Reconstruction of Cell Evolution: A Periodic System

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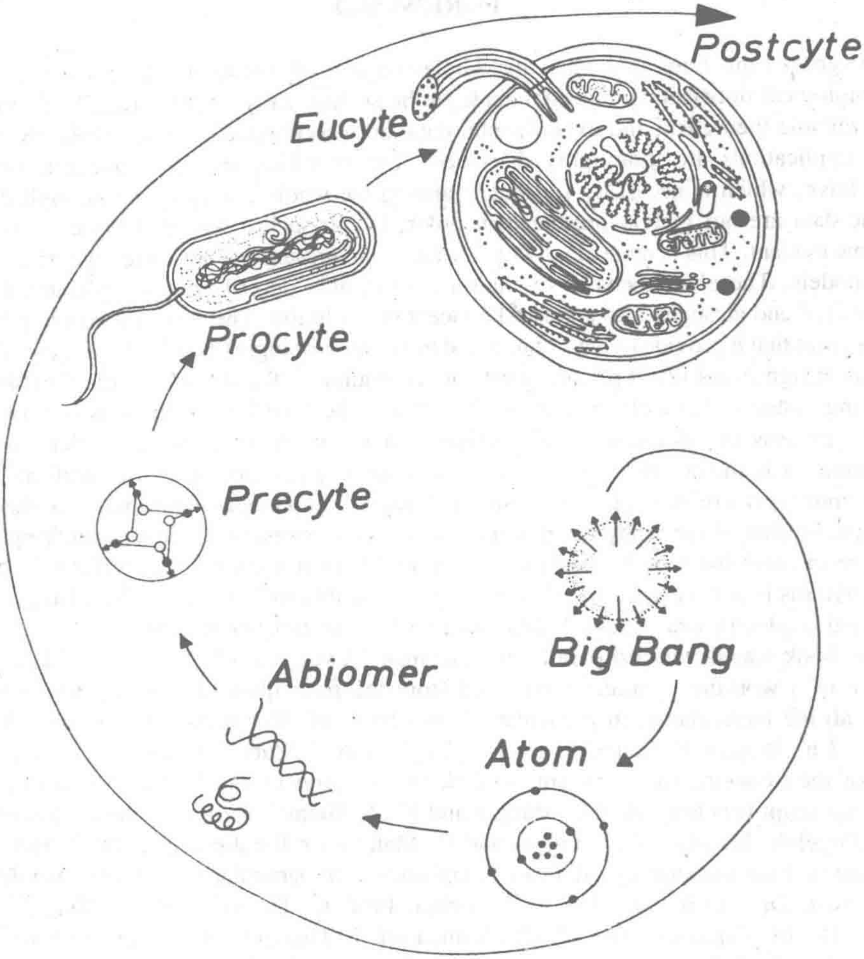

This book attempts for the first time to relate the mechanisms of cell evolution (ur-cells, bacterial cells, higher cells) to cosmic and chemical evolution. An outline of a modern cell theory is developed from the available data. One important aspect of this theory is the derivation of a periodic system of cell types. The analogies between this tentative periodic system of cells and the periodic system of the elements are discussed.

FOREWORD

The goal of this book is to make the whole complex of evolution in its cosmic, chemical, and biological dimensions understandable to the scientifically oriented reader. To this end, the available theoretical and experimental data are incorporated, and, qualitatively at least, their implications are thoroughly discussed. The transition from the quantitative to the qualitative, which is necessary for understanding the whole complex, is thus well defined.

The data are not merely presented in order, but in such a way that basic relationships become evident. This is most clearly expressed in the presentation of comprehensive systems and models. The phenomena of evolution are not only described and explained, but also systemized and arranged into a general concept of evolution. The essential criterion for such a concept is that it provides a least common denominator of logic for the facts and conclusions. The most significant result produced was the derivation of the periodicity of all evolved and evolving systems. Thus, this text not only caters to the need for comprehensive information on the process of evolution, it also offers a new and more complete understanding of evolution. It is the central goal of science to achieve ever more realistic, uniform models of the entire real world. In this sense, this book represents a modest contribution to theoretical biology. In view of the rising flood of data, there is a growing need for such unifying theory. The present inability to solve basic biological problems like cancer, cell differentiation, and endorhythms is not only due to a lack of technical ability or knowledge, but also to the lack of interdisciplinary evaluation of data and to a lack of unifying theory.

