not consider my views to be *generally known*, *trivial*, or *outright wrong*. Most people with whom I have discussed my meditations on biology have opted to postpone their final verdicts until some experimental results are in.

An abridged version of the paper containing my biological hypothesis appeared in 1991 as an article in an established Western journal.[19] At first, I shared my raw ideas with my friends, mostly specialists in biology. At that time, I did not feel my ideas were publishable. The first published statement came in 1984, covering less than a page of my book[20] (pp. 93-94) devoted to new trends in systems theory. A more elaborate version of my deliberations was published in the proceedings of an International Conference.[21] The final published report encompassed three pages of rather terse text.[22] (pp. 44-46). I was also honored when a former Soviet journalist, now living the United States, expressed interest in my biological speculations. Mark Popovsky – the author of many and articles on biology and medicine (some came out in Samizdat), – published a large article entitled "At the Crossroads of Science, or Cancer Through the Eyes of an Economist." The article appeared in the November 2, 1990 issue of the American Russian-language daily, Novoye Russkoe Slovo.

The book is intended for a broad spectrum of biologists, medical professionals, systems scholars, and philosophers. There is also another group of researchers who stands to gain from this book – those involved in genetic programming. By imitating the process of natural selection genetic programming seeks to solve problems without specifying exact procedures.

Unfortunately, this new discipline still employs rather rudimentary notions about the mechanisms of biological change (random mutations and crossing without taking into account the specific functions fulfilled by the crossing organisms).[7]

At the same time, genetic programming is actually not limited to uncovering and implementing nature-given evolutionary mechanisms. It creates room for hypotheses regarding novel forms of reproduction and tests them by simulation. Since these new types of mechanisms have not yet been found in nature, the mere feasibility of their existence is heuristically conducive to our search for them in nature.

I should be most grateful to all readers who take the time to send me their comments regarding my deliberations.

NOTES TO INRODUCTION

[1]. This approach is reminiscent of Oscar Wilde's aphorism that art is not a reflection of life, but life is a reflection of art.

[2]. The following statement regarding the theory cancer made by an outstanding Russian pathologist Ippolit Davydovskii is still highly pertinent: "No other branch of medical science can rival oncology in exposing the glaring up between the wealth of factual data and chaos of theoretcial explanations of the etiology and nature of tumors. This abundance of facts and theories have not fostered a real theory of cancer."[23] p. 16.

[3]. As James Graham mentioned: "I wrote this book to convince all who read it that cancer played a major role in evolution and in doing that I say nothing negative about the disease. At times I may even seem enthusiastic about its function or, at the very least, its results. This does not mean that I think it is doing anything "good" when it causes suffering and death. Although I am convinced that cancer is a biological function and that we would not exist without it, that is no reason to decrease efforts to cure anyone afflicted with it or to eliminate it. In fact, although I did not write the book as a guide to cancer researchers, it is conceivable (although I think it extremely remote) that someone in that most demanding field may find in its pages the inspiration to undertake a new approach that will prove fruitful. Nothing would please me more."[24] p. xiii.

[4]. "Monograph - a way to present a fanatical idea" - this definition is given in "Under the Mobious Strip" - a humor-filled book published in 1993 by a researcher at the Central Economic- Mathematical Institute of the Russian Academy of Sciences. This definition suits the present opus perfectly.

[5]. As James Shapiro mentioned,"...the prevailing evolutionary wisdom [is] based on notions of piece-meal, stochastic genetic change due to replication errors and physico-chemical instabilities."[25]

[6]. "The body of an animal can be viewed as a society or ecosystem whose individual members are cells, reproducing by cell division and organized into collaborative assemblies or tissues."[26] p.1187.

[7]. "To accomplish it, genetic programming starts with a primordial ooze of randomly generated computer programs composed of the available programmatic ingredients, and breeds the population using the Darwinian principle of survival of the fittest and an analog of the naturally occurring genetic operation of crossover (sexual recombination)."[27] (p.1)

PART ONE:

AN ANALOGY BETWEEN SOCIO-ECONOMIC AND BIOLOGICAL MECHANISMS OF CHANGE

My aim in this part is to prepare the reader for subsequent direct parallels, bypassing any intermediate language, between societal and biological systems. In other words, generalized examples of the mechanisms of change that are incorporated into societal systems reveal the importance of subsequent analogies with the process of change taking place in the biological world.

Let us begin with the economic system.

CHAPTER 1

ECONOMIC MECHANISMS OF CHANGE AND BIOLOGICAL EVOLUTION

1. GENERAL FEATURES

1.1. Paradigms of Economic and Biological Evolution

Theories of economic development and their influences upon biological thought have a long and distinguished history.

On September 28, 1838, Charles Darwin picked up Thomas Malthus's book, Essay on the Principle of Population. This work had a decisive influence upon the development of Darwin's concept of evolution. The economic paradigm, which Darwin borrowed from Malthus, led him to formulate the *survival of the fittest* principle as the cornerstone of his evolutionary theory.

Apart from incorporating the idea of natural selection advanced by an economist, the post-Darwinian concept of evolution implicitly reflects the prevailing economic paradigm of the time. Let me clarify this point.

Economists in the 19th century believed that *change* – technological innovations – was primarily the result of random processes engaged in by individual inventors. Consequently, the attention of scholars was centered on the mechanism of *selection*, namely the market where competition determined (selected) the fittest - the ones most adapted to the environment. The products selected received reinforcement from the institutions whose existence was a given within the general dynamics of the model - *heredity*.

Darwin's theory presumes that biological changes are random, that selection amounts to the survival of the fittest, and that the entire organism helps preserve (pass on) the hereditary traits.

Now, economic science has witnessed a profound change in its understanding of both the interaction among change, selection and preservation of innovations, as well as each of these processes individually.

Modern economic science possesses sophisticated tools to deal not only with the competitive win-lose paradigm of selection, but also with cooperative win-win relationships. These mixed competitive-cooperative market processes are further enhanced by both endogenous and exogenous coordinating bodies, such as the stock market and the government. Economic science has also made great strides in understanding the value of preserving and nurturing corporate culture ("genetic code") that has proved its worth in the world of business.

Rapid technological progress in the second half of this century has brought about a deep transformation in the paradigms of economic change. The scale of change and its more structured output have given rise to a new sector (sphere) of Research and Development (R&D in the most general sense of the word) that is incorporated in the economy as a whole. The performance of this sector is far from random, something that is especially evident in applied science and engineering, although many minor improvements are somewhat random, coming from factory workers or similar isolated sources.