This book was developed parallel to a seminar "Evolution of the Cell", with the cooperation of a working committee recruited from the participants in the seminar. I wish to thank all the participants, in particular M. Berthold, M. Herrmann, B. Luuring, H. Mündelein, Ch. Manger E. Schütte-Arnst, S. Vieth, and U. Zabel for their many suggestions and for their constructive criticism. I thank Dr. M. Brewer and P. Bradish for translating the manuscript into English, Ch. Manger and M. A. Biemelt for typing the manuscript, and Ch. Dörgeloh, M. Jupe, G. Kemner, and H. Mattow for the drawings, and P. Holzner for the photos. I am indebted to a number of colleagues, in particular Prof. C. G. Arnold, Prof. C. Bresch, Dr. M. Brewer, Dr. R. Dierstein, Prof. G. Drews, Prof. M. Eigen, Prof. J. Fuchs, Dr. M. Grasshoff, Dr. W. Gutmann, Prof. F. Hinderer, Ass. Prof. A. Karpf, Prof. W. Kaplan, Prof. P. Karlson, Prof. H. Kuhn, Dr. D. Mollenhauer, Dr. D. Peters, Prof. H. Schenk, Prof. P. Sitte and many others for their critical evaluations and helpful discussions of the manuscript. Their criticism made me aware of the difficulty involved when a single individual attempts to present such complex and voluminous material. Along with encouragement, I received such sharp criticism that I was forced to develop the courage to "jump into the gap", for the benefit of the potential readers, and because of the ever more acute need for a comprehensive and unified presentation. I hope that the specialists in those fields where I have no special competence will, in light of the above-mentioned goals of this text, excuse any errors or imprecise formulations which may still remain, in spite of my efforts. I shall also be grateful for any verbal or written criticism of the present work, which may be taken into account in subsequent editions. Finally, thanks are due to the publishers, CRC Press, in particular Sandy Pearlman and Mary Kugler, for their help and their consideration with regard to the author's wishes.

W. Schwemmler

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THE AUTHOR

Werner Schwemmler was born in 1940 in Offenbach, Germany (FRG). He studied biology, chemistry and geography from 1961 to 1966 at the Universities of Marburg, Giessen, and Freiburg. From 1968 to 1970, he held stipendia from the "Duisburg-Stiftung" and the "Max-Planck-Gesellschaft" to work with Prof. Vago at the Institute for Comparative Pathology and at the Institute for Invertebrate Pathology of Montpellier University in southern France. The author took his doctorate in 1972 with Prof. Sitte, Freiburg.

From 1972 to 1974 he held a research fellowship for "Habilitation" from the Deutsche Forschungsgemeinschaft (DFG) at the Microbiological Institute of Prof. Drews, Freiburg. In late 1972, he spent a short time at the University of Minnesota (Minneapolis) with Prof. Halberg and Prof. Brooks, with the financial support of the DFG and the "Freiburger Wissenschaftliche Gesellschaft".

From 1974 to 1980 Dr. Schwemmler was an assistant professor at the Freie Universität of Berlin. He took his "Habilitation" in zoology there in 1975 and is the head of an interdisciplinary group working on the physiology, ecology, genetics and evolution of cellular systems. He is author of the book "Mechanismen der Zellevolution. Grundriss einer modernen Zelltheorie", which has been published by De Gruyter, Berlin/New York. Also, he organized with Prof. H. Schenk an International Colloquium on Endosymbiosis and Cell Research, April 11—15, 1980, in Tübingen (FRG). They organized also the Second International Colloquium on Endocytobiology, April 10—15, 1983, in Tübingen. Dr. Schwemmler is co-editor of the proceedings for these colloquiums and co-founder of the new synthetic research area "Endocytobiology". In 1983 he was appointed ausserplanmässinger Professor at the Freie Universitat Berlin.

It is so easy to suggest no theories, with the excuse that the necessary basis of fact is not yet available. As if the theory did not first have to show where one should look for the facts!

These sentences are part of a letter written by the Freiburg zoologist **August Weismann** to the zoologist **Ernst Haeckel**, in Jena, after he had read the latter's treatise "Die Gastraea-Theorie, die phylogenetische Classifikation des Tierreichs und die Homologie der Keimblätter".

TABLE OF CONTENTS

Chapter 1

EVOLUTION RESEARCH: GOALS AND PROBLEMS

In the broadest sense, *evolution* is the process which has led from the origin of the universe to the rise of the modern world, including humanity and all other living beings. It can be divided into several phases, *cosmic,* chemical, biological,* and *cultural.* The most important junctions passed in the course of this evolution are the elementary particles, the atom, the cell, and human culture. The essential difference between these phases is the way in which information is stored.

The goal of evolution research is to reconstruct the entire sequence of this historical process, and thus to clarify the underlying mechanisms. In order to understand the nature of this undertaking, we must first explore the extent to which the concept "evolution" can be perceived or expressed in words. There are phenomena in the real world which are less complex than the senses and brain through which we perceive them. This is the world of atoms, and cells and their interactions, which are the main objects of research in the natural sciences. It is the task of *natural sciences* to examine these phenomena by means of *experiment* and to formulate the results precisely, objectively, and logically in terms of reproducible data (Figure 1).

There are other phenomena whose degree of complexity is roughly the same as that of our cognitive apparatus, such as the human being, human consciousness and culture. These are generally the subject of the *social sciences.* The criterium is *experience,* and the result is the assembling of data which are subjectively logical, but only reproducible within certain limits, and thus not amenable to exact formulation. Finally there must be phenomena which are more complex than our cognitive apparatus. Our senses are clearly limited and act as a filter which allows only a part of reality to our consciousness (e.g. we do not hear as well as bats, or see as well as birds of prey, or smell as well as dogs, etc.), quite aside from the limitations of our computer-like brain.* This more complex side of the real world is related to the position of humanity in the universe, and is dealt with by *metaphysics.* Metaphysical method is called *synopsis,* or consideration of the whole at once. Its imprecisely formulated statements, e.g. on telepathy, may be statistically only barely defensible, but they are no longer or not yet capable of logical formulation (Figure 2).

Evolution, the most complex and central phenomenon of our real world, belongs to all three areas, the natural sciences, the social sciences, and metaphysics. Therefore, only some aspects of evolution, such as the mechanics of molecular and cellular evolution, can be clearly understood, while other aspects, such as the psychic and intellectual achievements of man, can only be vaguely comprehended and still others, such as the origin and end of cosmic development, lie completely beyond causal explanation, at least for the present. A further problem is that the process of evolution, which has been going on for billions of years, is an historical phenomenon, which we can now only attempt to reconstruct on the basis of fossil and recent evidence. The criterion for the validity of such reconstructions is the lack of contradiction with the previously gathered data. The insight into the entire process of evolution is thus supported by much evidence, but can never be proven.

The lack of cognitive precision is compounded by the limitations of language, which can only describe the often simultaneous in the one-at-a-time of words. For this reason, the combination of language and visual expression in the form of tables and models is the best which can be achieved in representing the cognitively derived complex of evolution.

* Since evolution in the Darwinian sense did not occur in this phase, it is better to speak here of cosmic development.