Economic theories of scientific/technological change are at the embryonic stage compared to the rather evolved theories of production, distribution, organization and policy implementation.

> "The central problem facing England, France, and the United States was one of innovation, of developing new techniques and technologies, and of diffusion of these recently developed technologies throughout the economy. The "economics" of this process of innovation, though discussed by Schumpeter, Hicks, and Robinson, among others, is not as well understood as that of the production and allocation of goods and services using established techniques. Only recently has it become once again the center of attention."[28] (p. 4.)

Still, work on R&D gives us a glimpse of the mechanisms of economic change and their interactions with the mechanism of selection and preservation of hereditary traits. At this time, I am interested in tracing the truly revolutionary influence exerted by the R&D sector upon the conventional schemes of economic development, i.e., the emergence of an internal (endogenous) mechanism of change aimed at semi-ordered development of innovations, which does not preclude completely random processes. What makes this analogy relevant to biological issues is the fact that the theory of evolution is still very much enthralled by the assumption that biological changes occur via random mutations - an assumption which shifts the focus to the mechanism of selection and subsequent reinforcement of selected genetic characteristics.

1.2. Change, Selection, and Heredity

There are three basic processes that shape evolution: *change* (formation of a manifold), *selection*, and *heredity*. The implementation of these processes, both individually and as a set, is ordered to a varying degree, and is exemplified by the economic systems.

Contributing to the synthesis of these processes is their mutual feedback, i.e., there is a certain order governing the interaction among these processes. Whereas previously, within the framework of the traditional paradigm of economic development, the creation of the manifold and its realization were largely disassociated, the new paradigm, which includes the R&D sector as an integral part of the economic system, ties these two processes together. For instance, this interplay is manifest in the fact that the market, being a mechanism of realization of the manifold, not only imposes demands upon the manifold, but is also one of its major financing sources. Each of the three processes mentioned above also entails diverse mechanisms of non-random operations; a number of mechanisms related to the R&D sector will be examined below. Therefore, while random mechanisms have not vanished they play a subordinate role.

In analyzing a system's dynamics, we have many ways of assigning priorities to such processes as the formation of a manifold, its implementation and its reinforcement. For instance, if implementation is deemed most important, the other two processes - change and reinforcement - become subordinate to that goal. If, on the other hand, the key aim is the expansion of the manifold, then implementation and reinforcement must be made to support expansion.

Economic science has typically operated within the following conceptual framework: scientific/technological change (the manifold) and the preservation of accumulated experience (reinforcement) are subordinated to the attainment of optimality (equilibrium) via a coordinated interaction of the participants (selection). This approach is particularly prominent in optimization models with endogenous technological progress.[29] These models implicitly assume the existence of a planning mechanism which performs an orderly and efficient search/selection for the best allocation of resources employed in the production of existing products by using existing technologies as well as the development of new products and new technologies.

The ideas of Joseph Schumpeter surpassed classical economic theory by emphasizing the role of change, i.e., emergence of economic disequilibrium brought about by the random actions of entrepreneurs. The mechanism of coordination, which is supposed to balance the economy and prevent its collapse, was relegated to a subordinate role.[30] The supporting function of the equilibrium and stabilization mechanisms is two-fold: first, not to impede the expansion of the manifold, and, second, to prevent chaotic disintegration of the system.

Generally speaking, I agree with Schumpeter's approach to economic development. However, I think he has overstated the role of spontaneous events in driving economic innovation. The distinction between the process of development and the process of implementation is blurred, i.e., he views technological progress primarily through its performance in the market, overlooking non-market horizontal institutions, e.g.,universities, foundations, or government institutions that intervene in the process of development. I shall address this issue of diverse institutions involved in non-random scientific/technological progress.

Biological concepts of evolution are still largely governed by the pre-Schumpeterian paradigm: the cornerstone of the biological sytem is the process of implementation and reinforcement severed from the process of change; change itself evolves in a random fashion similar to Schumpeter's scheme. The biological paradigm advanced here, which could be termed *integrative evolution*, presupposes a certain regularity in the process of change, selection and heredity (random elements persist, but are limited). My emphasis is the interaction among these processes via a feedabck mechanisms such as adaptive mutations in the interplay between change and selection.

1.3. Allocation of Resources Between Innovation and the Preservation of Existing Wealth

Whatever will be the solution to this conflict between development and stabilization of the economic system, in order to develop (survive), society has had to resolve the problem of the allocation of resources among: a) raising the standard of living and productivity level today; b) increasing output based primarily on the already existing technologies geared toward raising the standard of living in the near future; and c) investing in R&D,

which might bear fruit tomorrow or the day after tomorrow or even in the more remote future.

Another factor in resource allocation is the service life of resources employed in both the established and the new methods of production. In terms of a simple dichotomy, we have durable goods, which require one-time expenses, e.g., equipment, buildings, and non-durable goods, which require day-to-day expenditures, e.g., materials, energy. The first group forms the skeleton of the system, its anatomy, and the second supports the ongoing (physiological) processes.

At the microeconomic level, the problem of resource allocation between today's needs and future development is resolved via the interests of the various individuals/groups who want to channel more resources into their own domain. All of the accusations against capitalists, such as their selfishness or exploitation of the workers, basically reflect the fact that any business struggling to develop (survive) tries to channel resources away from today's needs of the workers into expansion of production (which might call for investment in new ideas) in order to satisfy tomorrow's or even more remote needs. On the other hand, and this is especially true when the overall standard of living is low, the workers are more interested in satisfying their current needs. Businessmen, together with the creators of new ideas, regard workers, who merely carry out their ideas in a rather routine manner, as exploiters, because the latter take the bulk of the increment generated by new technological and organizational innovations.

This global view of the economy creates the problem of resource allocation among goods of different temporal significance. The problem is resolved through the exchange of goods among the many producers who pursue their own self-interests. Conflicts that arise are resolved either through the center (state) or through a struggle, within certain limits, among the various groups.

The problem of resource allocation between investment in innovation and current output has interesting repercussions for biological systems. For instance, it surfaced in connection with the so called *C-value paradox* and the related *selfish genes*. I believe that selfish genes are invovled in the mechanism of change inside the genome, and considerable resources diverted to support them represent the cell's expenditures on the internal "sector of R&D".

2. R&D AS A PROTRACTED SYSTEM

2.1. The Multi-Stage Process of Change and the Respective Mechanisms of Operation

Let us now examine, stage by stage, the structure of the R&D sector and the diversity of the mechanisms of operation arising as a result of some fundamental differences among these stages.