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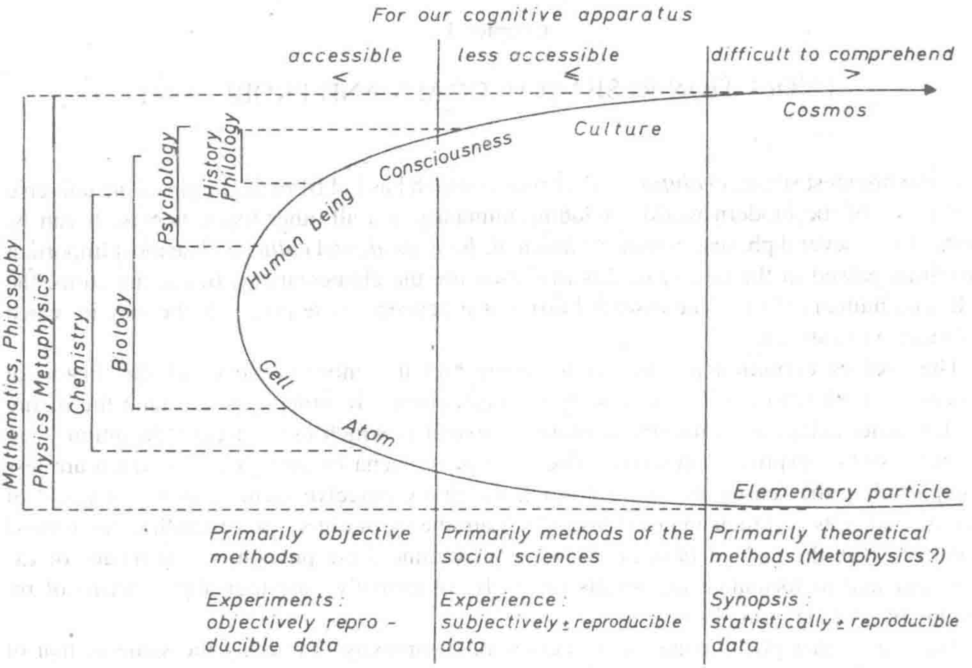
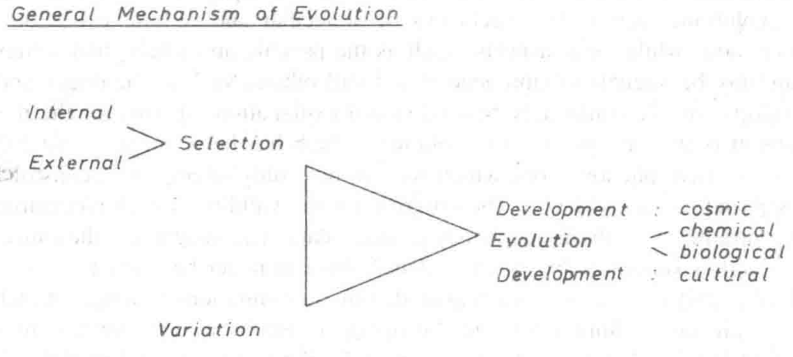


FIGURE 1. Correlation between the degree of complexity of the human cognitive apparatus, methods of examination, and forms of knowledge about the real world (for details, see text).

The central *theory of biological evolution,* which is now generally accepted, was proposed by the Englishman Charles Darwin ("On the Evolution of Species through Natural Selection", 1859). Darwin deduced the theory for the biological phase of evolution, but its applicability to the chemical phase of evolution has, in the meantime, become apparent. The mechanism of evolution is thus the same in the chemical and biological phases. The different variations (mutations) of those members of a population which are best adapted to their internal and external environment are the most likely to survive (be selected) in the competition for existence:



The general mechanism of the whole process of evolution is the modular principle.[20] Each level of evolution is reached through combination of different representatives of the next lower level, each representative being best adapted to a different milieu (Figure 3). How and when such developmental leaps occur is a matter of chance. That they occur, however,

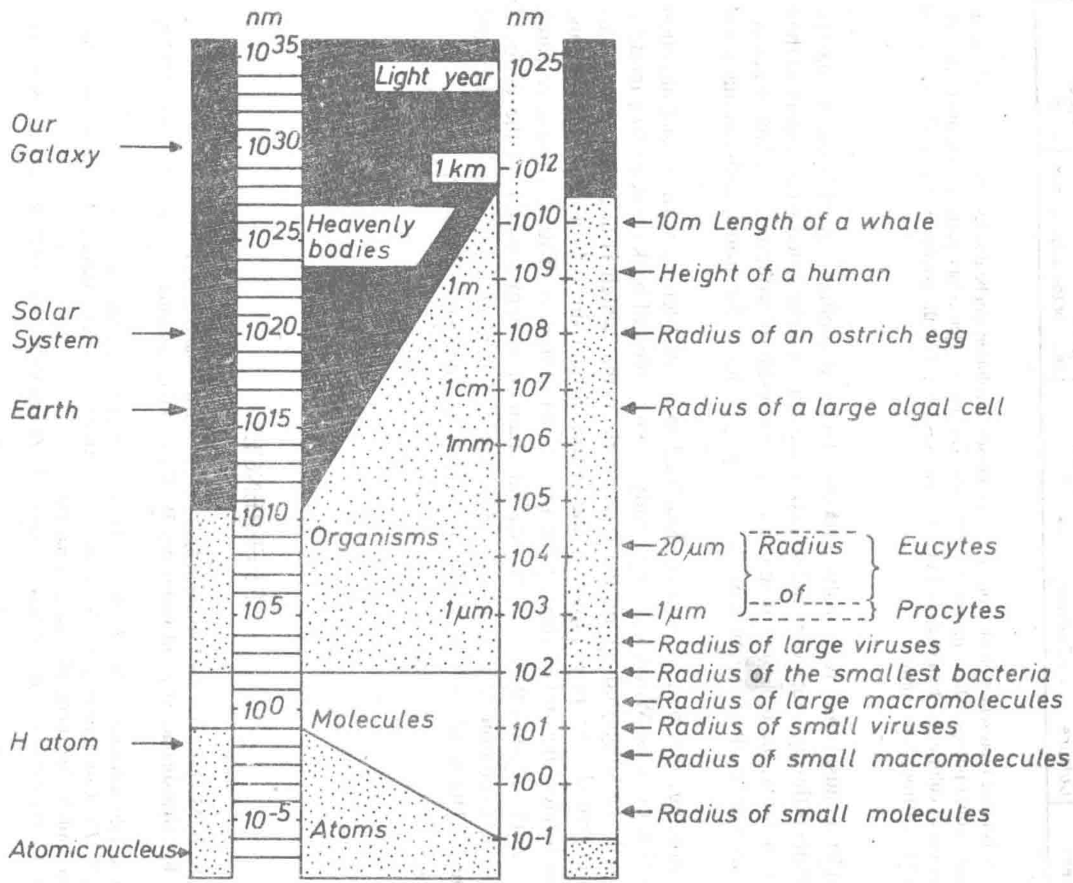


FIGURE 2. Size comparison of the individual evolutionary systems on a logarithmic scale (adapted from Laskowski and Pohlit[12]). 1 nm (nanometer) = 10^{-9} m = 10 Å.

PHASE	MODE OF DEVELOPMENT					COSMIC MILIEU	PERIOD (billion years ago)
Cosmic Development	?	+	?	→	Elem.particle	Big bang	<-8
	Elem.particle	+	Elem.particle	→	Atom	Galaxy	<-7
	Atom	+	Atom	→	Molecule	Solar system	<-6
Chemical Evolution	Molecule	+	Molecule	→	Abiomer	Earth	<-5
	Abiomer	+	Abiomer	→	Precyte	Primal soup	<-4
Biological Evolution	Precyte	+	Precyte	→	Procyte	Ocean bottom	<-3,5
	Procyte	+	Procyte	→	Eucyte	Ocean surface	<-2,5
	Eucyte	+	Eucyte	→	Human	Land	<-0,01
Cultural Development	Human	+	Human	→	Culture	Space	- 0,001
	Culture	+	Culture	→	?	Death of the solar system	< + 6

FIGURE 3. Schematic representation of evolutionary processes. Evolution can be divided into cosmic, chemical, biological, and cultural phases. Major milestones along the way are the elementary particles, the atom, the cell, and consciousness of culture. Each higher level of evolution was formed by the combination of representatives of the next lower level (from Schwemmler[19]).

is the result of a causal, highly probable process. To put it another way, this means that the systems obtained through variation and selection are not predetermined with respect to their individual structures, but that they arise in a necessary result of evolution, or a law of nature. This is just as true for the formation of elementary particles as for atoms, cells, humans and cultures.