General ideas associated with fundamental science are the fruits of basic research. These ideas are subsequently transformed into more formal concepts addressed by applied science, and then evolve into engineering designs subject to trial by semi-industrial pilot projects which might eventually develop into technologies of mass production. There are crucial differences among the various stages of development and implementation of new ideas which lead us to the notion of a *multi-stage process* of development of an economic system. This sort of linear stage by stage description does not imply any rigid order in the implementation of each stage. The various stages can evolve concurrently with feedback. Even the last of the above mentioned stages is not final because practical experience may point to further improvement.

Each stage of the R&D process has its own peculiar features and calls for an appropriate mechanism of operation. One essential precondition required by these mechanisms is the existence of horizontal relations, i.e., independence and parity of the various organizations taking part in the process of creation. Another crucial factor is pluralism, meaning a multitude of independent organizations working in parallel and financed by different sources. Vertical mechanisms, where some units are subordinated command-like to other units, that are manifest in the various forms of government intervention, e.g., tax breaks for corporations, funding for university research, direct funding, should not be ignored.

Horizontal mechanisms can be classified into market or non-market types. At the initial stages of development characterized by the birth of new ideas, the mechanism of selection ought to rely on the producer rather than some outside institution. The more innovative an idea, the more its originator should be shielded from professionals in the respective field. First of all, specialists are frequently *unable* to evaluate a radically new idea if only because it forces them to revamp the entrenched mode of thinking and enter an entirely new and still rather nebulous scheme proposed by the innovator. Secondly, it is not uncommon for specialists not to want to recognize new ideas in their field because it might hurt their professional status or detract from some other valuable asset they possess.

As new ideas evolve, the role of external mechanisms of selection increases, especially expert opinion, but not the market which typically handles the sale of the fruits of one's labor. The diversity of organizations involved in this stage of R&D prevents any single one from monopolizing the evaluation procedure. The organizational framework characteristic of this stage is the institution of foundations.

In summary, since the initial stages of R&D require that the producer be shielded from the overly pragmatic criteria of the consumer, what are called for are different types of non-market mechanisms. Universities, independent inventors, foundations, etc. represent the various institutions suitable at this particular stage.

As abstract ideas begin to materialize into more worldly things and the consumer's role of selection increases, market instruments, ranging from venture capital to public corporations, become the dominant force.

The above considerations pertain to the one-time implementation of innovations (in the organizational sense as well, i.e., confined to a given firm). The subsequent evolution of innovation entails expansion, meaning the capturing of a new habitat. As the process of innovation evolves and branches out, it tends to transform itself into a more imitative endeavor. This leads us to a very interesting realm of economics pioneered by a prominent economist Joseph Schumpeter. The issues addressed by this field include the alliance between R&D and the production sectors, the designation of organizations best suited to be innovators or imitators, the ratio of innovators to imitators, etc.

Market and non-market mechanisms in the R&D sphere are not isolated from each other. R&D conducted at corporations is coordinated not only via the market, for example, joint ventures set up for specific projects, but might involve institutions belonging to non-market horizontal mechanisms: organization of conferences, special journals and publications, etc.

Western countries have demonstrated the viability of diverse institutions by overcoming the notion that the R&D sphere can operate only if governed by one of two extremes, either the market or the state. These countries have (and continue to search for) a multitude of mechanisms designed for the creation of new things. The mechanisms work by integrating vertical structures, e.g., government intervention,with horizontal market and non-market structures. The more imitative ventures could remain, to a large extent, the prerogative of the market.

At the present time, biological science lacks this kind of a multi-stage analysis of the process of change if only because biology has long been dominated by the theory of random mechanisms of change. The search for internal mechanisms of change is in its infancy, still largely devoted to affirming the mere fact of its existence.

2.2. Tunnel Process

R&D can proceed from the *beginning* as well from the *end*. This two-ended approach, which I refer to as the *tunnel process*, is most conducive to rapid and effective progress in the R&D sector.

In the simplest case, an economic system can be represented by the production chain from consumer goods and services to military output. This means that a person takes from nature what he or she needs. Vestiges of this still survive – the collection of wild berries, mushrooms, and other gifts of nature.

As man evolved, or, perhaps, from the very beginning, there emerged multi-link production chains between nature and the final product. Increasingly sophisticated technologies, comprised of many stages with many intermediate goods, were developed before the final product could be obtained. These production chains are manifest primarily in the production of tools, including second-order tools, that is, tools for making other tools.

However, the production chains thus formed were largely atomized and relatively short. Once the tools and the intermediate products became more versatile, this tangle of production chains was transformed into a unified network.

As long as this network remained relatively simple, a change in any one of its nodes could be completely and consistently traced directly to the end result, the final product. Therefore, with respect to the deterministic domain of the economic system, i.e., the domain which yields consistent and complete links between some initial and future states, changes can proceed from the end. This means that the process of development is driven by a well defined practical objective, namely, the creation of new products or technologies which are integrated in the overall network in a rather complete and consistent manner. Under these conditions, the results are judged directly by the consumers.

At some stage of human evolution a question arose which marked a revolution in the history of the human knowledge: "Why not begin parallel development from the start?" The question was posed in the following way: "Why not proceed in a parallel fashion, taking any arbitrary link as a starting point and assuming it to be impossible to construct any local criterion that would allow that link to be integrated in a complete and consistent manner with the rest of the coordinated network?" Tremendous benefits could be reaped from this kind of a parallel development, akin to digging a canal from both ends. At the earliest stages of development, the network is comprised of units (links) that mainly produce versatile products. If these products can be developed quickly and ways of integrating them into the existing network found, this could accelerate the development of the system as a whole. These considerations give rise to basic and applied science, which eventually contributes to the creation of new products and technologies.

The tremendous benefits of the two-ended approach, however, exact a heavy toll. The problem is that at the beginning the potential worth of any given undertaking may be entirely unclear. In other words, the stage of development attained by individual units is not complete and consistent with the network as a whole. For this reason, investment in the initial link could easily lead nowhere or to a dead end.

Thus, many sectors of the economy become indeterministic due to the gaps arising as a result of development being initiated at the beginning; in effect, it is impossible to link the initial and the final states in a consistent and complete manner, even in terms of probabilities.[1]

With respect to biological evolution, tunnel process implies the existence of external as well as internal sources of change. It is further surmised that external sources of change operate from the *end*, meaning that they reflect external conditions (environment). Internal sources of change work from the beginning, creating predisposition toward future development. The joint action of these two sources of change creates the so called *tunnel process* in biological evolution. Possibly the genetic changes induced at the beginning are accumulated in the genome prior to their ultimate expression in the phenotype. Consequently, paleontologists need not seek all the intermediate changes, that might be redundant or even harmful, in the evolution of a phenotype of a new species.