In the following, this process will be described in general terms, with special attention to the evolution of cells. Where data are totally lacking, we fall back on deductive models, which can only be suggested within the framework of that which is already known. This framework is provided by monophyly, or the historical relatedness of all evolved systems, which demonstrates the universality of the evolutionary process. Thus evolution research always means the reconstruction of the causal chain of systems, based on the deduced mechanisms of evolution (e.g., Darwin[5], Gutmann,[9] Peters et al.,[14] Bonik et al.,[2] and Schwemmler.[20] The result is here the foundation of the modern cell theory.

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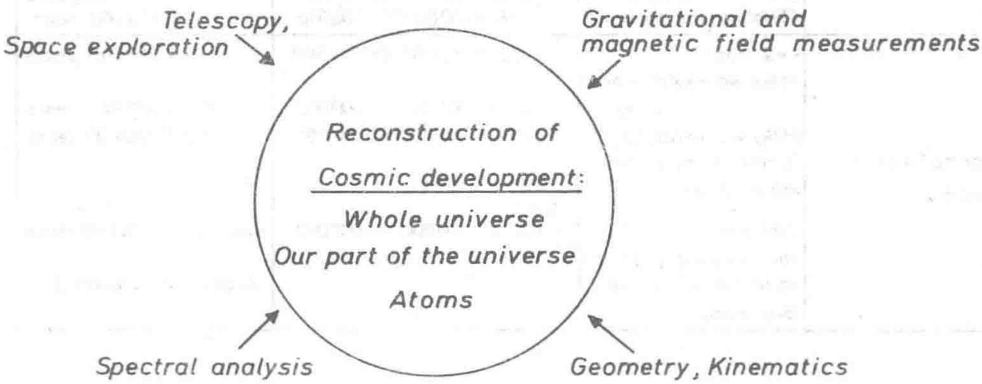
Chapter 2

EVOLUTION OF ATOMS

The formation of atoms is a side reaction in the process of cosmic development, the formation of the universe. The discipline concerned with this process is called cosmology, and it comprises three main areas of investigation:

- Structure and form of space
- Formation and development of the objects present in the universe
- Age of the cosmos and the course of its expansion.

These are examined with the current physical and mathematical methods, such as telescopy, spectral analysis, gravitational and magnetic field measurements, geometry, kinematics, etc. Cosmology can only bear fruit through an interplay of theory and observation. A fundamental difficulty of cosmology is that observation is subject not only to technical limitations, but also to those imposed by the very nature of the universe, while the theory should ideally encompass the universe as a whole.



I. THE MILKY WAY

It is difficult, given the unimaginable size of the universe, to generalize about the entire complex. Our knowledge is limited to those areas of the cosmos which we can observe directly, which have a radius of about 5 billion light years.* This we can simply call *our observable part of the universe* (Table 1, Figure 1). At the limits of the observable universe we can just make out the quasars (*quasi*-stell*ar* objects), which have a diameter of 2×10^{18} km and radiate extremely powerful radio waves. They are thought to be young, very distant galaxies. Quasars move through the cosmos with a velocity of 250,000 km/sec, or 84% of the speed of light. Within the limits of the observable universe we can see several thousand spiral nebulae, or *galaxies*, which are collected together in galactic clusters. The galactic cluster nearest to us contains about 20 smaller galaxies, including the two Magellanic Clouds, the Andromeda galaxy, and the Milky Way, which is about 1.8×10^{19} km from the Andromeda galaxy.

* A *light year* is the distance traveled by light in one year at a velocity of 300,000 km/sec; this is equal to 9.5 $\times 10^{12}$ km.

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