2.3. Calculating the Impact of a Given State upon Its Subsequent Development at a Point of Discontinuity

The generalization of the idea of a tunnel process brings us directly to the problem and degree of indeterminism. Indeterminism is one of the least developed philosophical categories. One indirect confirmation of this statement is the fact that mainstream philosophical literature, including contemporary theoretical investigations by Karl Popper,[31] fails to evoke the notion of degree of indeterminism: As a rule, indeterminism is opposed to determinism, with no mention of any intermediate stages.

We know that the concept of *measure* played a crucial role in the history of human knowledge. At the earliest stages, man operated with binary relationships reflecting extremes, such as hot-cold, black-white, etc. This is evident in a number of ancient languages. Subsequently, mankind developed the notion of *phases* reflecting the measure ascribed to a certain state – for instance, torrid-hot-warm-cool-cold-freezing. At a still more advanced level, the notion of temperature was introduced, allowing the user to measure change with the required degree of precision.

The notion of a phase is crucial in two respects: first, in measuring a given parameter with the required degree of precision, and, second, in developing methods to operate with structures associated with a given phase. For example, different phases of matter - plasma, gas, liquid, solid, etc. require different technologies.

In summing up my approach toward the category of indeterminism, I have arrived at a general systems concept of a multi-stage (multi-phase) process of change and the various mechanisms used to implement it.

I have (or, so I believe) uncovered a new and very important phase. Independently and based on different precepts, a number of scholars from the mathematical community have expressed interest in this philosophical category. Actually, one mathematician, Ron Atkin has provided a conceptual framework for this idea.[32] The phase I have uncovered within the spectrum of indeterminism involves the creation of *predisposition* toward development. Predisposition is a state which, on the one hand, is not completely ordered, not even in terms of probabilities, but neither is it complete jumble (unlike chaos, which, according to modern science, does exhibit certain patterns[33]).

In order to alleviate the potential waste caused by the gaps in the multistage process of change, it is essential to be able to evaluate the states belonging to these points of discontinuity, gaps, in terms of their potential impact on the future of the system. I believe this evaluation is rooted in the aesthetic method, i.e., measuring predisposition via the degree of *beauty*.[34]

The aesthetic method applies to situations where the path from the current state to some future desirable state cannot be fully and consistently calculated. These conditions call for the creation of the potential. Potential represents system's predisposition toward development. It is different from the probabilities-based approach which extrapolates on the basis of previous frequencies the impact of the current state upon the future. This concept of the potential is helpful in evaluating *unique* situations, since it does not require any knowledge of probability distributions in analogous cases in the past.

The system's potential creates structures aimed at:

1) inducing the environment in which the system is immersed to the system's advantage; 2) preparing the system to turn unexpected outcomes to the system's advantage, and 3) absorbing or reducing the shocks of unexpected events harmful to the system.

The creation of potential is based on the following four elements:

1) essential parameters as independent variables, 2) unconditional valuations of essential parameters, 3) relational parameters as independent variables, and 4) unconditional valuations of relational parameters.

These four elements make up the so-called weight function which measures the power of the potential as a scalar quantity.

What is new about this approach is that it introduces, on the one hand, unconditional valuations for essential parameters, and, on the other, relational parameters as independent variables. It is precisely the incompleteness/ inconsistency of the links between the present and the future states that necessitates the introduction of unconditional valuations of essential parameters supplemented by appropriate valuations of relational parameters. As part of this scheme the relational parameters also become guiding parameters on a par with the essential ones.

Uncovering the constituent elements comprising the potential, as well as the methods of these elements' synthesis, is really a rather ambitious attempt on my part to demonstrate that the category of beauty can be represented structurally, i.e., it can be decomposed, evaluated, and then synthesized.

Since scientific discoveries and inventions fall into the already existing R&D network, one should look at the system's predisposition toward innovation rather than focus on the random events leading to some particular novelty.

The idea of measuring predispositions by means of the aesthetic method extends beyond the human domain. It seems that the complex web of interactions among cells within an organism, among living creatures, and even chemical[35] and physical forces, is predicated not only upon the principles of determinism, but also upon the creation of predispositions.

2.4. The Organizational Structure of the R&D Sector and the Variety of Methods for Supporting Its Operation

The various stages of R&D correspond to different organizational structures. The R&D sector is comprised of many diverse institutions, ranging from universities, which deal primarily with fundamental principles underlying innovation, to firms, which combine applied research with the development of new technologies and their implementation, to inventors who, for the most part, develop new technologies based on the already known principles of pure and applied science.

In terms of power, the R&D sector is comprised primarily of *powerful* research organizations such as universities, specialized scientific institutes, e.g., laboratories, design groups, and special divisions within corporations. This sector also includes individual (or small group) *garage* inventors, individuals specializing in innovation within the corporation, etc. Between these large-scale organizations and "small-time" inventors there is an entire spectrum of organizations of varying power, including firms specializing in some narrow area of research, small groups involved in the development of new technologies in mid-size companies, etc. The R&D sector is not a homogeneous entity. Apart from the specialized and organizationally distinct entities involved specifically in innovation, this sector includes subdivisions dealing with specific products as well as autonomous individual-inventors dissolved in the economic system.

This heterogeneous structure of the R&D sector is financed through a wide array of sources that can be divided into several categories. The first is the revenue generated by a given unit from the sale of the fruits of its research, with money being used to finance new research. The second type of source is the unit's own money received from the sale of some final product/service, not the fruits of its research, or money saved from previous operations. The third source of financing is the government, i.e., the system as a whole. The fourth type includes donations from individuals/organizations directly or indirectly via money from private funds, inherited wealth, and so on. The fifth type of source is bank credit.

All of these sources for financing innovations are intertwined. This diversity creates more room for speculative pioneering research. It also raises a two-fold problem of the innovator's autonomy.

The first issue is the complexity of the organizational framework established by the innovator. Implementation of major innovations by such complex organizations as corporations is made possible, to a large extent, by profit. The capital raised through the sale of stock (this represents capital accumulated by individuals from their previous work) and the use of previously generated profit allows corporations to finance innovative ventures that are beyond the risk threshold tolerated by banks or even stock holders; bank credit is used by corporations to finance safer projects. Individual inventors, on the other hand, gain independence by setting up a relatively simple self-financing organizational environment. This drastically cuts down on current expenditures and permits reallocation of resources saved into innovative ventures to be recovered in the future.

The second facet of the problem is financing R&D units whose output is not for sale (which rules out profit-driven financing). This situation arises at the initial stages of basic research, and the institutions that come to the rescue under these circumstances include government, charities, etc.

It would be interesting to analyze the degree of autonomy exercised by the cells that partake of innovation in the light of the ideas expounded above and my assumption of an internal mechanism of change. A cell's autonomy may be expressed in a drastic alteration of its metabolism, e.g., a switch to a more primitive anaerobic metabolism that does not require oxygen), or in reduction in the number of receptors linking it to other cells, etc.

The more complex the R&D and productions sectors are, the more difficult it is to coordinate them and the more painful are the disorders in the R&D sector. Take, for instance, flaws in the engineering of nuclear power plants. When selection and reinforcement are carried out by more primitive centralized totalitarian regimes, the damage, which might extend far beyond the borders of a given country, can be immeasurable. It is not necessary to dwell on the dangers for mankind and our environment posed by genetic engineering or similar intrusions into the most basic building blocks of physical, chemical, or biological objects.[2]

3. THE LESSONS FROM THE ECONOMIC MECHANISMS OF CHANGE FOR THEIR BIOLOGICAL COUNTERPART

3.1. General Devices

What general devices relevant to biological evolution and biological mechanisms of change are suggested by our analysis of an economic system? It seems to me that one of these is program hierarchy*: program-changing programs*. Having discussed the various methods of operation associated with each stage of R&D, I would now like to consider these stages from a different perspective, namely in terms of a hierarchy of programs for creating innovation.

The category of a program as an independent object is a latecomer to the scientific scene. Its development was propelled by the great strides made by science in the twentieth century. The invention of computers, the study of the genetic code at the molecular level, the technology of mass production of complex goods – all these areas require a rigorous, sometimes even formalized, determination of complete and consistent relations among the various elements of the mechanism – precisely what the category of a program entails.

A behavioral program, which, according to Herbert Simon, governs the behavior of the system directly, will be denoted as a zero-level program. A first-level program changes the zero-level program. Changes in the zero-level program may be due to new information gathered over the course of its implementation or to the latent possibilities embodied in the first-level program. A second-level program works similarly upon the first level program. Moreover, assuming isomorphism among the various levels, the possibility of a feedback should not be ruled out. For instance, a third-level program can bring about changes in the second-level program (because of new information accumulated over the course of its execution or because of the possibilities intrinsic in the third-level program itself), or it can, itself, be altered because of changes in the second-level program.

The described hierarchy of programs resembles the process of change. Let us say that the zero-level program is a program which governs the production schedule for a particular product. Then, the first-level program is a program which generates the schedule. This program is based directly on the established principles of industrial management. Applied science represents a second-level program because it elaborates new principles of industrial organization. Basic science represents a third-level program, since it is supposed to alter, in a radical manner, the principles underlying the development of the principles of industrial organization.

As systems evolve and become more complex, the number of levels in a program hierarchy seems to increase. Perhaps living creatures, with the exception of man, possess about a three-tier hierarchy (behavioral program, a program that shapes it, and a program that changes the latter program, i.e., a learning program). In human beings the number may reach four, and in man-made artificial systems it may be even higher.

3.2. Specific Devices

What specific devices relevant to biological mechanisms of change are suggested by our analysis of an economic system?

The following ideas come to mind:

1) The production of goods needed today and based on routine procedures, and the creation of innovations needed tomorrow or in the more remote future, should be not viewed as isolated processes. At the microlevel, the actual volume of production of both kinds of products is determined by a tug-of-war between their respective producers who pursue their own interests. I shall qualify this statement later. There are many ways to resolve these conflicts - from the state exercising absolute control to the free struggle among the participants.

2) The creation of a scientific/technological idea is a multi-stage process of R&D with subsequent development of the final product and its realization by means of different mechanisms.

3) The multi-stage process of creation can give rise to the tunnel process, i.e., where the process of creation can be two-ended, originating at the beginning as well as from the end.

4) Gaps may arise within this multi-stage process of creation; evaluation of these gaps is done through the creation of predispositions.

5) The process of change can be viewed as a program hierarchy which includes program-changing programs.

6) In terms of its organization, the R&D sector incorporates a wide range of structures (units) supporting innovation - structures ranging from autonomous organizations, e.g., universities, foundations, to isolated individual inventors dissolved in the economic system and involved in innovative modifications of known technologies.

7) Innovation is supported through a variety of sources corresponding to the various organizational structures in the R&D sector. Particularly important are those sources that ensure independence of organizations involved in the fundamental early stages of innovation.

8) Both innovators and imitators seek to elude the control exercised by market-driven interaction among economic units. However, while the innovator strives to gain greater autonomy, innovation propagated by the imitators tends to master the established network.

9) The more complex the R&D and productions sectors are, the more difficult it is to coordinate them and the more painful are the disorders in the R&D sector.

The above considerations on the relevance and instructiveness of economic ideas for the analysis of biological systems suggest the following hypotheses regarding the latter:

Hypothesis number one. Beside the many mechanisms of change based on external factors affecting the zero-level program in the genome, (radiation, chemicals, gene recombination), there exists a variety of internal mechanisms of change. The scope of change produced by these mechanisms ranges from minor changes to the birth of new species.

Hypothesis number two. The structure of the mechanisms of change within the genome can perhaps be analyzed in terms of program hierarchy.

Hypothesis number three. The role of the tunnel process in evolution, meaning that biological changes can proceed both from the end as well as from the beginning.

Hypothesis number four. Mechanisms of change, especially those which operate from the beginning, possess certain structures which are first introduced in the somatic cells with information subsequently transferred to the germ cells.

Hypothesis number five. When change is initiated at the beginning, there exist structures within the genome that create potentials capable of developing in many different directions.

Hypothesis number six. Minor changes originate primarily at the end, while major ones are initiated at the beginning.

Hypothesis number seven. With change initiated at the beginning, there exist structures in the genome which minimize the occurrence of dead-end mutations .

Hypothesis number eight. As an organism develops, it faces the problem of resource allocation between a) supporting the creation and operation of the genome with an internal mechanism of change, and b) speedier multiplication and growth of the cells governed by routine genetic programs.

Hypothesis number nine. The humoral regulatory system incorporates mechanisms that allow innovator cells to break away from the organism's control, to gain autonomy, particularly at the early stages of their development. Once having evolved into a critical mass, innovator cells may actually get rid of the old regulatory mechanism and take over the control of the organism.

NOTES TO CHAPTER 1

[1]. The entire history of mathematics has exhibited two-ended development. One end was the need to solve practical problems, land surveying in particular. The other was the desire to explain the harmony of numbers as such. In Egypt the development of mathematics was driven by practical needs, such as geodesy and pyramid construction. Greek mathematics, Euclid and especially Pythagoras and his followers, professed aloofness from reality and the purity of mental constructs. Pythagoreans espousing the credo "numbers rule the world" despised practical applications of any kind. Only much later in the nineteenth and twentieth centuries, when the depths of mathematical structures were penetrated more deeply, did the two approaches begin to cross-fertilize each other, for instance, number theory, analysis, and theory of probability. Naturally, the connection between these two approaches hasnot been fully explained.

Originally, painting developed predominantly as a representation of the concrete. Gradually, as artistic sensibility evolved, the artists began to move away from concrete elements in their work. This is manifest, for instance, in the evolution of Vincent Van Gogh’s painting comparing his *Boots with Laces* with *The Abandoned Quarry*. My real point is that, along with the painting of concrete objects, there also appeared painting based on abstract elements and colors. Although all great artists recognized abstract qualities, for a long time they were considered subordinate. Apparently only in the twentieth century, beginning with the work of Wassily Kandinsky, did abstract painting begin to assert its independence. All these developments have led to many different forms of synthesis of abstract and concrete structures, to the mutual benefit of both. For example, in a number of paintings by Michail Shemiakin, a delightful synthesis — using the motif of Russian folklore — is achieved between the concrete structures of Hieronymas Bosch and the abstract structures of Kandinsky.

[2]. Not surprisingly, from antiquity people feared "the tree of knowledge" or "the Pandora's Box" and certain advanced civilizations, such as India and China, chose to curb technological development for many centuries. The common thread running through the two myths - the Tree of Knowledge and the Pandora's box - was pointed out to me by the late Professor Boris Moishezon. I refer an interested reader to my article[36] which discusses the relationship between introvert and extrovert cultures.

CHAPTER 2

MECHANISMS OF CHANGE IN SOCIO-POLITICAL SYSTEMS AND BIOLOGICAL EVOLUTION

Our discussion of socio-political systems is divided into two parts. I hope that the parallels between the socio-political and biological structures will help the reader understand not only the normal process of change, but the abnormal processes taking place in biological systems.

1. MACROLEVEL

What is called democracy seems to be a multidimensional, nonlinear entity. Its level of development is a function of many independent variables capable of assuming a range of different values. What is this multidimensional society? With respect to political systems, it incorporates such aspects as pluralism, not to be confused with relativism, democracy proper (unlike ochlocracy, or power of the mob), separation of power, and openness. Let us take a closer look at certain elements of a democratic society.

1.1. Separation of Power

At first glance, it seems that an enlightened monarchy, with one highly educated individual endowed with unlimited power and long-term commitment, should be capable of creating a new social institution quickly and efficiently with the best people in the country acting as the monarch's advisors. However, the "crazy" Charles Montesquieu (1689-1755) tried to show that representative democracy, with separation of power based on the principle of *checks and balances*, is, quite paradoxically, more conducive to a country's development. Under the system he proposed, the creation of new social institutions might take more time, but long-term results would be substantially better. I shall not dwell the advantages of Montesque's ideas for readers of the present work.

Separation of power in a multidimensional society, in turn, entails many view points. Of fundamental importance is the institutionalization of more or less equally powerful branches, both with respect to the scope of their activities, especially the separation of the ideological or religious function, and their territorial (central vs. regional power) and functional responsibilities. For the system as a whole, the last feature manifests itself in the separation of power between the bodies representing national unity, oneness, and national traditions, for instance, a constitutional monarch of the Anglo-Saxon variety, and other bodies that fulfill specific functions. The latter include, as part of the system of checks and balances, the legislative bodies, which lay down laws of fundamental long-range significance, constitution, for instance, and non-conflicting, more specific laws that are reviewed more often (parliamentary laws); the executive branch, which carries out these laws as required by the situation at hand; and the judicial branch, which sees that the laws, as well as the laws for changing the laws, are properly folowed, including preventive measures and injunctions. Interesting in this connection would the role of the fourth branch, empowered to make changes in the constitution. I merely wish to note here that the legislative branch, subject to certain provisions, does have the power to make some changes - amendments to the constitution.

These deliberations on the separation of power parallel our analysis of the social structure of biological systems as well as the role of different sexes. It is quite plausible that the mechanism of change is predicated upon multi-sexual reproduction which reflects the separation of functions fulfilled by the direct participants of the process of innovation. In effect, assuming that the male sex embodies the executive power and female sex the legislative power, a third sex could fulfill the function of the judicial branch.

1.2. The Pluralistic Mechanism

Consider the development of a political system. It is indeterministic by its very nature, and it operates based on a pluralistic mechanism. The objects of this mechanism are the various programs of development for a country. The pluralistic mechanism itself is characterized by the following features: 1) elaboration by independent participants of a manifold of programs of undifferentiated value, 2) selection of one program, or a combination of programs, to govern the country for a given period of time; this selection is based on the established procedure for setting the priorities among the various programs in the manifold, 3) supervision over the implementation of the selected program, and 4) replacement of the selected program if it proves inadequate or if the conditions change.

In more general terms, the objects comprising a pluralistic mechanism are not limited to the actual programs of development, but consist of inputs/outputs of the system, including operators who implement the proposed programs.

The process of biological development, which is indeterministic in nature, follows a somewhat similar course. It is carried out by means of a pluralistic mechanism whose objects are the living creatures.

In the initial stage, the manifold of living creatures is formed. This stage supports the creation of new creatures, their selection (preventive selection prior to birth), and ensures continuity between different generations necessary in view of the discreteness of mortal creatures. In the second stage, the created manifold of creatures "lives and works" in a specific environment, where the creatures' capacities to develop are actually realized. At this stage, as well as at later and earlier stages, the methods of operation of the living creatures change (the diversity of these methods expands), the best suited methods are selected, and, finally the actual performance of the selected methods is supervised and, if necessary, the methods are replaced. The third stage reveals how well the selected set of living creatures copes (and thus survives) in a given environment. In the fourth stage, the manifold of creatures undergoes restructuring with the ratios among the various species changing depending on the environment. Naturally, there is feedback from all these stages.

In summary, each stage reflects its own dynamics, which unfolds within the framework of a pluralistic mechanism.

The biological world is peculiar in this respect because the vehicles for implementing all these stages are the individual living creatures. This means that the creation of the manifold of living creatures entails not only changes in the anatomy or physiology, which was the primary focus of the evolutionists, but also the methods of their interactions with the environment. By methods of interaction I mean the capacity to develop new programs of behavior, including a) various mechanisms of evaluation such as emotions, biological drives, pain; b) ability to perceive the environment as well as the organism's own abilities; and c) "algorithms" to carry out the above. An organism possesses various physiological structures that support the development of its behavior. At the same time, there exist mechanisms for changing these structures.

Living creatures are capable of observing/assimilating the results of the interaction between their program of behavior and a given environment and modifying it through the process of learning. The learning program is fixed in the physiological structures of living creatures. Higher organisms, and man in particular, possess physiological structures capable of changing the learning programs.

Finally, if some species proves ill-adapted to a given environment, it might barely survive, yielding more space to other creatures.

From the process-oriented point of view discussed above, the volutionary process can be divided into the following stages: *creation* of the manifold of living creatures; *performance* - interaction of these creatures within a given environment; *revision* - evaluation of the creatures' performances in terms of their adaptation or changes in the manifold and finally; *replacement* - changes in the structures of the living creatures made possible by the expanding manifold and different external conditions (environment).

Each stage of the pluralistic mechanism incorporates change, selection, and heredity. Moreover, change encompasses not only the creatures themselves, but also the methods of selection and heredity, all implemented through the individual creatures. In our subsequent discussion, I shall use this broader notion of change. To the best of my knowledge, the currently prevailing view in biology states that change pertains only to the organisms themselves and that the mechanism of change is fixed, just as the methods of selection and heredity.

2. MICROLEVEL

2.1. Typology of Deviants

In the social realm, an individual attempting to change the established norms is labeled a *deviant*. I call a deviant who has a positive impact on society an *innovator,* and consider a deviant who is detrimental to society, as abnormal or sick.

There are two kinds of sick deviants - pathological and nonpathological. What distinguishes a pathological individual from a nonpathological one is the former's inability, given the resources available, to maintain normal functions and handle adverse situations.[4] Therefore, sickness should not be equated with pathology, since the latter implies one's inability to deal with one's ills. For instance, a person with the flu experiences both an abnormality and a sickness, but the state is not pathological if the body can deal with the sickness on its own.

In medical terms, deviants can be classified as *healthy* or *sick*, on the one hand, and *pathological* or *non-pathological,* on the other.

Other criteria can also be used to distinguish among different types of deviants. One is an ideology espoused by the deviants for transforming society and the degree of radicalism embraced by this ideology in terms of its claim to power and wealth. In a sense, these characteristics reflect general systems categories, which makes them applicable to biological systems. At the same time, "social deviants" might possess certain features that other systems lack, for instance, the perception of one individual by another.

The following table gives the taxonomy of deviants based on the parameters outlined above.

TABLE 2.1. Typology of deviants.

Usurpation	Ideology			
	Present		Lacking	
	Positive (innovator)	Negative	Positive	Negative
Desired	Revolutionary	Terrorist	Victim of a system	Bandit
Not desired	Reformer	Revisionist	Liberal	Opportunist

Deviants in the social realm can further be classified dichotomically into two groups - conditional (situation-specific) and unconditional. Conditional deviants can be both positive or negative, depending on the situation. For instance, a reformer is regarded as a positive figure, while a revisionist has negative connotations. Therefore, the same deviant can be both a reformer or a revisionist, depending on the circumstances. There are also unconditional deviants, deemed so no matter what the circumstances are. For instance, bandits are always judged to be bad. My concern here is primarily with the general case of conditional deviants.

2.2. The Role of Deviants and Their Interaction

Every developed pluralistic political system includes the entire spectrum of deviants espousing their own ideologies. Let us take radically-inclined deviants. It is not unreasonable to suppose that their programs include some valuable points which, under certain conditions, can actually improve the operation of the system that is founded upon other principles. I would say that, in general, the programs proposed by radicals are inadequate relative to the complexity of the problems they claim to solve. The danger of radicalism is the desire to impose its ideology upon others forcibly. The influence of radical programs depends on the radicals' capacities for self-control, as well as existing circumstances; under stressful social conditions such as wars, economic crises, etc. society is more prone to extremism. The radical element does not pose a grave danger, even in time of crisis, if it is capable of exercising some self-restraint and the political culture of the populace is sufficient to prevent radicals from usurping power. Now, if one or both of these conditions is lacking, especially during stressful times, the country can easily fall prey to these radicals who include anarchists, communists, fascists, and similar groups. During the devastating crisis of 1929-1933, communists in the United States could not gain power. One reason was that they exercised some self-control. For instance, in keeping with American tradition, they put their own personal interests first – they did not strictly follow the *party line*, and they were not totally obedient to party discipline, as was characteristic of the Russian communists. [1] Moreover, the political culture of the American people kept them from succumbing to radical views. At the same time, certain ideas advocated by socialists and communists were assimilated by American democratic institutions. These included all kinds of government-run social safety-net programs to protect the *down and out* – progressive taxes, minimum wages, unemployment compensation, social security, etc.

Meanwhile, in times of crises, communist (revolutionaries) were able to seize power in Russia, as did fascists in Germany, Italy, and Spain. The primitive "genetic program" proclaimed by the radicals penetrated deeply into the fabric of the social organism. It distorted the structure of the country and its mechanism of government, and it damaged people to such an extent as to lead the country, within an historically brief time period, to virtual exhaustion with all the ensuing consequences.

Let us now take a look at the typology of people from the standpoint of their attitudes toward other members of society.

We can distinguish three groups of people: egotists, individualists, and collectivists. An *egotist* is distinguished by the fact that he pursues his own interests while disregarding the interests of others. A *collectivist* is one who surrenders his own interest to the interests of the whole. An *individualist* is one who puts his own interests at the forefront, but takes into account the interests of others. In this context, an individualist represents a *microcosm* because he embodies his own interests as well as those of others. Democratic societies seek individualists, while totalitarian regimes hail collectivists. Frequently, a totalitarian society gains a large number of collectivists, but as they become disappointed, they turn into hard-core egotists.

This typology of individuals suggests a similar classification for cells. By analogy, an organism has conformist cells, i.e., cells which reproduce cells like themselves, as well as non-conformist cells. The latter category includes *innovators* - cells that are conducive to the development of an organism. Cells-innovators could be regarded as normal, since the change they undergo is in harmony with the changes they induce in other cells, including, perhaps, germ cells.

Deviant cells can be abnormal, posing a major threat to an organism. Abnormal cells, on the other hand, can be non-pathological, that is. capable of self-rectification; a pathological case refers to cells that are unable to revert to their normal state and, at the same time, cause harm to the organism.

Innovator cells can affect the genome of other cells (see in the following chapters), thus transferring their own positive "ideology of development" to other cells. There are also abnormal radical cells which, instead of helping an organism, attempt to impose their doctrines in a simplistic brute force fashion. Radicals who try to impose their destructive genetic programs upon other cells become *terrorists*. There are also *bandit* cells. Both use force, but bandits possess no "ideology" and do not affect the genome of their victims. Bandits can act like murderers out of control, perhaps damaging other cells' membrane, or like murderer-burglars who kill selectively in pursuit of personal gain, perhaps taking the nutrients from the victim-cells.

In principle, radical cells might well carry valuable genetic information, but the only way this can be beneficial is if the organism's immune system, analogous to political culture of a nation, curbs these cells, thus preventing them from usurping control over the organism.

My natural philosophical approach runs contrary to common wisdom, which holds that each individual cell must serve the interests of the whole, sacrificing itself, if necessary.

In my philosophical scheme, there is a variety of cells. Some cells behave like *individualists.* A cell-individualist pursues its own interests and seeks its own development. Cell specialization benefits this cell because its chances for development improve under this system of mutual exchange. At the same time, each cell must take the "interests" of other cells into account. The genome of every cells reflects its individualism: it contains information about the entire organism, the cell itself, and the program of development of this cell in its respective environment. There are perhaps *altruist* cells, willing sacrifice themselves "voluntarily" to save an organism (*apoptosis*). There are also *selfish* cells which subjugate the development of an organism to their own narrow interests, even if their behavior eventually leads to their own demise.

I also want to note that cancer represents a systemic disease, an expression of a pathology of the propensity of living creatures for change. It is a manifestation of selfish, turned pathological, radical cells, of terrorists or bandit variety, aggravated by the fact that the organism's immune system fails to bring these cells under control and, at the same time, save innovation-carrying cells from the same fate.[2] It is by no means indisputable that cancer cells, as defined above, are completely unmanageable or that their growth necessarily unstructured. Their destructive behavior and growth could be tamed and structured and their destructive program rectified by the immune system.

My speculations suggest a number of hypotheses pertinent to the way we view cancer. Here, I shall limit my argument to one illustrative hypothesis .

Essentially, my hypothesis states that the behavior of an innovator cell is almost identical to that of a cancer cell, especially at the early stages. The confusion between these cells could be extremely injurious to the evolutionary process because innovative cells categorized as cancerous are subject to destruction. The medical profession today employs all means at its disposal to destroy cells deemed oncogenic or turn them into what is conventionally regarded as normal cells, i.e., stable cells which reproduce a given organism.

It is particularly dangerous to destroy innovator cells under early diagnosis of cancer, since the behavior of a cancer cell at an early stage may be quite similar to that of an innovator cell.

I believe that innovator cells that may turn into terrorist cells should to be treated differently. Assuming that the future course of development of such cells is uncertain, meaning that there is no guarantee that the "society" - the organism's inner environment - will be able to cope with the innovative cells in case they turn out to be terrorists, it might make sense to isolate such cells "from society" rather than destroy them. The latter task should be carried out by the immune system. Its role is to promote as much as possible an organism's biological potential for development by preserving the necessary diversity of cells, rather than destroying the harmful cells, or other harmful ingredients. Over the course of time, once it becomes clear that the body can control the terrorist cells, these cells could be allowed to function normally.

I realize full well that at this point in time, when we are unable to stop the onslaught of cancerous cells, my remarks sound rather out of place: when the organism's survival is on the line, thinking about its development seems frivolous (as the saying goes, "Thank God just to be alive"). But, perhaps, it pays to look ahead, and not sever the link between the development of an organism and the development of a species, but to bridge the mechanism of change within an organism with the general process of evolution!

3. THE LESSONS FROM THE SOCIAL MECHANISMS OF CHANGE FOR THEIR BIOLOGICAL COUNTERPARTS

What specific devices relevant to biological evolution and biological mechanisms of change are suggested by our analysis of socio-political systems?

The following ideas come to mind:

1) Separation of power in the political realm ensures separation of functions needed to govern a society with subsequent integration of these functions via a horizontal mechanism of checks and balances.

2) A pluralistic mechanism permits a society to combine strategy, concerned primarily with expanding the manifold of objects and methods of their interaction, with tactics concerned primarily with selecting from this manifold the set of alternatives that best addresses the current goals and with supervising the implementation of the selected program.

3) The vehicle of change at the microlevel is the diversity of deviants, ranging from extreme radicals to moderate reformers; all of these groups ought to be preserved. The ways of preserving this manifold are contingent upon the circumstances peculiar to each country, particularly, the political culture of the nation.

The above considerations on the pertinence and instructiveness of socio-political ideas for the analysis of biological systems suggest the following hypotheses regarding the latter:

Hypothesis number one. It is quite plausible that the mechanism of change is rooted in multi-sexual reproduction that reflects the separation of functions fulfilled by different participants of the process of innovation .

Hypothesis number two. Evolutionary development calls for the preservation of the manifold of deviant cells, ranging from radicals to moderate imitators.

Hypothesis number three. Cancer can be viewed as a pathology of a normal somatic mechanism of change which involves radical deviants poorly controlled by the immune system. Since cells-innovators and cells-destroyers may appear to be very similar, especially at the early stages of the process of change, it is important, when diagnosing cancer, to make the distinction between these two types of cells. Moreover, under certain conditions cell-destroyers should be sequestered rather than eliminated.

NOTES TO CHAPTER 2

[1]. Interesting in this respect is the American movie Reds. The hero of the movie is a real-life character, an American communist, John Reed. He was not just an observer of the Bolshevik Revolution in Russian, but, to a certain extent a participant. There is a scene in the movie which depicts a conversation between Reed and one of the leaders of the revolution, Gregory Zinoviev. The discussion centered around Reed's insistent request to go back to America to share Christmas with his family. Zinoviev thought Reed's presence was crucial for the revolutionary meetings held in Azerbaijan.
I am grateful to my American friend, Norman Gross, for clarifying the differences between Russian and American Communists.

[2]. Paraphrasing the hypothesis advanced by Galina Filonenko regarding the analogy between cancer cells and abnormal individuals, slowly progressing cancer is akin to pathological egotist cells of the evolutionary type. Terrorist cells are associated with cancerous cells which partake of the "normal" course of cancer; bandit type cancer cells partake of rapidly progressing cancer, sarcoma.

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